AMBULATORY MEASUREMENT OF GROUND REACTION FORCE AND ESTIMATION OF ANKLE AND FOOT DYNAMICS

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INTRODUCTION

Traditionally, human body movement analysis is done in so-called 'gait laboratories'. In these laboratories, body movement is measured by a camera system using optical markers, the ground reaction force by a force plate fixed in the floor, and the muscle activity by EMG. From the body movements and ground reaction forces, joint moments and powers can be estimated by applying inverse dynamics methods. However, the main drawback is the restriction to the laboratory environment. In order to overcome this lab restriction, several research groups try to develop ambulatory measurement systems (e.g. [2]). This study presents an ambulatory measurement system for the measurement of the Ground Reaction Force (GRF), and the estimation of ankle and foot dynamics.

Figure 1: Picture of the instrumented shoe.

METHODS

The measurement system consisted of an orthopaedic sandal with two six degrees-of-freedom force/moment sensors beneath the heel and the forefoot (Figure 1). The position and orientation of heel and forefoot were estimated using the 3D accelerometer and 3D gyroscope of two miniature inertial sensors (Xsens Motion Technologies, http://www.xsens), rigidly attached to the force sensors. Moreover, a third inertial sensor was attached to the lower leg.

The GRF was measured by the force/moment sensors beneath the shoe. A derivation of the calculation of the dynamics of ankle and foot can be found in [1]. The performance of the developed measurement system was evaluated by comparing the ambulatory measurement system with a reference measurement system, consisting of an optical measurement system (Vicon) and a force plate (AMTI).

During the measurements, a healthy subject wearing the instrumented shoes, inertial sensors and optical markers, was asked to walk repeatedly over the force plate. In order to compare the signals measured with both measurement systems, a global coordinate system was defined with the *x*-axis pointing forward, the *y*-axis to the right, and the *z*-axis upward, resulting in a right-handed orthogonal coordinate system.

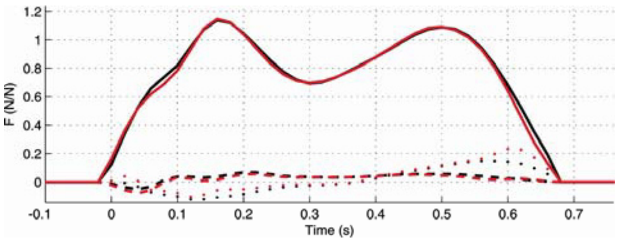

Figure 2: GRF measured by instrumented shoe (red) and force plate (black), *x* dotted, *y* dashed, and *z* solid.

RESULTS AND DISCUSSION

The three components of the measured GRF of a healthy subject are shown in Figure 2. The signals measured with the instrumented shoe show good correspondence with the signals measured with the force plate, which is confirmed by the root-mean-square error between the magnitudes of the GRF, being 0.02 N/N or 1.8 % of the maximal magnitude. Figure 3 shows an integration of the measured GRF with the estimated position of the heel and forefoot sensor. The figure indicates the possibility of the ambulatory measurement system to measure several steps during a single measurement, which is not possible with the reference system. A detailed discussion about the performance of the ambulatory measurement system can be found in [1].

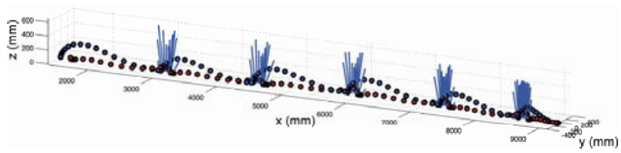

Figure 3: GRF and position of heel and forefoot during several steps. The GRF is indicated by the blue lines pointing upwards. The position of the heel sensor is indicated by the blue dots, the position of the forefoot sensor by the red dots.

REFERENCES

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