



DeepRoad: GAN-based Metamorphic Autonomous Driving System Testing

Prepared by: Zi Yi Chen

Prepared for: Professor Marsha Chechik
CSC2125
University of Toronto

Authors

- Mengshi Zhang – University of Texas at Austin
- Yuqun Zhang – Southern University of Science and Technology
- Lingming Zhang – University of Texas at Dallas
- Cong Liu – University of Texas at Dallas
- Sarfraz Khurshid – University of Texas at Austin

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



(a)



(b)

Motivation (cont.)

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



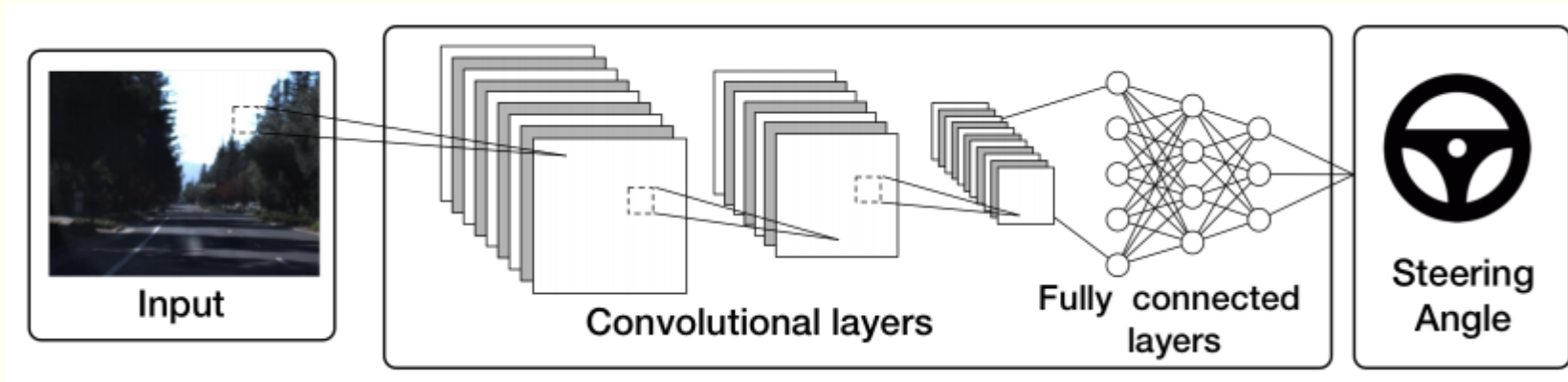
(a)



(b)

Approach

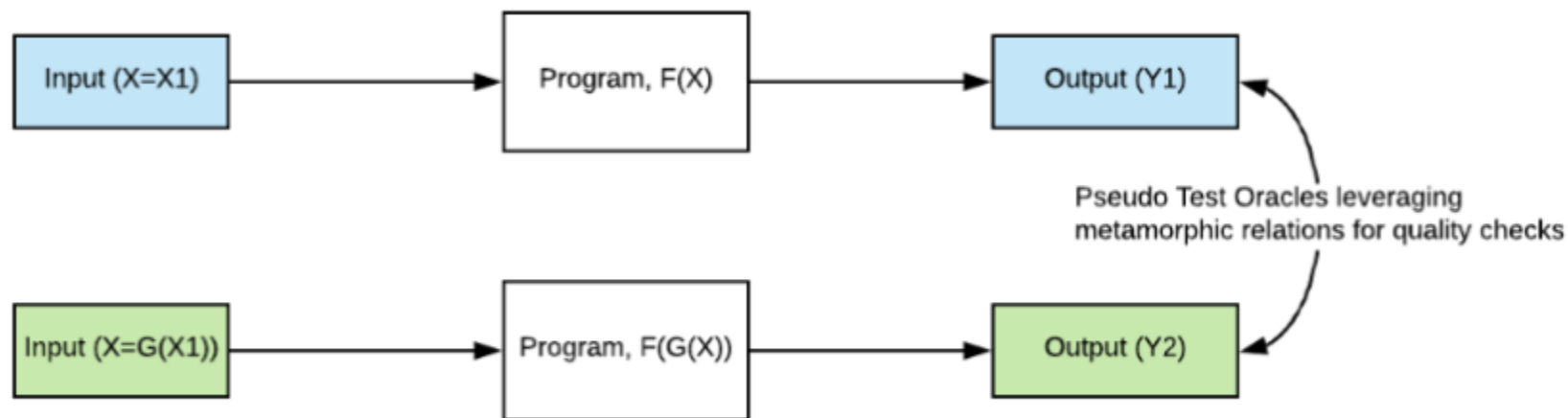
- Focus: DNN-based ADS with camera inputs and steering angle outputs



Approach (cont.)

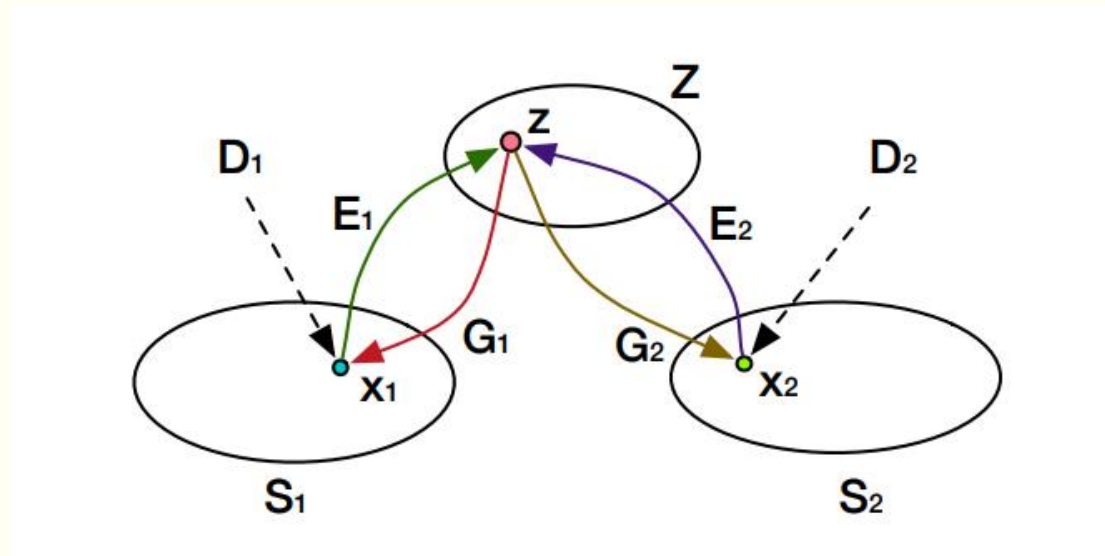
- Metamorphic DNN testing: cross-checking inputs and outputs with MR
- Metamorphic Relations: set of properties that relate multiple pairs of inputs/outputs

$$\forall i. p[f_I(i)] = f_O(p[i])$$



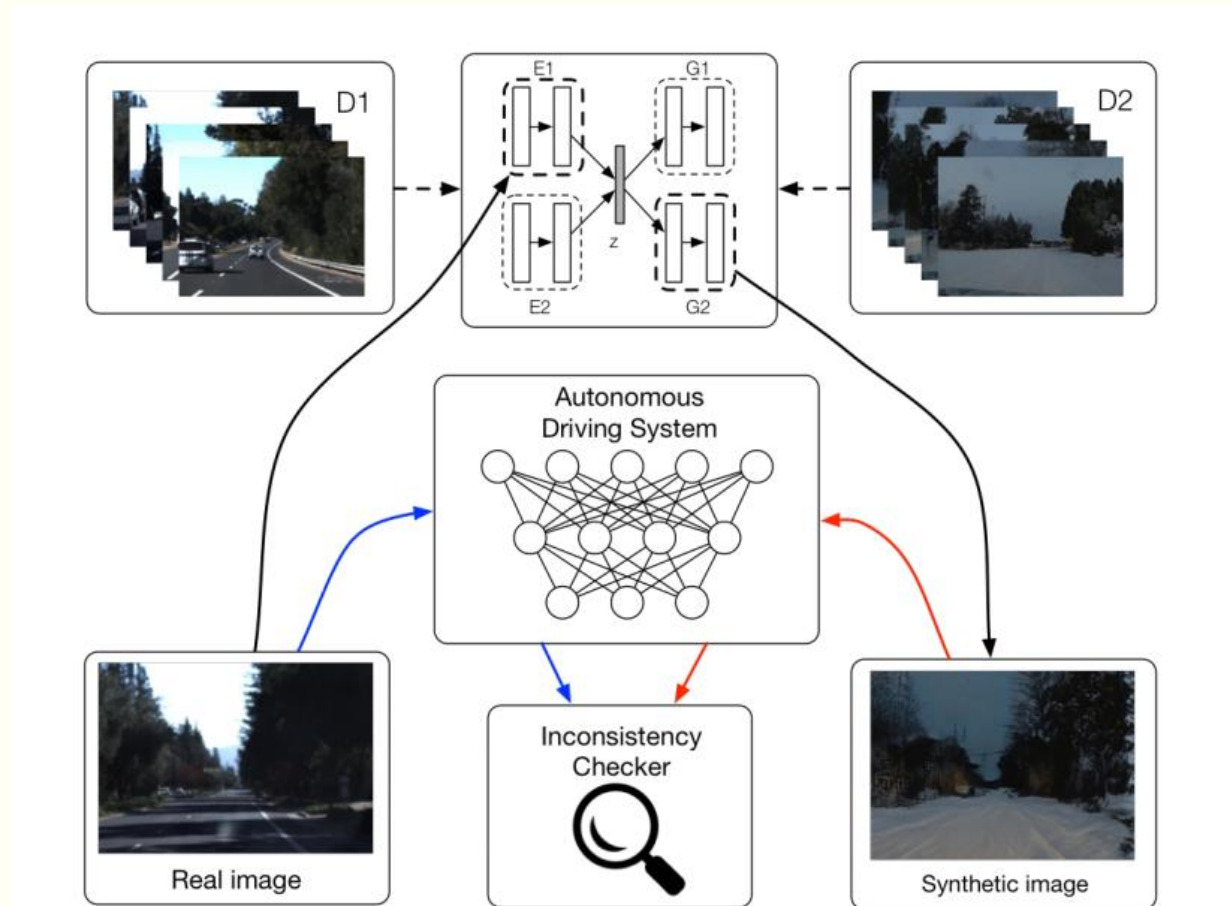
Approach (cont.)

- 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:

$$IB(DNN, \mathbb{I}) = \sum_{i \in \mathbb{I}} f(|DNN[i] - DNN[\tau(i)]| > \epsilon)$$

Experiments (cont.)

- Results



Experiments (cont.)

- Results



Experiments (cont.)

- Results

Scene	Model	Num. of Incon. Behaviors			
		10°	20°	30°	40°
Snowy	Autumn	11635	11602	11388	10239
	Chauffeur	4839	2105	1093	653
	Rwrightman	334	115	45	14
Rainy	Autumn	5279	5279	5279	5279
	Chauffeur	710	175	94	71
	Rwrightman	656	92	23	0

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