Edge Analytics: Shifting Autonomous Navigation for Self-Driving Cars into Top Gear

Abstract

Rapid innovation in advanced driver assistance systems (ADAS) powered by deep learning and AI technologies are enabling next-generation automaticity in co-pilot assisted and self-driving cars, leading to growing demand. The global autonomous vehicles market revenue is expected to grow at a robust CAGR of 39.6% during the forecast period 2017-2027, reaching USD 126.8 billion by 2027.[1]

Superior navigation and safety - including predictability, automaticity, reliability, and low latency - are critical for the success of autonomous vehicles. Currently available navigation solutions and frameworks depend on network connectivity to cater to automaticity requirements - ranging from assisted driving (Level 1) to conditional automation driving (Level 3). The advancing ecosystem, however, calls for an in-vehicle framework that can operate with or without network assistance to attain full automation (Level 5).

The paper proposes a targeted framework that integrates with autonomous vehicle sensors and leverages on-board computation to enable effective navigation and safety for fully autonomous cars. It also presents specific use-cases for the framework, including autonomous navigation with no network connectivity, and driver and passenger security for self-driving cars.

Are We Willing to Ride Autonomous Vehicles Yet?

According to a recent Gartner survey, 55% of surveyed respondents have inhibitions riding autonomous vehicles ranging from assisted driving and partial automation to conditional automation (Levels 2 to 4).[2] The concerns relate to handling unexpected drive scenarios, technology failures, and safety and security of the current solutions.

This means that even with the advancement of connectivity, sensor fusion and telematics, deploying a Level 5 in-vehicle framework is a necessary first step to handling unexpected technology failures in autonomous vehicles. One such unexpected scenario could result from loss of network assistance or connectivity when an autonomous vehicle passes through a cellular network dead zone.

Co-Pilot Framework: Using Edge Analytics for Foolproof Autonomous Car Systems

Currently, assisted vehicles depend on GPS to enable accurate navigation during their journey, making cellular network access vital to their operation. Lack of network connectivity results in stalled vehicles due to their inability to navigate the path ahead without GPS.

Such a scenario is not a viable option when considering fully autonomous vehicles. Consumers expect the vehicle to continue its journey without technical glitches. A co-pilot framework powered by edge analytics can help tackle the challenge effectively. It leverages image based localization that is superior to the current GPS or network-cell based methods. While GPS based systems can only provide positional information with an accuracy of one to two meters, image based localization provides the advantage of greater accuracy through precise positioning and orientation.

How does the co-pilot framework function? The approach is similar to how humans perceive the distance to a particular location that they have been to before. The ability to predict how close a person is to a certain building, intersection, or bridge is based on visual information (landmarks), learning, interpretation and inference much like that of the human mind.

The core of the framework (see Figure 1) consists of a robust architecture based on:

- Integration with dashboard camera for image acquisition for a view of the area of interest (front view) of the autonomous vehicle.
- Computer vision algorithm for transposing, flattening, resizing, shadow removal and brightness or contract correction of the acquired image.
- Edge analytics driven localization to extract the current position of the autonomous vehicle in terms of latitude and longitude from a trained model (of the travel route) mounted on-board.
- On-board deep learning for on-board GPU based training model depending on the travel route selected in the autonomous car system. The system self-learns the route with available geo-tagged images and landmarks.
- Sensor integration of the framework with the autonomous vehicle power train for reliable and precise navigation.

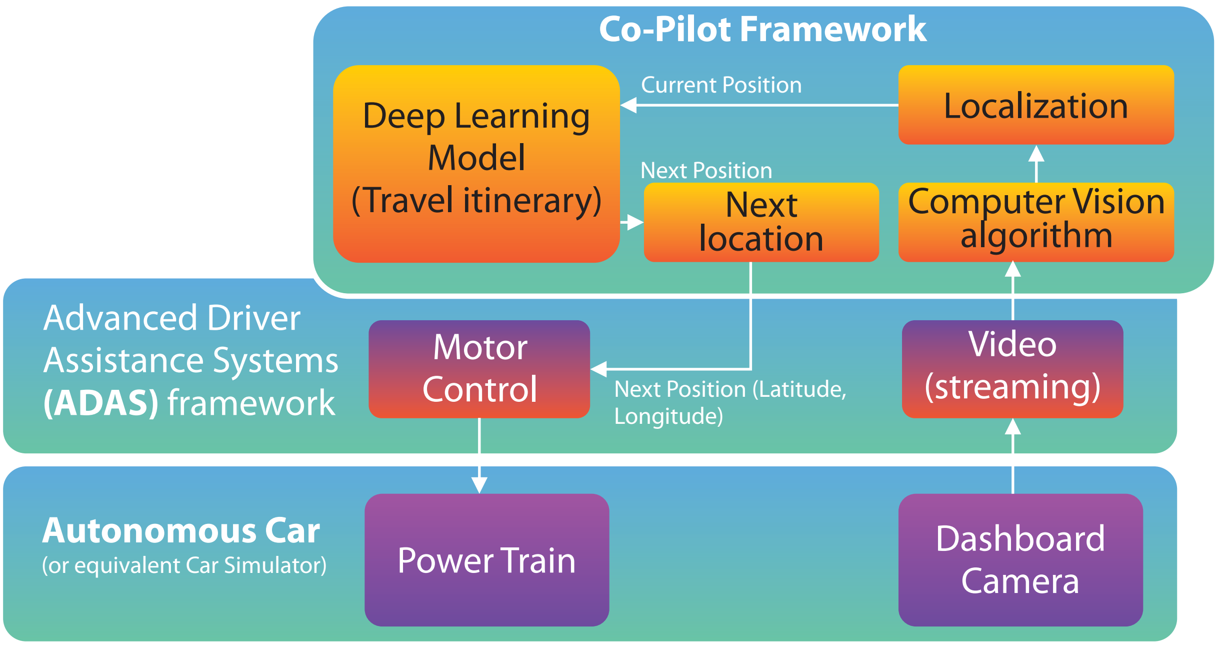

Figure 1: Co-Pilot Framework Architecture

Paving the Way for Fully Autonomous Cars with Real-time Computing

The deployment of the co-pilot framework on an on-board GPU in the autonomous vehicle accelerates read-time training, interpretation, and inference, making deep-learning intelligence available at the edge – in real time. A typical autonomous vehicle operates at the speed of 80 miles per hour which translates to approximately 35 meters per second. The co-pilot framework can achieve locational accuracy to the tune of 2-5 centimeters per second, leveraging a good data set trained with geo-tagged images. Edge analytics can therefore significantly enhance navigation in cases where GPS support is unavailable in a cellular network dead zone.

Video analytics is a critical part of the framework, ensuring the right computer vision algorithm is implemented and integrated to generate the real-time localized image. The core architecture required to enable edge analytics is showcased in Figure 2. The edge analytics pipeline provides an overview of the business logic and the computer vision algorithms. The pipeline depicts the building blocks that use video streams (dashboard camera) to draw inferences on location positioning (latitude and longitude) for real-time autonomous vehicle navigation.

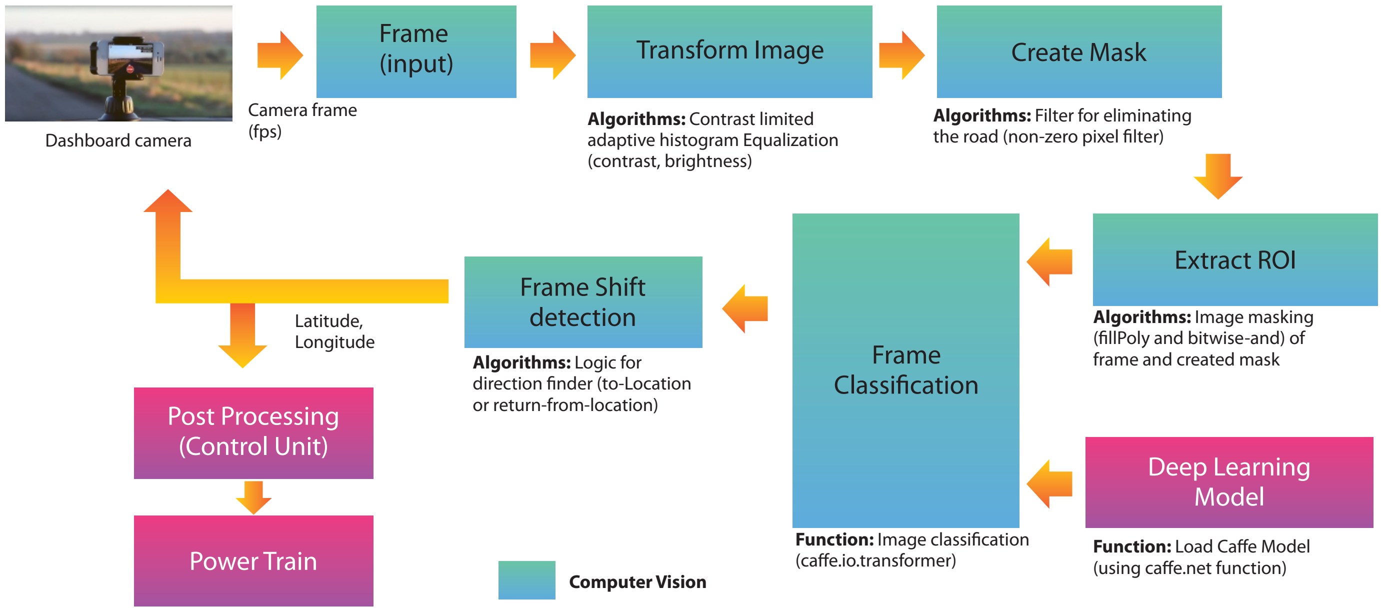

Figure 2: Edge Analytics – Computer Vision Algorithm Pipeline

In addition, the framework can be extended to enable accelerated training, computation, and navigational control at the edge, and integration with COTS ADAS boards used in autonomous vehicles.

Extensibility of the Co-Pilot Framework for Superior Road and Passenger Safety

Passenger safety and security is of utmost importance in the autonomous vehicle eco-system. Some typical safety scenarios where the co-pilot framework can be deployed include cases where drivers:

i. Experience fatigue such as frequently driving for 3-30 seconds with their eyes closed.

ii. Indulge in distracted behavior such as texting, reaching for objects at the back of the vehicle, or trying to operate the radio.

The co-pilot framework can be integrated with additional modular software components that leverage edge analytics and computer vision to ensure driver and road safety in such instances. The framework can be equipped to leverage the video stream of the driver to determine driver status, integrate with sensors (LiDAR and others) and also communicate (V2X, C-V2X) with other cars and surrounding ecosystem. The inference based on the ecosystem can then be used to initiate emergency procedures, resulting in assisted braking or parking, as needed.

Additionally, computer vision can be leveraged to auto unlock the autonomous cars for their owners. The on-board model can process and analyze driver or passenger identity against the authorized dataset provided for the autonomous vehicle. The proposed modular framework can also be extended to incorporate additional safety and navigation support features such as blind intersection navigation, left turn assists, road hazard bypass, and more.

Journeying to the Edge to Realize a Driverless Future

Consumer and social acceptance is key to autonomous vehicle adoption at scale. Gartner believes the full impact of autonomous vehicle technology on society and the economy will begin to emerge only around 2025.[3] To enable seamless and large-scale acceptance of autonomous vehicles, the industry is working on a roadmap that adopts a phased approach – developing assisted driving cars first, followed by the roll-out of self-driving cars.

Forward looking network companies such as AT&T are gearing up for self-driving cars by building an edge data center network, while car manufacturers such as Toyota have formed a consortium with other leaders such as Intel and Ericsson to capture the self-driving car market. For OEMs looking to beat their rivals, a framework such as Co-Pilot framework proposed in the paper will be critical to enabling a smooth transition from semi-automated to fully autonomous cars.[4]

References

1. PRNewswire, $126.8 Billion Autonomous Vehicle Market: Global Drivers, Restraints, Opportunities, Trends, and Forecasts 2017-2023 (July 2017), accessed May 2018, https://www.prnewswire.com/news-releases/1268-billion-autonomous-vehicle-market-global-drivers-restraints-opportunities-trends-and-forecasts-2017-2023-300486159.html
2. Toyota Global Newsroom, Industry leaders to form consortium for network and computing infrastructure of automotive big data (August 2017), accessed May 2018, https://newsroom.toyota.co.jp/en/detail/18135029/
3. Gartner, Gartner Survey Reveals 55 Percent of Respondents Will Not Ride in a Fully Autonomous Vehicle (Aug 2017), accessed May 2018, https://www.gartner.com/newsroom/id/3790963
4. Data Center Knowledge, AT&T to Build Edge Data Center Network for Self-Driving Cars, VR/AR, July 2017, Accessed May 2018, http://www.datacenterknowledge.com/design/att-build-edge-data-center-network-self-driving-cars-vrar

About The Authors

Partha Datta

Partha Datta is a Senior Domain Consultant who heads the Next-Gen R&D group within TCS' Technology business unit. He has over 18 years of experience in the telecom industry, and works closely with clients across the world to conceptualize technology solutions and enable value-added business processes transformation, specifically in the areas of SD-WAN, drones, robotics, and AI. Datta holds a Master's degree in Instrumentation from the Indian Institute of Science (IISc), Bangalore, India.

Halima Naim

Halima Naim, a Lead Solutions Architect with TCS' Technology business unit, specializes on drones and UAV traffic management. She has six years of experience in the implementation of proofs-of-concept leveraging the drone ecosystem, and has helped businesses minimize development costs and accelerate time-to-market. Naim holds a Master's degree in Computer Applications from Aligarh Muslim University, Aligarh, India.

Divya Chaudhary

Divya Chaudhary is a Domain Expert and part of the Next-gen R&D group within TCS' Technology business unit. She has more than four years of experience in software defined networking (SDN), drones, and robotics related solution accelerators. Chaudhary focuses on proofs-of concept and use cases to address industry challenges and enable clients to deploy differentiated services in the autonomous robotics or drone ecosystem. She has a Bachelor's degree in Information Technology from the Institute of Technology and Management, Gurgaon, India.