Dead Reckoning from the Pocket

Abstract
We present a novel approach to enable dead reckoning in a scenario with unconstrained placement of a device in the user’s trouser pockets. Utilizing the rotation of the device due to body motion, we estimate the user’s walking direction robustly to different placements in the pocket and without additional body-worn sensors.

Keywords
pedestrian dead reckoning, location awareness

Introduction
Dead reckoning (DR) presents an interesting, incremental positioning modality, complementary to absolute positioning by GPS or WiFi of modern mobile phones. To enable positioning with a DR approach, we need both detection/estimation of steps and an estimate of motion direction. To enable step detection, most pedometer applications rely on body affixed sensors on a specified body position; existing DR solutions (e.g. [3, 6, 7]) depend additionally on a known stable sensor orientation on the body for direction estimation.

In contrast, we allow unconstrained placement in the trousers’ front pockets, which is a common location for carrying a mobile phone, especially for young males [2]. Due to phone and pocket shape the device orientation in the pocket is mostly stable and the motion/rotation is coupled with the thigh motions [1,4], making it a promising place for a DR approach.
Approach
In our experiments we fitted XSens MTx sensors—which provide inertial data as well as a global 3-D orientation estimate for the sensor—vith a battery and Bluetooth module to a mobile phone sized package, and placed them loosely in the trouser pockets. To estimate direction, we exploit the coupling between the rotational motion of the thigh and a device in the trouser pocket, since the latter exhibits also a rotation axis approximately orthogonal to the motion direction. To be independent of the particular device placement in the pocket, we use only the difference of global sensor orientations over half a second (approx. 1 step) to extract rotation axis/angle. Subsequently we determine a forward vector from a window of rotation axes and time of foot step, using a fixed step length currently. To detect footsteps we found the variance of acceleration in the global Z-axis to be a good feature, even benefiting from rocking due to loose pocket placement.

Results
In initial experiments we confirmed, with additional sensors on the legs, a general correlation of rotations of a pocket placed device and the thigh. For ground truth more exact than GPS, we implemented a DR approach with a dorsally mounted sensor, yielding results comparable to commercial solutions [6]. In Fig. 1 we show results of a complex track, while Fig. 2 presents two runs on a longer track, both with the sensors freely placed in the pockets. Table 1 shows as error measure the mean and 75 percentile for absolute deviations per double step (one foot’s heel down to heel down) to ground truth. The obtained relative errors of 5-15% are promising, even on the complex Garden trace and similar on further tracks with different trousers/device orientations. Compared to the error by fixed step length (to be addressed by a step length estimation), the directional error is clearly the dominating error source, introduced e.g. by interfering rotations of the sensor around the front facing body axis and sensor inaccuracies. Besides obvious problems with single steps, starting/stopping poses no difficulty.

<table>
<thead>
<tr>
<th>Track</th>
<th>deviation per double step (1.57m)</th>
<th>diectrical error</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>in cm</td>
<td>directional</td>
</tr>
<tr>
<td>Garden</td>
<td>12.5[19.9]/23.4[46.5]</td>
<td>5.8°[9.3°]/9.4°[17.2°]</td>
</tr>
<tr>
<td>Park1</td>
<td>17.6[21.0]/13.6[20.7]</td>
<td>8.4°[11.3°]/6.2°[7.9°]</td>
</tr>
<tr>
<td>Park2</td>
<td>11.7[17.5]/8.5[11.2]</td>
<td>5.2°[7.4°]/4.6°[4.8°]</td>
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</tbody>
</table>

Conclusion & Outlook
The poster shows the promise of dead reckoning based on global orientation features, using solely a device placed freely in a trousers’ front pocket. Generally, it could help as an incremental sensor to improve positioning from absolute position sensors outdoors [5], also in combination with map matching to counteract directional errors. Another promising direction is the extension to indoor environments, alone or in combination with WiFi/ BT-positioning, where a single sensor location would be beneficial for unobtrusive long term logging of user location, in scenario such as [4], but only from the pocket, and avoiding extensive training as in [1].

References