# Which way am I facing: Inferring horizontal device orientation from an accelerometer signal

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## Abstract

*We present a method to infer the orientation of mobile device carried in a pocket from the acceleration signal acquired when the user is walking. Whereas previous work has shown how to determine the the orientation in the vertical plane (angle towards earth gravity), we demonstrate how to compute the orientation within the horizontal plane.*

*To validate our method we compare the output of our method with GPS heading information when walking in a straight line. On a total of 16 different orientations and traces we have a mean difference of 5 degrees with 2.5 degrees standard deviation.*

## 1. Introduction

The work described in this paper is part of a larger effort of our group to facilitate the use of standard sensor enabled devices such as a mobile phone for context recognition. A major issue that has to be considered is the fact that users carry such devices in a variety of ways. In general neither the location (pocket, belt, bag) nor the orientation of the device can be assumed to be known. In previous work we have demonstrated how to detect where on the body the device is located by analyzing the accelerometer signal during various activities [3]. We have also shown how to deal with sensor displacement [4]. In this paper we show how to infer the orientation of the device with respect to the user's body. We extend existing work by [5] that has shown how the orientation in the vertical plane (angle towards gravity) can be computed by inferring the orientation in the horizontal plane. Our method is based on the observation that while walking, the most variations in the horizontal plane of the acceleration signal will be parallel to the direction of motion. To distinguish between front and back we look at the integral of the signal over time.

We focus on the trouser pocket, as it is by far the most likely placement for peoples mobile phones(see [2]). This work is partially inspired by [1].

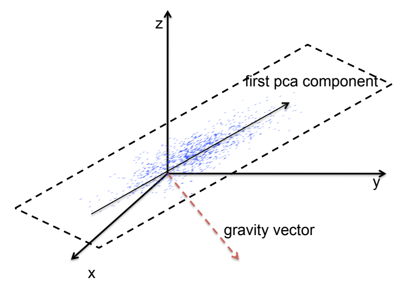


Figure 1. Accelerometer coordinate system in relation to the gravity vector (vertical component) and the walking direction infered using pca.

## 2. Approach

We base the approach on three assumptions:

- The user walks facing forward.
- The device is placed in a trouser's pocket. Our approach should also yield similar results on the persons torso or similar on-body placements. However, we did not test them in this paper.
- We apply our approach on a walking segment in which the user walked fairly straight.

As already described by Mizel [5], one can estimate the gravity vector component of a 3-axis accelerometer. We use a slight variation of this method to get the acceleration axis parallel to the persons torso: We apply a sliding window over over all 3 axis. If the variance of all axis is close to 0 and the magnitude approaches 9.81 $m/s^2$, the signal is very likely to be dominated by the vertical orientation component.

Using this heuristic, we infer the vertical component. Now we project the accelerometer signal in the plane perpendicular to the vertical gravity vector (=horizontal plane). We apply principle component analysis on the projected data points (see Figure 1) to get the direction where the acceleration variations is greatest. This is the axis that is parallel to the walking direction. Assuming that the user is walking forward, integration over the component will allows us to determine which way is front (leads to positive integral)

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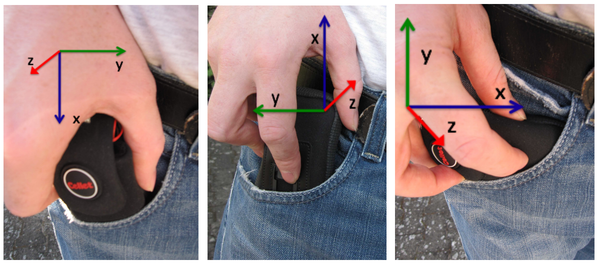


Figure 2. The Mtx motion sensor in the phone casing placed in the pocket depicted with the different axis orientations.

and which is back (see Figure 3).

## 3. Experimental Setup

We test the approach described above with following setup. We use a MTx motion sensor (equipped with 3-axis accelerometer, gyro and magnetic field) with a custom bluetooth sender placed in a mobile phone casing as data source for our algorithm. As reference we use a GPS device We stream all data to a Nokia N810 running the context recognition network toolbox[1] for recording and labeling.

Note that in the MTx sensor the magnetic field sensor axes are oriented in parallel to the acceleration sensor axes. This means that if our algorithm can infer the orientation of the acceleration axis with respect to the user's body we automatically have the orientation of the magnetic field sensor with respect to the body. This is equivalent to knowing which way (in terms of longitude and latitude) that the user is facing. If the user is walking forward this direction is also the user's heading. By comparing the heading computed this way with the heading provided by GPS we can verify the accuracy of our method for determining the horizontal orientation of the sensor.

Two test subjects walked a straight path outside (around 30 meters) with the MTx sensor in the right trouser pocket and the GPS in hand. We repeat this experimental setup 8 times per person changing the sensor orientation each time. We pick only 8, as comparing the device with a mobile phone, users will most likely no place the device with the thin side facing towards the body. So we place the phone casing with the sensor in the right trousers facing front rotating it always 90 degrees for the following experimental trial (the same procedure with the backside facing front), leaving us with 8 distinct orientations.

Three of the 8 orientations are shown in Figure 2.

## 4. Results

Using the approach presented above, we can reliably detect the side of the sensor facing in walking direction for all

1. http://crnt.sf.net

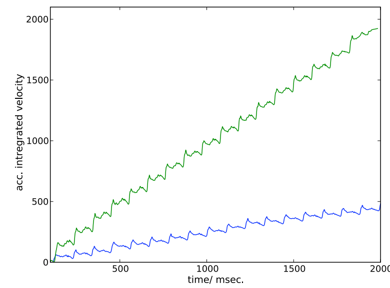


Figure 3. The accumulated integrated velocity of the first pca component direction for 2 trials with different sensor orientations, one in which the test subject was walking slowly (blue) and fast (green).

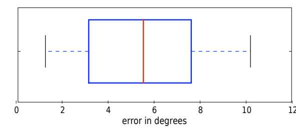


Figure 4. The errors between the accelerometer and gps based approaches, mean at around 5 degrees with a standard deviation of 2.5 degrees.

of the 16 experimental trials. Figure 3 shows an incremental integration over the principal component acceleration axis for a person walking slow (blue graph) and walking fast (green graph) with different sensor orientations.

Comparing now the rotation angles using the two complimentary methods to calculate them for all 16 trials, we get a mean difference of 5 degrees with a standard deviation of 2.5 degrees, as depicted in Figure 4.

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