A hybrid/geomagnetic field indoor localization technology *

G. Cutrí
GiPStech s.r.l, Italy
g.cutri@gipstech.com

L. D'Alfonso
GiPStech s.r.l, Italy
l.dalfonso@gipstech.com

G. D'Aquila
GiPStech s.r.l, Italy
g.daquila@gipstech.com

M. Faggin
GiPStech s.r.l, Italy
m.faggin@gipstech.com

G. Fedele
D.I.M.E.S.
University of Calabria, Italy
giuseppe.fedele@unical.it

ABSTRACT

The request for accurate and inexpensive indoor localization techniques to run on consumer electronic devices (i.e. smartphones) has attracted the attention of much research over the last decade resulting in a number of different promising approaches. While solutions based on cellular signals have not successfully solved the problem of insufficient accuracy, the use of IEEE 802.11 wireless networks, i.e. Wi-Fi, has been widely adopted for real-time indoor localization purposes. The rapidly growing usage of Wi-Fi access points as navigation beacons is, among other reasons, due to their ubiquitous availability and to their intended compatibility with smartphones. Received Signal Strength Indication (RSSI) values of several Wi-Fi access points are used to determine current position of a receiver [3, 4]. The advent of cheap Bluetooth low energy (BLE) beacons, a.k.a. iBeacons, is among other usage favoring their use for the same purpose. Regardless of the beacon type and of localization algorithm, absolute indoor localization methods rely on a dense beacon mesh to allow for accurate localization. Indeed, along with a generally low reliability of RSSI-based approaches, these techniques require a dense infrastructure and their performances are strongly related to the quality (number, density, etc.) of the measured signals. For example, if the environment is equipped with an infrastructure intended for other uses and not properly set-up to guarantee a full signal coverage, the localization accuracy is typically drastically compromised. Other solutions are based on geomagnetic signal fingerprinting (more details below). These methods do not use any installed infrastructure, relying on a naturally present vector signal, but suffer from low reliability as the geomagnetic field repeats itself in multiple locations. Further localization solutions are based on inertial data and pedestrian dead reckoning algorithms [2]. Although these techniques have not infrastructure requirements since they use information local to the device, they result largely ineffective due to the initial condition determi-

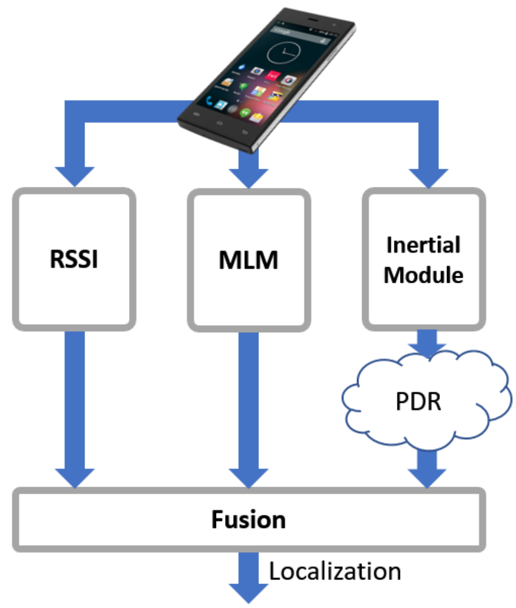

Figure 1: Localization algorithm diagram

*(Produces the permission block, and copyright information). For use with SIG-ALTERNATE.CLS. Supported by ACM.

IPSN 2017 April 18–21, 2017, Pittsburgh, PA, USA

DOI:

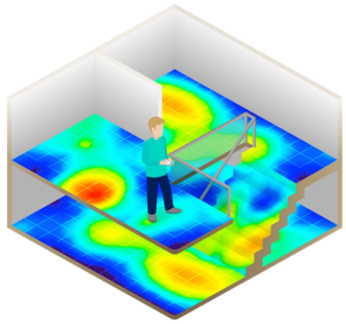

Figure 2: Environment magnetic field map 2-D rendering

nation and the integration error accumulation on long paths. The technique hereby described can be used on a commercial smartphone and/or other smart hardware with no further requirements on auxiliary infrastructure and it is based on the fusion of an *a-priori* absolute information about the environment and the relative motion data from sensor units. The localization algorithm scheme is summarized in Fig. 1. To achieve effective and precise localization the method combines complementary localization algorithms of dead reckoning, geomagnetic signal fingerprinting and opportunistically other RSSI signals possibly existing in the environment. The earth's magnetic field resembles that of a simple magnetic dipole [1]. The lines forming this magnetic dipole start at a point near the south pole and terminate at a point near the north pole. The above points are usually referred to as the magnetic poles. These field lines vary in both strength and direction about the earth surface but they can be assumed to be locally constant. However, in an indoor context, like a building floor or room, due to the presence of ferromagnetic elements (electric cables, reinforced concrete, etc.), the magnetic field varies depending on the position where it is measured. The main idea behind a fingerprinting geomagnetic based localization technique is to use the above local variations and anomalies of the geomagnetic field to infer information on the mobile device position. To this end, the localization algorithm requires a preliminary mapping step in which the magnetic field is acquired and related to the physical position to provide an environment map with magnetic fingerprints, see Fig. 2. This step can be easily accomplished by walking, in a systematic way, on known paths in the environment while acquiring magnetic measurements. In the proposed method this initial phase has to be performed only once and the map holds validity for all subsequent uses, also with different devices, as it is appropriately normalized. The proposed Magnetic Localization Module (MLM) consists in a fingerprinting-based technique: when a magnetic measurement is acquired, it is compared with the fingerprints stored into the map and a first position estimation is given by the place related to the fingerprint nearest to the measured magnetic field.

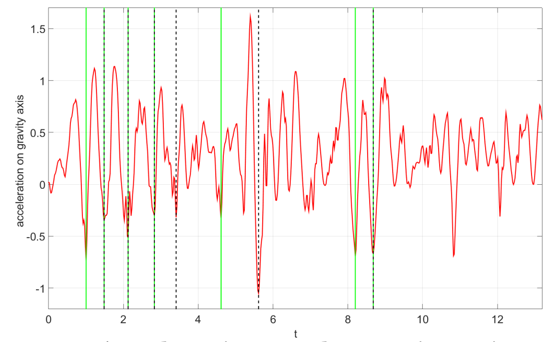

Figure 3: Acceleration on the gravity axis: green lines are step starting time instants, black dotted lines are steps ending time instants. 6 steps have been detected and classified as actual ones.

A second position estimation is provided by the inertial based and the pedestrian dead reckoning (PDR) modules. In particular, these modules detect motion and estimated orientation starting from the measurements provided by an inertial measurement unit, emphasizing the step information provided by the acceleration data if they are projected on the gravity axis (see Fig. 3) and discarding false steps and related data. The proposed solution fuses magnetic field based localization and the inertial estimated position using a patent pending approach. Moreover, if a RSSI signal is present inside the building where the system is used, it can be fused too improving localization performance (RSSI module). The main advantage of the proposed algorithm is that it uses signals always available with no specific requirements about installation of any infrastructure. The above solution has been implemented in demo and commercial applications on selected smartphones, in different indoor environments including offices, museums and shops. It was found to achieve high accuracies compared with existing technologies. This combination of accuracy and low cost of infrastructure has been deemed interesting from multiple parties to become the technology base for a variety of new navigation and context-aware applications.

1. REFERENCES

[1] R.H. Good and T.J. Nelson. *Classical Theory of Electric and Magnetic Fields*. Elsevier, 1971.

[2] A. Noureldin, T.B. Karamat, and S. Georgy. *Fundamentals of Inertial Navigation, Satellite-based Positioning and their Integration*. Springer-Verlag Berlin Heidelberg, 2013.

[3] J.F. Sanford, M. Potkonjak, and S. Slijepcevic. *Localization in Wireless Networks*. Springer-Verlag New York, 2012.

[4] Y. Xu. *Autonomous Indoor Localization Using Unsupervised Wi-Fi Fingerprinting*. University press kassel, 2015.