AI Delta Learning: simplifying the small differences

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07/10/2021 When changing the environment or the sensor technology, neural networks in vehicles today have to be trained again and again from scratch. The AI Delta Learning research project aims to solve this problem – and substantially reduce the effort involved.

Stop signs look similar in many countries – red, octagonal, with the word STOP in the middle. There are exceptions, however: in Japan the signs are triangular; in China 'STOP' is replaced by a character; in Algeria, a raised hand is shown. Visiting drivers have no problem with these small differences: by the first junction, they know what the local stop sign looks like. The artificial intelligence (AI) in an autonomous vehicle, on the other hand, needs to be completely retrained to be able to process the disparity.

These ever-changing lessons take a lot of time, generate high costs and slow down the development of

autonomous driving as a whole. So the automotive industry is now taking a joint step forward with the AI Delta Learning project, which aims to find ways to selectively teach autonomous vehicles something new. Or, to stick with our example, it is hoped that in the future, the autopilot will simply need to be told: “Everything remains the same except the stop sign”.

Cooperation of major partners

The importance of the task is demonstrated by the list of participants in the project, which is being funded by the German Federal Ministry for Economic Affairs and Energy. In addition to Porsche Engineering, partners include BMW, CARIAD and Mercedes-Benz, major suppliers such as Bosch, and nine universities, including the Technical University of Munich and the University of Stuttgart. “The objective is to reduce the effort required to be able to infer things from one driving situation to another without having to train each thing specifically,” explains Dr Joachim Schaper, Senior Manager AI and Big Data at Porsche Engineering. “The cooperation is necessary because currently no provider can meet this challenge alone.”

The project is part of the AI family, a flagship initiative of the German Association of the Automotive Industry aimed at advancing connected and autonomous driving. Since January 2020, around 100 people from 18 different partners have been working on AI Delta Learning. At workshops experts exchange views on which approaches are promising – and which have proved to be dead ends. “In the end, we hope to be able to deliver a catalogue of methods that can be used to enable knowledge transfer in artificial intelligence,” says Mohsen Sefati, an expert in autonomous driving at Mercedes-Benz and the head of the project.

The stop sign example conceals a fundamental weakness of all neural networks that interpret traffic events in autonomous vehicles. They are similar in structure to the human brain, but they differ in a number of crucial points. For example, neural networks can only acquire their abilities all at once, typically in a single large training session.

Domain changes demand huge efforts

Even trivial changes can require massive efforts in the development of autopilots. For example, in many autonomous test vehicles, cameras with a resolution of two megapixels were previously installed. If they are now replaced by better models with eight megapixels, in principle hardly anything changes: a tree still looks like a tree, except that it is represented by more pixels. However, the AI needs millions of snapshots from traffic again to recognise the objects at the higher resolution. The same is true if a camera or radar sensor on the vehicle is positioned just slightly differently. After that, complete retraining is necessary.

Experts call this a domain change: instead of driving on the right, you drive on the left; instead of bright sunshine, a snowstorm is raging. Human drivers usually find it easy to adapt. They intuitively recognise

what has altered and transfer their knowledge to the changed situation. Neural networks are not yet able to do this. A system that has been trained on fair-weather drives, for example, is confused when it rains because it no longer recognises the environment due to the reflections. The same applies to unknown weather conditions, to the change from left- to right-hand traffic or to different traffic light shapes. And if completely new objects such as e-scooters appear in traffic, the autopilot must first be familiarised with them.

Aim of the project: learning only the 'delta'

In all these cases, it has so far not been possible to teach the algorithm only the change, that is what in science is called the 'delta'. In order to become familiar with the new domain, it again needs a complete dataset in which the modification occurs. It's like a student having to go through the entire dictionary every time they learn a new word.

This kind of learning gobbles up enormous resources. "Today, it takes 70,000 graphics processor hours to train an autopilot," explains Tobias Kalb, a doctoral student involved in the AI Delta Learning project for Porsche Engineering. In practice, numerous graphics processing units (GPUs) are used in parallel to train neural networks, but the effort is still considerable. In addition, a neural network needs annotated images, that is images from real traffic events in which important elements are marked, such as other vehicles, lane markings, or crash barriers. If a human performs this work manually, it takes an hour or more to annotate a snapshot from city traffic. Every pedestrian, every single zebra crossing, every construction site cone must be marked in the image. This labelling, as it is known, can be partially automated, but it requires large computing capacities.

In addition, a neural network sometimes forgets what it has learned when it has to adapt to a new domain. "It lacks a real memory," explains Kalb. He himself experienced this effect when using an AI module trained with US traffic scenes. It had seen many images of empty highways and vast horizons and could reliably identify the sky. When Kalb additionally trained the model with a German dataset, a problem arose. After the second run, the neural network had trouble identifying the sky in the American images. In the German images, it was it was often cloudy or buildings blocked the view.

"Until now, the model has been retrained with both datasets in such cases," Kalb explains. But this is time-consuming and reaches its limits at some point, for example when the datasets become too large to store. Kalb found a better solution through experimentation: "Sometimes very representative images are enough to refresh the knowledge." For example, instead of showing the model all American and German road scenes again, he selected a few dozen pictures with particularly typical highway distant views. That was enough to remind the algorithm what the sky looked like.

Two AIs train each other

It is precisely such optimisation possibilities that AI Delta Learning aims to find. For a total of six

application areas, the project partners are looking for methods to quickly and easily train the respective AI. This includes, among other things, a change in sensor technology or the adaptation to unknown weather conditions. Proven solutions are shared among the organisations involved in the project.

Another promising approach is for two perception AIs to train each other. First, a teacher model is built for this purpose: it receives training data in which a class of objects, for example signs, is marked. A second AI, the student model, also receives a dataset, but one in which other things are marked – trees, vehicles, roads. Then the teaching begins: the teacher system imparts its knowledge to the student as it learns new concepts. So it helps it recognise signs. After that, the student in turn becomes the teacher for the next system. This method, 'knowledge distillation', could save OEMs a lot of time in localising their vehicles. If a model is to be introduced in a new market, all that needs to be done when training the autopilot is to use a different teacher model for the regional signs – everything else can stay the same.

"The solution will lie in a clever combination of several methods"

Much of what the researchers are currently testing is still experimental. It is not yet possible to predict which method will ultimately allow a neural network to best adapt to new domains. "The solution will lie in a clever combination of several methods," expects expert Kalb. After a year of project work, those involved are optimistic. "We have made good progress," says project manager Sefati from Mercedes-Benz. He expects to be able to show the first methods for AI Delta Learning when the project ends at the end of 2022. That could yield huge benefits for the entire automotive industry. "There is high potential for savings while increasing quality if the training chain is highly automated," explains AI expert Schaper. He estimates that human labour input in the development of autonomous vehicles can be halved through AI delta learning.

The AI project family

AI Knowledge
Developing methods for incorporating knowledge into machine learning.

AI Delta Learning
Developing methods and tools to efficiently extend and transform existing AI modules of autonomous vehicles to meet the challenges of new domains or more complex scenarios.

AI Validation
Methods and measures for validating AI-based perceptual functions for automated driving.

AI Data Tooling
Processes, methods and tools for efficient and systematic generation and refinement of training, testing and validation data for AI.

In brief

When changing the environment or the sensor technology, neural networks in vehicles today have to be trained again and again from scratch. The AI Delta Learning project aims to teach them only the differences after such a domain change, therefore significantly reducing the effort involved.

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