Automotive GMTI Radar for Object and Human Avoidance

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Abstract—Automotive radar can be used to detect and identify roadway obstructions including slowly-moving personnel, but must also reduce or remove the effect of platform motion. We measured the capabilities of a 77-GHz system under various conditions, such as rural and urban environments, and on various terrains, such as asphalt and grass. We utilized range-Doppler map processing capabilities to correct for platform motion using the variation in the clutter line and identified stationary obstacles as well as vehicles and personnel moving along the path of the system. We tracked pedestrians and vehicles, and detected stationary objects like road boundaries, a fire hydrant, picnic table and utility poles.

I. INTRODUCTION

Equipping automobiles with a collision avoidance system based on radars is a growing area of research. Millimeter wave radars, primarily used by the military until recently, have become a candidate for collision avoidance systems due to their high range resolution and limited propagation range, which reduces interference effects. The FCC has proposed allocating several exclusive-use frequency bands for unlicensed use. One band proposed would allow operation from 76-77 GHz.

II. METHODOLOGY

A 100-milliWatt 77-Ghz radar system generating a Frequency Modulated Continuous Wave (FMCW) waveform was used in this study. The radar transmitted a total of 16 beams sequentially from a 2x8 port array. Each port was offset by two degrees, covering an azimuth field-of-view of 32 degrees. A bandwidth of 150 MHz resulted in a range resolution of 1 meter. The Doppler resolution of the system was 0.25 meters-per-second.

The radar was mounted atop an SUV and driven past typical highway and off-road situations. A 13-second measurement was identified for detailed analysis. The scene consisted of a pedestrian walking along the right side of the road and an SUV parked behind a tree at a distance. The pedestrian was tracked from a starting relative range of 55 meters to a final range of 15 meters, at which point the near-range clutter dominated. The SUV began moving around 7 seconds and was detected at a relative range of 115 meters.

The methodology selected for representing the radar sensor data shown in Figures 1 and 2 was based on the occupancy map framework introduced by Elfes [1]. A discrete spatial lattice of cells was defined over the region to be traversed by the radar platform. Sensor observations were used to update individual lattice locations. Occupancy maps were separated into a stationary object map (SO-Map) and a moving object map (MO-Map) [2]. The occupancy maps for this work used a resolution of 1 meter by 1 meter. Each cell of the map was checked to see if a given beam had made a measurement within the area covered by that cell. Measurements within a given cell were merged to compute a mean radar cross-section (RCS) representation of the scene.

Moving object maps were created by examining the non-zero Hertz Doppler bin in the range-Doppler map. If the platform was in motion, the zero-Hertz frequency appeared at other bins within the range-Doppler map. Persistent moving objects can be extracted from the MO-map as candidates for a tracking algorithm.

Figure 1. Stationary objects sensed in front of the radar for a snapshot view. The edges of the road are clearly defined for more than 50 meters. The road boundaries, a fire hydrant, picnic table and utility poles can be identified in Fig. 1. Detections of the moving person and SUV are shown in Fig. 2.
When the platform was in motion, the zero-Hertz Doppler return shifted to a frequency bin in the range-Doppler map proportional to the velocity of the platform. In order to generate a SO-map, the platform motion had to be removed using the velocity of the clutter line. Note that if a GPS estimate of the platform velocity is available, the frequency bin can be computed. An alternative method for estimating the zero-Hertz bin when INS or GPS data is not available is to use a voting method based on the range-Doppler frequency bins with the maximum signal over ranges of interest. This assumes that clutter from the ground is the dominate signal over most of the ranges.

III. MEASUREMENTS

A test facility at the NIST Nike Annex in Gaithersburg, MD was used to test the radar capabilities in a rural setting that included buildings, cars and pedestrians. An overhead image of the NIST obstacle course is shown in Fig. 3. The stationary object map produced by the radar for the site is shown in Figure 4, where multiple objects in the path are detected.

A Real Time Kinematic (RTK) differential GPS system was available to measure ground truth coordinates. Fig. 5 shows the SUV heading estimates based on the GPS coordinates of two receivers placed atop the SUV. Each measurement provided an absolute location within the obstacle course, so this method did not accumulate errors. Estimates of the heading were compared with frames from a video camera running at 30 frames-per-second mounted in the cab of the SUV. Every fourth frame was compared to compute a pixel shift, which was then converted to a change in heading angle. Errors in estimating the heading angle using this method can accumulate due to integer frame shifts.

Fig. 6 shows the velocity estimates based on GPS (red) and the range-Doppler map stationary clutter frequency bin (blue). Both the heading and velocity measurements correlated well with the differential GPS measurements. Having a secondary method for estimating heading and velocity was important for those locations within the obstacle course that experienced GPS dropouts.
IV. DISCUSSION

The collision-avoidance radar can generate stationary object maps and moving object maps while on the move, which can assist the platform in avoidance of both stationary and moving objects like people and other vehicles. The radar can also use moving object maps to try to predict the motion of objects that may move into the path of the radar. Object trajectory tracks can be computed and safe routes can be planned that would avoid the future location of the object. By closely analyzing the velocity characteristics of tracked objects, a classification of the type of object can also be attempted. Comparative examples of a runner and cyclist are shown in Figures 7 and 8.

CONCLUSIONS

A real-time automotive radar system with both stationary and moving obstacle detection has been demonstrated. Differential GPS receivers and radar-based speed measurements were used to create stationary and moving object maps. Road edge detection out to a range of more than 50 meters was shown. The system was able to detect moving personnel, perform vehicle tracking and assist with object classification.

REFERENCES