AI and the Progression of Autonomous Vehicles

Stephen Woods

Northwestern University, Introduction to Data Science

10/31/2021

1. AI disrupting transportation with Autonomous Vehicles

Artificial intelligence is in the early stages of disrupting consumer transportation by enabling the progression of autonomous vehicles. Self-driving cars will replace human operation with artificial intelligence, negating the long term need for both consumer and professional drivers in the transportation industry. This paper covers a brief history of the evolution of autonomous vehicles, specific artificial intelligence methods involved, and the resulting future social and environmental changes to the transportation industry.

1.1 Description and Evolution of Autonomous Vehicles

Autonomous vehicles use sensors to capture road conditions, hardware and software to process those road conditions, and algorithms to navigate those road conditions to automate the role of the human driver. There are five levels used to define autonomous driving, with level one involving significant human driver assistance and level five requiring no driver assistance (Grigorescu et al. 2020). Currently, Tesla's autopilot represents the most advanced self-driving technology available to consumers, which the National Highway Traffic Safety Administration categorizes as level two (Ni et Al 2020). Vehicles that meet level five are currently in progress, but some obstacles to legal adoption include navigating construction zones, accidents, and extreme weather (Ni et Al 2020). Autonomous vehicles have been in development since the 1980s, and in the 1990s Carnegie Melon achieved 98% autonomous driving over 6,000 kms in a test environment (Grigorescu et al. 2020). In 2005, an autonomous vehicle enabled by machine learning won a self-driving competition, segmenting AI and machine learning as central to autonomous vehicle progression (Grigorescu et al. 2020). From Baidu's deep learning institute to Google, many top technology companies are investing heavily in the development of artificial intelligence for self-driving cars.

1.2 Key Turning Points

Hardware and software advancement are two key turning points to the development of fully autonomous vehicles (level 5). Autonomous vehicles need advanced hardware and software to be able to process a near infinite amount of data in real time to mimic human decision making. Rapid development of hardware and software has enabled this, with NVIDIA's new "Drive PX2 driverless car platform" capable of performing "30 trillion deep learning operations per second" (Ni et Al 2020). This platform is currently capable of achieving level four on the autonomous driving scale. TensorFlow is an example of a dominant software enabling self-driving cars (Ni et Al 2020). TensorFlow facilitates the development and training of deep learning models in programs like python and java. Overall, recent advances in hardware allow data to be rapidly collected and processed, complemented by advances in software allowing for real time decision making on that data.

1.3 Social Implications

Autonomous vehicles have the potential to improve the safety, efficiency, and general access of transportation to the public. Manual human driving currently results in 1.25 million deaths per year and experts such as Elon Musk and Mat Honan believe AI will negate human driving (Mueller and Gogoll 2020). Fully autonomous vehicles would also enable those legally unable to drive, due to ailments such as blindness or old age, to do so (Mircica 2019). While the implications of autonomous vehicles are mostly positive, there are some potential drawbacks. The integration of consumer smartphones and other data with the autonomous vehicle network may pose data security concerns or related vulnerabilities (Mircica 2019). Similarly, those that work as drivers will likely lose their jobs once fully autonomous vehicles are developed and adopted.

2. Deep CNNs and RL

Deep neural network techniques can be used to train self-driving cars from real driving behavior collected by a vehicle's camera and computer. This allows autonomous vehicles to learn how to respond to obstacles incurred in roadways (Zaghari et al 2021). Deep convolutional neural networks and deep reinforcement learning are two common artificial intelligence methods enabling this process (Grigorescu et al. 2020). Convolutional neural networks (CNNs) are used to process the visual environmental information collected by a car's cameras in many layers, replacing human vision (Grigorescu et al. 2020). Convolutional neural networks will allow vehicles to navigate urban areas by identifying traffic patterns and any other roadway obstacles. Deep reinforcement learning is one method by which vehicles can learn how to navigate from starting point to destination (Grigorescu et al. 2020). Deep reinforcement learning (RL) works at a high level by computing the optimized series of actions to take to get from point A to point B. One set of algorithms applied to deep reinforcement learning is called a "deep Q-network and is used for estimating the approximate action-value function" (Grigorescu et al. 2020). Examples of these actions include acceleration, braking, engaging turn signals, and turning. The deep Q-network function would optimize the direction of magnitude of these actions. (Grigorescu et al. 2020). Both CNN and RL methods require ample training data representative of all real-world driving scenarios that these artificial intelligence methods need to learn from.

3. Personal Reflection and the Future

Just as self-driving robots powered by AI have become dominant in warehouse fulfillment centers, autonomous vehicles are set to take over public roadways (Zaghari et al 2021). How extreme will this takeover be? Mueller and Gogoll 2020 explore the possibility that manual driving could become outlawed in the future as autonomous vehicles progress to be significantly safer. Autonomous vehicles on public roadways currently require some level of human oversight, with humans having the ability to override the actions of AI. Mueller and Gogoll 2020 argue this phenomenon could be reversed, giving AI the final say, as self-driving technology develops to become markedly safer than human drivers. To get to that point, key hardware, software, and deep learning techniques must continue to develop. The speed at which humans can process and respond to diverse driving conditions still exceeds the current capabilities of deep learning in autonomous driving (Ni et Al 2020). Hardware platforms for self-driving cars from companies like NVIDIA must continue to advance to process data from a mix of sensory systems at even faster speeds to support level five autonomy. Sobczak et al. 2021 explore the use of LiDAR point cloud simulation as one potential step to achieving level 5 autonomy. Innovations like Lidar point cloud simulation will help train models with simulated data on extreme events or obstacles that would be difficult and expensive to collect in the real world (Sobczak et al. 2021). This is one example of the many emerging hardware and software solutions ambitiously targeting the realization of fully autonomous vehicles.

Abbreviated Annotated Bibliography

Grigorescu, Sorin, Bogdan Trasnea, Tiberiu Cocias, and Gigel Macesanu. 2020. "A Survey of Deep Learning Techniques for Autonomous Driving." *Journal of Field Robotics* 37, no. 3: 362–86. https://doi.org/10.1002/rob.21918.

Grigorescu et al. 2020 open with a history of advancements in self driving cars. First attempts at self-driving cars were in the 1980s, with 95% self-driving cars in the late 1990s and the use of machine learning with self-driving cars in the mid-2000s. This article then covers the deep learning techniques enabling self-driving cars, including convolutional neural networks, recurrent neural networks, and deep reinforcement learning.

Mircica, Nela. 2019. "The Design, Implementation, and Operation of Self-Driving Cars: Ethical, Security, Safety, and Privacy Issues." Contemporary Readings in Law and Social Justice 11, no. 2: 43–. https://doi.org/10.22381/CRLSJ11220196.

Mircica 2019 reviews the ethical, safety, and privacy implications of self-driving cars. Self-driving cars will make roadways safer and more efficient. The integration of consumer smartphones and data with the autonomous vehicle network may pose data security concerns and vulnerabilities.

Mueller, Julian F, and Jan Gogoll. 2020. "Should Manual Driving Be (Eventually) Outlawed?" Science and Engineering Ethics 26, no. 3: 1549–67. https://doi.org/10.1007/s11948-020-00190-9.

Mueller and Gogoll 2020 explore the possibility that manual driving could become outlawed in the future as autonomous vehicles progress to be significantly safer. Manual driving currently results in 1.25 million deaths per year and experts such as Elon Musk and Mat Honan believe AI will negate human driving. Manual driving may exist at this point in the future, but it would be supervised by AI.

Ni, Jianjun, Yinan Chen, Yan Chen, Jinxiu Zhu, Deena Ali, and Weidong Cao. 2020. "A Survey on Theories and Applications for Self-Driving Cars Based on Deep Learning Methods." Applied Sciences 10, no. 8: 2749–. https://doi.org/10.3390/app10082749.

Ni et al. 2020 cover progress made in self driving cars from 2015 to present. Google and Tesla lead the way in autonomous vehicles among the many large companies exploring this technology. Advancement in hardware and software processing power are fundamental for supplying near instant processing of data needed for self-driving cars. TensorFlow is a common deep learning software used with autonomous vehicles.

Sobczak, Łukasz, Katarzyna Filus, Adam Domański, and Joanna Domańska. 2021. "LiDAR Point Cloud Generation for SLAM Algorithm Evaluation." Sensors (Basel, Switzerland) 21, no. 10: 3313–. https://doi.org/10.3390/s21103313.

Sobczak et al. 2021 cover the use of LIDAR sensors to aid other sensors to potentially achieve level 5 of autonomous driving. Gathering all the real-world driving data needed to train algorithms to respond to dynamic road conditions is challenging and expensive. LiDAR point cloud simulation is one potential way to generate this data.

Zaghari, Nayereh, Mahmood Fathy, Seyed Mahdi Jameii, Mohammad Sabokrou, and Mohammad Shahverdy. 2021. "Improving the Learning of Self-Driving Vehicles Based on Real Driving Behavior Using Deep Neural Network Techniques." The Journal of Supercomputing 77, no. 4: 3752–94. https://doi.org/10.1007/s11227-020-03399-4.

Zaghari et al. 2021 point out the early application of autonomous vehicles as robot-vehicles used in supply chain management. This paper focuses on how deep neural network techniques can be used to train self-driving cars from real driving behavior collected by a vehicle's camera and computer. This allows autonomous vehicles to learn how to respond to obstacles incurred in roadways.