Imitation via Abstraction and Planning

[Talk at ETH]

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What We'll Discuss

* TransFuser: SOTA driving agent on CARLA
* Imitating algorithms
* New directions via data-driven simulation
"Autonomous Intersection in Action"

[Video Credit: Black Sheep Films]
CARLA Leaderboard

- 10 routes x 2 weathers x 5 repetitions
- 173 Km of driving experiences

[Slide Credit: German Ros]
Evaluation

\[ \frac{1}{n} \sum_{i=1}^{n} c_i p_i \]

- \# of routes
- Completion of route \( i \)
- Infraction penalty for route \( i \)

\[ p_i = \prod_{j \in J} (p^j)^{v_i^j} \]

- Number of infractions of type \( j \) in route \( i \)
- Penalty for infraction of type \( j \)
>>> How?

* Modular pipeline?
How?

- Modular pipeline?
- Reinforcement learning?
How?

* Modular pipeline?
* Reinforcement learning?
* Imitation learning?
Step 1: Abstraction

Pixel-Level Representation

Scene

Object-Level Representation

Vehicle
x=0 y=12 w=1.2 h=2.1 yaw=4.3 spd=8

Vehicle
x=-9 y=11.2 w=1 h=1.2 yaw=3 spd=9

Vehicle
x=0 y=-7 w=1.2 h=2.3 yaw=0.2 spd=4

...
Step 2: Planning

Optimal Path

Model Predictive Control

[TransFuser: Imitation with Transformer-Based Sensor Fusion. Chitta et al., PAMI 2022]
Step 3: Imitation
TransFuser: Imitation with Transformer-Based Sensor Fusion. Chitta et al., PAMI 2022
<table>
<thead>
<tr>
<th>Method</th>
<th>Driving ↑</th>
<th>Completion ↑</th>
<th>Safety ↑</th>
</tr>
</thead>
<tbody>
<tr>
<td>Late Fusion (LF)</td>
<td>22 ± 4</td>
<td>83 ± 3</td>
<td>0.27 ± 0.03</td>
</tr>
<tr>
<td>Geometric Fusion (GF)</td>
<td>27 ± 1</td>
<td>91 ± 1</td>
<td>0.30 ± 0.02</td>
</tr>
<tr>
<td>TransFuser (Ours)</td>
<td>47 ± 6</td>
<td>93 ± 1</td>
<td>0.50 ± 0.00</td>
</tr>
<tr>
<td><strong>Privileged MPC</strong></td>
<td>77 ± 2</td>
<td>89 ± 1</td>
<td>0.86 ± 0.03</td>
</tr>
</tbody>
</table>

* GF, TransFuser and MPC have similar completion
* Clear trend in infractions (MPC > TransFuser > Baselines)
CARLA Leaderboard (Challenge 2021)

<table>
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<th>Driving ↑</th>
<th>Completion ↑</th>
<th>Safety ↑</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAV</td>
<td>62</td>
<td>94</td>
<td>0.64</td>
</tr>
<tr>
<td>TransFuser (Ours)</td>
<td>61</td>
<td>87</td>
<td>0.71</td>
</tr>
<tr>
<td>GRIAD</td>
<td>37</td>
<td>62</td>
<td>0.60</td>
</tr>
<tr>
<td>WOR</td>
<td>31</td>
<td>58</td>
<td>0.56</td>
</tr>
</tbody>
</table>

* Simple (competitors have complex multi-stage training)
* Rank 2, with least infractions among top methods
* Still gets blocked more often than LAV
* With engineering improvements (3x data), won the map track in 2022

[TransFuser: Imitation with Transformer-Based Sensor Fusion. Chitta et al., PAMI 2022]
Imitating Algorithms

Legged Locomotion

Driving

[Imitation via Abstraction and Planning]
Superhuman?
Step 1: Abstraction

Step 2: Planning

Optimal Path

Model Predictive Control

Step 3: Imitation

Summary: Imitating Privileged Planners

Abstraction and Planning →

Imitation

State → Action

State ← Action
Abstraction in the Real World
Step 1: Mapping
Step 1: Mapping
Step 2: Auto-Labeling
Step 2: Auto-Labeling
Step 3: Moving Things
nuPlan Planning

Task Description

Previous benchmarks focus on short-term motion forecasting and are limited to open-loop evaluation. nuPlan introduces long-term planning of the ego vehicle and corresponding metrics. Provided as docker containers, submissions are deployed for simulation and evaluation.

Participation

The primary metric is the mean score over three increasingly complex modes: open-loop, closed-loop non-reactive agents, and closed-loop reactive agents. Participants can follow the steps to begin the competition. To submit your results on EvalAI, please follow the submission instructions.

Important Dates

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test Phase End</td>
<td>May 18, 2023</td>
</tr>
<tr>
<td>Finalist Notification and Verification</td>
<td>May 19, 2023</td>
</tr>
<tr>
<td>Winner Announcement</td>
<td>Jun 02, 2023</td>
</tr>
<tr>
<td>Winner Presentation</td>
<td>Jun 18, 2023</td>
</tr>
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</table>
Summary

* Simple imitation of algorithmic expert is SOTA on CARLA
www.github.com/autonomousvision/transfuser
Summary

* Simple imitation of algorithmic expert is SOTA on CARLA
  www.github.com/autonomousvision/transfuser

* nuPlan: an exciting new challenge!
  www.github.com/motional/nuplan-devkit/
Other Work


BEV predictions from 2D images via neural fields can improve safety
   \textit{BEV predictions from 2D images via neural fields can improve safety}

   \textit{Optimizing train data to contain near-collisions halves collision rates}
Other Work

  *BEV predictions from 2D images via neural fields can improve safety*

  *Optimizing train data to contain near-collisions halves collision rates*

  *Transformer planners can identify the most relevant object while driving*
End-to-End Autonomous Driving: Emerging Tasks and Challenges

CVPR 2023 Workshop
June 18, 2023, Vancouver, Canada
Scene Representations For Autonomous Driving

Hybrid workshop in conjunction with ICLR 2023, May 5th, Kigali City, Rwanda, Africa

SUBMIT A RESEARCH INSIGHT (PAPER/BLOG/REPO) OR ORIGINAL CONTRIBUTION OF YOUR OWN WORK!