PORTABLE GAIT LAB: TRACKING GAIT KINETICS AND KINEMATICS USING ONLY THREE INERTIAL MEASUREMENT UNITS

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ABSTRACT

There have been several efforts in developing minimal inertial measurement units (IMU) setups for ambulatory gait tracking. IMUs are small, and wearable, and can be integrated into the shoe or the clothing of the user. This has several potential uses including remote monitoring, or as a simple measurement tool to record gait recovery after an impairment.

An ideal minimal sensing setup to track the kinematics of feet and centre of mass (CoM), would be to place three IMUs; one on the hip and one on each foot. Two major issues that needs to be dealt with, among others, is reducing the uncertainty in distance between segments, and avoiding the use of magnetic sensing for estimating the heading direction. As part of AMBITION, an NWO project, we developed solutions for these issues.

Our methods allow tracking of 3D ground reaction forces (GRF), and kinematics of feet and CoM during gait using the three IMUs [1]–[3]. The Centroidal Moment Pivot (CMP) theory [1], [4] plays a pivotal role in these solutions. We validated the algorithms for variable over-ground gait against reference systems such as VICON© and ForceShoes™. The different walking tasks tested included straight line walking, walking with turns, slalom walking, as well as simulated asymmetrical walking. Our average absolute errors across all these tasks in estimating step lengths and step widths were 4,6 +/- 1,5 cm and 3,8 +/- 1,5 cm, which were slightly larger than the variability in these measures in healthy and stroke populations. Nonetheless, our approach was able to track variable walking, and distinguished step length asymmetry during asymmetrical gait.

In addition to the efforts, we introduce the concept of body centric reference frames. This was defined by combining relative movement information from the three sensors, and thereby avoids the use of magnetic sensing [1]–[3]. Next, we plan to test our algorithms on subjects with gait impairment.

REFERENCES

[1] M. I. Mohamed Refai *et al.*, “Portable Gait Lab: Zero Moment Point for Minimal Sensing of Gait*,” in *2019 41st Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, 2019, pp. 2077–2081.

[2] M. I. Mohamed Refai, B.-J. F. van Beijnum, J. H. Buurke, and P. H. Veltink, “Portable Gait Lab: Estimating 3D GRF Using a Pelvis IMU in a Foot IMU Defined Frame,” *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 28, no. 6, pp. 1308–1316, Jun. 2020.

[3] M. I. Mohamed Refai, B.-J. F. van Beijnum, J. H. Buurke, and P. H. Veltink, “Portable Gait Lab: Tracking Relative Distances of Feet and CoM Using Three IMUs,” *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 28, no. 10, pp. 2255–2264, Oct. 2020.

[4] M. B. Popovic, A. Goswami, and H. Herr, “Ground reference points in legged locomotion: Definitions, biological trajectories and control implications,” *Int. J. Rob. Res.*, vol. 24, no. 12, pp. 1013–1032, 2005.