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Why We Compete in DARPA's Urban Challenge Autonomous Robot Race

The robots will have to find their own way, sensing and predicting their whereabouts through automated perception, planning, and control.

On November 3, 20-some cars will engage in an unprecedented race. To win, they will have to drive to a series of target destinations in a city, just like a postal delivery truck making its rounds. Sounds simple. What makes it difficult is the fact that no human driver will be in any of them, and no remote control will be allowed. The race will be executed entirely by autonomous robots sensing, thinking, and acting on their own. The world will learn whether the field of robotics and artificial intelligence is indeed ready for such a challenge, and the robotic racers will show whether they can safely navigate urban traffic for extended periods of time over extended distances.

The Urban Challenge is the third in a series of autonomous robot races organized by the Defense Advanced Research Project Agency (DARPA, www.darpa.gov). The first two, in 2004 and 2005, were called DARPA Grand Challenge. Originally envisioned as a race from Los Angeles to Las Vegas, the first led from Barstow, CA, to Primm, NV, mostly along narrow, unpaved desert trails. The rules of the race were elaborate, and the course was revealed to each team on a CD only two hours before the start. The CD contained a list of 2,586 GPS waypoints with associated speed limits. To minimize robot interaction along the course, the start was staggered, with individual autonomous racers starting in five-minute intervals. During the race, no communication was permitted between the robots and their (human) creators. The robots had to navigate the course entirely on their own.

On March 14, 2004, after a selection phase to cut down from 106 registered teams, 15-some robots had earned a place at the starting line. But the race was over quick. All entrants got stuck in the

"Junior," a driverless 2006 Volkswagen Passat modified by the Stanford Racing Team for the 2007 Urban Challenge.

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first few miles, some in plain view of the starting chute, as they drove off the road and ran into obstacles, clueless as to how to recover. None made it past the 5% marker of the 142-mile-long course. The field of robotics was clearly not ready for such a challenge.

This changed dramatically the following year. On October 8, 2005, the course started and ended in Primm. DARPA had selected 23 finalists from a pool of 195 registered teams. The 131-mile-long course led through narrow winding roads, over steep hilltops, along treacherous mountain passes, and through narrow underpasses. My team at Stanford University entered "Stanley," a modified 2004 Volkswagen Touareg, full of the latest and best in probabilistic robotics and AI technology. In fact, while several other teams built robots from scratch, our focus was entirely on software, especially for environment perception and motion planning and control; we left it to our automotive partner Volkswagen to take care of the vehicle.

Our AI emphasis paid off. Stanley navigated the course in record time—6 hours, 53 minutes, 8 seconds—earning us the $2 million prize. The even bigger news, however, was that five robots made it completely through this grueling race, some just minutes slower than Stanley. Bringing five autonomous robots home was a tremendous achievement for the robotics community. It spoke to the stunning scientific advances that had occurred in just over a year. This time the robotic community had indeed been ready.

Will the robots be ready again on November 3 for the many new challenges DARPA has planned for them? First, they will have to be able to navigate in moving traffic. While the Grand Challenge was set up to avoid interactions among moving vehicles, such interactions are the focus of the Urban Challenge (www.darpa.mil/grandchallenge/). The robots will have to yield the right of way, pass slow-moving vehicles on multi-lane roads, and patiently wait at stop signs until it is their turn to proceed. They will have to navigate parking lots, accommodate road blocks, and execute U-turns—all in compliance with the California Traffic Rules and Regulations. Additionally, robots, like our 2006 Volkswagen Passat we call "Junior" (see the figure here), must find their own way around the environment. They must select their own paths from a network of road segments. Roads in the network will have variable characteristics (such as single-lane vs. multi-lane) affecting the expected time of travel. Making these choices wisely and safely will be of great importance in this challenge and in the likelihood of finishing the race intact.

To meet the Urban Challenge, the robotics community must still advance in a number of scientific areas. Chief among them is perception. The robots will have to look in all directions, not just straight ahead; at Stanford, we call this "surround sensing." Whereas in the Grand Challenge it sufficed to classify the environment as "drivable" and "nondrivable," now the robots will have to be able to detect moving objects and predict their future whereabouts—by no means an easy task.

Perception in the Urban Challenge will involve the ability to identify and avoid other vehicles and localize environment features (such as lane boundaries). In predicting the future, robots will have to understand interaction among multiple robots. Thus, the Urban Challenge will require perceptual capabilities that are much closer to their human sensory counterparts. Achieving them will itself be a significant step forward in robotic technology.

The second technical challenge is planning and control. Vehicles in the Urban Challenge will have many more choices than before. They'll be able to change lanes, turn, stop, follow cars, pass cars, and turn around—all behaviors not required in the earlier Grand Challenge races. Some choices are strategic (such as the global path a robot decides to pursue). Others are more tactical (such as avoiding a local obstacle). AI researchers will have to build planners and controllers that make split-second decisions—an important challenge, as a single poor decision is likely to get a robot stuck or disqualified.

DARPA deserves a huge round of applause for organizing these challenges. In record time—and at remarkably low cost to the U.S. taxpayer—the original Grand Challenge(s) led to a huge leap forward in unmanned ground-vehicle technology. This result may be apparent from the fact the robots performed so much better in 2005 but was even more manifest in a body of new scientific insights that are still emerging in major scientific conferences and journals.

I am especially hopeful the Urban Challenge will be an even greater leap forward. I am convinced that the robotics community will ultimately succeed in building safe vehicles that are able to drive us (not just themselves) reliably in urban traffic. When this happens, the military will be a step closer to its congressionally mandated goal that "by 2015, one-third of the operational ground combat vehicles are unmanned" (see the National Defense Authorization Act for Fiscal Year 2001, H.R. 4205, Sec. 220). On the civilian side, the technology may save many thousands of lives each year by making cars safer. It may even enable blind and aging people to operate cars. Moreover, self-driving cars promise to help reduce energy consumption and increase highway throughput via more regulated highway driving. It will also affect the overall work force, enabling it to work during the daily commute or take a nap while being chauffeured safely to and from work.

No matter what happens November 3, the research carried out under this program will eventually affect us all in positive ways. I encourage you not to miss this historical event and follow along as the robots take to the road. C

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