When Will Cars Be Fully Self-Driving? The technology isn't anywhere near where it needs to be to replace human drivers. Three experts weigh in on what the future holds for autonomous vehicles.

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Abstract

None available.

Full Text

Around now, we should be relaxing in the driver's seat of our autonomous cars, streaming a TV show or perhaps even taking a nap while the vehicles drive us safely to our destinations.

That was the prediction several years ago by some auto-industry executives and technology experts. But after billions of dollars in research-and-development spending, autonomous-vehicle technology hasn't advanced anywhere near the point where it can replace human drivers.

Some car companies and tech startups have scaled back their ambitions or pushed out their timelines as a result. In October, Ford Motor Co. and Volkswagen AG shut down their driverless-car company, Argo AI, and Ford Chief Executive Jim Farley told analysts on a quarterly earnings call that "we will have a very long road" to develop autonomous vehicles.

Regulators also are weighing in. Federal safety authorities in December said they were investigating General Motors Co.'s Cruise subsidiary after reports that its self-driving taxis caused several rear-end crashes. Tesla Inc.'s driver-assist technology also has been implicated in numerous accidents .

SAE International, formerly the Society of Automotive Engineers, categorizes self-driving technology into five levels. Level 1 cars have either lane-centering technology or adaptive cruise control, which keeps the vehicle a defined distance from the car ahead. Level 2 vehicles have both features. In either level—which are now widely available—the driver is still in control.

Level 3 and 4 cars would drive themselves under limited conditions, such as on certain types of roads and in certain weather conditions. Level 5 vehicles would operate themselves on any road in any weather that a skilled driver would drive in.

The Wall Street Journal gathered three experts to discuss the future of autonomous vehicles: Alexandre M. Bayen, a professor of electrical engineering and computer science at the University of California, Berkeley; Raj Rajkumar, a professor in the electrical and computer engineering department at Carnegie Mellon University; and Juergen Reers, a senior managing director at consulting firm Accenture who is part of its mobility practice.

Below are edited excerpts from our conversation, which was held online.

Human-level AI

WSJ: Will cars ever reach the Level 5 category of autonomous driving, where they might even lack a steering wheel and pedals? If so, when?

MR. REERS: That would require human-level artificial intelligence, and there is no commonly accepted theory on how to get there. As long as there is no human-level AI, autonomous mobility will be limited.

Alexandre M. Bayen PHOTO: WSJ

PROF. BAYEN: The promise of full autonomy at a given time usually leads to unrealistic expectations, when in fact the development of autonomy is by nature incremental. It isn't clear if fully automated everywhere all the time is the ultimate endgame. The market will tell.

MR. RAJKUMAR: This may in fact never be possible—or it is at least many years or decades away. It is beyond the means of technology that exists today or will be available in the foreseeable future. However, more limited but very useful solutions will be deployed sooner rather than later.

WSJ: Let's talk about the technologies needed for self-driving cars below Level 5. First, what needs to be improved when it comes to the systems that take the place of human eyes, such as radar, cameras, GPS and lidar, the laser-based system that creates a 3-D representation of the vehicles, structures, pedestrians and roadway around the car?

MR. REERS: Overall, the level of technology is well advanced, but a key challenge is the cost. In high levels of automated driving, a high degree of redundancy is needed. Combining camera, radar and lidar systems with high-definition maps and high computing requirements would make a Level 4 vehicle too costly for individual use. So we expect these vehicles to be used as shuttles, carrying multiple passengers, ideally 24/7 to absorb the cost.

MR. RAJKUMAR: There are two distinct issues. First, some companies only want to rely on cameras for economic reasons—making the final system very affordable thanks to the fact that cameras in smartphones have made them ubiquitous, compact and inexpensive. Unfortunately, today's vision technology using only cameras won't match, for a long time to come, the cognitive capabilities of human eyes plus human neural processing.

Two, lidar is a critical component, but while costs are coming down, the costs are still on the higher side. Radar, ultrasonic and GPS are well within acceptable cost limits already.

WSJ: What about artificial intelligence? Critics say that unlike human drivers, AI can't reason and lacks intuition, and that it relies too much on the driving situations that have been programmed into its data and can't contend with unfamiliar situations.

Juergen Reers PHOTO: WSJ

MR. REERS: AI is a key prerequisite for automating driving functions. But it cannot cover all "edge cases," [unusual events such as a dog running in front of a vehicle or a lane shift at a construction site], because it cannot reason and lacks intuition. Neural networks in AI do what is called "model blind curve fitting" to minimize error margins. For that they need millions of examples. AI cannot learn from little data like humans do.

MR. RAJKUMAR: Thanks to recent significant advances in AI, the autonomous-driving problem has been cast entirely as an AI problem. This is a red herring! Humans built the sprawling passenger aviation industry, rail networks, nuclear power plants and spacecraft, all of which have different degrees of autonomy. They don't use AI, and instead depend on ingenious engineering built on science. AI today isn't where it needs to be to build autonomous vehicles. But AI is only one of many tools in the autonomous-vehicle toolbox.

Dealing with 'edge cases'

WSJ: How can AI systems be improved to deal with "edge cases" that they haven't been programmed to handle and that could lead to dangerous driving situations?

Raj Rajkumar PHOTO: WSJ

MR. RAJKUMAR: When a camera looks at such scenarios, its corresponding neural network may or may not be able to detect it correctly, particularly if the obstacle wasn't included in its AI training data set. When radar or lidar look at it, they will detect an obstacle but likely not know what type of obstacle it is. But the vehicle is still aware of the presence of some obstacle—whether it be a kid, dog, cow, cat, kangaroo or even a pedestrian dressed in a funny-looking costume—and can slow down or stop. Redundancy of sensors is key. Depending on AI to deal with an infinite number of known and unknown scenarios and obstacles won't work.

PROF. BAYEN: What if we had enough experience and data to train the neural network for the dog and the cat but not enough for the sheep or the cow? Would we let the car drive in rural France?

The AI community is working on these problems. The field called transfer learning focuses on learning for one specific set of scenarios and applying it to a previously unknown setting. So the cow and the sheep might have a chance.

WSJ: AI also can't do other things human drivers do, such as reading the body language or facial expression of a pedestrian stepping off a curb, or of a driver in an approaching vehicle at an intersection. Will technology ever be able to do this?

MR. RAJKUMAR: There is ongoing work on detecting human intent, reading human expressions, etc. However, these techniques are not foolproof. Since there will be incorrect conclusions, the vehicle must very likely be conservative and cautious for the foreseeable future.

PROF. BAYEN: The cat, dog, the sheep and the cow can all be detected as moving by algorithms; standard tools in machine vision will do this. But what about their intent? Humans are even more complex to model and anticipate in many ways.

The field of mixed autonomy (in which humans interact with machines) is still at its infancy, hence the ability of a fully automated vehicle to interact with an unknown human is still a question not fully solved by machine learning.

MR. REERS: I agree that autonomous vehicles will improve in recognizing and dealing with more complex patterns. Already today, neural networks are astonishingly good at matching complex patterns in data sets. But they do that by mere correlation. Correlations can be spurious. Automated vehicles shouldn't be expected to mimic human brains.

WSJ: Will autonomous-vehicle technology be able to handle weather conditions such as fog and heavy snow that obscure road markings and cloud the vehicles' camera lenses and sensors?

PROF. BAYEN: Sensing and actuation will make progress, more data will be collected, and more weather conditions will be learned and become acceptable to vehicles. There is a nice analogy in aviation. Historically, aerospace engineering led to the construction of more and more robust aircraft. Over time aircraft became capable of flying through more and more dangerous turbulence levels. Yet there is a "safe set" of operations, defined by both sensing and conditions. Staying within this set is important to maintain safety.

MR. RAJKUMAR: Sensor companies and car makers have been looking at various approaches to keep the sensors clean. For example, mounting them inside the car, mounting them inside an enclosure outside the vehicle, having heating elements to de-ice and de-snow, using wipers, etc.

The more important question is whether the sensors can detect artifacts on the road under different weather and lighting conditions. This is the reason why early robotaxi deployments have been in regions with very little if any rain or snow. This situation does again point to the need for redundant sensing. Camera lenses may be dirty. However, radar can still see through bad weather conditions, and lidar works pretty well even with moderate rain and snow.

MR. REERS: I agree that sensing will make a lot of progress. However, it will continue to face limitations in severe conditions. We need to balance the improvement of vehicle technology with upgrading the infrastructure in the context of smart cities, such as using sensors to complement traffic signals, road markings, etc.

The infrastructure factor

WSJ: How important for self-driving cars is vehicle communication with the infrastructure, such as with traffic lights, as well as with other vehicles?

PROF. BAYEN: As long as safety-critical event detection solely resides onboard vehicles, it subjects them to higher degrees of scrutiny and certification. If some of this functionality was achieved by infrastructure integration, it might bring faster deployment of higher degrees of automation.

MR. RAJKUMAR: Cellular vehicle-to-everything technology, called CV2X, will enable a vehicle to communicate with appropriately equipped vehicles, traffic signals, road signs, pedestrians, the cloud, etc.

The return on that investment is that the vehicle can precisely know the correct status of a traffic light, without AI, several hundred meters away—more than five to 10 times the range of computer vision! It can also receive information about road closures, automotive crashes and traffic congestion ahead.

MR. REERS: CV2X has significant potential. However, there are still different systems in use across car makers and regions, hindering interoperability. So establishing standards is a key success factor. Furthermore, CV2X requires investment in the infrastructure.

WSJ: Are expectations for AV safety too strict, considering that today's cars have accidents and no one bans them?

MR. RAJKUMAR: We are used to the notion of humans causing automotive crashes, but since AVs are a new phenomenon, even a single crash or fatality receives outsize attention from the media and the public. There have been perhaps 30 or so fatalities to date, but they are dwarfed in number compared with the roughly 40,000 highway deaths every year in the U.S. alone. This expectation of perfection from computers puts the burden of making AV technology safer on AV developers and researchers.

MR. REERS: Regulations need to be strict to build and maintain trust, even more so than in conventional vehicles. It goes without saying that regulation shouldn't restrict innovation, but I don't see this as a key challenge for the moment.

Mr. Ziegler is a former Wall Street Journal editor. He can be reached at reports@wsj.com .

Credit: By Bart Ziegler

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