End to end driving model interpretability & System Functional safety

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1. Introduction/Context

*This research topic is part of the **NEMODRIVE** research group. Read the group profile first at: url.*

Learning to drive faithfully in highly stochastic urban settings remains an open problem.

Currently most major self-driving frameworks are developed based on multi-modal system that parses the entire scene to make a driving decision. Usually each module analyzes data from a limited number of sensors and upstream in the system flow a module fuses all the information to make a planification. There is although one idea that dates as far back as to 1989, when Pomerleau built the Autonomous Land Vehicle in a Neural Network (ALVINN) [1]. This technique can be described as a behavior reflex approaches that directly maps an input image to a driving action (acceleration, brake and steering).

We believe that learning a generic vehicle motion model from large scale video data and developing an end-to-end trainable architecture for learning to predict future vehicle commands can not only offer a practical self-driving algorithm, but coupled with a multimodal framework such as the Apollo platform [6] can greatly improve the autonomous driving performance.

Driving behavioral cloning through end-to-end neural network training ([2], [3]) has seen an increase in interest with the incredible recent success of deep learning. As with other state of the art algorithms, abandoning all prior beliefs and developing an algorithm that can learn everything from data has proven successful. We are interested in putting this belief to the test and guide research in the direction of combining control theory and machine learning algorithms to train a car to drive itself from data. We will also be investigating the possibilities of enhancing supervised learning with unsupervised techniques to take advantage of vast quantities of unlabelled data and reinforcement learning to adjust the policy for off-course scenarios.

Once we have our neural network trained and the score looks promising on the test set, how will we have the confidence to test it on the street?

Neural networks seem to have trouble with shifts in data distributions. There has recently been a surge of work in explanatory artificial intelligence. This research area tackles the important problem that complex machines and algorithms often cannot provide insights into their behavior and thought processes. This research topic comes with great importance in the currently applied case. It would be very important, for example, to be able to automatically detect erroneous behaviors of DNN-driven vehicles that can potentially lead to fatal crashes [7]. We will be investigating state of the art solutions to better understand the process behind the network's policy and have better evaluations of its capabilities and limitations.

"*They need to explain themselves: why did they do this, why did they do that, why did they detect this, why did they recommend that? Accountability is absolutely necessary*." (Manuela Veloso talking about Deep Neural Networks, 2017)

2. Objective

- Develop a state of the art neural network based algorithm able to learn from data (e.g. [4], [5] or simulators) and to predict steering, acceleration and brake commands directly from 2D images, enough to guide a vehicle on public streets (e.g. keep lane, avoid obstacles, make turns).
- Develop a functional safety solution for a end-to-end self-driving module.
- Implement visual and structural reporting for network policy, investigating interpretability and explainability of the predictions.
- Publicly report and open-source the solution through an article and a *Apollo* framework module ([6]).

3. Required and Learned Skills

- Requirements
  - Good knowledge of Python and/or C++
  - Prior Machine Learning knowledge is preferred
  - Fast learner, proactive mindset
  - Comfortable working in a team

- Learned skills
    - Working with a complex autonomous driving framework (Apollo)
    - Practical experience with many of the technologies sustaining autonomous-driving
    - Experience working with ML algorithms and training of deep neural networks
    - Experience working with frameworks such as: ROS, Pytorch, Scikit-learn, OpenCV, Pandas
    - Experience of contributing to the common goal of a large research team
    - Support and guidance for writing academic research papers

4. References

[1] https://www.youtube.com/watch?v=ilP4aPDTBPE

[2] Bojarski, Mariusz, et al. "End to end learning for self-driving cars." arXiv preprint arXiv:1604.07316 (2016).

[3] Mehta, Ashish, Adithya Subramanian, and Anbumani Subramanian. "Learning End-to-end Autonomous Driving using Guided Auxiliary Supervision." arXiv preprint arXiv:1808.10393 (2018).

[4] Yu, Fisher, et al. "BDD100K: A Diverse Driving Video Database with Scalable Annotation Tooling." arXiv preprint arXiv:1805.04687 (2018).

[5] nuScenes a self-driving dataset, by nuTonomy

[6] https://github.com/ApolloAuto/apollo

[7] Tian, Yuchi, et al. "Deeptest: Automated testing of deep-neural-network-driven autonomous cars." Proceedings of the 40th International Conference on Software Engineering. ACM, 2018.