Multiple Target Tracking and Separation Technique Based on Texture Information in Range-Time Image using Ultra-Wideband Radar

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Abstract **–Multiple target tracking and separation techniques using ultra-wide-band (UWB) radar are promising for use in robotic and security-related applications. Some methods for tracking and separation of echoes from multiple targets using radar texture information have been proposed. However, the conventional methods cannot be implemented in real time applications due to its iterative nature. To resolve this problem, we propose a technique that can be used in real time applications. First, we estimate the required target velocities using the texture method and multiple target velocities using an extended texture method that can determine the velocities of two targets. Second, we estimate the number of targets that exist at each pixel. Finally, we label each pixel to associate pixels based on their estimated velocities and positions. Through measurements, the proposed method succeeded in accurately tracking and separating the echoes from two pedestrians in real time.**

Index Terms **—Ultra-wideband radar, pedestrians, echo labeling, texture**

1. Introduction

It is important to detect and track multiple people and separate their individual signals for various applications, including collision avoidance techniques for cars and robots, and surveillance systems. Ultra-wideband (UWB) radar, which has high range resolution, can be used even when the view is poor and cameras cannot be used. Therefore, many studies have been reported on the use of UWB radar for the detection, identification, and tracking of humans [1]–[3].

Recently, a technique that uses UWB radar to track and separate multiple targets has been proposed [4]. The method, called the texture method, uses the texture information from radar images in the time-range domain and estimates the line-of-sight velocity at each pixel in the image. However, this method cannot estimate velocities when multiple targets exist in a single pixel, i.e., in the same time- and range-bins. Iterative refinement processes that involve off-line processing are required and this prevents implementation of the method in real-time applications.

Furthermore, a technique, which is called extended texture method, has been proposed to estimate the velocities of two targets that exist within a single pixel [5]. However, experimental evaluation of the method was not discussed and the study was focused only on the estimation of velocities; tracking and separation techniques were not studied.

Therefore, in this work, we apply the extended texture method to experimental data and propose a new separation and tracking method for use in real time applications.

2. Materials and Methods

(1) Velocity Estimation Using Extended Texture Method

Here, we first introduce the original texture method [4]. The method estimates the velocity in all pixels of the range-time image of the received signal. When a single target exists at range r and slow time t, the received signal $s(t,r)$ can be expressed as $s(t,r) = p(r + vt)$, where t is the slow time, and p is the waveform of a scattered echo. Because the velocity corresponds to the slope of $s(t,r)$, the estimated velocity is expressed as:

$$v = (\partial s/ \partial t)/(\partial s/ \partial r). \quad (1)$$

When multiple targets are present, the method cannot estimate the target velocities. To overcome this shortcoming, we use the extended texture method [5], which can estimate two different velocities whose echoes are overlapping.

(2) Estimation of the Number of Targets

Because the equation used to estimate each target's velocity depends on the number of targets that exist in the measurement pixel, we must therefore estimate the number of targets present in the pixel. First, we use original texture method to estimate the target velocity. Next, we estimate the waveform using the estimated velocity. The estimated waveform, $s'(t+\Delta t, r)$, is given by:

$$s'(t+\Delta t, r) = s(t, r+v_1\Delta t) \quad (2)$$

If we fail to estimate the number of targets correctly, the estimated waveform should then differ from the received signal $s(t+\Delta t, r)$. Thus, when the difference between the received signal and the estimated waveform normalized with respect to the signal intensity is higher than a specific threshold, we determine that two targets exist and then estimate the two target velocities using extended texture method.

(3) Tracking and Separation of Multiple Targets Without Iteration Process

We track and separate multiple targets based on estimated velocities and without an iteration process. First, we extract pixels with powers that exceed a specific threshold to determine the pixels in which targets should exist.

Second, we estimate the target positions at $t = 0$. We detect the peaks in the received signal envelope and recognize these peaks as the estimated target positions. Based on this process, we can then estimate the number of targets that exist when the measurement begins.

Next, we attach integer labels to the pixels at the estimated target positions and to pixels located adjacent to the target position pixels.

Finally, we attach labels to the pixels that exist at $t > 0$. Fig. 1 shows a schematic illustration of the labeling technique. Because the same target should have a similar velocity when measured at two closely spaced times, we attach the target pixel label to the pixel that minimizes the following evaluation function, F.

$$F = |v(t_i, r_i) - v(t, r)||t_i - r|, \quad (3)$$

where i is the pixel number in the search region. Because the target position at the previous time is predicted based on the estimated velocity, we can thus limit the search region. In this study, we search triangular regions surrounded by three points: (t, r), $(t - T, r - v(t, r)T - R)$ and $(t - T, r - v(t, r)T + R)$, where T and R are constants.

(4) Experimental Setup

Fig. 2 shows the experimental setup. The radar system's center frequency is 4.2 GHz, the bandwidth 2.2 GHz, the slow-time sampling frequency 200 Hz, and the fast-time sampling frequency 16.39 GHz. The pedestrians, A and B, start to walk simultaneously. Target A walks from $r = 1.0$ m to $r = 5.0$ m and then back to the start point. Target B walks from $r = 4.0$ m to $r = 1.0$ m and back to the start point.

3. Experimental Results

Fig. 3 shows the amplitude of the received signal from the situation in which two pedestrians are walking. Fig. 4 then shows the results. The colors indicate the attached labels. The proposed method thus tracked and separated the targets and applied different labels to the different targets.

4. Conclusion

We proposed an algorithm for tracking and separation of multiple targets using the extended texture method without an iteration process. We demonstrated that the proposed method can successfully separate and track the echoes from multiple targets in an experimental study. Because the method does not require an iteration process, the method would be implemented in real time applications. The actual real time implementation of the method is an important topic in future studies.

References

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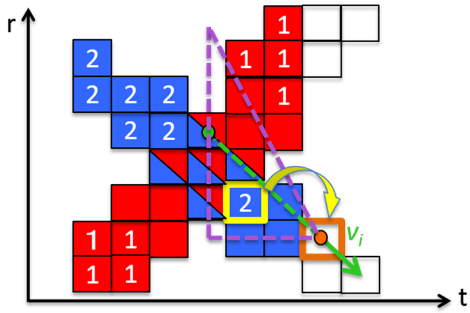

Fig. 1. Schematic illustration of the proposed labeling algorithm.

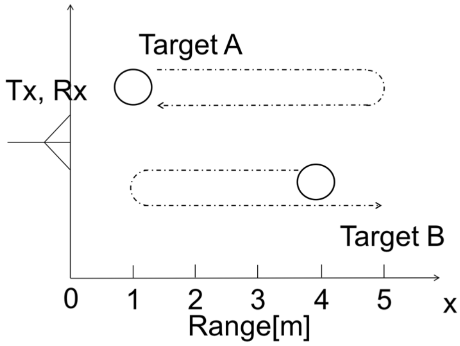

Fig. 2. System model used for the experiment.

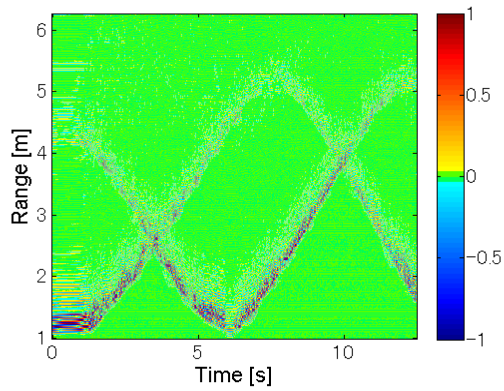

Fig. 3. Received signal from the experimental data.

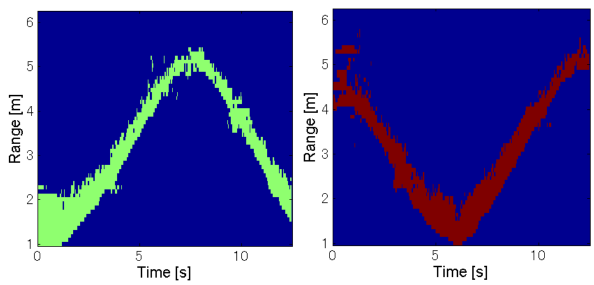

Fig. 4. Experimental results. The colors represent the attached label numbers.