Ambulatory Estimation of Relative Foot Positions using Ultrasound

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Introduction

The instrumented shoes (Figure 1) can be used for ambulatory assessment of walking kinetics and kinematics [1], which is important for the assessment of balance (Figure 2).

Figure 1: Xsens ForceShoe (Xsens Technologies B.V. [2]), containing two 6D force/moment sensors and two inertial sensors.

The relative position of the feet is currently not measured directly but estimated from double integration of feet accelerations. However, this method immediately leads to large position errors (drift) when the estimated inertial accelerations are inaccurate.

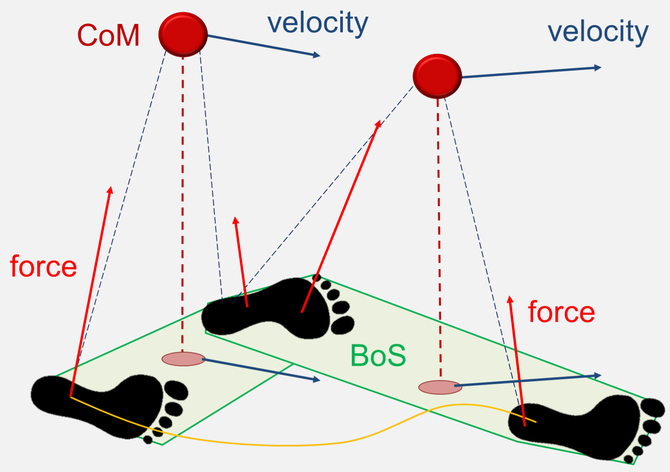

Figure 2: Qualitative parameters of balance; position and velocity of centre of mass related to the relative foot positions and borders of base of support.

Goal

The goal is the ambulatory estimation of the relative positions of the feet using ultrasound transducers.

Methods

On one shoe we mounted a 400PT120 Air Ultrasonic Ceramic Transducer (13 mm diameter, 10 mm height, 85° beam angle) sending a 40 kHz pulse to a similar transducer on the other shoe. Using the time of flight, the distance is estimated.

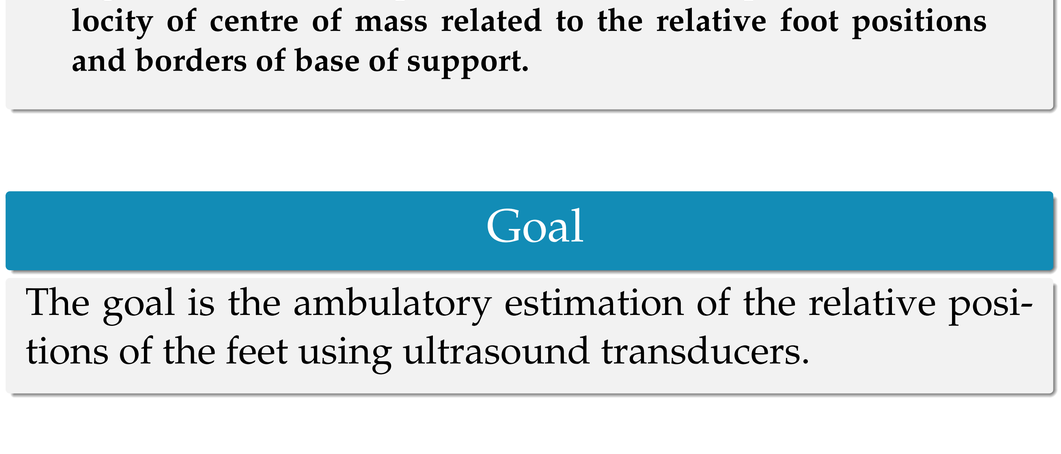

Figure 3: Measurement setup.

Results

Under static conditions the average mean absolute error across the range is 5.7 ± 0.8 mm. Below 40 cm, this error drops to 1.3 mm (Figure 4).

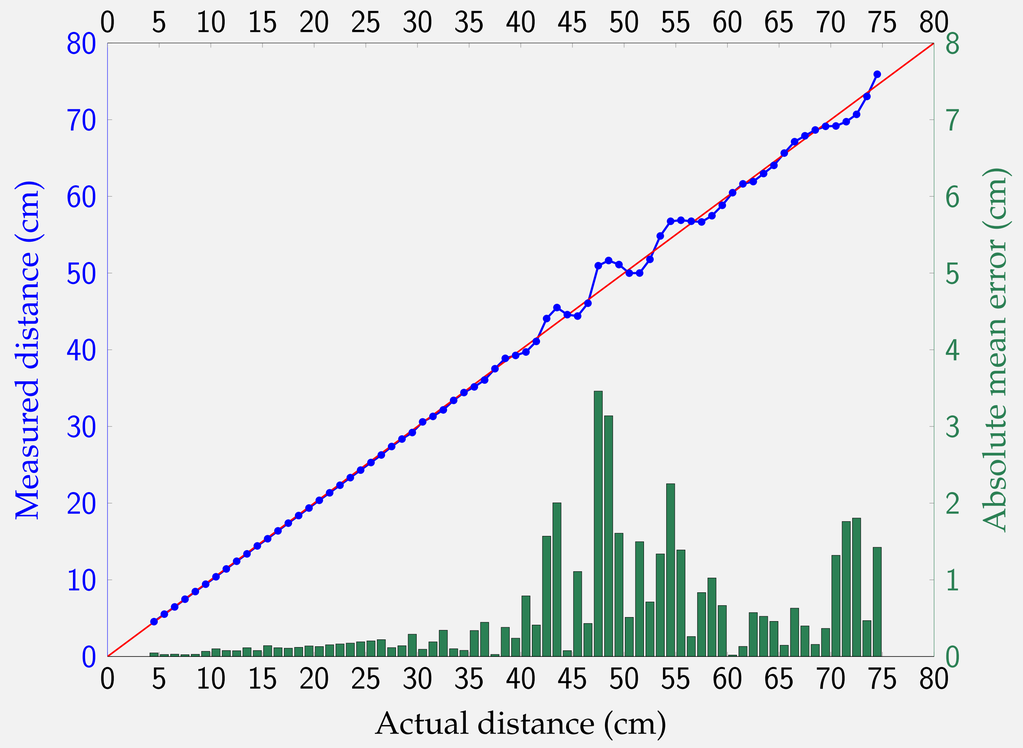

Figure 4: Actual distance (—) versus measured distance (•), together with the mean absolute error at each distance (▬).

The entire system consumes approximately 0.36 W and weighs less than 130 g. The measurement frequency is about 5 Hz [3].

Conclusions and future work

From this pilot study we concluded that the distance between the feet can be estimated ambulatory using small and low-cost ultrasound transducers.

Future research includes the improvement if the distance estimates in the 40-80 cm region. Also the relative positions of the feet will be investigated by fusing the distance estimates with inertial sensor data.

Acknowledgment

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References

[1] H. M. Schepers, "Ambulatory assessment of human body kinematics and kinetics," *PhD thesis, University of Twente*, 2009.

[2] "Xsens Technologies B.V. website," http://www.xsens.com, january 20, 2013.

[3] A. A. G. Geessink, B. Verstoep, F. J. van der Hoek, and M. van der Coelen, "Happy feet," *Electrical Engineering B2 project, University of Twente*, 2012.