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Air-based multi-hop Sensor network for the localization of persons

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Abstract

In this work an air-based sensor network for the localization of persons at extensive areas is presented. The developed network consists of a localization device which the person is wearing (BodyGuard-System), a mobile relay station in the air, and a base station. All three parts communicate with the same radio chip. The BodyGuard-System is an inertial navigation system which was developed for localization in difficult environments with high accuracy and low measurement uncertainty. To increase the range of the system, a multi-hop network was built up. The measured data of the BodyGuard-System and the mobile relay station is visualized on a PC in the base station. This multi-hop network is necessary for example for fire department missions.

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1. Introduction

In the last years the inertial navigation systems are improved for indoor and outdoor localization of objects or persons. Therefore different projects were started. In cooperation with the FOG GmbH (Germany), BAM Federal Institute for Materials Research and Testing started an approach for the localization of persons at extensive areas, the OMEGa Project [1].

The approach presented in this paper is mainly motivated by a fire department scenario where different missions in extensive areas occur, as for example forest fires, demonstrations, or other operations in extensive areas. Therefore the approach of an air-based multi-hop sensor network was developed. The network consists of a system worn by the members of the emergency service (BodyGuard-System), an aircraft relay station (UAV-MAJA,

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Bormatec, Germany) and a base station. It is important that the developed routing method virtually increases the range of each single node at a low self-transmission range. This point makes the network unique. Due to this approach the position data of each member of the emergency service can be transmitted save and resilient.

In this paper the different components will be explained in the following chapter. In the following, the sensor network and the routing method are presented. For a quantitative evaluation, the advantages and disadvantages are discussed at the end.

2. Air-based sensor network components

In this section the different air-based sensor network components, namely the BodyGuard-System [2], the mobile relay station and the base station are presented. The functionality of the different components is shown. The information is used in the next chapter for better understanding of the approach of the multi-hop sensor network system.

2.1. BodyGuard-System

The BodyGuard-System is a self-developed localization device for indoor and outdoor application and presented in Fig. 1. It is a device which is worn at the hip of the observed person. The BodyGuard-System detects with the use of three 3D-Sensors the position of an object or person. It works with the RF Modul ATZB-900-B0 [5] using the radio chip AT86RF212B [6] at O-QPSK-RC-400 with 100 kb/s head bit rate and 400 kb/s PSDU (PHY Service Data Unit) data rate to improve the transmission quality when there is noise in the air, caused for example by a fire. The position data is measured by the use of a gyroscope, a magnetic field sensor, and an accelerometer. With the self-calibration method [3] the accuracy of the system is improved compared to standard systems.

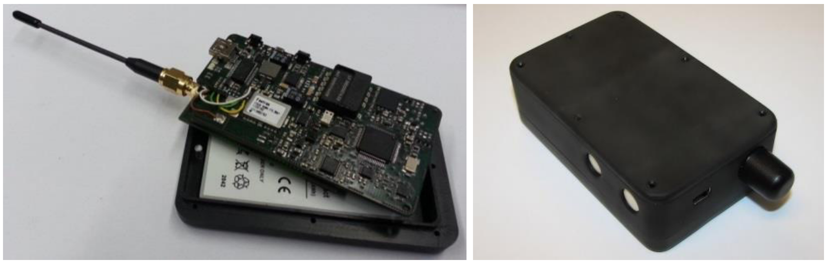

Fig. 1: BodyGuard (BG)-System Version 2.0, left: the board of the BG-System with the used sensors, right: BG-System ready for action.

2.2. Mobile relay station

The mobile relay station (Fig. 2) is a self-sustaining aircraft so named UAV-MAJA of the company Bormatec. An autopilot is integrated in the UAV-MAJA which allows using the aircraft without specifically trained staff. Only the starting and landing of the aircraft needs to be controlled. However, the UAV-MAJA aircraft is mandatory as air-based control system for the developed multi-hop sensor network. In the multi-hop wireless sensor network the aircraft works as relay station.

One important technical detail is that the flight time of the UAV-MAJA is about 1 hour. The actual flight record with a MAJA XL is at 2 hours 46 minutes and a distance covered of 126 km [4]. Another technical detail is that the aircraft uses different radio systems with regard to data transmission technology. The multi-hop relay station works with 869 MHz to connect the person on the ground (BG-System), in contrast the base station, the remote control and the autopilot uses the 2.4 GHz band, and the wideband video transmission system uses the 5.8 GHz band.

Fig. 2: Image of the relay station MAJA and the different radio systems.

2.3. Base station

The base station is integrated in an emergency vehicle equipped with PC technology. Amongst others, the data of the BG-System is coordinated with the PC in the emergency vehicle and the coordinates are calculated and visualized using the 3D-position for every member of the emergency service, wearing a BG-System. Furthermore the UAV-MAJA aircraft especially the autopilot is controlled with the PC. That means a flight route for the corresponding scenario is defined.

To sum it up, the base station is the controlling point of the multi-hop sensor network. There all devices used in the network are managed and coordinated for the success of a mission.

3. Principle of the wireless multi-hop sensor network

The wireless sensor network whose components are explained in the chapter above is based on the multi-hop mesh routing method. The mesh routing method is a reactive routing protocol. In this reactive protocol the route to the base station is determined when the position data of the member of the emergency service is transmitted. During the development of the reactive protocol, special attention was paid to the mobility of the operators. The members of the emergency service (or operators) are moving around the scenario area leading to permanent changing positions and hence the routing path during the mission. The transfer of the mission data to the base station via the relay station occurs by the use of always changing routing paths. The relay station moves continuously in the air and has a stable radio contact to the base station. Special attention during the development process of the reactive mesh log was paid to a low latency, a low additional load, and to the installation, respectively to the reorganization of the network. In addition for the realization of the routing protocol attention was paid to a low number of protocol packages for the setting, respectively the rebuild of a new routing path. Furthermore the number of the necessary floating packages is minimized by the network for the path setting and for the stability of the network.

In Fig. 3 the sensor network and the principle of the mesh routing method is illustrated. The transfer of the position data by the mesh routing is first carried out from P1 to P2. Then the data is transmitted to the relay station and after that further to the base station. The routed data from P3 can be transferred directly to the base station or over the relay station to the base station.

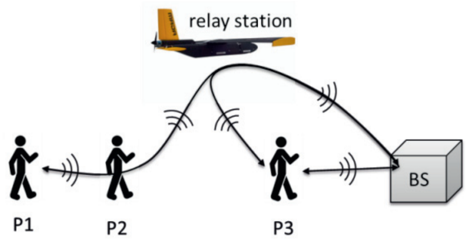

Fig. 3: Scheme of the bi-directional data transmission.

4. Advantages and disadvantages of the approach

In this chapter advantages and disadvantages of the developed approach are discussed briefly for a quantitative evaluation. First the advantages are in focus. By the implementation of the mesh routing protocol the transmission range of the individual member of the emergency service could be increased. Another advantage is the low energy consumption due to the on this reason unnecessary power amplifier (Send: TX-mode +10 dBm with 26.5 mA; Radio Reception: RX-Mode 15 mA and TRX_OFF Mode 0.45 mA). An increased mission time results in the low energy consumption which is a great improvement. In average the relay station needs 24 mA (radio and microcontroller) and the BodyGuard (BG)-System Version 2.0 needs 5 mA for radio plus 60 mA for the sensors (GPS, inertial system), and for the microcontroller. The next advantage is the stable data transmission by the O-QPSK method. It is also an advantage that the maximum transmission time plus confirmation (acknowledge) is 3 ms at a maximum package length of 127 octets (8 Bit/1 Byte). The maximum number of confirmed transmitted data packages is 330 packages. The reduction of 60 % of the transmitted packages is caused by the package collision and the waiting time in the CSMA-CD procedure of the mesh routing protocol of the physical layer. One more advantage is that the members of the emergency service can work spatially distributed due to the relay station. This is mandatory in realistic missions. Additionally due to the relay station there are short routes for a testing area of 1 km². In tests there are 2 up to 3 hop routes in maximum. At least it is an advantage that more than 10 members of the emergency service can be controlled with a transmission of 10 position packages per second.

In this following part disadvantages are named. First there is the risk of losing data because of imperfect routes. Furthermore the delay of the incoming routes is a problem and the position error due to the loss of packages (accumulation of the position data).

5. Summary

In this paper an approach for localization of persons in extensive areas is shortly discussed. Therefore a so called air-based multi-hop sensor network was built up and a mesh routing protocol was developed. The combination of the self-developed BodyGuard-System with the UAV-MAJA and a base station offers a lot more possibilities for application. The great advantage is that it becomes possible to measure long ranges and immense areas.

References

[1] BAM, FOG, ZIM-AiF Kooperationsprojekt, Abschlussbericht (german languages), Ortung und Monitoring von Einsatz- und Rettungskräften in Gefahrenszenarien (OMEGa) (Förderkennzeichen KF2201041), www.bam.de (2014)

[2] E. Köppe, M. Bartholmai, A. Liers, J. Schiller, "Radio-based multi-sensor system for person tracking and indoor positioning", 9th Workshop on Positioning Navigation and Communication (WPNC), (2012)

[3] E. Köppe, D. Augustin, A. Liers, J. Schiller, "Self-calibration-method for an inertial navigation system with three 3D sensors", ISISS 2014, 1th International Symposium on Inertial Sensors and Systems, (2014)

[4] Bormatec, Flugrekord MAJA XL, www.bormatec.de, http://diydrones.com/profiles/blogs/anatomy-of-a-126-km-flight (2014)

[5] Atmel Corporation., "ZigBit™ 700/800/900 MHz Wireless Modules, ATZB-9000-B0", Datasheet, 8227C–MCU Wireless–06/09 (2014)

[6] Atmel Corporation., "Low Power,700/800/900MHz Transceiver for ZigBee, IEEE 802.15.4, 6LoWPAN, and ISM Applications, AT86RF212B", Datasheet, 42002C–MCU Wireless–08/13 (2014)