GiPStech *WalkSense* Technology

PDR Engine - Brief description

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CONFIDENTIALITY

EXECUTIVE SUMMARY

This document is a short overview of the GiPStech proprietary *WalkSense* PDR engine.

Document Updates

Date	Rev.	Author	Change Reference
01/10/2015	0.1	L. D’Alfonso	First release
15/10/2015	0.2	G. Fedele	General review
20/10/2015	0.3	L. D’Alfonso	Created section 3 – General Architecture
15/10/2015	0.4	G. Fedele, L. D’Alfonso	Updated section 2.4
10/11/2015	0.5	G. Cutri	Final release
20/12/2015	0.6	G. D’Aquila	Approved

Summary

1 Summary

The GiPStech proprietary core inertial technology is available under the product name "*WalkSense*" that embed a full PDR (pedestrian dead-reckoning) engine comprising five main sub-modules:

1. ATTITUDE ESTIMATOR;
2. WALKING DIRECTION ESTIMATOR;
3. STEP DETECTOR;
4. STEP VALIDATOR;
5. STEP LENGTH ESTIMATOR.

2 Inertial Modules

2.1 Attitude Estimator

Let O_{xyz} be an absolute North-East-Down (NED) reference frame, formed by a z-axis aligned with the gravity vector, an x-axis pointing to the North and a y-axis orthogonal to the other two axes.

Let O'_{uvw} be a reference frame placed on a device body (smartphone) and the axes of which aligned with the device inertial sensors axes.

The ATTITUDE ESTIMATOR provides an estimate of the relative rotation from the body reference frame (or smartphone frame, right part of the following figure) to the NED reference frame (left part of the following figure).

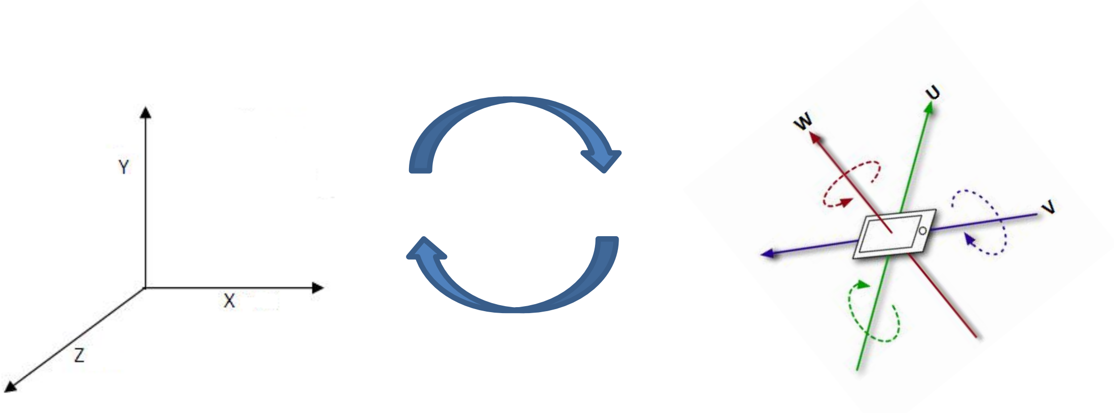

Figure 1 - NED frame (left) and body or smartphone frame (right)

The estimate can be provided in the quaternion-based notation, Euler angle (roll, pitch, yaw) notation and rotation matrix notation.

The attitude estimator provides continuous estimate with **high accuracy** regardless of any **geomagnetic anomalies** typically present in closed spaces.

2.2 Walking Direction Estimator

Let $O'_{x'y'z}$ be the user reference frame, formed by a z-axis aligned with the gravity vector, an x'-axis pointing to the direction of movement of the user and an y'-axis chosen to comply with the right-hand rule.

Using the attitude provided by the ATTITUDE ESTIMATOR module, the phone reference frame can be rotated on the plane orthogonal to the gravity axis. The resulting rotated phone frame exhibits a w-axis aligned with the z-axis and a couple uv-axes rotated with respect to the xy-axes of an angle θ (yaw angle in the Euler-angles-based notation). By defining the moving plane is the plane orthogonal to the z-axis, the user walking direction is represented by the angle α between the u-axis, rotated on the, moving plane and the x'-axis of the user reference frame.

The WALKING DIRECTION ESTIMATOR provides an estimate of the α angle whatever it is the phone attitude. The sum of the α angle plus the θ angle allows estimating the full walking direction referenced to the North (magnetic or geographic).

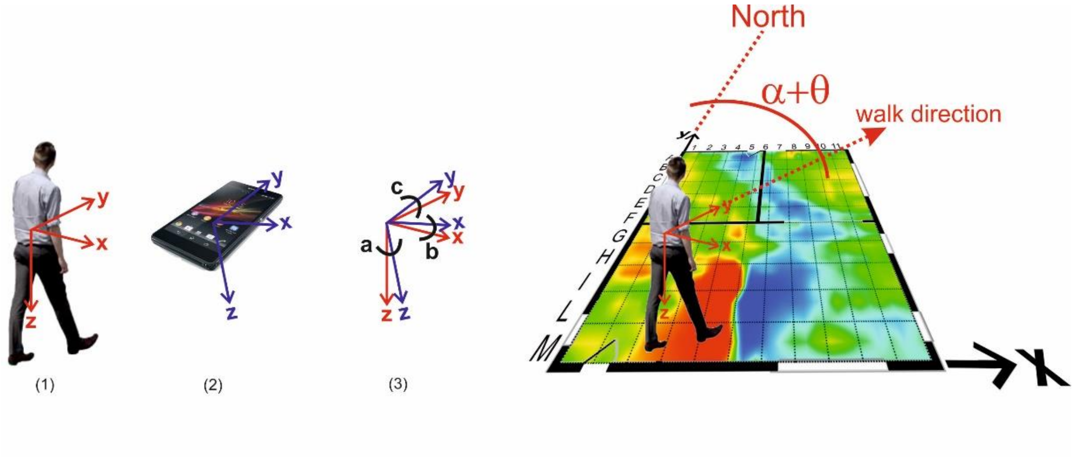

Figure 2 – Reference frames

2.3 Step Detector

The STEP DETECTOR module provides in real time information about the device user walking steps.

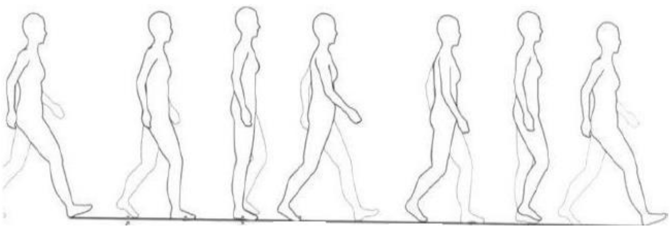

Figure 3 - Step detection

More precisely, the module examines the waveform of the measured inertial signals and it detects each starting and ending step time. Differently form other such modules that perform step detection and counting by attaching the device into a specific position, the STEP DETECTOR performs under any device configuration/attitude and specifically both with phone hand-held or in a pocket or bag.

The STEP DETECTOR provides step detection capability in real time.

2.4 Step Validator

The STEP VALIDATOR module uses as input steps information provided by the STEP DETECTOR module and processes them with the aim of classifying false-steps.

Under normal use phone movements are in fact not necessarily related with walking activity, with resulting inertial signals inducing the STEP DETECTOR to wrongly classify some movements as steps (false step detection). False steps may occur when the user gesticulates with the phone in hand or moves on the spot.

The STEP VALIDATOR module is able to discard with great accuracy false steps so that the combination of STEP DETECTOR and STEP VALIDATOR provides an estimate of real steps only relating to the user walking movements (Fig.4).

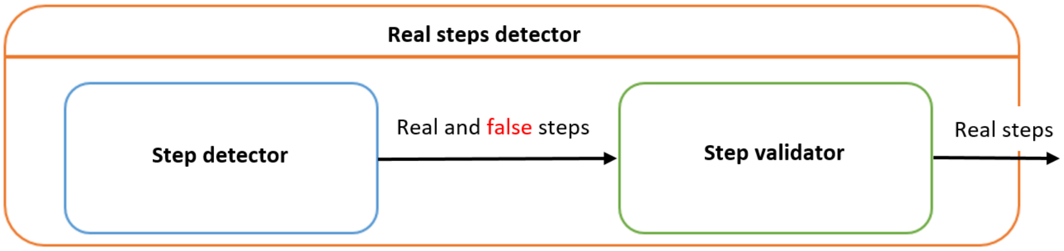

Figure 4 – Step detection and validation

The STEP VALIDATOR is a real-time module that works on variable parameters that can be optimized on the habits and walking patterns of specific populations.

2.5 Step Length Estimator

The STEP LENGTH ESTIMATOR module provides information on length of each user step in real time during user walking activity.

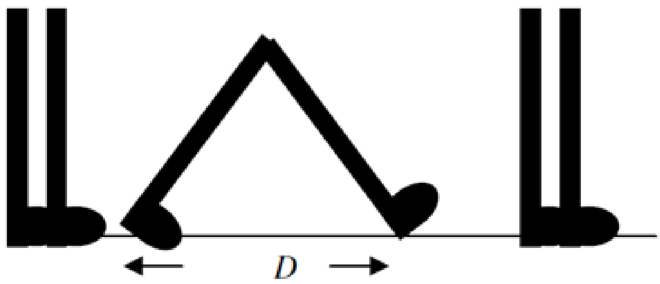

Figure 5 – Step length estimation

Referring to the above figure, the module provides an estimate of the distance *D* covered at each step by the user. The estimation is completely independent from the user height, the walking speed, the type of phone and the phone attitude. Moreover it is able to provide an estimate also for small real distances *D*.

3 GiPStech *WalkSense* Technology

The five inertial modules above described work largely independently, but jointly concur to build a coherent PDR technology, improving the resulting performances of GiPStech WALKSENSE TECHNOLOGY.

The modules connections in the overall WALKSENSE TECHNOLOGY are plotted in the below figure, where an arrow from module A to module B implies that the output of module A is used by module B as an input.

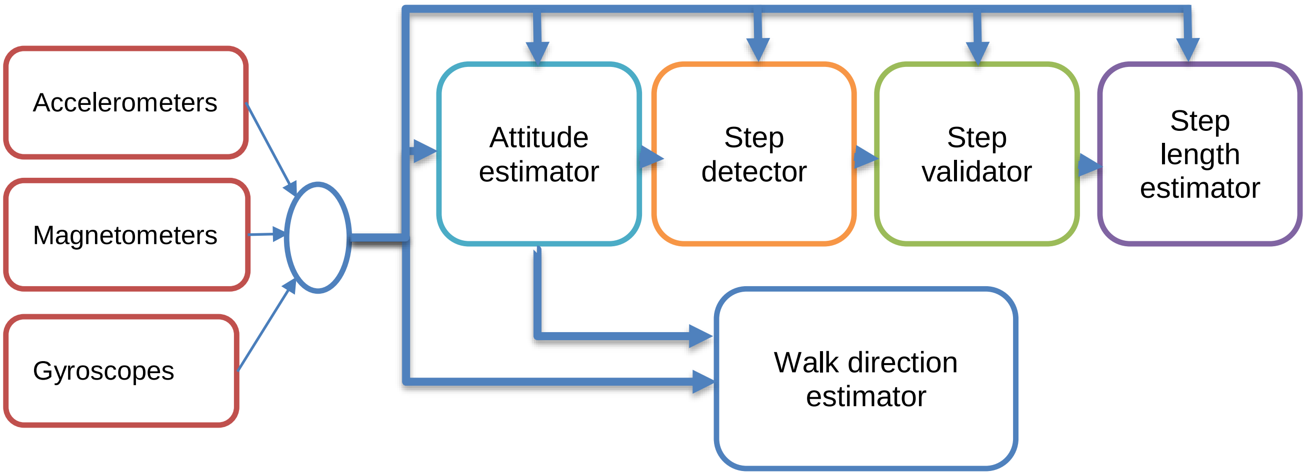

Figure 6 –GiPStech WalkSense Architecture

By properly combining all the estimates provided by the five inertial modules jintly, an estimate of the trajectory performed by the user is obtained. The user trajectory is fully estimated excep for the initial user position.

The following picture plots a closed trajectory performed by a user during an independent test. The left part is estimated without the walking direction correction and the right part also takes into account the walking angle. The following chart also shows the detected steps.

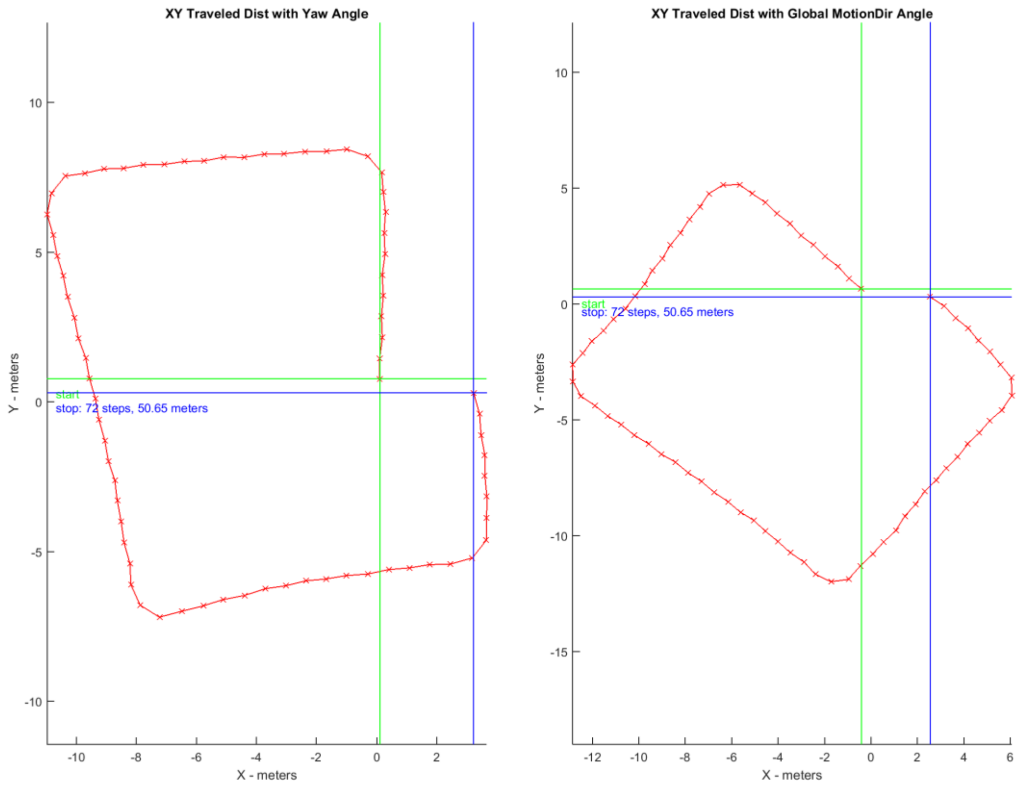

Figure 7 - Inertial Trajectory estimation

GiPStech WALKSENSE TECHNOLOGY has been tested under multiple circumstances by company officials and third parties, always providing excellent results compared to alternative available solutions.