Evaluating the Best arrangement for Microradars at a crosswalk

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Introduction Smart intersections are increasingly being scrutinized to monitor the driver's and pedestrian behaviors and thus to improve road safety. Recently, a new non-intrusive solution for round-the-clock monitoring has emerged. Wireless sensors installed within the pavement transmit discrete data and fast algorithms are used to classify the different modes of trajectory. While experiments and studies have already been carried out to ensure the relevance of the classification, the question of the best arrangement for sensors to separate the trajectories of the different modes of transport (vehicles, pedestrians, bicycles) has not yet been studied in detail. In this regard, we propose to build a pedestrian crossing simulator that will simulate the output of micro-radars in function of pedestrian trajectories taken as input. Maximizing the classification of the different modes (F1 score or accuracy) under the position of the sensors will yield us the best arrangement possible under our assumptions.

Proposal

1. In a first part, I will focus on developing a python package modeling a smart crosswalk and returning simulations of sensors outputs according to specified pedestrians trajectories.

2. In a second time, I will validate this model by using the data from the Danville intersection.

3. Finally, given a distribution of possible pedestrian trajectories at crosswalk and given an algorithm to recover those trajectories, I will try different arrangements aiming at maximizing the accuracy score of the algorithm.

1 Crosswalk modeling

For now, I have looked the MicroRadar documentation to understand the functionning of a single sensor. I am now blocked to understand how does the radio signal is transcribed into a detection bins graph.

1.1 User Input

- The crosswalk is modelised as a rectangle with dimensions fixed by the user. The center of this rectangle is set to be the origin of the referential. (0,0)
- The sensors are fixed by the user as a list of three reals : (x, y, α) the location of the sensor and its angle with respect to the x-axis.
- The pedestrian trajectories are fixed by the user. At first, a trajectory is defined as a list of points that the trajectory must visit. The speed of the pedestrian will be taken as constant.

1.2 Assumptions

- All the sensors are identical and are modeling Sensys Network MicroRadar product.
- A pedetrian is completely defined by the location of its barycenter.

1.3 Sensor Modeling

Let us for now focus on the modeling of a single device, i.e microradar. The challenge will be to simulate the features that effectively communicate a microradar based on the location of an object.

1.3.1 Understanding the output of a sensor

According to [2], a sensor communicates the following four features :

1. Duration (in seconds): time period for which a triggered microradar event was active.
2. BulkMax: maximum bulk value achieved during an active microradar event. The bulk value of an inactive microradar is defined to be 128. An active microradar event would observe an increase in bulk value in increments of 2,
3. BulkMean: average bulk value during an active microradar event.
4. BulkChanges: the number of times bulk value changed within a microradar event.

1.3.2 Functionning of a microradar

According to one article [3] by researcher at Sensys, a microradar is emitting a RF microwave pulse of frequency f_p 6.3 GHz at the sample rate 8Hz. The sensor "mixes the transmitted RF burst with a received RF reflection to generate an IF signal". I suppose that the sensor operates a Heterodyne operation to select the signal corresponding to the reflection of the burst. This would explain why in the resulting IF Sample given, the frequency of the IF signal is significantly lower than 6.3 GHz.

From the IF sample, the sensor computes a "detection" bins graph. This crucial step is not explained. For me, it could be two things : either a Fourrier decomposition of the signal, either it could be a sampling. However the Y axis being in DB, it is more likely that it is a Fourrier decomposition. I would to have more precision about this.

Finally, from this graph a detection event is raised. "If any bin is above the baseline it triggers a detection event". The bulk value can be defined either as the number of bins above the baseline (i.e. the number of distances that yield a reflection) or by summing the overall log energy above the baseline (i.e. related to the overall reflected energy).

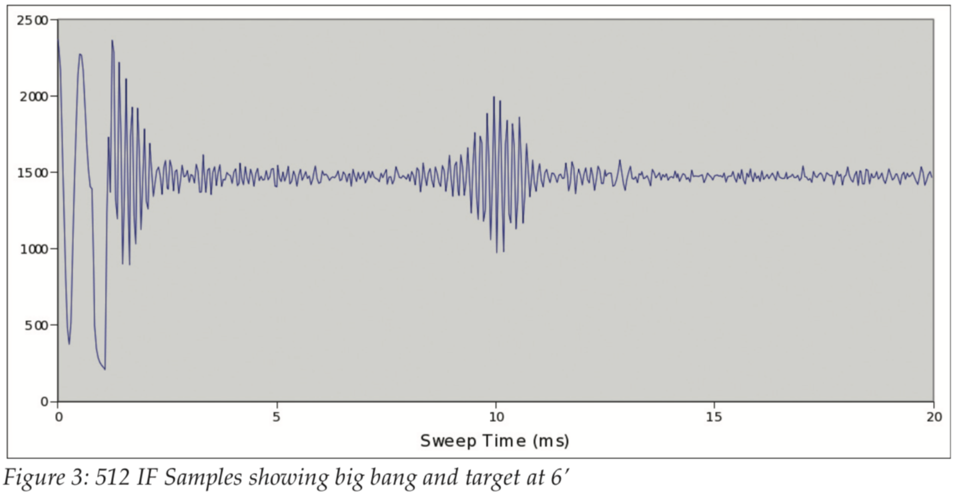

Figure 1: An example given of a ”IF Signal”

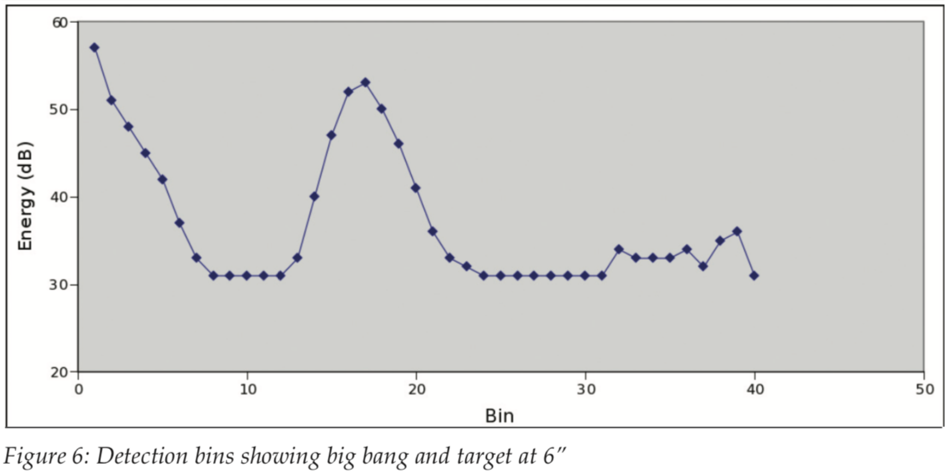

Figure 2: An example given of a ”detection bins” graph

References

[1] Offer Grembek, Alex Kurzhanskiy, Aditya Medury, Pravin Varaiya, Mengqiao Yu, *Making intersections safer with I2V communication*. Transportation Research Part C 102 (2019) 396–410.

[2] Aditya Medury, Mengqiao Yu, Offer Grembek *Multi-modal Trajectory Classification at Signalized Intersections using In-Pavement Sensors:*

[3] Michael T. Volling, Sensys Networks, *A New Solution to the Growing Problem of Bicycle Detection*

[4] Bernard C. Soriano, *Autonomous vehicles in California*. Conference at UC Davis, October 2019.

[5] Mohammad Shokrolah Shirazi and Brendan Morris, *Observing Behaviors at Intersections: A Review of Recent Studies & Developments*, Conference Paper, June 2015.

[6] Stephanie Lefevre, Christian Laugier, Javier Ibanez-Guzman, *Risk Assessment at Road Intersections: Comparing Intention and Expectation*, Conference Paper, June 2012.

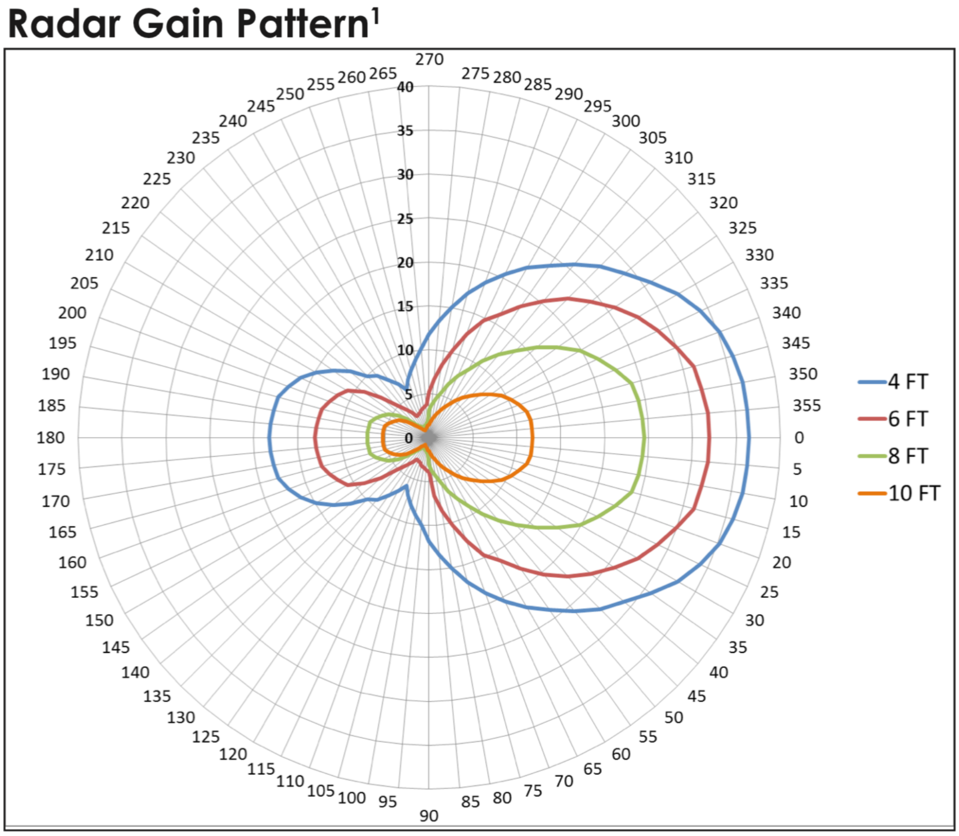

Figure 3: Caption