Implementing GIS in DARPA's Grand Challenge Race

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Abstract

This paper presents GIS use in autonomous vehicles navigation. It will cover three main subjects. First, an introduction to DARPA's Grand Challenge Race, the first autonomous vehicle race to be conducted ever; second, the applications of GIS in autonomous vehicles in the defense market; and third, the different concerns that were addressed for one of the vehicles in the race. Specifically covered will be aspects of GIS integration, autonomous path following, mapping input requirements, and approaches to terrain and mobility analysis. Unique problems related to vehicle physical characteristics and performance would also be addressed.
Who is DARPA?

- DARPA is the central research and development organization for the U.S. Department of Defense.
- DARPA manages and directs basic and applied research and development projects for the Department of Defense.
- DARPA pursues research and technology where the risk and payoff are both very high and where success may provide dramatic advances for traditional military roles and missions.

Information courtesy of DARPA
What is the Grand Challenge Race?

DARPA announced that it would award a cash prize of $1 Million to the team that builds an autonomous robotic ground vehicle that will successfully win a race from Los Angeles to Las Vegas. The race will include on-road and off-road navigation and must be completed in under ten hours. The date of the race was set for March 13, 2004.
Autonomous Vehicles in Defense

Main Roles
- Supply
- Surveillance
- Reconnaissance
- Targeting
- Countermine

FCS (Future Combat Systems)
- It shall be the goal of the armed forces…
  that by 2015, one-third of the operational ground combat vehicles of the armed forces shall are unmanned

National defense authorization act for fiscal year 2001 (S. 2549, Sec. 217)
DGCR’s General Rules

- Vehicle should be completely autonomous
- Vehicle is given the exact route two hours prior to the race, via Route Data Definition File (RDDF)
- Vehicle must stay within the course boundaries and within defined upper limit velocity as defined in the RDDF

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The Race Course

Photos courtesy of DARPA
The Teams

- 25 Teams (out of 109) selected for participation in the QID
- 15 Teams participated in the race itself

Photos courtesy of DARPA
Typical vehicle configuration

- Stereo Vision
- Vertical Laser
- GPS, DGPS
- Radar
- Pin Hole Cameras
- Horizontal Laser
- Acoustic Sensors
Qualification Inspection and Demonstration (QID)

Vehicles obstacles

Power Line obstacles

Cattle Guard Obstacles

Underpass obstacle

Vehicles obstacles
GIS System

Composed of the following ESRI products

- **ArcMap – ArcInfo**
  - Geometric Network analysis
  - Advanced Editing

- **Spatial & 3D analyst extensions**
  - Slope, Aspect and interpolate to raster
  - Calculation of Shortest path

- **ArcSDE**
  - Storage of Raster data

- **ArcPAD**
  - Acquiring DGPS tracks on the field

- **ArcObjects – additional programming**
  - RDDF file acquisition
  - Route separation to sub-stations
  - Automatic conflict calculation within route
  - Conflicts editor user interface
  - Route unification, smoothing
  - Write file to UGV usage interface
Mapping Products

Topographic Maps
- Scales: 1:250K, 1:100K and 1:24K
- Accuracy [CE90%]: 12m, 80m and 201m

Digital Elevation Model
- National Elevation Dataset (NED)
  - 30m pixel posting
  - ~8m Vertical accuracy
- LIDAR based data (terrain & surface)
  - 1.3m pixel spacing
  - Accuracy: Horizontal: 0.5m [CE90%]; Vertical: 20cm

Digital Ortho Quarter Quads (DOQQ's)
- 1m/pixel resolution
- Horizontal Accuracy [CE90%]: 10m
DGPS Tracks

- Collected directly into ArcPAD
- Preprocessed by Trimble® for higher accuracy
- Semi-automatic tracks smooth and correction
- Detailed information for each track recorded
Putting it All Together
GIS Team (T-2 hours) 4:30 AM
Approaches to terrain and Mobility analysis

**Raster Based**
- General
  - Based on pixel cost weight and distance
- Pros
  - Whole area approach
  - Not confined to specific tracks
- Cons
  - Slow on large dataset
  - Per Pixel approach

**vector based**
- General
  - Based on geometric network approach
- Pros
  - Fast
  - Weighted
- Cons
  - Defined trails/roads only
Unique Characteristics for UGV

- Good mobility map is required
- Unique problems
  - Direction specific
  - Vehicle limitations
  - Physical path (turning radius)
- High resolution required (sub-meter level)
Acknowledgments

- DARPA media gallery
  - [http://www.darpa.mil](http://www.darpa.mil)

- USGS – U.S. Geological Survey
  - DRG, DEM, NED and DOQQ courtesy of the U.S. Geological Survey

- ESRI dedicated volunteers...
The Defense Advanced Research Projects Agency (DARPA) of the U.S. Department of Defense announced that it will hold a second Grand Challenge for Autonomous Robotic Ground Vehicles on October 8, 2005.

As with the inaugural event held in March 2004, autonomous vehicles will attempt to navigate a challenging course of varying terrain.

The team that completes the Grand Challenge 2005 route within a specified time will receive a cash prize of $2 million.
References

- DARPA web site
  - http://www.darpa.mil
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