Radar Techniques for Human Detection and Classification in Urban Areas

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Radar detection/identification of humans from far distance is difficult, especially in urban environments. Prior research has primarily focused on micro-Doppler signature analysis, which suffers from poor discernability at long range. However, in highly complex problems such as urban sensing, where many factors interplay, conventional approaches may not be sufficient. Secondly, hand-crafted features are typically task-specific and often fail to generalize to new datasets. Therefore, we instead propose using deep learning to extract high-level features and then analysing their temporal patterns to classify person, vehicle, and clutter.

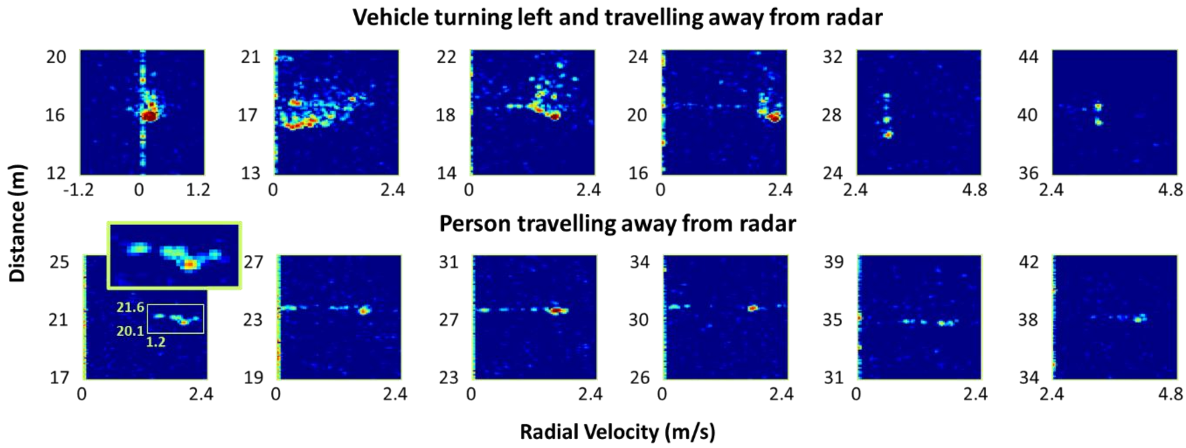

Figure 1 Range-Doppler heat maps of car and person taken from radar (height 0.75 meters)

In this work, we use TI's AWR1642 – a frequency-modulated continuous wave (FMCW) radar operating in the 76 GHz to 81 GHz frequency band, to establish a proof of concept. Using range-doppler heatmaps, we first demonstrate the various time-varying properties of vehicles and human targets. In Fig. 1, we positioned the AWR1642 radar 0.75 meters above ground in a carpark. Each range-doppler map is cropped to display information around the targets. The first row depicts a car traveling out of its parked location (side facing radar) and then away from radar (back facing radar). The second row shows a person walking away from the radar. In Fig. 2, the experiments are repeated with the radar mounted at a height of 7.4 m above ground.

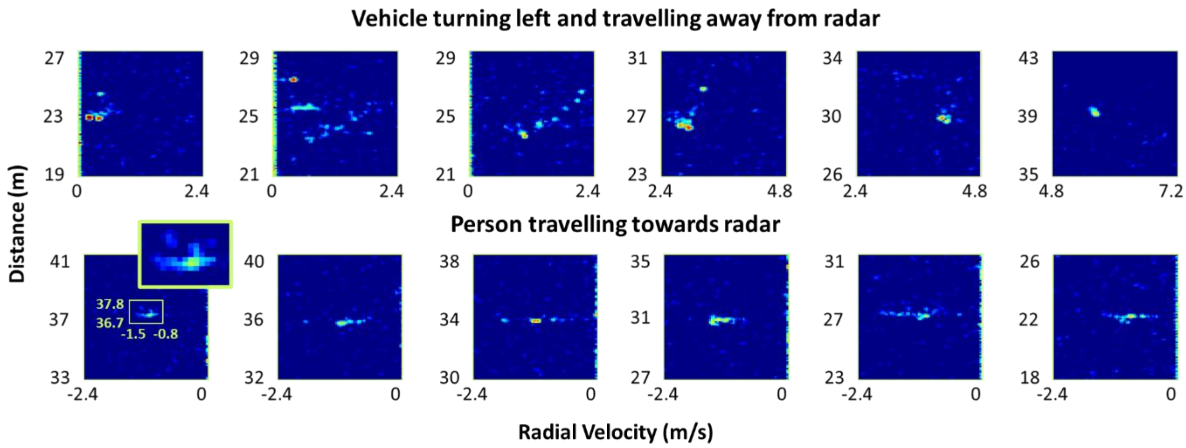

Figure 2 Range-Doppler heat maps of car and person taken from radar (height 7.4 m)

In both figures, we can observe that vehicle and human targets display different temporal patterns in target length/shape and doppler shift. However, changes in the radar cross section of the targets at different distance, target orientation, and radar elevation angle, as well as interplay between the target and its high-clutter surroundings increases the complexity of this classification problem. Therefore, we argue that by analysing sufficient data using deep neural networks, we may identify high-level temporal features that can reliably classify human/vehicle targets regardless of environments.

A general pipeline of our proposed method is presented below, which consists of three main parts. First, we obtain a point cloud through a signal processing chain, as illustrated in Fig. 3.

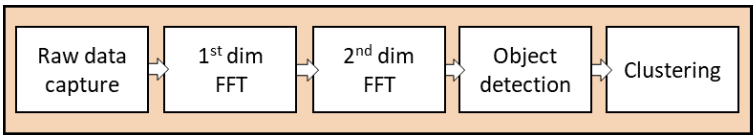

Figure 3 radar signal processing chain

Subsequently, we cluster the points that belong to the same target. Each cluster contains a number of points which can be characterized by parameters (x, y, v, I), where x and y are its egocentric coordinates relative to the radar, v is its radial velocity, and I is the return signal intensity. We apply feature extraction to each cluster to extract n features.

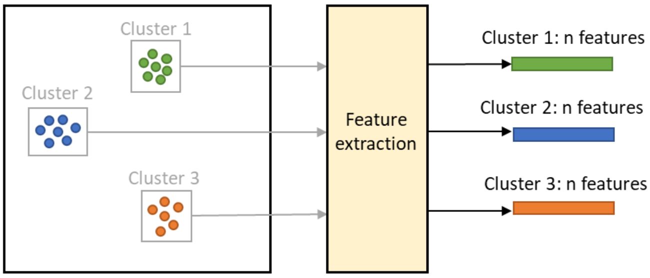

Figure 4 cluster feature extraction

Through tracking algorithms such as the Kalman filter, we can observe the movement/position and change of each target (cluster) in consecutive frames. We monitor the changes in the n features of the target over time and view this problem as a time series classification task. We proposed to first test 1d convolution layers with different kernels and stride length along the time axis to form a baseline approach. Further, we want to explore with self-attention mechanisms and experiment with transformer-based models, such as BERT, which recently attained state of the art results in multiple natural language processing tasks.

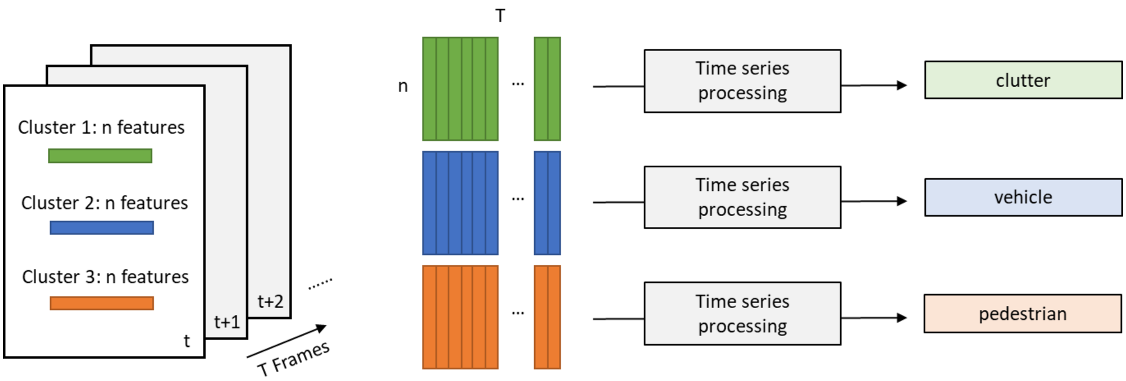

Figure 5 classification

A label: clutter/vehicle/pedestrian is assigned to each cluster based on the classification result. More data will be collected, and the results will be available in near future.