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Development of Person Identification and Tracking System with Wearable Acceleration Sensors in Intelligent Space

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Abstract: This paper proposes a human identification and tracking system with a wearable acceleration sensor and networked laser range scanners in an intelligent space. Human walking activities are measured and associated between laser range scanners and acceleration sensor. In this paper, a proposed person identification system between two types of sensors is described. A module of each sensor is implemented as RT component. The proposed distributed sensor system was developed by integrating these RT components. Information on walking behavior of human is communicated between components and shared in this system. Some experimental results with this system show a possibility of person identification and tracking.

Keywords: Acceleration sensors, Human identification, Human tracking, Intelligent Space, Laser range finders

1 INTRODUCTION

Recently, sensor network for configuring intelligent spaces has been actively studied [1][2]. There are various sensors, such as laser range sensors and cameras installed in the environments or mobile sensors with human in intelligent spaces. Especially, in order to support activities and understand behaviors based on movements of human in the environments, various methods to track the position of human have been proposed. Existing studies can be classified into three types according to properties of sensors.

(1) Vision sensor [3]

System with vision sensors can provide not only human position but also appearance and motion of human. However, they are lacking robustness, because false detections frequently occur due to change in lighting conditions or occlusions by obstacles in the environment.

(2) Laser range finders (LRF) [4]

LRFs have higher reliability and less noise signal because they are not affected by conditions in the environments. However, scan data obtained from laser range scanner cannot get personal identification. Therefore, when tracking multiple people, ambiguity occurs in identifying targets.

(3) Portable sensors [5]

Recently, small devices such as ID tags, acceleration sensors or other sensors have been developed, and they are often installed in mobile phones. Then, humans can easily carry such sensors. ID information can be easily associated to human based on information from mobile sensors. They are effective to ensure individual identification. However, position estimation with these mobile sensors is not accurate. In order to accurate position estimation with only mobile sensors, humans have to wear various kinds of sensors [5].

There are several studies as the solutions for obtaining human ID information and accurate positions simultaneously. Literature [6] shows that ID information can be obtained and human positions can be estimated accurately by integrating touch sensors or pressure sensors installed on the floor and acceleration sensors. Literature [7] shows person tracking and identification based on similarities between angular velocities obtained from gyro sensor with human and estimated by LRFs installed in the environment. In the literature [8], acceleration sensors and cameras installed in the environment are integrated. Correlation between movement of human extracted in images captured from vision sensors and acceleration signals from acceleration sensor with human are calculated.

This study developed a system which performs the person identification, and tracking based on the acceleration sensor with human and laser range scanners installed in the intelligent environment. A module of each sensor is implemented as RT component. The proposed distributed sensor system was developed by integrating these RT components. Information on walking behavior of human is communicated between components and shared in this system. Actually experiments of person identification using this system was performed. Experimental results show the validity of the proposed system. Fig.1 shows a concept of the proposed system.

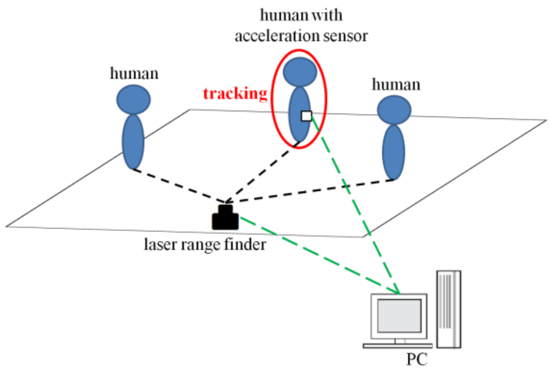

Fig.1 Concept f the study

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2 TRACKING AND IDENTIFICATION SYSTEM WITH NETWORKED LASER SENSORS AND WEARABLE ACCELERATION SENSOR

In this study, human walking behaviors are detected in networked laser range scanners in the intelligent space and an acceleration sensor with human respectively. Walking behaviors of two types of sensors are associated according to steps of walking.

2.1 Walking detection using an acceleration sensor

First, the two low-pass filter (LPF, cut-off frequency: 0.5Hz, cut-off frequency: 10Hz) are applied to raw acceleration signals. LPF of 10Hz cut-off is used to eliminate the noise. In addition, DC components are obtained by LPF of 0.5Hz cut-off. DC components are treated as gravitational acceleration components. Fig.2 shows a vertical direction and a forward direction used for analysis of walking motion. If specific changes as shows as Fig.3 were appeared in the measured acceleration data, that motion is detected as "walking". Details of this "walking" detection are described in [9].

2.2 Walking detection using laser range scanners

First, moving objects are extracted by networked laser range sensors installed in the intelligent space calculating difference between current range data and background range data. Then, the position information of only moving objects are detected. Second, hierarchical clustering is applied to the extracted range data. After that, each moving object can be separated and tracked. Fig.4 shows detection and tracking of the human with two legs. If movements of detected human are bigger than threshold amount during a given period, the human is detected as "walking". Details of detecting and tracking human are shown in [10].

2.3 Matching based on walking behaviors

"Walking" behaviors are detected by networked laser range scanners installed in the intelligent space and the acceleration sensor with person. In this study, we focus on the occurrence and duration of walking and stopping. In the matching process, association between behavior detections by laser range scanners and the acceleration sensor are performed. The matching process evaluates whether "walking" behaviors at the same time are detected. A similarity of behaviors between two types of sensors is introduced to evaluate matching. A similarity s_{ij} is calculated with Eq.(1) to each combination of detections by acceleration sensor i and laser scanner j.

$$S_{ij} = 1 - 1/(1 + \exp(l_{ij})) \tag{1}$$

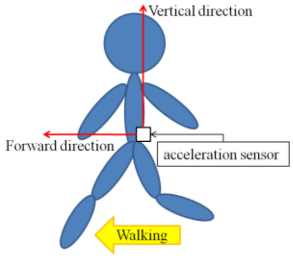

Fig.2 Axis definition of vertical direction and forward direction

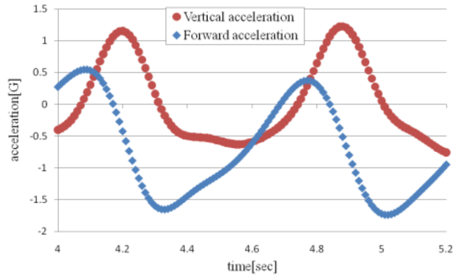

Fig.3 Acceleration change in one cycle walking

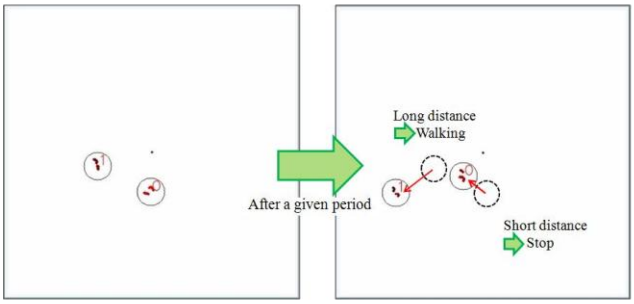

Fig.4 Human tracking and walking detection by laser sensors

l_{ij} changes based on behavior detections. If "walking" or "Stopping" is detected at the same time with both sensors, l_{ij} increases. On the other hand, when different behaviors are detected in both sensors, l_{ij} decreases. Then, a similarity also increases with same behavior and decreases with different behaviors from both sensors. Details of this matching method described in [11].

2.4 System development using RT component

The proposed system which performs walking behavior detection was implemented using RT middleware [12]. Each sensor module described in sections 2.1 or 2.2 was developed as RT component.

First, the component of acceleration sensor is explained. The component of acceleration sensor is executed at a computer set in the intelligent space. In the first operation "on activated", the component of an acceleration sensor reads default settings and connects to an acceleration sensor via Bluetooth from the computer that the component is running. In "on execute" process which it iterates acceleration data acquisition every 0.01 second. LPFs are applied to the acquired acceleration data, and removal of

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noises and calculation of gravitational acceleration are performed every loop. Acceleration data for calibration of human's forward direction is stored for the first 10 seconds after state transition to "on execute". Then, forward direction calibration is performed using principal component analysis based on acceleration data of the first 10 seconds. After 10 seconds, from two acceleration data, the vertical direction and the forward direction, walking behavior detection of the person with the acceleration sensor is performed. Results of walking behavior detection are transmitted to the other component. Flag "1" for walking behavior, or flag "-1" for stopping behavior as TimedLong type transmitted in this component.

Next, the component of laser range scanner is explained. In the first operation "on activated", the component of laser range scanner acquires range data used as a background. This range data is used for calculation of the background subtraction for extracting moving objects. In "on execute" process, human legs are detected from the moving objects as human. Position data of humans are acquired and the humans are tracked every 0.1 seconds. Walking or stopping detection results received from the component of wearable acceleration sensor is matched with walking or stopping behaviors of each tracking persons detected in the component of laser range scanner. A person with the best similarity is recognized to be a target person.

This system is based on small data communication between two sensor modules. Then, even if those who exist in the intelligent space increase in number, the system is executed by communicating only the information on walking or stopping detections.

Fig. 5 shows the structure of this system. The left is a component of an acceleration sensor. The right is a component of laser range scanner. Advanced components are required to handle many laser range scanners installed in the intelligent space in near future.

3 EXPERIMENT

3.1 System setup

Laser range scanners (Hokuyo Electric Machinery URG-04LX) are set at the height of about 25cm on a smooth floor. The target person wears the sensor (ATR-Promotions WAA-006) with gyro of three axes and acceleration of three axes on the waist. Components including the interface with each sensor and processing of walking detection are developed in each sensor by using the Open Robot Technology Middleware (RT Middleware) of AIST[12].

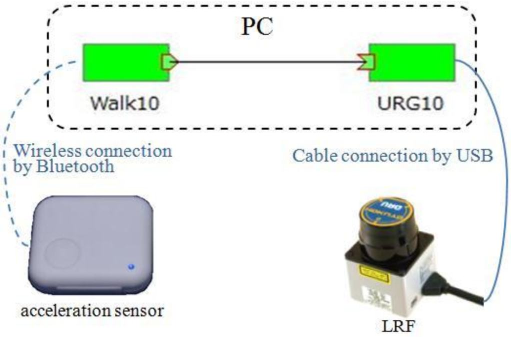


Fig.5 Wire connection figure of a system

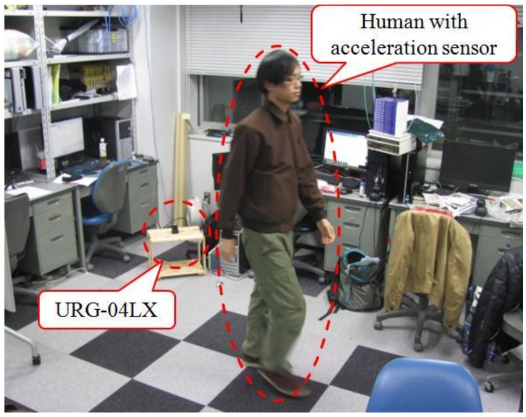


Fig.6 Experimental environment

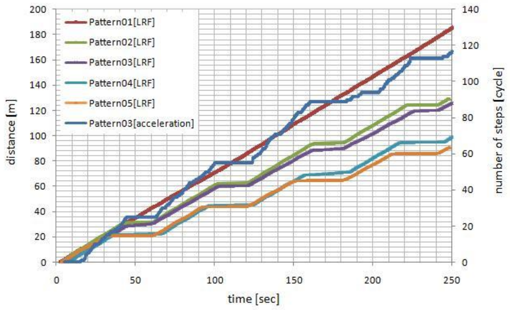
Detected results of "walking" are communicated between components. Fig.6 shows the experimental environment.

3.2. Experiments of human identification

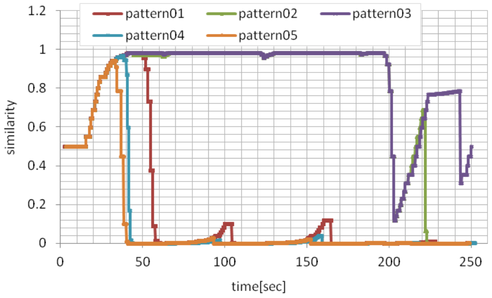
Experiments on identification of the target human with the acceleration sensor were performed. Five persons with the acceleration sensors walked around in the intelligent space. Laser range sensor is installed in the intelligent space for person tracking. Five persons walked and stopped as shown as Table.1 respectively. Pattern 02 and Pattern 03 are similar behavior. Pattern 04 and Pattern 05 are also similar. The algorithms for detecting correct persons in these similar behaviors are required for person identification. Seconds for walking or stopping were measured by a stopwatch. Fig.7 shows the examples of identification experiments among a target person and non-target persons.

Fig.7 also shows the case of Pattern 03 person. In this figure, the first vertical axis shows the walking distance measured by the laser range scanner, and the second vertical axis shows the number of walking steps detected by the acceleration sensor in [a]. This figure [b] shows similarity changes of all persons using the optimal parameters.

As shown in Fig.7, one of non-target persons performs a similar walking pattern compared with the target person (Pattern 03). In this figure, the similarities of Pattern 01, 04 and 05 were suppressed smaller than the similarities of



[a] Number of steps measured by acceleration sensor of target person and distance of five persons



[b] Grade of similarity of five persons

Fig.7 Results of five persons [Target is patturn03]

Pattern 02 and 03 after around 60 sec. Although it took more time to distinguish Pattern 03 with Pattern 02 than the other patterns, the highest similarity was obtained after around 200 sec.

This result introduce the association based on behaviors focused in this study has a possibility to identify a specific person from several persons and track him in high accuracy with laser range sensors in the intelligent space

4 CONCLUSION

This study aimed to identify a specific person with the accurate position measurements by integrating the networked laser range scanners installed in the intelligent space and an acceleration sensor with the person. This paper proposed the identification of a person based on associating the detections of walking behaviors from both sensors. Some experimental results showed the feasibility of the method. Improvement in accuracy of the decision of behavior in each sensor, and how to evaluate the similarity should be reconsidered in order to improve the performance as the future work. Experiments to identify the target from many persons should be performed.

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