

Collaborative Research: CPS: Medium: Spatio-Temporal Logics for Analyzing and Querying Perception Systems

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<https://sites.google.com/a/asu.edu/s-taliro/>

Project Description: Develop methods for reliability & performance analysis of perception systems

Problem Challenges:

- How to specify performance requirements for perception systems?
- What are meaningful quantitative metrics for such requirements?
- How to efficiently monitor and reason over perception data streams?
- How to mine requirements and detect patterns on data streams?

Some motivating examples:

- Should the perception system detect and track all vehicles within lidar range or camera visibility? (or both?)
- If an object is misclassified, for how many frames should this be the case?
- If an object is occluded for how long should be tracked?

Technical Approach: Define a new spatio-temporal logic

Example: Monitoring the quality of SqueezeDet object detection on KITTI data set

Remark: This requirement would not need ground truth data!

“At every time step, for all the objects (id) in the frame, if the object class is cyclist with probability more than 0.7, then in the next 5 frames the object (id) should still be classified as a cyclist with probability more than 0.6”

$$G(x. \forall id @ x, (C(x, id) = Cyclist \wedge P(x, id) > 0.7) \rightarrow G(y. ((x \leq y \wedge y \leq x + 5) \rightarrow (C(y, id) = Cyclist \wedge P(y, id) > 0.6))))$$



The data stream D does not contain an object classified as cyclist in Frames 84 and 85.

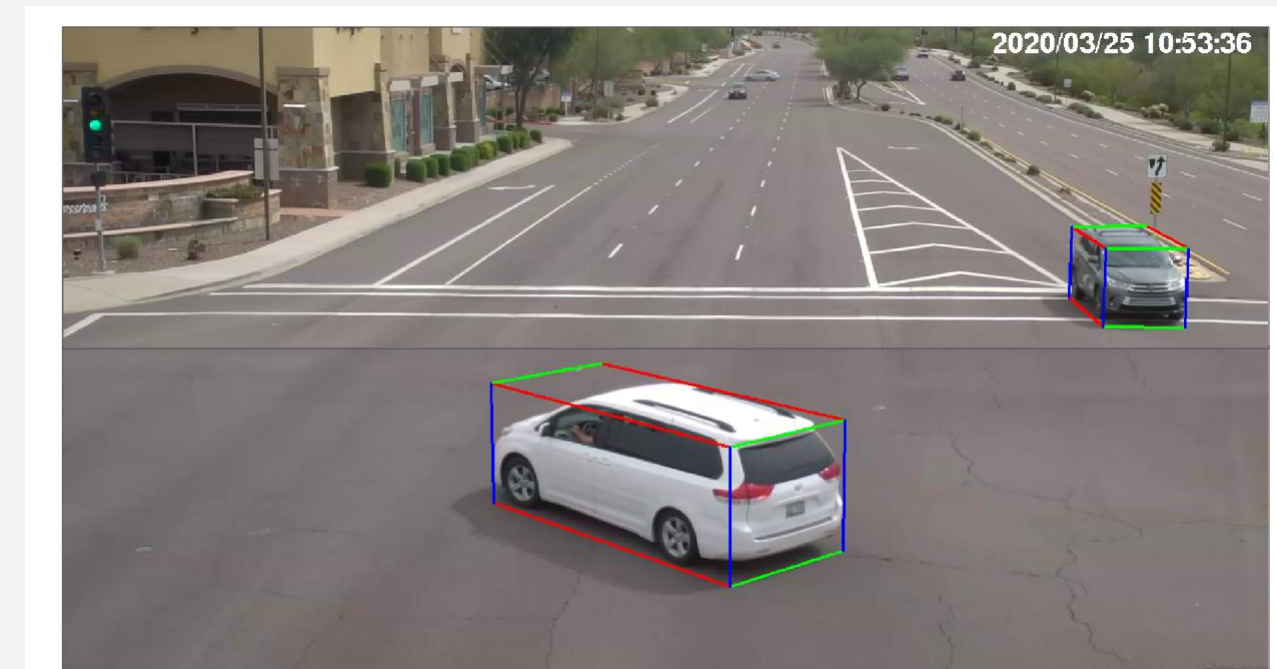
Relaxed requirement: “... then in the next 5 frames the object (id) should still be classified as a cyclist ... or a pedestrian should be detected within 40 pixels from where the cyclist was detected”

Impact:

- Perception systems are central to the safety and functionality of automated driving systems and mobile robots
- Currently, there is no clear/formal way that OEMs and suppliers can exchange information on perception system requirements
 - Suppliers have no formal way to capture targets/requirements for development
 - OEMs have no systematic way to test and verify the perception components provided by the suppliers
 ⇒ Major issue for interoperability and certification/validation of updated components
- In addition, there is no:
 - systematic way to query streaming perception data for events that satisfy do not satisfy the requirements
 - systematic way to mine such requirements from perception data

Evaluation:

- Demonstrate that the logic can capture existing metrics used for the evaluation of perception systems on KITTI dataset and the nuScenes dataset
- Evaluate runtime performance on the F1/10 platform
- Real life application:
 - Do Automated Driving Systems (ADS) deployed in AZ satisfy safe driving requirements?
 - Can we query interesting scenarios for simulation based testing?



Preliminary work:

1. Dokhanchi et. al. Runtime Verification (RV), 2018 (https://link.springer.com/chapter/10.1007/978-3-030-03769-7_23)
2. Lu et.al. ICRA 2021 (<https://arxiv.org/pdf/2104.00893.pdf>)