Multiple Object Tracking Intern Report

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I. Introduction

Multiple object tracking is an essential part of the perception pipeline. In order to solve this problem many methods have been developed. My internship subject was to approach this problem using classical methods which are proposed in the master thesis provided to me. To be more precise used methods are: IMM(Interaction Multiple Model) for modeling object trajectories with different kinematic models, UKF(Unscented Kalman Filter) for nonlinear filtering of the obtained measurements and JPDAF(Joint Probability Data Association Filter) for a sophisticated data association method. I have implemented all of them in python and prepared mock data to assess their results.

II. Problem Definition and Approach

The objective of multiple object tracking is to link and filter object detections across the sampled timeline. This way each object's trajectory and state estimation can be obtained. The difference between single object tracking and multiple object tracking is, later needs to associate object detections with existing tracks so that their states can be estimated correctly based on these associted detections.

The supplied master thesis uses UKF(Unscented Kalman Filter) to estimate the object states. Kalman filter needs a prediction model to predict the next state. In the thesis multiple kinetic models are used; Constant Velocity(CV), Constant Turn-Rate Velocity(CTRV) Model and Random Motion Model(RM). CTRV has nonlinear nature, hence the need for UKF. In order to use these different models to give only one unified estimation IMM is used.

In order to track multiple objects an data association method is required. JPDAF is used for this purpose. JPDAF is a soft data association method, meaning it does not associate the detections with existing tracks one to one. It associates all detections to all tracks based on their calculated joint association probabilities.

III. Objectives

*Explain why you had to implement the algorithms yourself *Talk about other possible methods to solve multi object tracking problem

To be honest, no clear objectives were provided in the beginning of my internship, only the master thesis. After have read the thesis and searched internet for some context I have determined the objectives myself, which were seem to be approved by my supervisor Dr. Berker Logoglu. Here is the list.

- Implementation of IMM, UKF, JPDAF algorithms
- Development of an test environment for the algorithms using mock data
- Test of the algorithms on Nuscenes dataset

IV. Project Structure

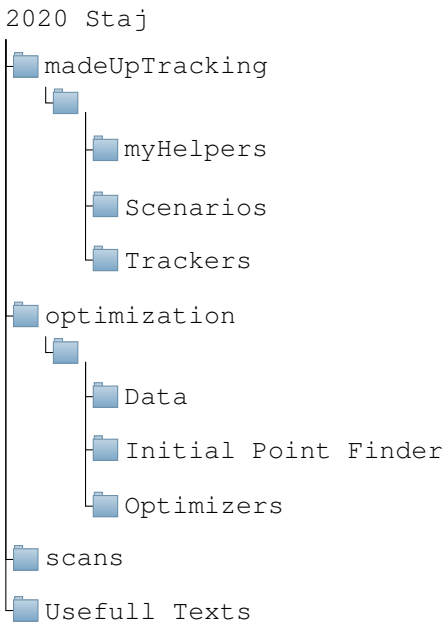

Fig. 1: *Project Structure*

V. IMM-UKF-JPDAF

In this section, I will give details about the algorithms and their implementation details with some insights I have gained.

Indices	
K	Number of ...
T	Number of ...
Parameters	
c	something

TABLE I: *Notation Table*

A. IMM

This may be a modified version of your proposal depending on previously carried out research or any feedback received.

1) Mixing:

$$\mu^{ji}_{k-1|k-1} \triangleq P(r_{k-1} = j \,|\, r_k = i, y_{0:k-1}) \tag{1}$$

$$\mu^{ji}_{k-1|k-1} = \frac{\pi_{ji}\ \mu^{j}_{k-1}}{\sum_{l=1}^{N_r} \pi_{li}\ \mu^{l}_{k-1}} \tag{2}$$

$$\hat{x}^{0i}_{k-1|k-1} = \sum_{j=1}^{N_r} \mu^{ji}_{k-1|k-1}\ \hat{x}^{j}_{k-1|k-1} \tag{3}$$

$$P^{0i}_{k-1|k-1} = \sum_{j=1}^{N_r} \mu^{ji}_{k-1|k-1} \left[P^{j}_{k-1|k-1} + (\hat{x}^{j}_{k-1|k-1} - \hat{x}^{0i}_{k-1|k-1})(\hat{x}^{j}_{k-1|k-1} - \hat{x}^{0i}_{k-1|k-1})^T\right] \quad (4)$$

2) Mode Prediction Updates:
3) Mode Measurement Updates:
4) New Mode Probabilities:

$$\mu^{i}_{k} = \frac{N(y_k; \hat{y}^{i}_{k|k-1}, S^{i}_{k}) \sum_{j=i}^{N_r} \pi_{ji}\, \mu^{j}_{k-1}}{\sum_{l=1}^{N_r} N(y_k; \hat{y}^{l}_{k|k-1}, S^{l}_{k}) \sum_{j=1}^{N_r} \pi^{j}_{jl}} \quad (5)$$

5) Output Estimate Calculation:

B. UKF

Describe your first solution here.
1) Unscented Transform:
2) Prediction:
3) Update:

C. JPDAF

Bla Bla
1) Association Events:
2) Validation Matrix:
3) Joint Association Probabilities:

D. PDAF

Bla bla

E. Putting It All Together

Bla bla
1) Mixings:
2) Predictions:
3) Joint Data Association Probabilities Calculation:
4) Updates:
5) New Mode Probabilities Calculation:
6) Final Output Estimations:

F. Testing of the Algorithms

The main difference between this section and the one in your report *Do not include your findings in this section.*

VI. Trackers

In order to test algorithms independently, I have created 4 different tracking classes. First I have implemented Single Object Single Model Tracker and then moved to the others until have finished the final goal Multiple Object Multiple Model Tracker.

A. Single Object Single Model Tracker

It is used to track single object with single model. The measurement to be fed to the tracker in each sampling time is expected to exist and be one. The algorithm of the interest to be validated is *UKF*.
*Reference to code location *How it is used *Rationale about the validation of the target algorithms

B. Single Object Multiple Model Tracker

*What it does and target algorithms to be validated *Reference to code location *How it is used *Rationale about the validation of the target algorithms

C. Multiple Object Single Model Tracker

*What it does and target algorithms to be validated *Reference to code location *How it is used *Rationale about the validation of the target algorithms

D. Multiple Object Multiple Model Tracker

*What it does and target algorithms to be validated *Reference to code location *How it is used *Rationale about the validation of the target algorithms

VII. Trackers in Action

The main difference between this section and the one in your report *Do not include your findings in this section.*

VIII. The Need For Optimization

Use the subsubsection command with caution—you probably won't need it at, but I'm including it this an example.
1) Optimization: Use the subsubsection command with caution—you probably won't need it at, but I'm including it this an example.

IX. Performance Assesment

Use the subsubsection command with caution—you probably won't need it at, but I'm including it this an example.

X. Fullfilment of the Objectives

Use the subsubsection command with caution—you probably won't need it at, but I'm including it this an example.

XI. Conclusion

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REFERENCES

[1] H. Kopka and P. W. Daly, *A Guide to LaTeX*, 3rd ed. Harlow, England: Addison-Wesley, 1999.

[2] D. Horowitz, *End of Time*. New York, NY, USA: Encounter Books, 2005. [E-book] Available: ebrary, http://site.ebrary.com/lib/sait/Doc?id=10080005. Accessed on: Oct. 8, 2008.

[3] D. Castelvecchi, "Nanoparticles Conspire with Free Radicals" *Science News*, vol.174, no. 6, p. 9, September 13, 2008. [Full Text]. Available: Proquest, http://proquest.umi.com/pqdweb?index=52&did=1557231641&SrchMode=1&sid=3&Fmt=3&VInst=PROD&VType=PQD&RQT=309&VName=PQD&TS=1229451226&clientId=533. Accessed on: Aug. 3, 2014.

[4] J. Lach, "SBFS: Steganography based file system," in *Proceedings of the 2008 1st International Conference on Information Technology, IT 2008, 19-21 May 2008, Gdansk, Poland.* Available: IEEE Xplore, http://www.ieee.org. [Accessed: 10 Sept. 2010].

[5] "A 'layman's' explanation of Ultra Narrow Band technology," Oct. 3, 2003. [Online]. Available: http://www.vmsk.org/Layman.pdf. [Accessed: Dec. 3, 2003].