Steps – An Accurate Relative Positioning Method for First-Responders

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***Abstract*—Consider the case of fire-fighters rushing into a burning building. A navigation system for such case is required to be both robust and accurate. Naturally such system can not be based on visual navigation as the smoke allows only limited visibility, moreover, such system can not relay on RF finger-printing as the map of building might not be present or simply change significantly due to the fire (e.g., electric-break). In this work we present a foot-mounted navigation system designed for first-responders, the system works as a standalone $3D$ positioning system. The presented method requires no personal calibration, works autonomously and is very light weight. The system is composed from a single foot mounted device which can accurately approximate the length and the global orientation of each step in real-time. Preliminary simulation and field experiments show that the expected error is smaller than 1% in most real life scenarios.**

I. Introduction

Indoor positioning is an important capability for first-responders. This mission-critical-service should perform well in scenarios which are not suitable for standard positioning technologies, such as: $GNSS$, RF finger-printing, Optic Flow, Visual SLAM, Ultrasound and RF $DTOA$ as the position of each first-responder should be computed regardless of environmental changes (e.g., smoke or changes in the building structure). A common method for such positioning system uses foot mounded pedometer (see [1], [2], [3] for examples for such general systems). Although such solutions were presented by several research-groups in the last two decades - the robustness and accuracy of existing step-counter systems are insufficient for most mission-critical position platforms.

Although there are many different types of applications which require indoor mission critical pedestrian positioning, it seems that the following properties should be optimized with respect to almost any such method:

Accuracy: often the main and foremost parameter which is being tested.

Real-time: for a natural and intuitive positioning results, especially for highly dynamic movements.

Fully standalone mode: the solution should work without any need of mapping or knowledge of existing infrastructure.

Auto path mapping: allowing efficient "follow-me" of "save-me" applications.

Keep It Simple: Simplicity is a key factor: the system should work automatically with no manual overhead operation or calibration.

A. Our Contribution

This paper presents a standalone solution for first-responders' positioning system (see Fig 1). The suggested algorithm is based on a simple yet accurate ranging device which approximate the $3D$ global vector between the two legs - which is accumulate to a $3D$ path. The improved $3D$ pedometer is then fused with barometric sensor to allow an accurate relative path computation while maintaining all the above properties.

II. Relative Positioning Framework

The proposed positioning method is based on a know starting point, such point can be seen computed according to the last $GNSS$ point or event-driven marked starting point (e.g., elevation change point). The approximated position is computed according to the path from the starting point, where the path is simply computed by summation of the steps. Figure 1 shows the first version of shoe-mounted system with duel IMU and range sensors (one for each shoe).

The suggested framework uses the following concept in order to approximate the length and orientation of each step.

1) Global orientation - computed by the device's 9 DoF ($MEMS$-Gyro, $MEMS$-Acc, Manometer), such sensors are common in smart-phones and allow relatively accurate orientation at 100Hz and more.
2) Camera based step length ranging - this sensor utilizes an IR camera (on one leg/shoe) and a set of two (or more) LED lights (on the other leg/shoe). The distance between the camera and the LED lights is approximated by computing the distance ratio between the LED lights in the camera prospective and in reality.
3) Given the orientation of the "rare-leg" and the length from it to the "front-leg" the global orientation between the legs can be computed by transforming the LEDs camera orientation to the global orientation (using the 9 DoF sensor).
4) Instead of having a ranging device on each leg (as in Fig. 1) - we can locate two ranging devices on one leg (one "front-facing" and the other "rare-facing") this will

Fig. 1. The first version of the system: "These boots were made for walking..." yet, the electronics embedded into them were highly sensitive and the measurements were noisy. The system is composed from the following components: $\#1$ a ranging device, $\#2$ few IR-LED targets, $\#3$ Micro-controller with 10 DoF sensors, $\#4$ a $GNSS$ device for testing: compering the approximated path with the Ground Truth (GT).

simplify the system: one leg with the sensors and the other with just LEDs as markers.

5) Due to the nature of walking the global vector between the legs is only computed when they are both stationary.

III. Experimental Results and Demo setting

We have tested the presented algorithm in several use-cases and indoor scenarios both in simulation and using field experiments (e.g., Fig. 2). The overall performance of the algorithm allows (in most cases) sub 1% error - with respect to the path length.

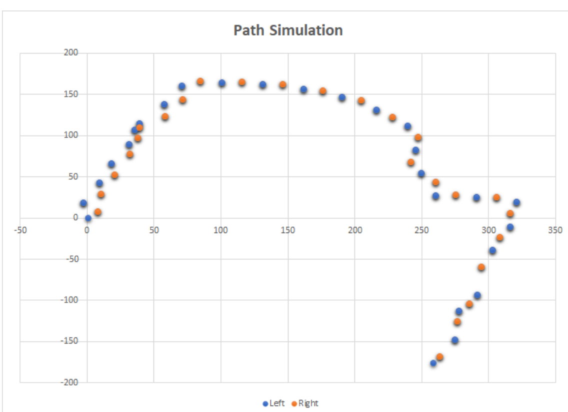

Fig. 2. An example of simulated path which includes a wide range of steps (sideways, front and sharp turns). In this example the overall error rate is smaller than $\%1$.

In the demonstration we plan to use a known (fixed) starting point and compute the $3D$ path from it simply by adding the steps - as a sum of vectors. The results will be available for performance evaluation using a GIS tool which allows a complete accuracy testing.

References

[1] Jimnez, A. R., Seco, F., Prieto, J. C., Guevara, J.. Indoor pedestrian navigation using an INS/EKF framework for yaw drift reduction and a foot-mounted IMU. In Positioning Navigation and Communication (WPNC), 2010 7th Workshop on (pp. 135-143). IEEE.

[2] Krach, B., Roberston, P.. Cascaded estimation architecture for integration of foot-mounted inertial sensors. In Position, Location and Navigation Symposium, 2008 IEEE/ION (pp. 112-119). IEEE.

[3] KRACH, Bernhard; ROBERTSON, Patrick. Integration of foot-mounted inertial sensors into a Bayesian location estimation framework. In: Positioning, Navigation and Communication, 2008. WPNC 2008. 5th Workshop on. IEEE, 2008. p. 55-61.