

Estimating relative foot positions for assessment

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Introduction

- Patients who suffered a stroke are trained to recover adequate control over their movements with the objective to optimize their daily-life functional performance.
- Continuous daily-life monitoring of balance control of stroke survivors is essential for optimal guidance of rehabilitation therapy.
- Instrumented force shoes were developed for the ambulatory assessment of the ground reaction force and the estimation of the position of centre of mass (CoM), to evaluate dynamic balance control in stroke patients [1] (figure 1).
- A detailed evaluation of qualitative parameters of motor function in stroke survivors will be conducted to demonstrate expected different parameter values [2,3] (figure 2).
- Using the instrumented force shoes, the relative foot positions cannot be measured accurately (overall error below 0.05 meters) over longer distances due to signal drift.
- The purpose of this study is to evaluate the estimation of relative foot positions during double stance using inertial and magnetic sensors on the leg segments and pelvis, combining orientation estimation and tracking.



Figure 1: Instrumented force shoe: in orange the inertial sensors; left from them, the force sensors

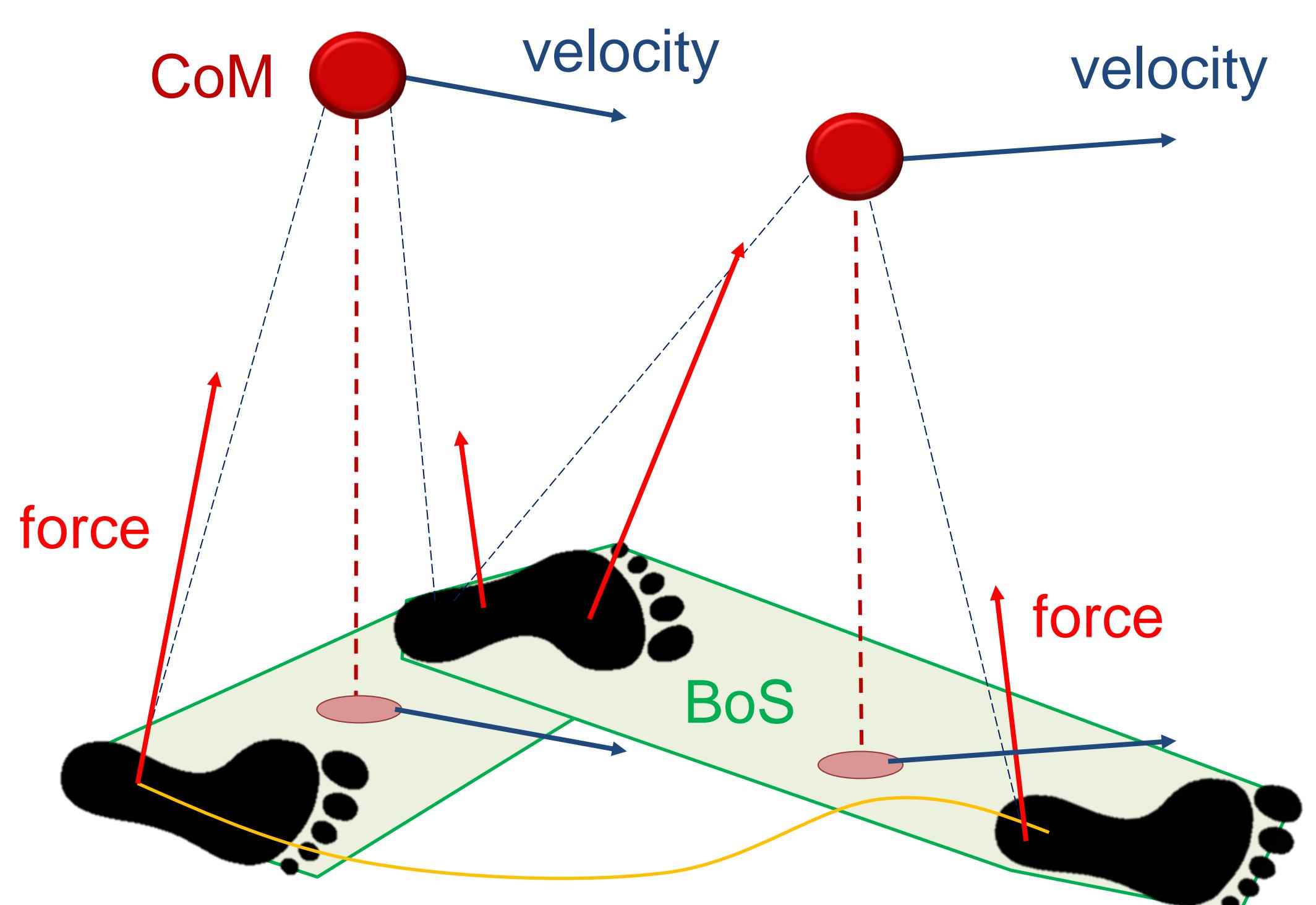


Figure 2: Position and velocity of CoM related to the relative foot positions

Methods

- In order to estimate the relative foot position, we used the Xsens (Enschede, the Netherlands) MVN Biomech system. Which is an unobtrusive movement analysis system [4] (figure 3-left).
- Position information was estimated using all 17 inertial and magnetic sensors in combination with Xsens' software package: MVN studio Pro (figure 3-middle).
- Three healthy subjects walked straight and curved paths which were already marked on the ground.
- Subjects were allowed to walk at their own preferred speed (while wearing MVN Biomech and the instrumented force shoes).
- A Vicon system, an optical tracking system, was used as a reference system (figure 3-right).

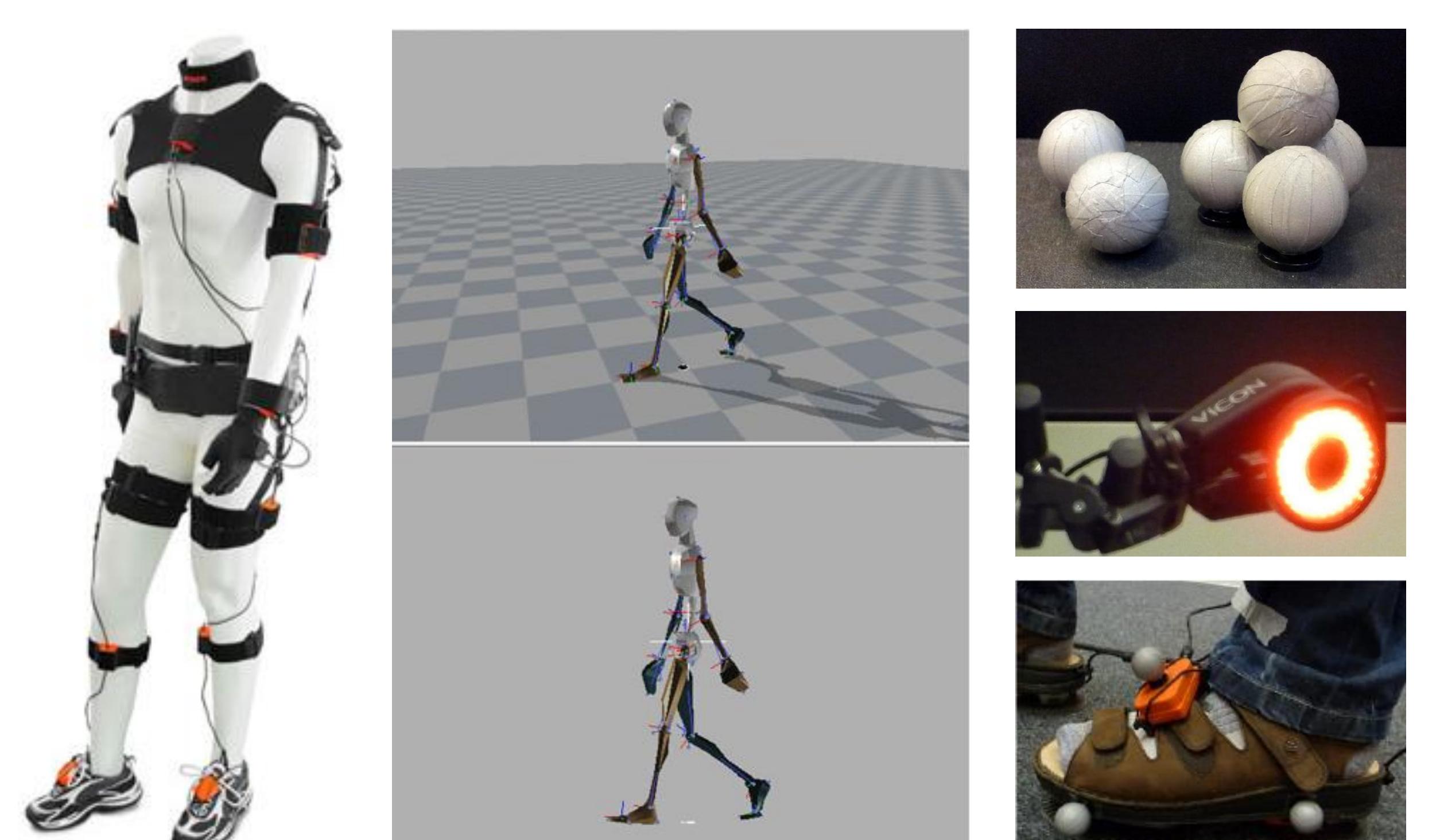


Figure 3: left, the Xsens MVN Biomech system; middle, representation of a walking person made using Xsens MVN Studio Pro; right: the optical reference system attached to the instrumented force shoe en the foot sensor of the MVN system



ent of body balance in an ambulatory setting

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Results

- In figure 4, position data of single trials is plotted for a subject walking a straight path (upper) and walking a curved path (lower).

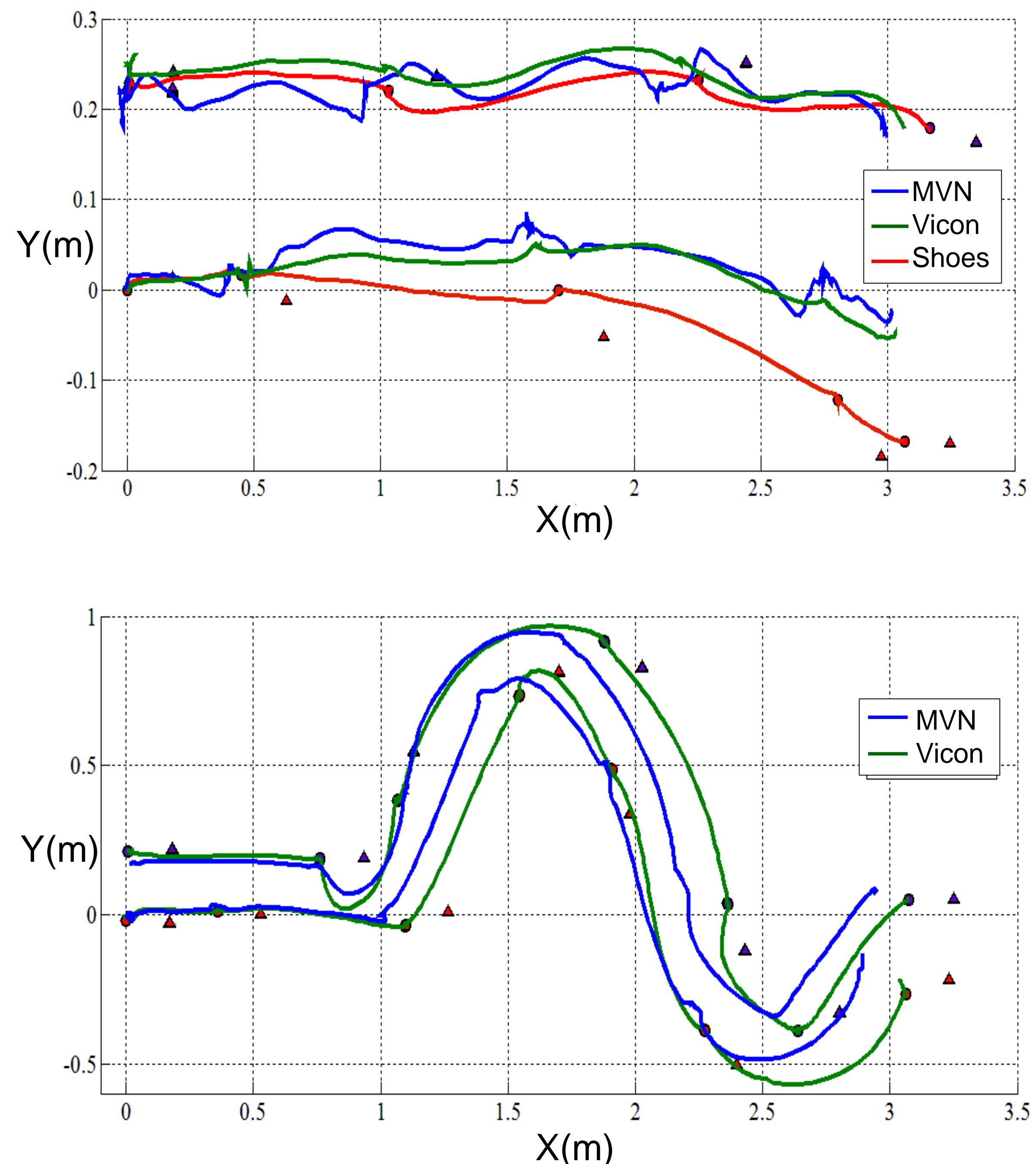


Figure 5: Subject walking a straight path (upper) and curved path (lower) while wearing MVN Biomech, the instrumented shoes and Vicon

- The results of the measurements with the MVN system and the reference system, show a RMS value of 0.048 meters of the relative foot positions during the double stance phase.
- The variance of the heel-heel distance estimated with the MVN system and the reference system increases along with the increase of the average heel-heel distance.

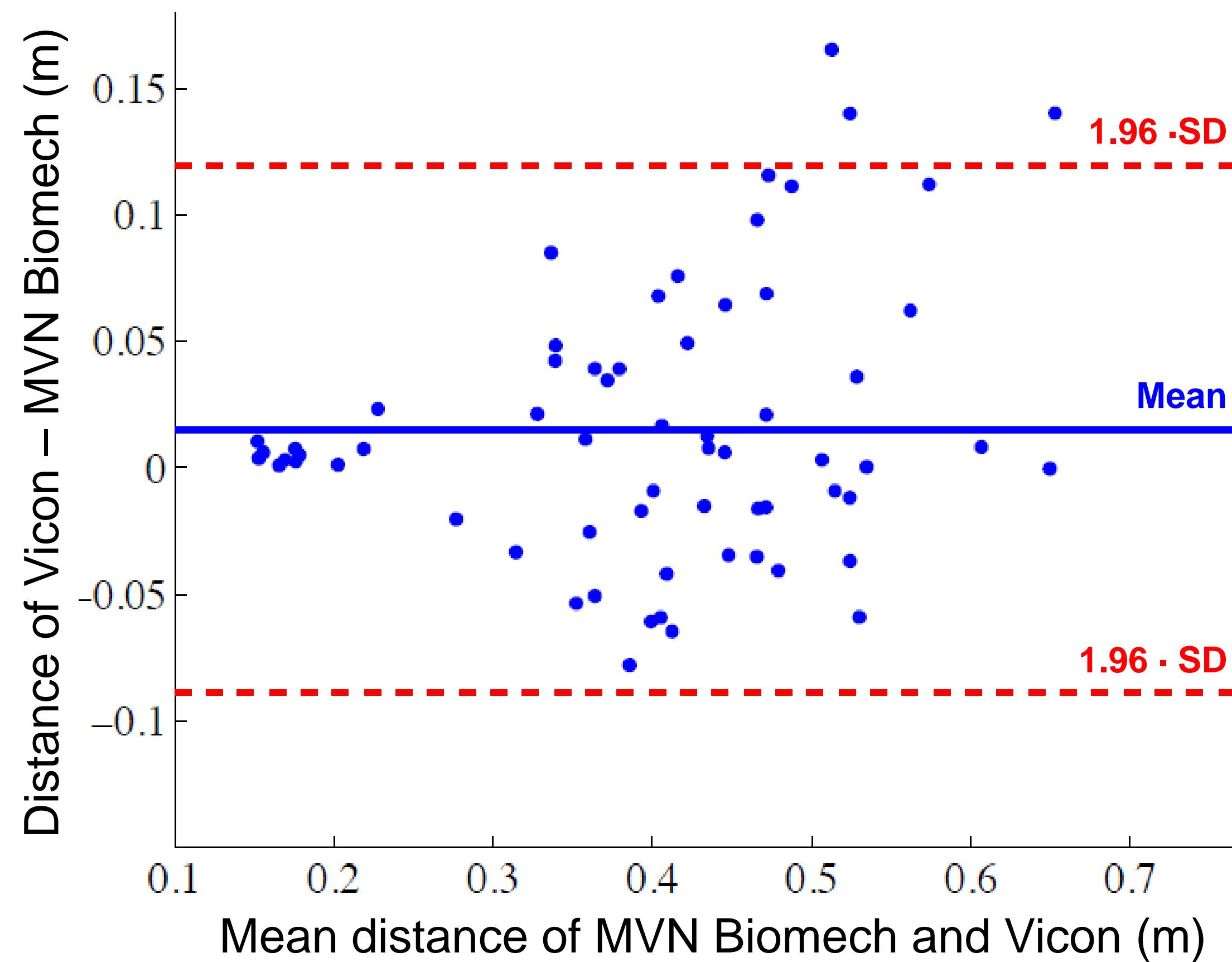


Figure 6: Bland-Altman plot, the average distance versus the difference of both systems, at the double stance phase, during a curved path walk

Conclusion

- The estimates of the relative foot positions with MVN Biomech will be of added value to the instrumented force shoes, when used in combination. The MVN Biomech system is currently just accurate enough.
- Using both systems, quantitative and qualitative parameters of walking [5] could be estimated in an ambulatory setting.
- The instrumented force shoes need to be redesigned to make them applicable for measurements during daily-life as an ambulatory measurement system.
- Further developments of the instrumented shoe could make it possible to directly estimate the relative foot positions without using the MVN Biomech system.

References:

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- [2] Kuo et al. *Phys Ther.* 2010
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- [4] Roetenberg et al. *Xsens Motion Technologies BV, Tech. Rep.* 2009.
- [5] Martinez-Ramirez et al. 2012, Submitted

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