Visage Technologies Student Internship 2025

Model Nonlinearity Evaluation for Multiple Object Tracking

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Prerequisites:

Working knowledge of Python. Knowledge of dynamical systems (both linear and nonlinear), linear algebra and Kalman filter. Knowledge of multiple object tracking is a bonus.

Summary:

Traditional multiple object tracking (MOT) approaches rely on sensor fusion, typically implemented through a state estimator such as the Kalman filter (KF). The choice of KF depends on the properties of the system model and the specific use case. However, selecting the appropriate version can be challenging and is often an iterative process.

The aim of this internship is to use a concept called measure of nonlinearity (MoN) to evaluate the suitability of models for object tracking with specific state estimators. Open-source MOT datasets and standard mathematical models will be analyzed and the nonlinearity of these models evaluated across different state-space subsets, creating a "nonlinearity distribution." The goal is to identify high nonlinearity scenarios, their frequency, maximum nonlinearity, and potentially other useful properties. Sequences with varying linearity will be tested using a sensor fusion library to determine if MoN correlates with Kalman filter performance. These insights could streamline dataset analysis and simplify model and KF version selection.

Weekly timeline:

Week 1: Introduction to MoNs, mathematical models and Kalman filter

- **Tasks:**
  - do a literature review of measures of nonlinearity
  - do a literature review of different mathematical models used for MOT
  - do a literature review of Kalman filter and Unscented Kalman filter
- **Expected outcomes:**
  - understanding of measures of nonlinearity and their potential importance
  - understanding of mathematical models used for MOT and when to use them
  - understanding of (Unscented) Kalman filter

Week 2: Experiment definition and environment setup

- **Tasks:**
  - choose the dynamical models which will be used
  - set up environment for running the Kalman filter
  - do a review of proposed datasets and decide which would be the most suitable for MoN analysis
  - download and inspect the dataset
- **Expected outcomes:**
  - clearly defined models which will be analyzed
  - completed environment setup
  - able to start the implementation

Week 3: Implementation

- **Tasks:**
  - extract necessary states from the chosen dataset (depending on the selected dynamical models)
  - emulate MOT framework using extracted data and Kalman filter (without the detector)
- **Expected outcomes:**
  - dataset preprocessed to be suitable for selected dynamical models
  - have a mockup of MOT framework suitable for KF performance analysis

Week 4: Implementation

- **Tasks:**
  - implement a script which calculates MoN based on a given dataset and a given dynamical model
  - calculate how MoN changes for chosen models based on the regions of the extracted systems states
  - identify state-space region with low/high nonlinearity
- **Expected outcomes:**
  - MoN calculation script implemented
  - MoN evaluated for different regions of the dataset
  - regions of low and high nonlinearity detected

Week 5: Experimentation

- **Tasks:**
  - select a few sequences with low and a few sequences with high nonlinearity
  - run KF and UKF on each of those sequences and evaluate their performance
  - compare performance of Kalman filters to the MoN value and draw some conclusions

- **Expected outcomes:**
    - sequences analyzed based on the nonlinearity measure
    - correlation of MoN value and KF performance evaluated

Week 6: Report

- **Tasks:**
    - perform final analysis of the results
    - finalize MoN analysis script
    - create a presentation of used methods, results and obstacles
- **Expected outcomes:**
    - report of the results
    - MoN analysis script
    - presentation of the internship topic

Literature:

Straka, Ondřej, and Jindřich Havlík. "Design of Unitless Normalized Measure of Nonlinearity for State Estimation." *2024 27th International Conference on Information Fusion (FUSION)*. IEEE, 2024.

McIntyre, Gregory A., and Kenneth J. Hintz. "Comparison of several maneuvering target tracking models." Signal processing, sensor fusion, and target recognition VII. Vol. 3374. SPIE, 1998.