Feature Matching and Adaptive Prediction Models in an Object Tracking DDDAS

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1. Introduction

- Optical target tracking problem using an adaptive sensor is considered.
- The OpenStreetMap source provides additional data to identify road networks and intersections.
- DDDAS can be used to control an adaptive sensor.
- An Adaptive sensor similar to the RIT Multi-Object Spectrometer can take spectral data at a small number of locations.
- Several adaptive sampling strategies are employed to assign locations for spectral measurements.
- Synthetic hyperspectral images are generated by the Digital Imaging and Remote Sensing Image Generation(DIRSIG) Model

1. Introduction

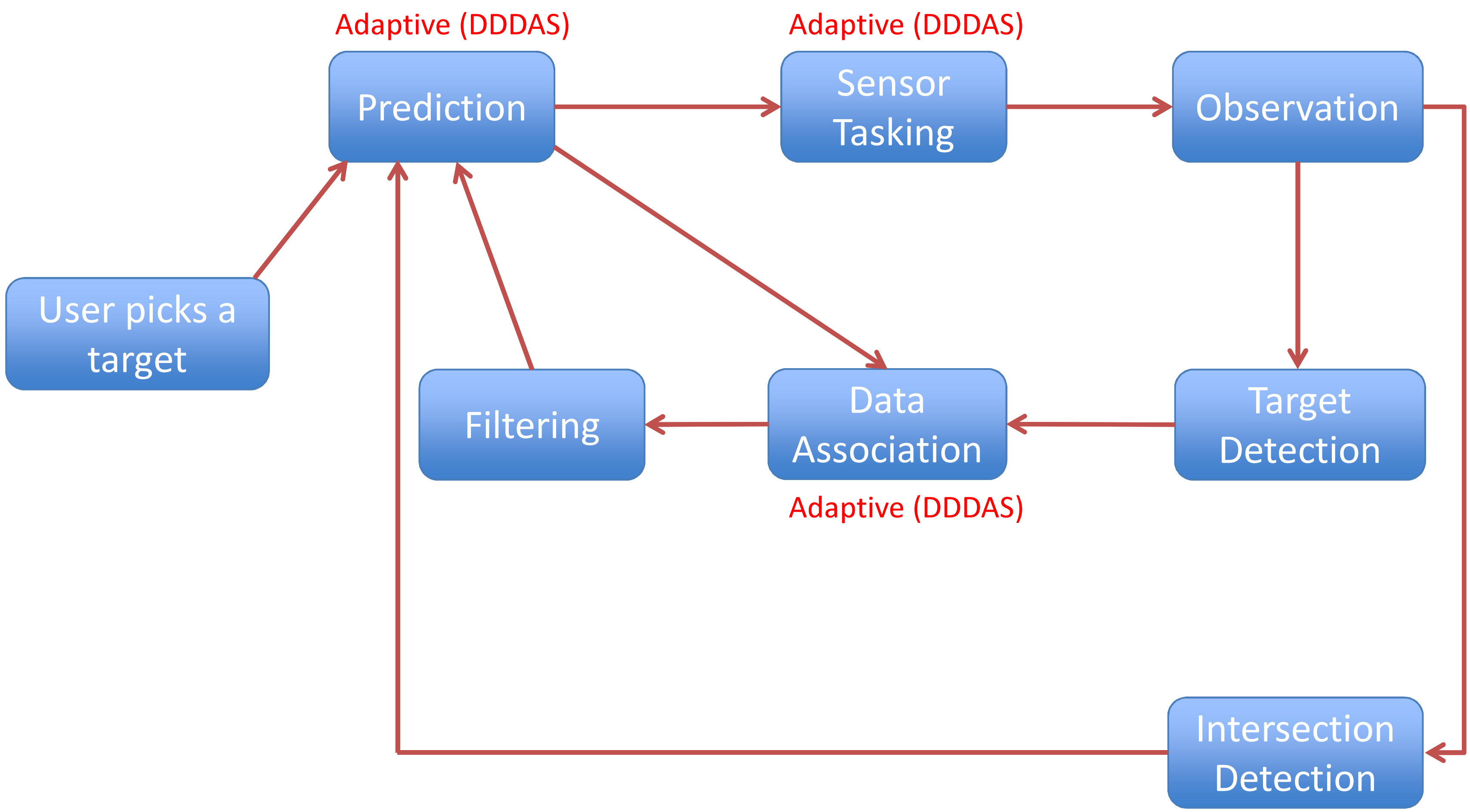


Figure 1: Flowchart of the optical target tracking algorithm

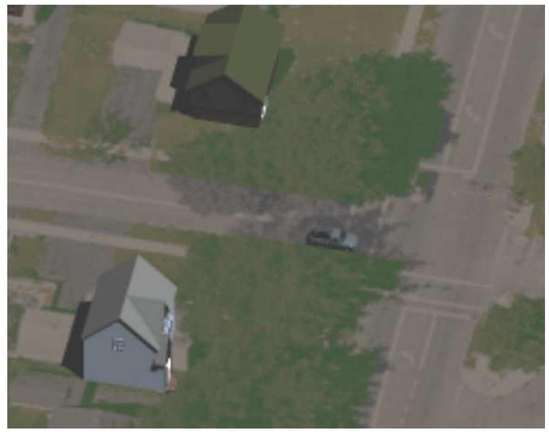
2.DIRSIG SCENE

- The simulation uses hyperspectral imaging from a fixed aerial platform assuming a static sensor mount.
- Simulation of Urban Mobility (SUMO) is integrated with DIRSIG to produce dynamic imagery for tracking scenarios.
- SUMO has the capability to simulate realistic vehicular and pedestrian movement.

Figure 2: DIRSIG Scene built to resemble part of Rochester, NY

2. DIRSIG SCENE

Frame 1

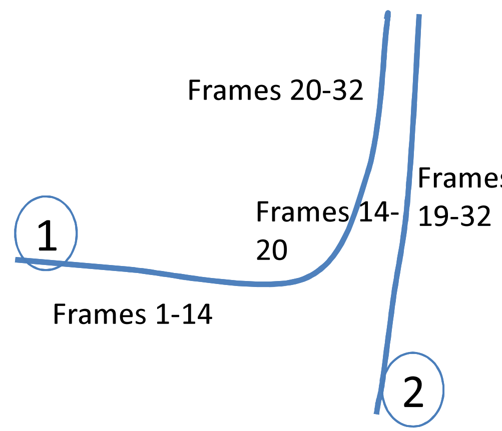


Frame 11

Frame 15

Frame 20

Frame 26



Paths followed by the two targets

2. Target Detection / Data Association

- Change Detection method is basically differencing multiple frames at different time periods.
- RX Detection detects the spectral differences between a region and its neighboring area.
- When both used in concert, a good target detection performance can be obtained.
- Data association algorithm associates new observations with corresponding tracks.

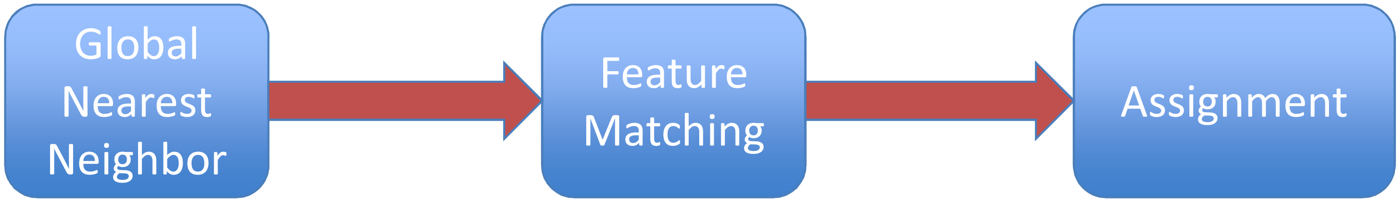


Figure 3: Basic flowchart of data association

3. Gaussian Sum Filter

- It represents the state probability density function by a mixture of Gaussian components.
- The components are placed in the vicinity of the ±3σ of the mean. (σ=standard deviation of initial covariance matrix)
- Each component is assigned a same initial weight.
- Gaussian components approximate the conditional pdf as:

$$p(t, x(t)_k^n | z_k) = \sum_{n=1}^{M} w(t)_k N(x(t); \mu(t)_k^n, P(t)_k^n), \qquad \sum_{n=1}^{M} w(t)_k^n = 1$$

- 13 individual Gaussian components are used for each track.
- Each component is propagated by Extended Kalman filter (EKF).

Terejanu G. , Singla P. , Singh T. , Scott P. D. (2011), Adaptive Gaussian Sum Filter for Nonlinear Bayesian Estimation, *IEEE Transactions on Automatic Control*, Vol:56, No:9

4. Feature Matching

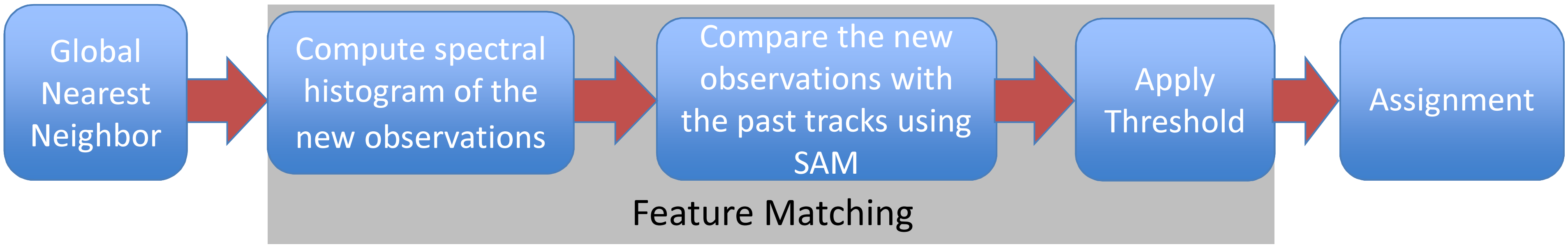
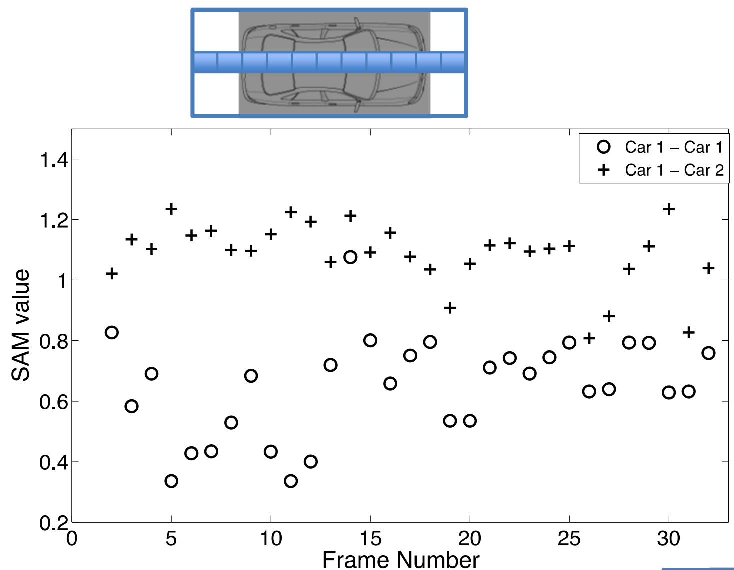


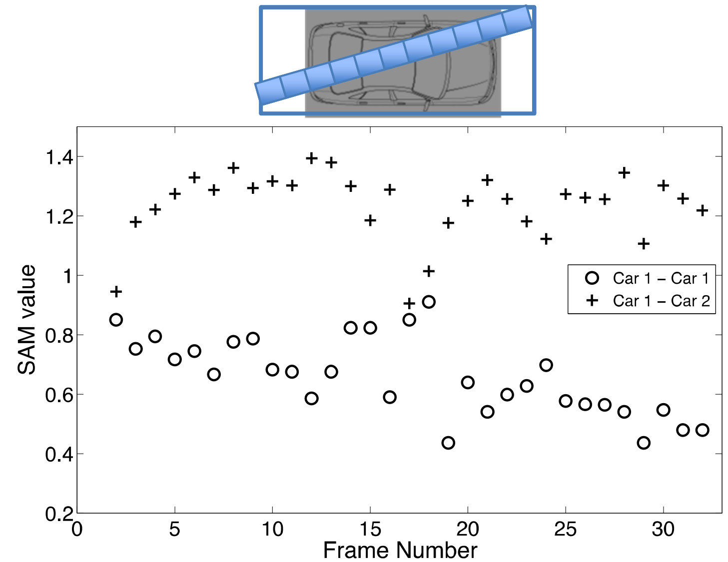
Figure 4: Flowchart of feature matching algorithm

- The tracking system must adaptively guide the sensor to collect the limited spectral observations.
- Adaptive Sampling method is applied to compute spectral histograms of a track.
- The RITMOS sensor only allow us to take one pixel of spectral data per row or column per frame.
- Histograms are compared using the Spectral Angle Mapper (SAM) metric.

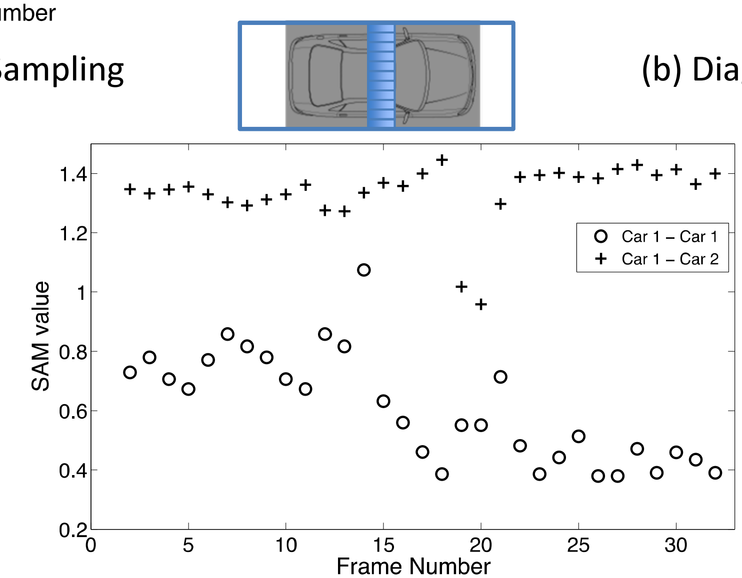
5. Adaptive Sampling



(a) Horizontal Sampling



(b) Diagonal Sampling



(c) Vertical Sampling

5. Adaptive Sampling

- Adaptive sampling is a key step on assigning new observations to correct tracks.
- It helps us collect car pixels instead of road pixels.
- Sampling strategy is adaptively implemented based on :
    1. Predicted location of target
    2. Intersection location

Figure 5: Adaptive sampling strategy

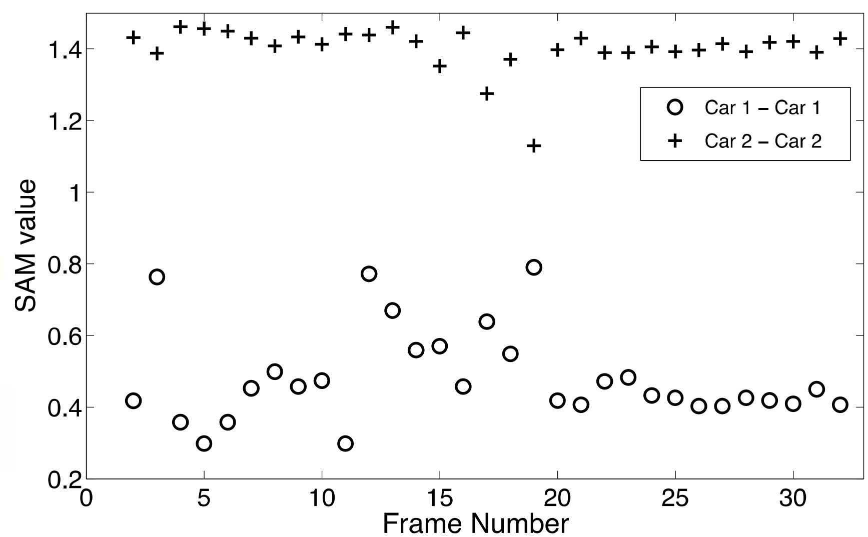


Figure 6: Adaptive sampling strategy result

6. Intersection Detection

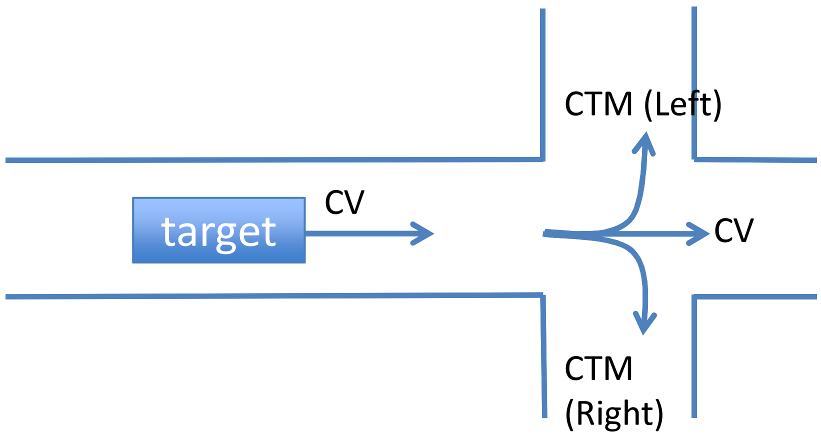
- The OpenStreetMap project is a regularly updated open source map.
- Using the OpenStreetMap source, we can detect location and type of an intersection. (T, Plus type intersection etc.)
- By using this information, adaptively we can switch to better representative models for an intersection.

Figure 7: The detection of intersections

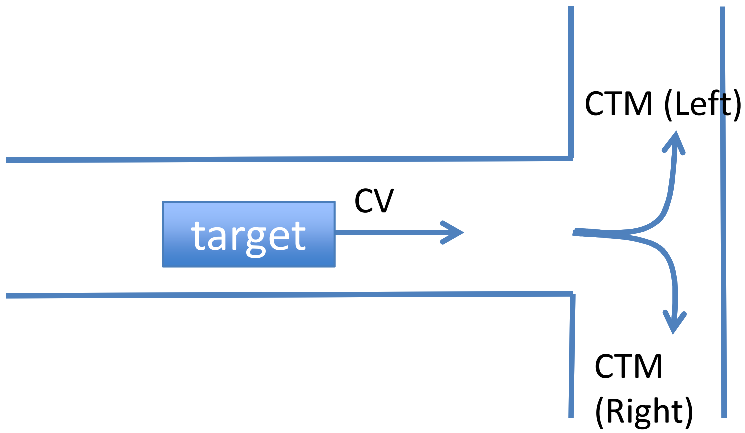
and curvy roads in an image using the OpenStreetMap source

7. Prediction in an Intersection

- We change prediction model based on whether or not the target is in an intersection.
- Based on the type of the intersection, an appropriate multiple model set is employed.
- Each component of GSF is randomly assigned a different turning model (left or right turn) while in the intersection.



(a) Plus type intersection scenario



(b) T type intersection scenario

7. Prediction in an Intersection

- In a T type intersection, half of the components turn left and the other half turns right.
- By using multiple models, it is more likely to have a component on the tracked target.

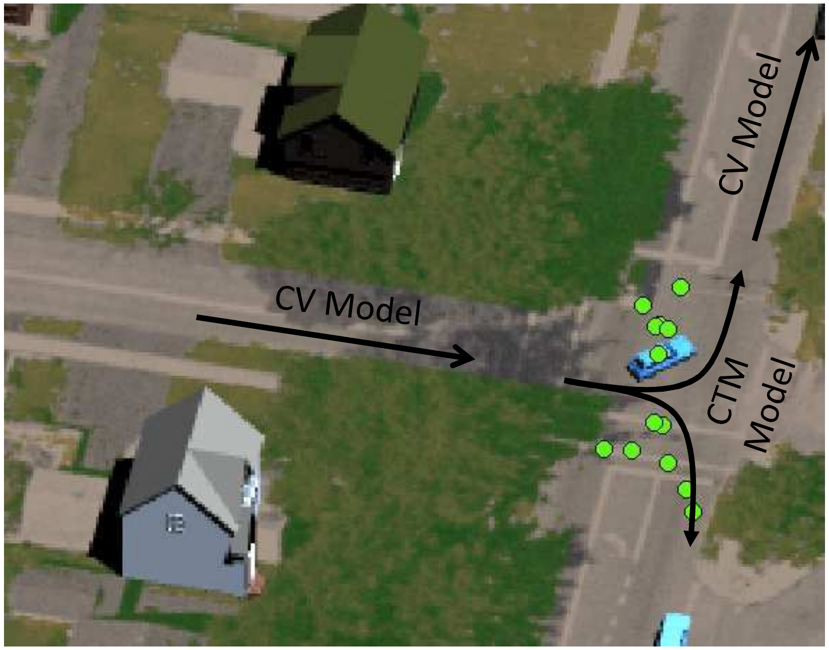


Figure 8: Tracking a target in a T type intersection by employing multiple models.

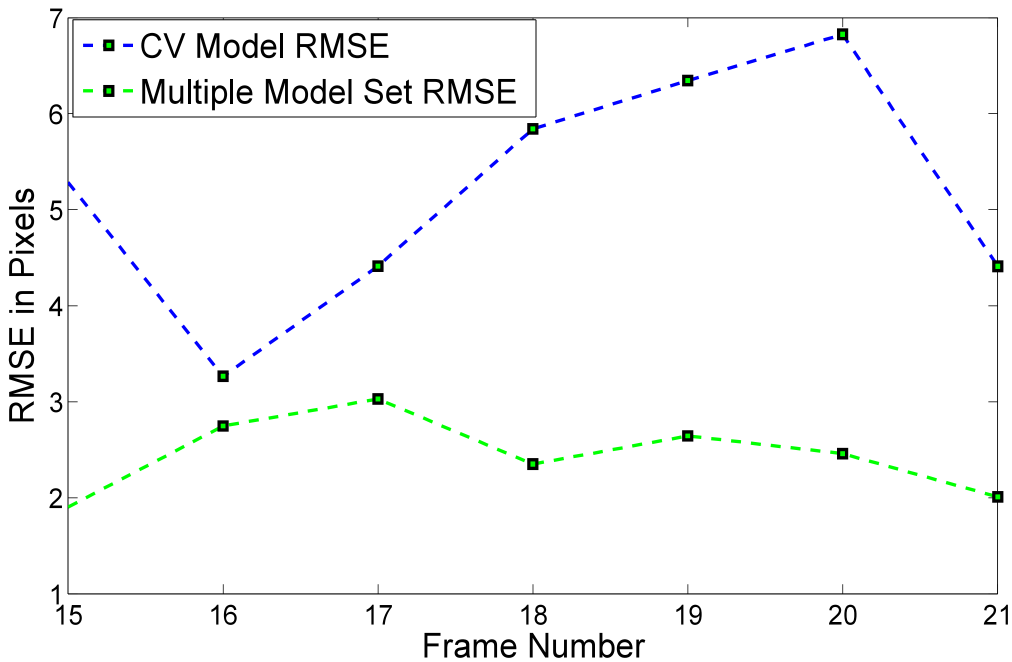
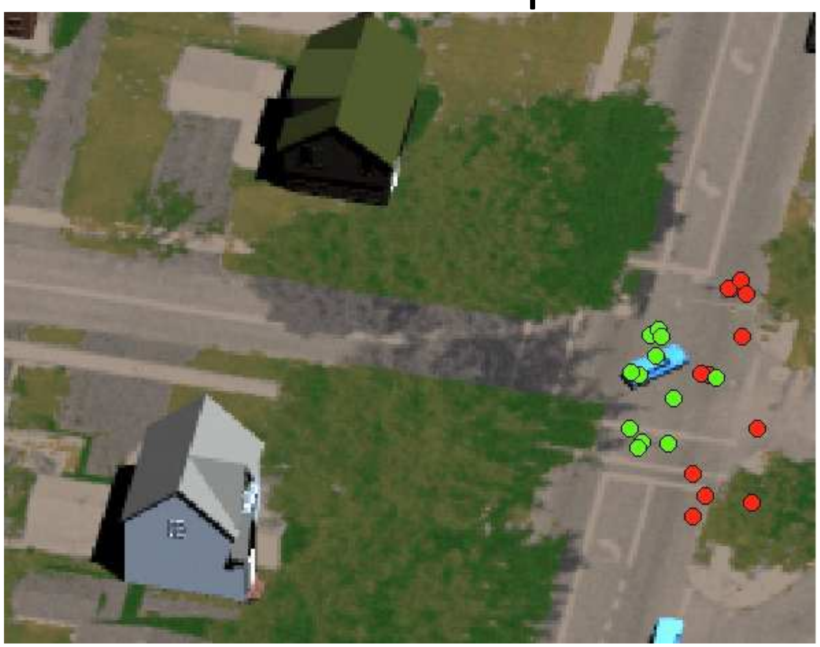


Figure 9: Root Mean Square Error (RMSE) for the frames when the target turns

8. Background Detection

- Removing background pixels can help us collect more target pixels.
- Predicting two steps ahead of time is performed and spectral information is saved.
- In the next step, prediction for the current step is compared to the stored future prediction in the past.



Predictions for the future frame

Predictions for the current frame

Figure 10: Predicting target's future and current position when the target executes a left turn

9. Conclusion

- The OpenStreetMap source can lead to more accurate predictions and analysis from data assimilation.
- Adaptive sampling based on the OpenStreetMap can help us improve feature matching.
- Adaptively changing models in an intersection improve prediction performance.
- More reliable turn models can be designed to improve the accuracy of prediction during an intersection.
- More research needs to be performed on background elimination problem.