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3—29 Pedestrian Tracking using Single-row Laser Range Scanners

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Abstract

In this research, we propose a novel method of monitoring and tracking pedestrians in wide and open area, such as shopping mall and exhibition hall, using a number of laser range scanners (LD-A). LD-A, produced by IBEO Lasertechnik, is a single-row type laser range scanner with a high profiling rate of 10Hz and wide viewing angle of 270 degree. LD-As are set on the ground doing horizontal scanning, so that horizontal cross sections of the surroundings, containing moving legs of pedestrians as well as still objects, are obtained in a rectangular coordinate system of real dimension. Each LD-A is controlled by a client computer, which gathers laser data, extracts the data of moving objects by background subtraction, and sends them to a server computer through network. The server computer synchronizes all client computers, integrates the data of moving objects from client computers to a global coordinate system, and tracks trajectories by identifying the pattern of moving legs. An experiment is conducted in Tokyo BigSite to monitor the pedestrian's movement in an exhibition hall, where three LD-As are used, and trajectories of more than 50 pedestrians are tracked simultaneously.

1 Introduction

Analyzing or monitoring human activities, such as counting the number of passengers, or measuring their trajectories, is considered very useful in various fields such as building security, planning and management assistant in shopping mall, railway station and so on. So far, motion analysis with video data has been a major method to collect such a data. However due to the limited viewing angle and resolution, video cameras are restricted to the use in relatively local area under constant illumination condition, and applications of video-based surveillance are restricted to the extraction of rather few objects [2,3,4,5]. In addition, it is also difficult to digitally fusing the data of multiple cameras, which requires accurate calibration and complicated calculation between different perspective coordinate systems. On the other hand, laser range scanners using eye-safe laser have been demonstrated through many research efforts of efficiency in obtaining object geometry and safety to human being if properly be used [1,6]. In recent years, single-row type laser range scanner with high scanning rate, wide viewing angle and long range distance has been developed, and can be bought with rather low price on market.

In this research, we propose a novel method of tracking using single-row type laser range scanners, aiming at real-timely counting and tracing pedestrians in a relatively wide and open area.

2 Outline of the System

2.1 Single-row laser range scanner for tracking

Single-row laser range scanners, LD-A, produced by IBEO Lasertechnik, are exploited in this research (see Fig.1). In one scanning (frame), LD-A profiles 1080 range distances equally in 270 degrees on the scanning plane, which can be easily converted to rectangular coordinates (range points) in the sensor's local coordinate system. A blind area of 90 degree exists due to the hardware configuration. LD-A has a maximum range distance of 70 meter and an average distance error of 3cm. Frequency of LD-A is 10Hz, implying that it captures 10 frames per second. LD-As are set on the ground doing horizontal scanning, so that cross sections of the same horizontal level containing the data of moving (e.g. legs) as well as still objects (e.g. building walls, desks, chairs and so on) are obtained in rectangular coordinate system of real dimension. A background image is generated and updated at every time interval (e.g. every 30 minutes), containing the data of still objects only. Algorithm for background image generation will be addressed in next section. The data of moving objects can be easily extracted by subtracting background image from the current range frame. Figure 2 shows a sample frame, where range points are colored through background subtraction.

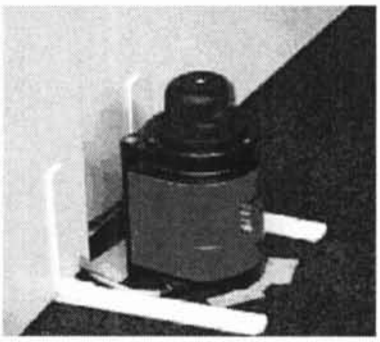

Figure 1. Single-row laser range scanner

2.2 Integration of multiple laser range scanners

A number of laser range scanners are exploited, so that

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a relatively large area can be covered, while occlusions and crossing problem could be solved to some extent. Each laser range scanner is set at a separate location and controlled by a client computer. All client computers are connected to a server computer through network, which gathers the range measurements from all client computers, and commits tracking (see figure 3). There are two issues have to be addressed here. They are how to spatially and temporally integrate the range frames from different laser range scanners, how to divide the computation tasks between client and server computers to accomplish real-time tracking.

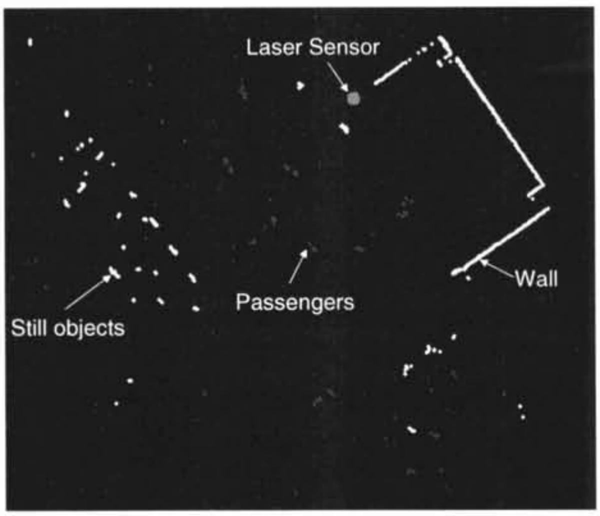

Figure 2. A sample frame, range points are colored through background subtraction

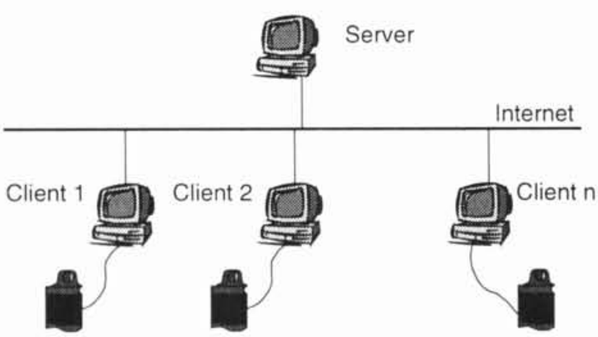

Figure 3. Integration of multiple laser range scanners through network connection

2.2.1 Integration of the range frames from different laser range scanners

Since the range measurement from each laser range scanner is relative to the sensor's local coordinate system, they are integrated to a global (common) coordinate system before being processed for tracking, where integration is conducted in spatial (x, y axes) and temporal (*time* axis) levels.

For the sake of spatial integration, locations of laser range scanners are elaborately planned. All laser range scanners form an inter-connected network, and range measurements between each pair of neighboring laser range scanners keep a certain degree of overlay. Relative transformations between the sensor's local coordinate system of neighboring laser range scanners are calculated by pair-wisely matching the common features from duplicated measurement in overlapping area. Specifying a sensor's local coordinate system as the global one, range measurement from each laser range scanner is transformed to the global coordinate system by sequentially aligning the relative transformations. A detailed address on registering multiple laser range scanners can be found in [6].

For the sake of temporal integration, a trigger is shot from the server computer to all client computers. The time point at which the client computer received the trigger is defined as the origin of the *time* axis of the client computer. The *time* axis is tessellated at an interval of 0.1sec according to the profiling rate of the laser range scanner (10Hz) being used. Whenever a new range frame is recorded, a time stamp (integer) is allotted by projecting the recording time onto the *time* axis of the corresponding client computer. In the case two or more range frames of the same client computer are allotted one time stamp due to fluctuation of profiling rate, the one that has a recording time nearest to the time stamp is kept, but others are dumped away.

Integration of the range frames from different laser range scanners is conducted as follows. At each time stamp, find out the range frames from different laser range scanners, which are allotted the time stamp, transform them to the global coordinate system, and make up an integrated range frame.

2.2.2 Task division between client and server computer

Each client computer controls a single laser range scanner, while server computer triggers all client computers for synchronized recording of range frames and accomplishes tracking.

Server computer sends two kinds of triggers to client computers, *start* and *end*. When the client computer receives a *start* command, it resets the *time* axis, and starts recording range frames from the laser range scanner being controlled. In addition, a background image containing the range data of still objects under the coverage of the laser range scanner is generated previously and/or updated at every time interval by the client computer. Whenever a new range frame is recorded, it is subtracted with the background image, so that the data of moving objects are extracted. Attached with a time stamp at which it is recorded, the data of moving objects only is sent to the server computer by the client computer on the air. The process stops when the client computer receives an *end* command.

Server computer collects the synchronized range frames of moving objects only from all client computers.

For the range frames attached with the same time stamp, they are transformed to a global coordinate system to make up an integrated one. Transformation matrixes from the sensor's coordinate system of each laser range scanners to a global one is calculated by the server computer previously by registering sample range frames from each laser range scanners. Assuming that the moving objects in the environment are normal pedestrians only, server computer counts and tracks the trajectories of pedestrians by identifying and tracing moving legs among integrated frames.

3 Tracking Algorithm

3.1 Extraction of moving objects

Client computer generates/updates background image using a number of range frames that are continuously recorded from the laser range scanner. For each sampling angle of range scanning, a histogram is generated using the range values from all range frames being examined. A pick value above a certain distinctness (percentage) is found out, which tells that an object is continuously measurement at the direction, so that sounds a still one. A background image is made up of the pick values at all sampling angles.

The number of range frames for background image generation, and the time interval for background image updating are decided case by case according to the environment being measured. In the case that physical layout of the environment is not changing, and pedestrians may stand at a point for a long period, a background image is generated previously and not updated on the air to avoid mishandling of range data.

Whenever a new range frame is recorded, it is compared with the background image at the level of each sampling angle. If the difference between the two range values is larger than a given threshold (considering the fluctuation of range measurement), the newly measured range value is extracted as the data of a moving object, and sent to the server computer.

3.2 Tracking pedestrians

For a normal pedestrian, one of the typical appearance of moving legs is, at any moment, at least one leg is landing while another moves or keeps still. Two legs interchange their duty by landing and moving shifts so that the pedestrian goes ahead. A tracking algorithm is developed consisting of four steps, *clustering, grouping, seeding and trajectory tracking* (see Figure 4).

Since there might be many points shooting on one leg, the first step *clustering* means that extracting the point clusters (*cluster*) that representing the same legs. The second step *grouping* means that looking for the pair of clusters (*group*) that representing the same passenger. A *seed trajectory* is a sequence of *groups* from successive *frames*, where for any *group* in the sequence there is at least one *cluster* locating at the same position with a *cluster* of next *group*, and the directional vectors between neighboring groups do not have drastic change in their directions. The third step *seed extraction* means extracting such *seed trajectories* by examining cluster locations and directional vectors of the *groups* among successive *frames*. Many occlusions happen especially when measuring a large crowd, since a leg might be blocked whenever it coincides with others in the viewing direction of laser range scanners. The forth step *trajectory extraction* means linking *seed trajectories*, which are broken into short segments due to occlusions.

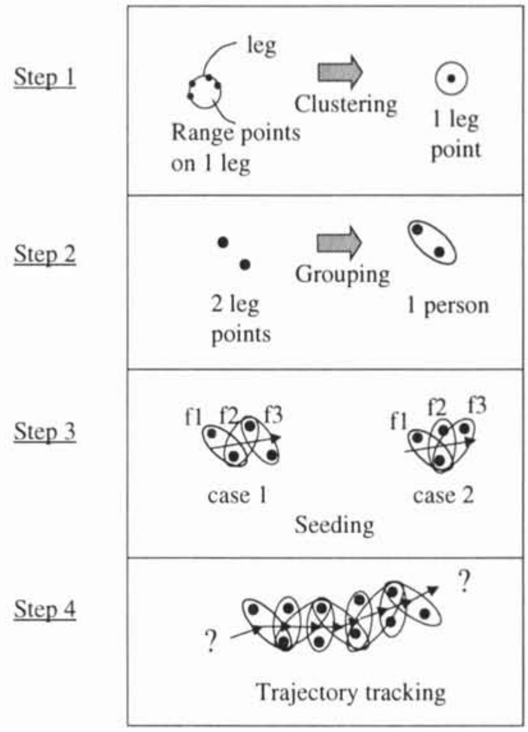

Figure 4. Procedures in tracking pedestrians

4 Experimental Results

An experiment is conducted in Tokyo BigSite, where three single-row laser range scanners are used to cover a local area of the exhibition hall. Figure 5 shows the layout and measurement coverage of the laser range scanners. Laser range scanners are set about 20 meters far from each other, covering an area of about 60*60 square meters. Four computers are exploited in the experiment, where three control laser range scanners, and one servers as the server computer. Four computers are connected using LAN cables.

Background images are generated previously before the opening of exhibition. They are sent from each client computer to the server computer for two reasons. First, they are registered to find the transformation matrixes from the sensor's coordinate system of each laser range scanner to a global one. Secondly, they are shown on the display as well as the data of moving objects being recorded as each range frame for visualization purpose.

Visitors are counted and trajectories are tracked in a real-time mode. Maximal number of the visitors (trajectories) being counted at one moment is up to 50. Figure 6 shows a screen copy of the server computer, where green points represent background image, white points represent moving objects, lines represent trajectories during the last 50 frames, and circles represent the grouped legs of the same pedestrians.

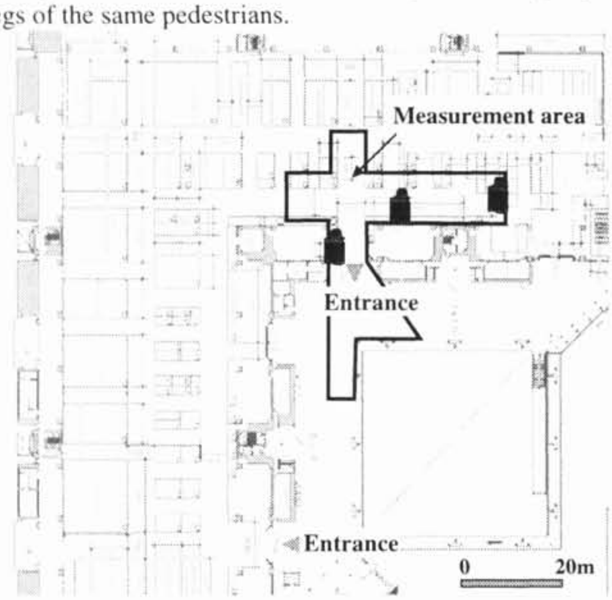

Figure 5. Layout of the laser range scanners and their measurement coverage at an exhibition hall

5 Conclusion

In this research, a novel method is proposed of monitoring and tracking pedestrians in wide and open area, such as shopping and exhibition hall, using a number of single-row type laser range scanners. An experiment is conducted to real-timely monitor the visitors' movement in an exhibition hall, where three laser range scanners are exploited, and trajectories of more than 50 pedestrians are tracked simultaneously. Comparing the tracking using normal video cameras, it can be concluded that the method using single-row laser range scanners has the following advantages. First, they are a kind of direct measurement. Extraction of moving objects in real-world coordinate system is not such a time-consuming work as that of using normal video camera. Secondly, laser range scanner has high accuracy (about 3cm), wide viewing angle (270 degrees), and long range distance (up to 70m). Thirdly, calibration and integration of multiple laser range scanners are easy to cover a relatively large area, as the range measurement can be easily converted to a rectangular coordinate system of real dimension on a horizontal plane. Fourthly, tracking can be achieved in a real-time way due to the low computation cost.

In future work, a tracking algorithm will be developed for the monitoring of an environment not only pedestrians, but also shopping carts, baby cars, bicycles, motor cars and so on.

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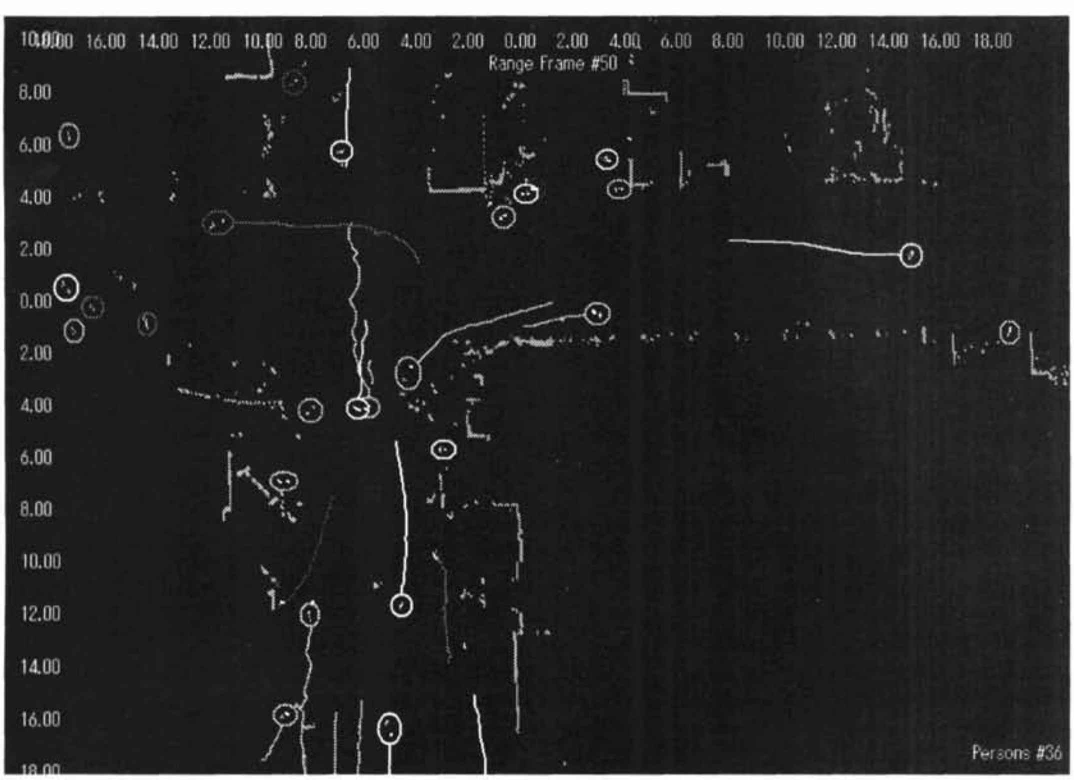

Figure 6. A screen copy of the server computer monitoring a corner of the exhibition hall