Towards Scalable Coverage-Based Testing of Autonomous Vehicles

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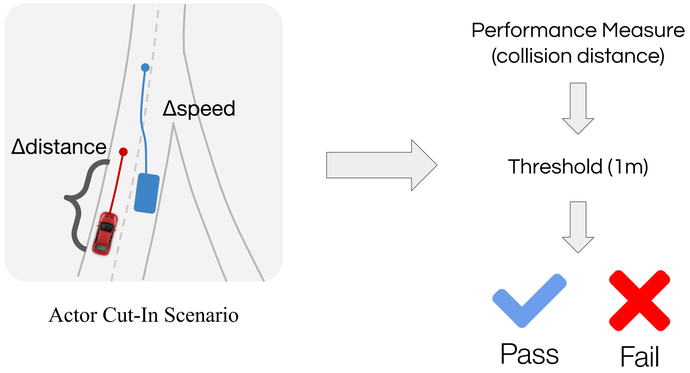
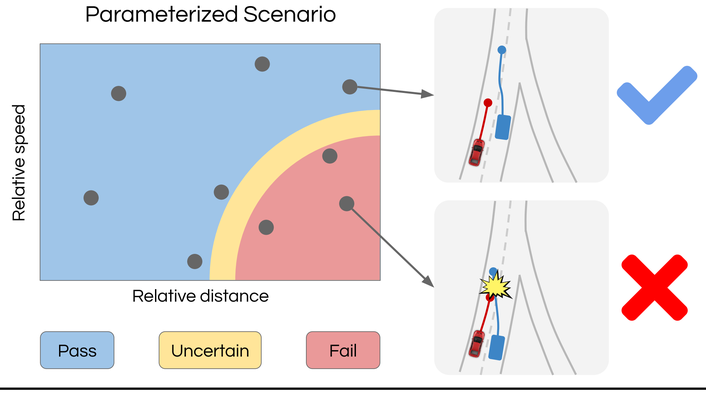
AV Testing

- Autonomous Vehicles are often tested in simulation through **parameterized scenarios**
- Each parameter combination yields a **concrete scenario**
- Pass/fail from thresholding underlying continuous metric



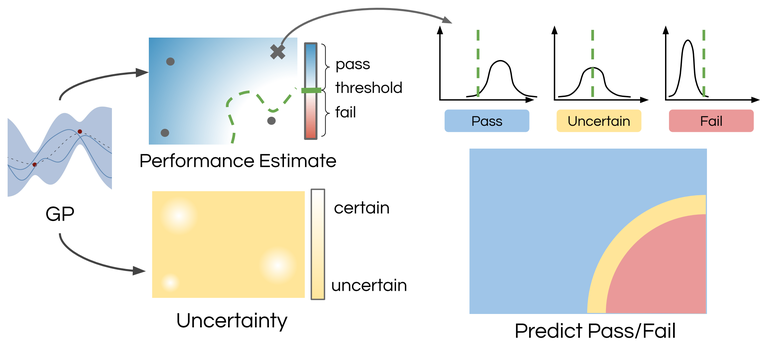
Task

- Goal of testing - understand if the AV will pass or fail on concrete scenarios across parameter space
- Difficult to directly **cover** the continuous space, because infinitely many concrete scenarios
- Need to leverage observed test outcomes to **estimate** the outcome on unseen tests
- Task: execute a **finite** set of concrete scenarios and partition the parameter space into 3 regions: **pass, fail, unknown**

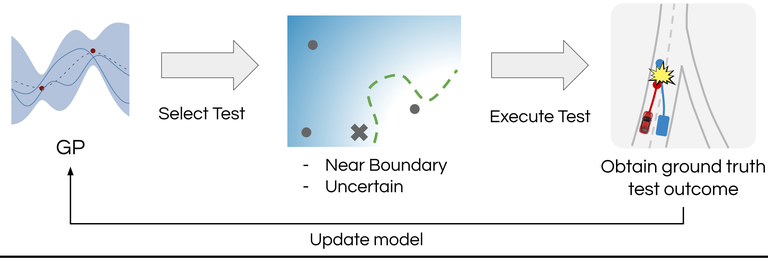


Our Testing Framework - GUARD

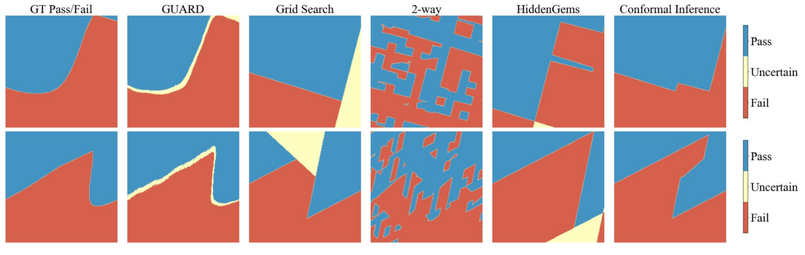
- Gaussian Process (GP) leverages observed concrete scenarios tests to estimate the **probability** of passing across the parameter space
- Use a probability **threshold** to partition the space into pass/fail/unknown
- Coverage = percent of parameter space that is not unknown



- Samples near the **pass / fail boundary** are more informative
- Samples where the GP is **uncertain** is more informative
- Testing process - iteratively sample concrete scenarios using these two criteria, update GP model

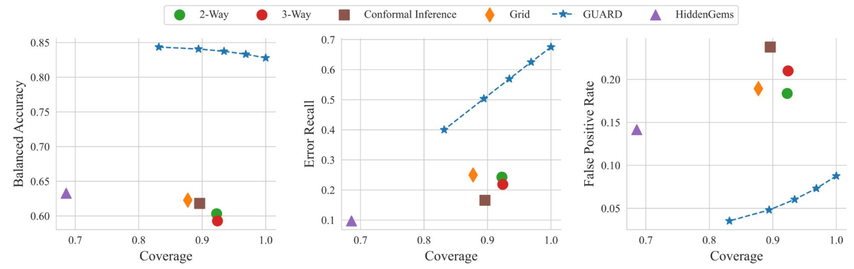


Qualitative Results



- 2D slice of 5D parameter space
- Existing methods limited by **discretization** of parameter space

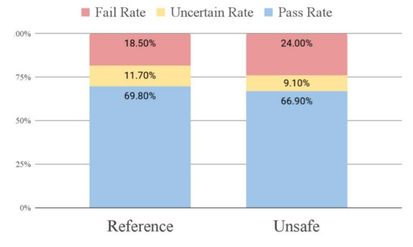
Comparison With Baselines

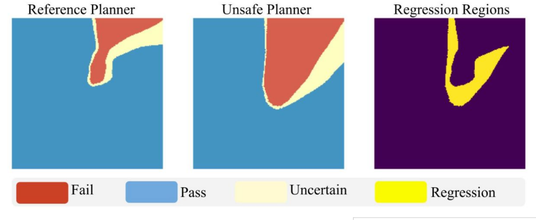


- **Coverage:** percent of parameter space that is not unknown
- **Balanced accuracy**: how accurate pass / fail predictions are, correct class imbalance since fails are much more rare
- **Error recall:** percent of ground truth failures that are predicted to be fail by the GP. Useful for autonomy development
- **False positive rate**: percent of predicted passes that are correct. Incorrectly predicting passes can be detrimental to safety

GUARD In Practice

- GUARD is able to benchmark two versions of the AV and compare their safety performance
- Can discover scenarios where the system regressed





- Visualization of pass/fail landscape and showing the regression region
- Sampling in the regression region yields a concrete scenario where the outcome has changed from pass to fail