DeepRoad: GAN-based Metamorphic Autonomous Driving System Testing

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Agenda

- Motivation and Background
- Approach
- Experiments
- Conclusion
Motivation and Background

- DNNs enable autonomous driving systems to adapt their driving behaviours
- These systems may exhibit erroneous behaviours and cause accidents
- Add error-inducing inputs to training dataset to improve reliability
Motivation (cont.)

- DeepTest – generate test cases by applying various effect filters

- Problem: test cases don’t reflect real-world driving scenes
Motivation (cont.)

- Goal: synthesize authentic driving scenes for testing
- DeepRoad: GAN-based metamorphic testing approach
Approach

- Focus: DNN-based ADS with camera inputs and steering angle outputs
Approach (cont.)

- Metamorphic DNN testing: cross-checking inputs and outputs with MR

- Metamorphic Relations: set of properties that relate multiple pairs of inputs/outputs

\[ \forall i. p[f_1(i)] = f_0(p[i]) \]
Approach (cont.)

- DeepTest
  - Also applies MT to test DNN-based ADS
  - But only performs simple synthetic image transformation

- UNIT
  - DNN-based method to perform unsupervised image-to-image transformation
  - Composed by GAN and VAE
Approach (cont.)

- The overall framework
Experiments

- Data:
  - Real-world dataset from Udacity
  - Youtube videos with snow and hard rain conditions

- Models:
  - Autumn
  - Chauffeur
  - Rwrightman

- Metric:

\[ IB(DNN, \mathcal{I}) = \sum_{i \in \mathcal{I}} f(|DNN[i] - DNN[\tau(i)]| > \epsilon) \]
Experiments (cont.)

- Results
Experiments (cont.)

- Results
### Results

<table>
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<tr>
<th>Scene</th>
<th>Model</th>
<th>Num. of Incon. Behaviors</th>
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Conclusion

- DeepRoad applies metamorphic testing methodology to test ADS
- Experimental results show it can successfully detect thousands of inconsistent driving behaviours
- Plans to support more weather conditions
Discussion

- How do you determine the error bound in the metric equation

- Is metamorphic testing a good testing method for ADS