Development of an INS Integrated Positioning System for Assisting Effective Fire-fighting Activity

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Abstract: This paper describes the development of an INS (Inertial Navigation System) integrated positioning system, which can monitor and track the firefighter's position for assisting effective fire-fighting activity and rescue services. The INS consists of highly accurate three-axis gyro sensor and three-axis accelerometer. By integrating an INS to positioning system, it is also possible to obtain the information of firefighter's physical state (e.g. standing, collapse and crouch) of posture including velocity. Consequently, this research would obviously make a contribution to effective rescue activities and safety of firefighters. Besides, this paper presents results from field tests conducted at Tokyo University demonstrating its viability and utility. We also summarize the overall system requirements and architecture, and describe the hardware and software used in the prototype system in detail.

Keywords: Effective Fire-Fighting Activity, INS (Integrated Positioning System) integrated positioning system

1. Introduction

The complexities of fighting fires in a large-scale underground space like rail and road tunnels have been amply demonstrated in disasters like the 1999 Mont Blanc fires and Korea subway fire this year. Images of intense smoke, trapped people and firefighters unable to intervene are still vivid in the public's mind.

The use of underground space in large urban areas is becoming more and more intense, because of the various uses of these spaces. However, the accidents that have occurred in the large-scale underground spaces, where many and unspecified persons get together, have revealed the problems facing the fire and rescue services: they have not been able to carry out effective assistance of evacuation and rescue operations due to confined spaces and bad visibility arising from the immense amount of smoke in the tunnel. Furthermore, because of the lack of exterior information, rescue operations are often not carried out as desired. Therefore, in order to ensure firefighter's safety and to perform more effective rescue activities, it is very crucial to monitor the positions and the conditions of the firefighters in real-time. It is well known that the satellite-based positioning system like Global Navigation Satellite System (GNSS) is capable of determining latitude, longitude, and altitude of the individual users. However, in such areas as underground spaces or inside buildings, the use of satellite-based positioning is unable to use because the line-of-sight (LOS) between user and satellites is obstructed. As mean to resolve these problems, it is desirable to have positioning system, which can track the position of firefighters where GNSS signal cannot be tracked.

This paper describes the development of an INS integrated positioning system for assisting effective fire-fighting activity.

2. System Description

The system, which can monitor and track the firefighter's position for assisting effective fire-fighting activity and rescue services, consists largely of three parts. i.e. INS integrated positioning system, display system of 3-dimensional map and communication system using laryngeal microphone.

1) INS Integrated Positioning System

INS integrated positioning system is made up of the terminal unit and RFID (Radio Frequency Identification) system for detecting, identifying, locating, and tracking assets and personnel. RFID equipment can be divided into two different groups: tags and readers. In this research, the accumulated errors from the calculation of angular velocity affects the rotation angle between the sensor coordinates and global coordinates while the accelerator measurement error accrues to affect the movement vector. For example, in the case of the aircraft

navigation equipped with the INS integrated positioning system, aircraft navigating had a standard deviation of cross-track (lateral) deviations of approximately 2.2 km. Therefore, in this research, error correction is conducted during the firefighting activity at the periodic interval. For the correction of positioning errors, there are two methods, i.e. Coordinate Update (CPUT) and Zero Velocity Update (ZUPT) method. The former involves the correction of position by accepting the actual position data from an external source through RFID equipment. The latter method carries out positioning correction by resetting all values to zero by physically coming to a stop for INS error calibration. In this research, both methods have been implemented. Fig. 1 and Fig. 2 show schematic system setup of software and hardware of INS integration positioning system.

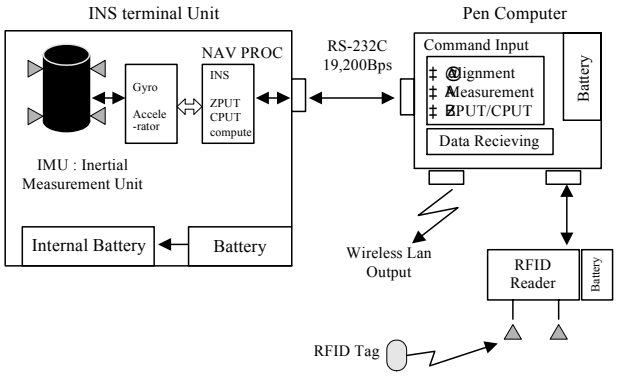

Fig. 1. Schematic System Setup of software

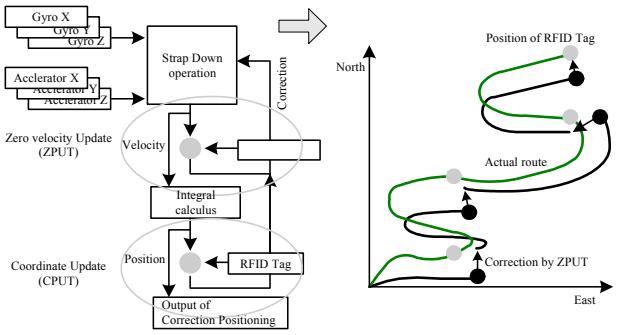

Fig. 2. Schematic System Setup of hardware

The positioning equipment in principle not only enables identification of the firefighter's position but also provides information of his/her physical posture, thus one can obtain invaluable data regarding the firefighter's posture and undergoing activity. The actual positioning system is shown in fig. 3.

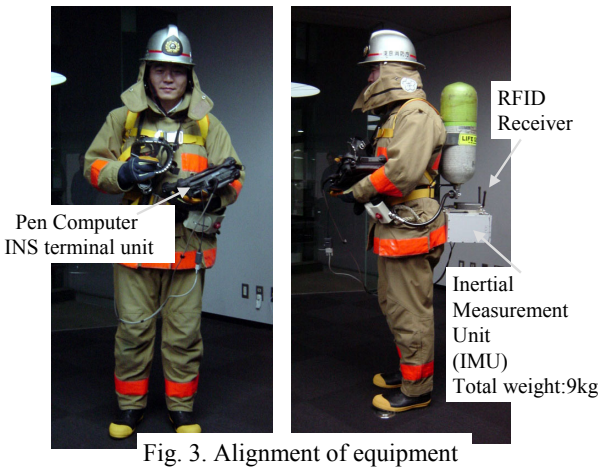

Fig. 3. Alignment of equipment

2) Display System of 3-Dimensional Digital Map

The display system is a system for displaying the firefighter's position and posture on a 3-dimensional digital map. In the actual firefighting scene, appropriate orders can be given to any specific firefighter based on what is shown on the display system. Information regarding the position and posture is transmitted virtually real time to the 3-D display system through the server. Based on these data, an icon representing the firefighter is displayed on the digital map and this data is refreshed every 0.5s thus enabling real time recognition of the firefighter's movement. Furthermore, from these data, it is useful in making out the interior layout of the building, which is difficult when only relying on the floor plan.

3) Communication System using Laryngeal Microphone

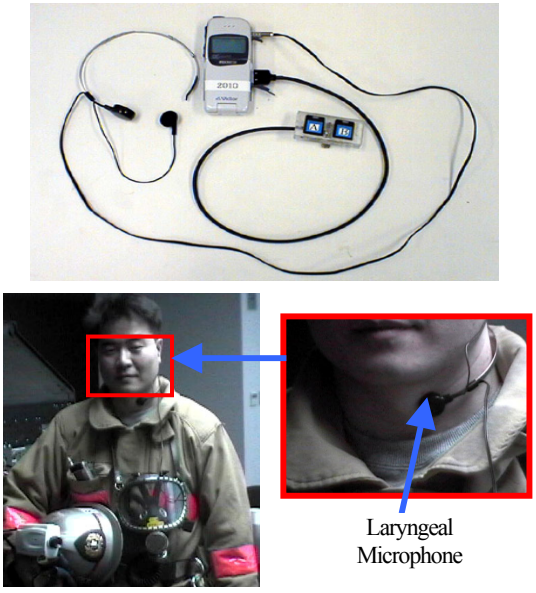

Fig. 4. Fire fighting and Rescue Communication System

During a firefighting activity, the frequency of the walkie-talkie is limited to a narrow band leading to confusions when backup are required from support team. In an attempt to solve this problem, this research used Fire fighting and Rescue Communication System (FiReCOS) which is developed by National Research Institute of Fire and Disaster, Japan. FiReCOS consists of a high precision portable transmitter and the relay broadcast system, which is based on PHS (Personal Handy-phone System) communication technology and TCP/IP network technology. Particularly, FiReCOS prevents confusion from arising and enables transfer of data including digital image by utilizing MCA (Multi-channel Access) and digital networking technologies. Fig. 4. shows the overall of FiReCOS.

3. Experiment and Results

In order to evaluate the validity of the developed system, field experiment has been performed inside building on the assumption of actual firefighting environment. Experimental results are as follows.

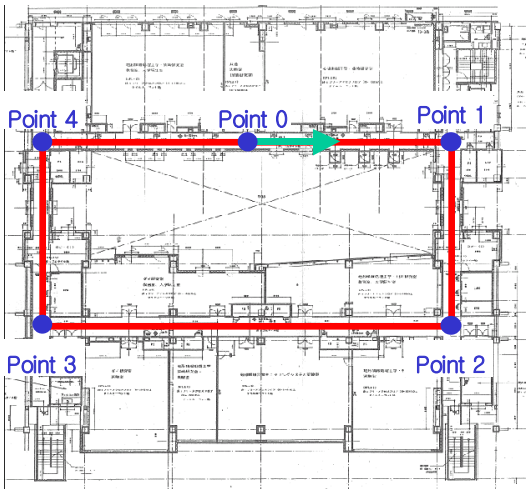

Fig. 5. Map of Testing Site and Trajectory

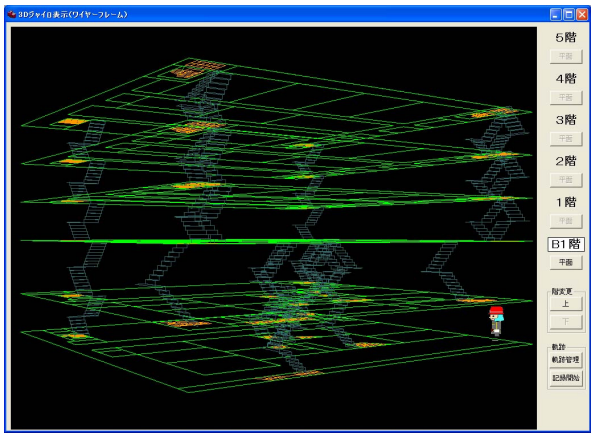

Fig. 6. Position of firefighter on the digital map (Bird ‘s eye view)

Fig. 7. Position of firefighter on the digital map (Plane figure view)

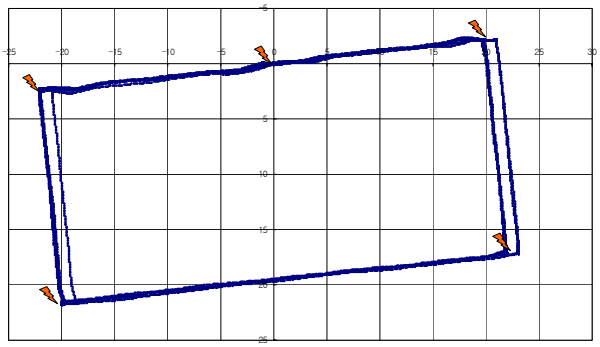

Fig. 8. Results of horizontal values

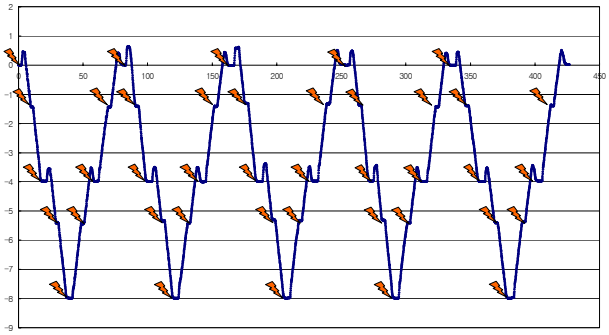

Fig. 9. Results of vertical values

4. Conclusion

This paper describes the development of an INS integrated positioning system for assisting effective fire-fighting activity. It would obviously make a contribution to effective rescue activities and safety of firefighters.

References

Tamura, H., Matsubara, Y., Hosokawa, N., Takanashi, K., Siga, T., (2000). “Development of Fire fighting and Rescue Communication System (FiReCOS)”, Report of National Research Institute of Fire and Disaster (in Japanese)