Feature Matching and Adaptive Prediction Models in an Object Tracking DDDAS

Burak Uzkent, Matthew J. Hoffman, Anthony Vodacek, John P. Kerekes, Bin Chen
Rochester Institute of Technology, NY, USA

Funded by the Air Force Office of Scientific Research
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

Paths followed by the two targets:
1. Frames 14-20
2. Frames 19-32

Images:
- Frame 1
- Frame 11
- Frame 15
- Frame 20
- Frame 26
- Frames 20-32
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:

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

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

4. Feature Matching

- 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.

**Figure 4:** Flowchart of feature matching algorithm
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](image1)

![Figure 6: Adaptive sampling strategy result](image2)
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.](image1)

![Figure 9: Root Mean Square Error (RMSE) for the frames when the target turns](image2)
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.

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.