SHIFT: A Synthetic Driving Dataset for Continuous Multi-Task Domain Adaptation

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CVPR JUNE 19-24 2022 NEW ORLEANS LOUISIANA

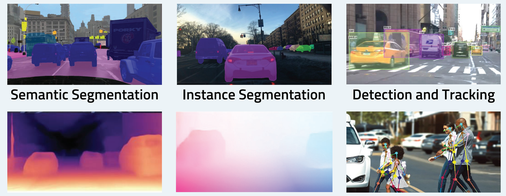
SHIFT builds upon the open-sourced CARLA Simulator.

Homepage
www.vis.xyz/shift

Motivation & Challenges
What is missing in existing driving datasets?

Multiple Tasks in A Single Dataset

Ideal: One dataset for multi-sensory and multi-task ML research.
Reality: Datasets have **distinct subsets** of sensors/tasks.

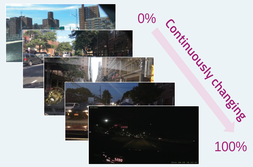


Diverse Conditions

Ideal: Diverse domains to learn general and robust models.
Reality: Only **coarse** domain separation, e.g., day vs. night.

Continuously Changing Environments

Ideal: Datasets reflecting the continuously-changing world nature.
Reality: Videos are too **short** to capture the continuous changes.



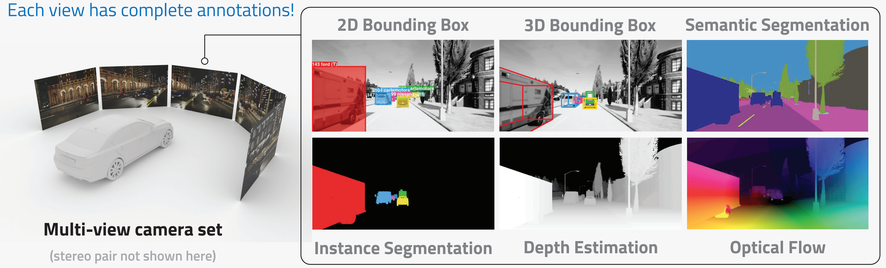
Dataset	# Seq.	Max. Length
KITTI	22	106 sec
H3D	160	20 sec
Waymo	1150	20 sec
nuScense	1000	20 sec
AIODrive	100	100 sec
BDD100K MOT	2000	40 sec
SHIFT (ours)	**4800+**	**66 min**

Dataset Design
How does SHIFT meet these challenges?

Complete Annotations for All Mainstream Driving Tasks

Multi-view sensor suite: 6 views (front, front left, left/right 45°, left/right 90°)
Annotation types: 2D/3D bounding boxes, multiple object tracking (MOT), instance/semantic segmentation, optical flow, depth estimation, LiDAR, GNSS/IMU, vehicle types, body keypoints, etc.

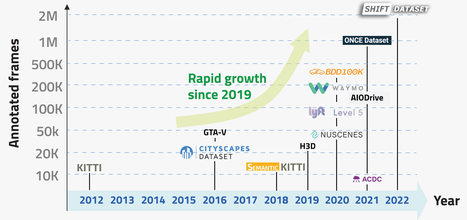
Each view has complete annotations!



Fine-Grained Domain Annotations

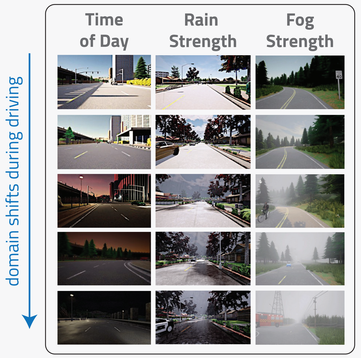
Fine-grained numerical domain annotations discretized into **24** coarse domains, for a total of **486** possible combinations.

2.5M+ Annotated Frames: A New Record!



Continuous Domain Shifts

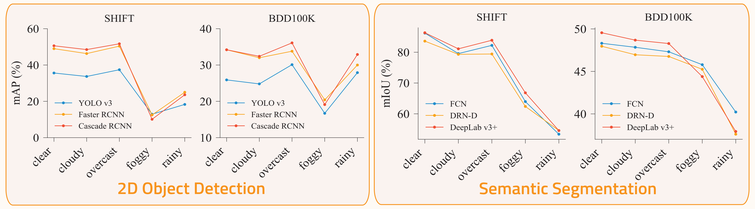
Continuous shifts during driving allow research on **test-time adaptation** and **robustness evaluation** under varying intensity.
Length: Each sequence records over 1 hour of driving under realistic domain-shift speed.



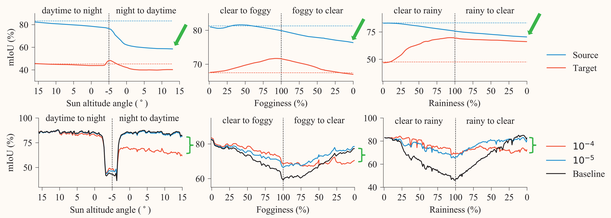
Use Cases
What problems can we study on SHIFT?

Real-World Compatibility

We assess the realisticity of SHIFT by comparing the performance trends for 2D object detection and semantic segmentation under domain shifts on both SHIFT and BDD100K (real-world dataset).



Investigation on Test-Time Learning and Incremental Domain Adaptation



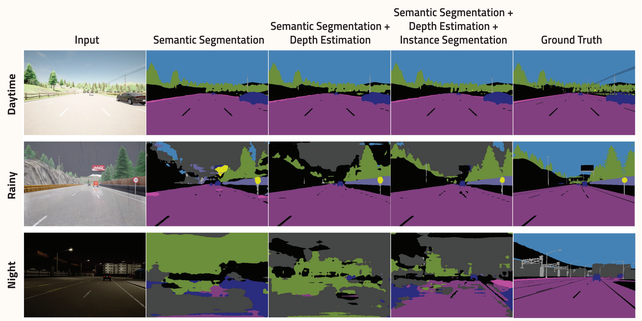
Domain Adaptation Strategies

Discrete and continuous shifts enable investigation of incremental, test-time, and other domain adaptation (DA) strategies.

Catastrophic Forgetting Issue

SHIFT poses challenges to DA methods. We found catastrophic forgetting both in **target** domains and after **looping back** to the source domains.

Exploring Task Combinations for Multi-Task Learning

SHIFT uncloses new opportunities to study multi-task learning. We find:

- Both **performance** and **robustness** against domain shifts improve under specific task combinations, e.g., depth + semantic segmentation + instance segmentation, revealing the presence of features that are potentially shareable across tasks.
- Certain tasks, e.g., optical flow, are heavily **affected** by other tasks when jointly trained, suggesting that combining different tasks is non-trivial. We hope SHIFT will foster further exploration of these challenges.