Localization of Emergency First Responders Using UWB/GNSS with Cloud-based Augmentation

Short Paper

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ABSTRACT

We[1] propose a real-time system for indoor/outdoor localization of first responders in emergency situations based on networking of wearable devices and cloud-based GNSS (Global Navigation Satellite Systems) augmentation. We present outdoor tests that validate this concept. With good network geometry, accuracy of the indoor positioning is similar to the accuracy commonly achieved outdoors by GNSS.

CCS CONCEPTS

• Computer systems organization → Embedded systems • Hardware → Communication hardware, interfaces and storage → Wireless device.

KEYWORDS

Localization, Positioning, Global Navigation Satellite Systems, Ultra-wideband, Wearable, First Responders, Emergency.

1 INTRODUCTION

In many emergency situations (such as fires or terrorist attacks), the safety and effectiveness of operations are hampered by not knowing location of personnel. This is particularly true within large buildings, which could be partially or completely damaged and in smoke. There were more than 3.3 million fires in Europe and USA every year, with more than 35% of structure fires [1]. The rate of firefighter deaths at structure fires is constant over the past 40 years, partially due to untimely tracking of emergency first responders (FR, e.g. firefighters) indoors.

To improve emergency management and deliver valuable field information to incident commanders, we set a goal to build real-time system for localization of FR everywhere and anytime with accuracy on "a meter" level. Emergencies demand localization in seamless and non-distracting way, hopefully without any fixed infrastructure. Thus, we propose networking of the custom wearable devices and ad-hoc localization using multi-technology positioning.

At good sky visibility, standard single frequency GNSS provides position with accuracy 2-7m, and quite often much better. Challenging part is indoor positioning, that is still not standardized concept. Indoor positioning commonly relies on combination of technologies – GNSS, Bluetooth, Wi-Fi, sensors and where reliability and accuracy are paramaunt – Ultra Wide Band (UWB) [2][3]. UWB brings: higher resolution and precision than any other radio, very accurate range measurements, and inherent communication link. Modern off-the-shelf UWB modules provide accuracy of 0.1m (line-of-sight) to 0.5m (non-line-of-sight). Known UWB shortcoming is range up to 300m outdoors (in Europe) since it operates at deep noise to enable co-existence with other radios.

Finally, our wearable devices exploit: a) UWB; b) close to a hundred global navigation satellites; c) Satellite Based Augmentation Systems (SBAS) and corrections from the internet services, such as EGNOS Data Access Service (EDAS)[4]; d) Motion sensors for activity and fall detection.

2 UWB/GNSS WITH AUGMENTATION

If a FR is captured within the building, his wearable device ("TARGET") will trigger localization, especially if it detects fall, absence of motion or use of panic button. Devices use UWB radio (at 3.1-4.2 GHz) for two-way ranging. It is assumed that one or more surrounding, outdoor devices ("ANCHORs") are in UWB range, either carried by other FR or mounted on the utility vehicles or Unmanned Aerial Vehicle for situation awareness.

If UWB link budget is sufficient to penetrate building and reach TARGET device, system will estimate position of the endangered FR by multilateration. Low-cost UWB and GNSS can typically provide 5-20 new measurements per second. Assuming that trapped FR is quasi-static, even single external device can do sequential ranging from multiple outdoor positions, by simulating presence of multiple ANCHORS on "known GNSS positions".

Accuracy of low-cost GNSS receiver is far below the UWB accuracy, so satellite positioning is augmented by EDAS. Wearable devices forward raw GNSS data (pseudoranges) over Bluetooth to a dedicated mobile application, which acts as a gateway to cloud-based augmentation algorithm [5] (Fig. 1). At severe infrastructure damages which affect cellular networks, system will need to locally compute positions.

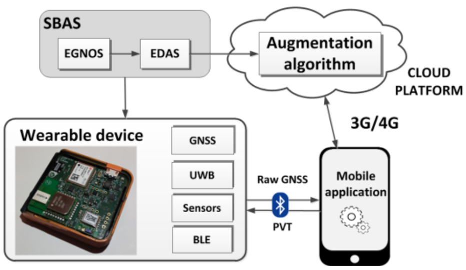

Figure 1: System block diagram.

3 EXPERIMENT AND RESULTS

We evaluated proposed approach in a planar field-test, using custom designed wearable device. Wearable device captures raw GNSS/SBAS carrier phase data and UWB at 5Hz. Achieved outdoor UWB range was 100-120m with usual obstruction by surrounding pedestrians. Indoor range was limited to 12-15m, with standard deviation below 0.1m. ETSI LAES Directive [6] permits use of UWB with 20dB higher transmission power for tracking firefighters in Europe. Consequently, with this modification, UWB radio should increase indoor range above 100m. That is sufficient for reliable and accurate tracing.

Field-testing was at the football stadium of size 68x99m. TARGET device at virtually "unknown position" was placed on a 1.1m-high tripod, right on the center of stadium at (34m; 49.5m). There were two kinds of ANCHOR devices –with the internal GNSS antenna ("A", Fig. 2) and one device with the external near-survey grade GNSS antenna ("B", REF-GNSS). Position of TARGET device was calculated using GNSS positions of ANCHORS and the required coordinate transformations, UWB measurements, and Gauss–Newton method to solve least-squares problem. All measurements were first transferred to the local tangential East-North-Up frame, then to local Cartesian X-Y frame fixed to one of the corners.

Two tests were carried out: "corner test" with ANCHOR devices placed right at the 4 stadium corners; "edge test" where ANCHORS were carefully moved along the edges. Results of the "corner test" (Fig.3 and 4) show key impact of GNSS on final result. Prototype devices were used without any antenna optimizations and fine impedance matching. Final error includes systematic error due to coordinate transforms. At the "edge test", the 7 random GNSS-REF positions of ANCHOR devices along the edge were combined with UWB to estimate TARGET location. The mean position error was 0.34m, which is acceptable.

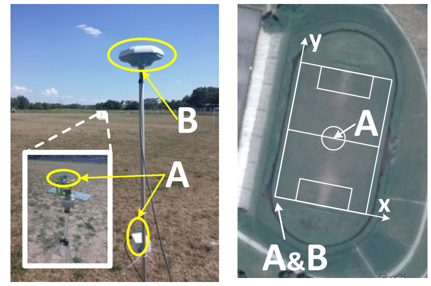

Figure 2: Test setup and configuration.

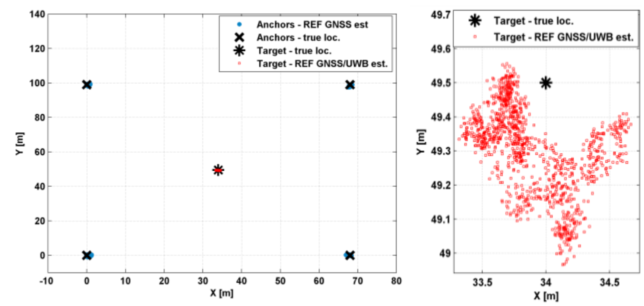

Figure 3: "Corner test" REF-GNSS, right-zoomed.

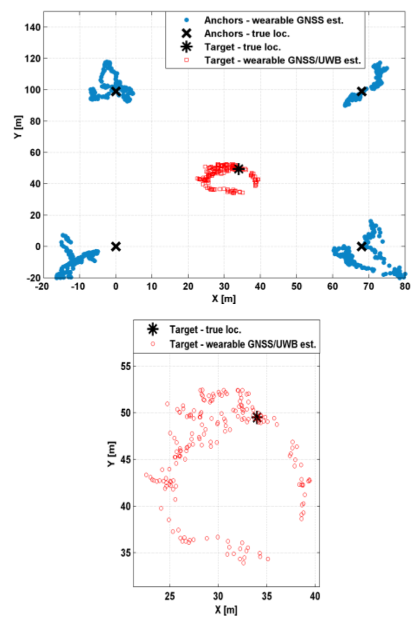

Figure 4: "Corner test" wearable GNSS, right-zoomed.

ACKNOWLEDGMENTS

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