Cornell University
DARPA Grand Challenge Team

Progress Update

February 2005

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Our Progress

A lot has happened since 2004

Topics covered in upcoming updates
LIDAR (LIght Detection And Ranging)
Road detection & following
INU (Inertial Navigation Unit)
Path planning
Artificial Intelligence

Due to the generous support of our sponsors, the team has made progress in many areas – including artificial intelligence, sensing, and the vehicles themselves.

The artificial intelligence consists of a working simulation of our vehicles, which is capable of navigating a world map. In addition to excellent navigation, it can generate vehicle commands and also drive itself based on the virtual world that it creates.

Our sensory equipment involves a robust beta version of a road detection system; this has been optimized for simulated desert roads that are difficult to detect. Automatic terrain quality estimation allows the sensory components of the car to determine the quality of the course. Three LIDAR units have been purchased, and we plan on using a fourth in the near future. These three units will be mounted on the front of the vehicle, and the fourth on the back. Currently, vehicle actuation has been completed and tested on both vehicles and has displayed incredible performance. Finally, the stereo version system has been tested, and results suggest an output of high-quality data and real-time speeds, enabling fast and accurate obstacle detection.

As of February 6, 2005, Titan successfully followed GPS waypoints for the first time. Although the truck has not driven itself through a course, it took a significant 'first step' by steering itself through a set of points. At this stage, the truck has not controlled its own speed, but that test is slated for the very near future. Our engineers are working toward the goal of the first totally autonomous test, and rudimentary obstacle avoidance mechanisms will then follow soon thereafter.

Because Code Red was significantly more custom-designed, work on it requires more time than Titan. Code Red has not reached Titan's current level of development, but it is catching up quickly and will be ready to go soon. We anticipate that Code Red will be suitable for driving within the next week and running autonomously in the next two weeks.

Our engineers have accomplished a considerable amount on the two vehicles. The progress on both trucks is very promising, though far from complete, and we look forward to the next few months of development followed by a summer of testing and refining.

Working on Titan in the lab

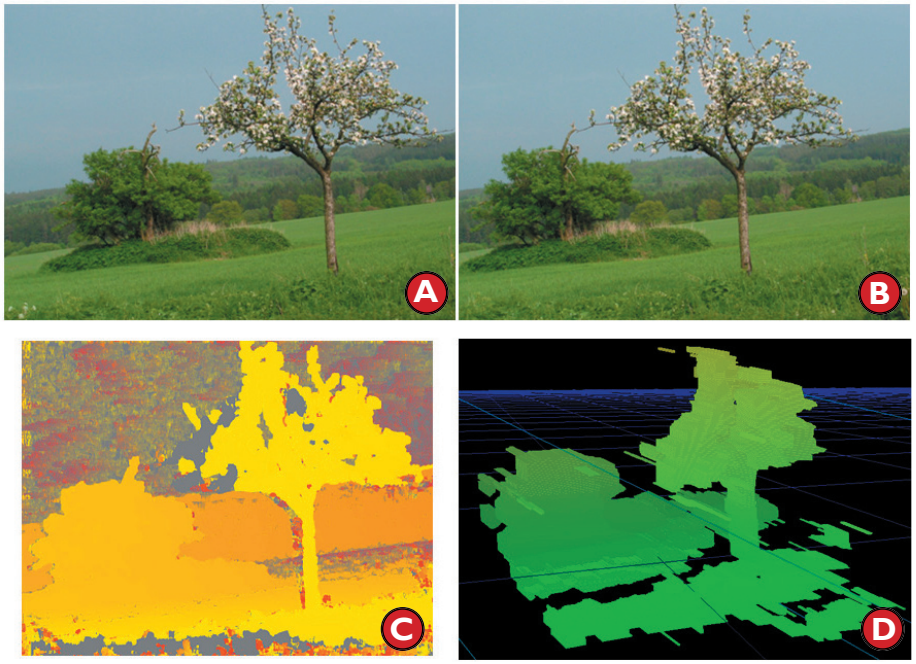
Stereo Vision

Seeing with stereo vision

Stereo Vision is a fascinating technology that works based on exactly the same principle as human vision. Two cameras are placed at a known separation: these cameras act as the vehicle's eyes. The design of this mechanism allows each camera to capture an independent view of the truck's environment.

The system then compares the images produced by the two cameras. By noting the slight differences between each pair of images, it has the remarkable ability not only to view the surrounding environment, but also to determine which objects are closer than others.

The vehicle's computing systems are able to interpret this information, convert it into a 3D model of the surrounding terrain, and enhance it with depth perception.



Our Stereo Vision system has been proven to work exceptionally well in testing. The Cornell Team is currently in the process of "speeding it up," and the goal is to ultimately generate and interpret images at about 50 hertz – an incredible speed for a system like this. Stereo Vision, operating simultaneously with LIDAR, GPS and an Inertial Navigation Unit, will equip the vehicle with significantly more information than even the most experienced driver could hope to have.

Milestone: **GPS Waypoints**

Titan plots its own course using GPS waypoints

On February 6, 2005, the Spider successfully followed Global Positioning System (GPS) waypoints for the first time. This is a major accomplishment for the team, because GPS waypoints define the Grand Challenge course. The truck can recognize a GPS point as its destination, and steer to get there.

The Global Positioning System is enabled by an array of satellites; using distance measurements from four overhead satellites, a receiver can pinpoint its location anywhere on the surface of the earth. A GPS 'waypoint' represents the precise latitude and longitude of a geographic location – each one is similar to a gate in downhill skiing; it is necessary for the vehicle to pass through every point to complete the course.

The vehicle follows a series of GPS waypoints by navigating between pairs, taking an initial point (such as 55deg N, 120deg W), traveling to a destination (such as 56deg N, 119deg W), and then repeating the process. In order to navigate between each pair successfully, the vehicle must utilize its sensors to detect obstacles in the path, as well as follow any roads or flat terrain that connects the two points. The vehicle must also use GPS waypoints to make commands – turn 17.2 degrees right, apply 34% throttle, shift down one gear, or brake at 75% capacity, for example – to maneuver from one waypoint to another. Finally, the vehicle must make sure that its chosen path neither violates the laws of physics nor exceeds the vehicle's performance specs. For example, demanding the vehicle to accelerate from 0 to 100 mph in 10 feet, or make a 90 degree turn at 30 mph, is not allowed!

GPS sponsored by
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Titan in front of Rhodes Hall

No Ordinary Spider

A look at our Singaporean military vehicle

A cutting-edge vehicle developed by Singapore Technologies Kinetics, the Spider is practically indestructible. ST Kinetics donated this Light Strike Vehicle to the Cornell University team as a platform on which to build for the Grand Challenge. Designed for rapid troop transport and reliable maneuverability, this robust truck is capable of traversing across hills, mountains, and rough desert terrain like no other.

The Spider LSV is powered by a 4 cylinder turbo-diesel engine that is certified up to Euro III emission standards. This vehicle also has handling and off-road capabilities superior to any commercially available vehicle. It travels on 35 inch tires with state-of-the-art independent suspension for enhanced shock absorption and stability, and was built with a lightweight patented space frame that vastly reduces weight. This allows for increased speed, as well as heightened performance and agility.

Performance is enhanced not only by the lightweight frame, but also by the exceptionally high payload of the vehicle – which allows it to accommodate a wide variety of equipment. This includes a light detection and ranging system, an array of computers, and several cameras. The addition of motors supplied by Maxon Precision Motors has helped to fully actuate "Titan," (as the Cornell team proudly named this innovative vehicle). As a result of these technologies and an enthusiastic team, Titan has already demonstrated an impressive ability to follow GPS waypoints through the use of automated path planning. One thing's for sure, this mean machine is no ordinary spider.

Behind Code Red

Updates on our custom-built rock crawler

Constructed to fit any kind of landscape, the Avalanche, also known as "Code Red," is a custom truck capable of handling both natural and synthetic obstacles. Avalanche Engineering, Cornell's DARPA Grand Challenge Team, and several sponsoring companies (Dana, Interco Tire, and Sway-A-Way) jointly designed Code Red to be a powerful vehicle, suitable for desert terrain.

Code Red is built on the chassis of a rock crawler, a type of vehicle that excels in extreme, off-road regions. Dana provided Code Red's durable axles and differentials; Interco Tire supplied rugged 38-inch tires, and Sway-A-Way contributed high-performance 14-inch suspension components. With these components, Code Red is capable of tackling a variety of rocks, ditches, bumps, and boulder fields—anything that the desert racecourse might throw at it. Its lightweight design affords outstanding performance when matched with the array of guidance equipment needed to assemble an autonomous vehicle. Like Titan, Code Red's robotic systems specialize in discerning obstacles in a timely fashion – and the custom-built vehicle will have the agility to perform.

Code Red, a unique vehicle, is currently under development. Stay tuned for more updates as our engineers continue to assemble this extraordinary vehicle!

Code Red on delivery this January

The Cornell University DARPA Grand Challenge Team

Cornell University DARPA Grand Challenge Team

The whole is greater than the sum of its parts

We all know the feeling of taking our hands off the wheel while driving. The feeling of sensory enhancement, knowing that one move or lack thereof could be the last. It is a momentary excitement to drive a car with no hands, defying the rules of driving; however, the thrill is much more tremendous when driving a vehicle without even being in it.

The attitude of the Cornell University DARPA (Defense Advanced Research Projects Agency) Grand Challenge Team is rooted in this feeling. Our group is developing an autonomous ground vehicle capable of independently traversing through an extended distance of rough and difficult desert terrain. The entire Cornell University team, students and faculty advisors alike, are intensely passionate and excited about this endeavor. Every member, no matter their field of expertise, has been pouring their hearts and souls into the project, and with such a rich tradition of excellence, this Cornell University team is poised for success.

Cornell University's rich engineering heritage dates back to 1868, the founding year of the Cornell School of Engineering. Our team's exceptionally high standards stem from Cornell Engineering's continuous flow of remarkable achievements and innovations. Our school was founded based on the simple concept of producing well-educated and useful graduates; our engineers still benefit from this

founding principle of a liberal arts education that stresses the application of practical skills.

Cornell Engineering School's rich tradition of success has produced remarkable teams such as Formula SAE and the Autonomous Underwater Vehicle Team. Formula SAE is a group of undergraduate and graduate students who design, manufacture, test, and race a formula-style, open-wheel race car in the Formula SAE competition every May. The competition is held annually in Michigan with over 140 schools from 12 countries. The Cornell University Formula SAE team has a long-standing history of success in this competition, winning the world championship seven times and placing in the top ten almost every year. The successful Cornell Engineering tradition also comes through in the Autonomous Underwater Vehicle Competition—the 2003 team won the AUV championship.

To capitalize on the Cornell tradition of cutting edge research, the Cornell DARPA team has united with four exceptional, intelligent professors who aide in the logistics of the project—Professor Ephrahim Garcia, Professor Hod Lipson, Professor Dan Huttenlocher and Professor Bart Selman. Each professor brings different strengths to different aspects of the project, resulting in an involved, technical approach to advising.

Professor Ephrahim Garcia and Professor Hod Lipson are members of the Mechanical and Aerospace engineering department at Cornell. Professor Garcia, who was named a Presidential Faculty Fellow by Bill Clinton, has worked for the Department of Defense and the Central Intelligence Agency. At Cornell Professor Garcia specializes in Mechatronics and Actuator Modeling. Professor Hod Lipson was a postdoctoral researcher at Brandeis and lecturer at MIT; he spent several years as a research engineer before settling in academia at Cornell University.

Professor Dan Huttenlocher and Professor Bart Selman, who advise the team along with Professor Garcia and Professor Lipson, have pioneering backgrounds in their respective fields. Professor Dan Huttenlocher is a professor of Information Science and Business within the Cornell School of Engineering. He has 24 U.S. patents and was named the New York State Professor of the Year in 1993. He prides himself on the practical experience gained from serving as CTO of Intelligent Markets, and is an extremely valuable asset to our team. Professor Bart Selman is an associate professor of computer science. He has received four best paper awards at the American National Artificial Intelligence Conferences, and is a Fellow of the American Association for the Advancement of Science. At Cornell, Professor Selman specializes in the connections between Computer Science and Physics. Our faculty advisors pride themselves on practicality through advanced education. The support and success they bring to the team is essential, and they share the students' dedication to victory.

A setting which is conducive to achievement will not win the competition alone; rather, the Challenge will be realized through the drive and commitment of the students, coupled with the faculty guidance and support. The team is composed of students from all areas within the university, spanning an array of majors from engineering to communication to applied economics and management. This intellectual diversity forms the heart of the team, and fosters an attitude that the whole is greater than the sum of its parts. Weekly full-team meetings are necessary to coordinate projects and organize how individual talents are applied in and across subgroups. Communication is achieved through the World Wide Web (http://dgc.cornell.edu), where each member can post updates on his or her individual progress. This ensures a flow of information that keeps everyone on the same page. In addition, students are required to spend time in the lab, working with fellow team members from different parts of the project. The team's dedication to an active communication network creates efficiency and a sense of community, which will hopefully be rewarded with outstanding performance in the Grand Challenge.

The Cornell University DARPA Grand Challenge team has both the attitude and tools for success. Growing from a rich academic tradition, and precipitated through outstanding faculty advisors, the team has set a Grand Challenge goal of nothing short of success. All persons involved in this project are poised to take their hands off the wheel, and drive to victory.

Q&A

Some common questions about our team

Q. Why is building an autonomous vehicle so expensive?

A. Even at considerable discounts, cutting edge technology is still expensive. While a two or three thousand dollar piece of equipment might not cost a corporation much, Cornell Grand Challenge is funded almost entirely through the generosity of corporate sponsors and must cut costs wherever possible. Acquiring technologically advanced equipment is by far the most costly aspect of this project.

Q. Why develop an autonomous vehicle?

A. Autonomous technology has been in development at Cornell for many years, including autonomous robots in the RoboCup competition and the prestigious Mars Rover. Autonomous capabilities can advance society in the areas of space exploration, national defense, nuclear waste management, topographical mapping, and much more.

Q. How much money is in the budget?

A. Cornell Grand Challenge has raised just under $90,000 in cash support and nearly $200,000 of in-kind sponsorships and donations. While the team has raised an impressive amount of money, we are still far from our goal. To finance an extended testing period through the summer and the associated travel expenses, Cornell Grand Challenge has set its sights on raising an additional $50,000 cash by the end of the Spring 2005 semester. Thank you to all of our sponsors; Cornell Grand Challenge could not possibly compete without your generous support.

Current Sponsors

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