System for Tracking Human Position by Multiple Laser Range Finders Deployed in Existing Home Environment

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Abstract. This paper describes construction of a system for measurement of human position from laser range finders (LRFs) deployed in real home environment. The system gathers and stores scan data from LRF modules equipped with room corners at different hip heights by network. We also develop a tracking method based on a particle filter framework. In the filter, after scan data is subtracted with background data and noise data is eliminated with grid map that represents room layout, the position is estimated based on detected scan points with the filtering framework. This method realizes robust tracking of the occupant in real cluttered environment. We demonstrated the system can measure human position accurately in real home environment.

1 Introduction

People tracking and measurement of people's trajectory in real home environments are important topics for location-aware system, intelligent support system, monitoring human activity of elderly people and automation system of home appliances. Currently, we have been developing the system for monitoring elderly people who live alone at remote area by using pyroelectric sensors[1]. The measurement of people position and analysis of trajectory are useful for optimization of the numbers and the locations of pyroelectric sensors.

Currently, some researchers utilizes laser range finder (LRF) for human tracking in indoor environments. Since the LRFs capture accurate distances on two-dimensional plane, it is suitable to measure accurate position of people and objects. Zhao[2] developed the method to measure people's positions in station with multiple LRFs at ankle heights by Kalman filter. Glas[3] realized tracking of people's positions and directions in hall with multiple LRFs at hip heights by particle filter. The targets of these researches are tracking people in crowded space. They assume the almost all outer shapes are captured with LRFs at the same heights in the space where no objects except people exists. However, in home environment, there are many occlusive objects such as walls and tables. Only fragments of outer shape are captured with LRFs. In real home environment, since deployment of fixed base is difficult, the heights of LRFs are various and integration of outer shape fragments is difficult. Thus, it is impossible to apply their approaches to real home environment directly.

Y. Lee et al. (Eds.): ICOST 2010, LNCS 6159, pp. 226–229, 2010.

We develop system for tracking person in real home environment with multiple LRFs. The system consists of the devices that are easily introduced into real environment and the software including the method to track the person in real home environment with multiple LRFs. In home environment, scan data at ankle height is very cluttered and occlusive with table legs and objects on the floor in real home environment. We assume the devices are deployed at hip heights and single person lives in home environment. Our tracking method measures person's position robustly in real home environment with grid map approach and design of tracking filter for fragmented contour data in real home environment where many occlusion objects exist.

2 Measurement System by Using Multiple LRFs

We develop the LRF module for easy introduction of LRFs into real home environment. The module is shown in the left upper part of Fig. 2. The module consists of the LRF and the microprocessor board. Specifications of the LRF are maximum range distance 5.6[m], range area 240[degree], angle resolution approx. 0.36[degree] and 10Hz sampling rate. The module's size is a cube whose edge length is about 15[cm]. The height is variable with spacers and horizontal angle of LRF is also variable in 45 degree unit.

The LRF scan data in each module is gathered by wired LAN for reliability of measurement. Electric power of the module is supplied with Power over Ethernet (PoE). This mechanism reduces wiring tasks and cost of deployment in real home environment. We also developed the management software for modules. The software automatically detects modules in network, gathers scan data and accumulates the data into the database system.

3 Person Tracking by Particle Filter

We utilized a particle filter similar to the Glas's approach [3]. In the particle filter framework, the filter is easy to design filtering model and the filter tracks targets robustly. We consider 2D position $x_t = (x, y)$ as a state in the filter. As transition model, we assume the occupants move in uniform speed. As for evaluation model, Since the heights of deployed LRFs are not equivalent, fitting of fixed shape to scan data is difficult. Thus, we have the simple approach that the particles are evaluated with distance between state (x, y) of particle and projected positions of scan data below the equation.

$$p(\boldsymbol{y}_t|\boldsymbol{x}_t) = \prod_{i=0}^{m} exp(\frac{-(d_i - R)^2}{\sigma^2})$$

Where m is number of foreground points. σ is distributed variance, defined empirically. R is distance from center of body to outer shape. We define R = 15[cm] in our method.

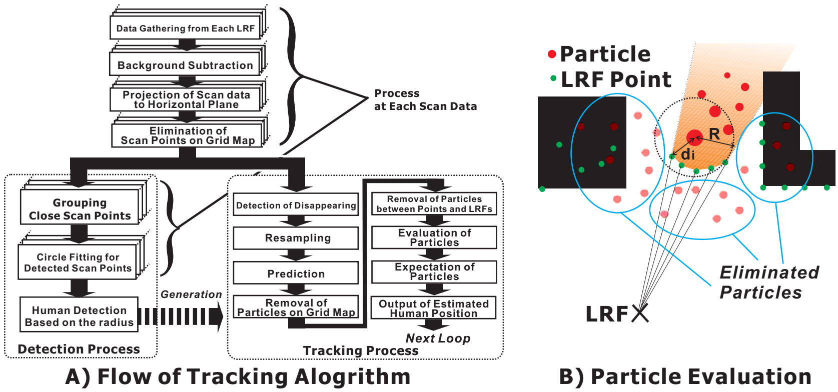

Fig. 1. Flow of Tracking Algorithm and Particle Evaluation

The flow chart of our method is shown in Fig. 1. At scan data of each LRF, background subtraction of distance and 2D projection of scan data to horizontal plane are calculated. The background distance is captured when the occupant is absent. The projected points that are not associated to body contour still remain by only background subtraction because the outer shape of objects on tables and door contour are frequently changes as human activity. For elimination of these scan data points, we utilize grid map of room layout. In mobile robot, grid map represents for room layout and obstacles. In our method, we prepare simple grid map. The occupied grid, which represents walls and fixed furniture and objects, is black and empty area is white. Scan point on the occupied grid is eliminated.

For detection of appearance, the filter detects clusters of projected scan points, fits the circle to detected points with least squares method and detects position of the habitant if the radius of fitting circle is within the range. As for detection of disappearance, when the filter misses the tracking in the several frames, the filter decides that the person has disappeared. In tracking, the particle on the occupied grid of the map are eliminated, which means the particles' weight become zero. The particle whose position is between foreground of scan points and LRF is also eliminated. This elimination improves tracking stability. Particle evaluation and removal is shown in the right of Fig. 1.

4 Experiment about Person Tracking

We introduce our system into the real environment (the left part of Fig. 2). The modules are deployed on the existing objects. The subject is 20's male. The scan data are stored during about 1 year without stopping the modules.

We evaluated tracking performance with typical trajectory data stored in the home environment. Since introduction of other position sensor into the home is difficult, we generated reference position manually by watching raw scan data of LRFs. The positions and directions of LRFs ware calibrated by hand. Grid map, which is shown in background of the experiment result, was written by hand with layout data of home environment. The number of total frames in the experiment was 709. The number of

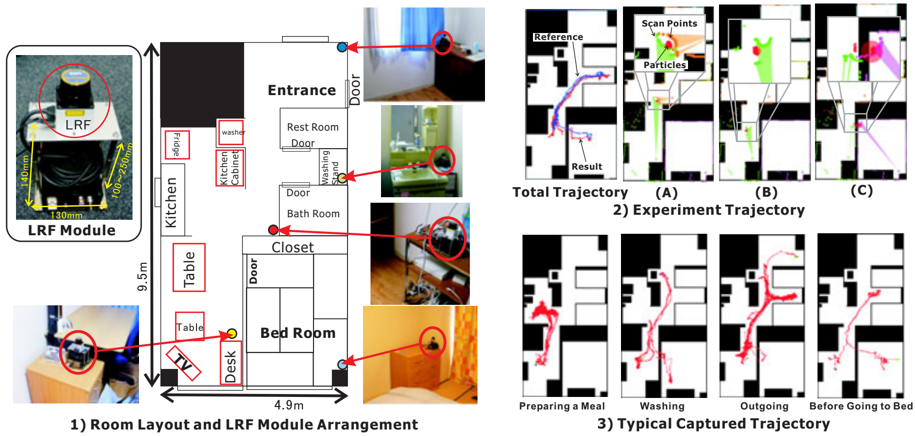

Fig. 2. Layout of Experimental House, Experiment Trajectory and Typical Trajecto- ries: 2-A) Positions is estimated accurately even if the outer shape at the different heights are different. 2-B) Contours of both body and arm are captured. The particles shift to arm positions. 2-C) the particles are separated because the particles exist over door position.

particles is 1000. In the experiment, the filter missed the occupant in no frame. The average of position error was 18 [cm]. Since this value is within radius of human body at hip height, the accuracy of tracked position is sufficient. The calculation time in one frame is within 50[ms], which is sufficient to track the person online. Tracking scene and captured trajectory is shown in the right part of Fig. 2.

5 Conclusion

We construct the system for measurement of human position with multiple LRFs. The system consists of measurement modules that are easily introduced into real home environment and the software that estimates human position with the filter. The filter based on particle filter framework estimates the human position robustly in cluttered real home environment. Grid map and design of evaluation model improve the tracking performance in scan data fusion from hip-height LRF scan data. We demonstrated that the system can measure human position accurately in real home environment.

References

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