Autonomous Ground Vehicle

Senior Design Project

<table>
<thead>
<tr>
<th>EE</th>
<th>ME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anshul Tandon</td>
<td>Donald Lee Hardee</td>
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<tr>
<td>Brandon Nason</td>
<td>Ivan Bolanos</td>
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<tr>
<td>Brian Aidoo</td>
<td>Wilfredo Caceres</td>
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<tr>
<td>Eric Leefe</td>
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</tr>
</tbody>
</table>

**Advisors:**

Mr. Bryan Audiffred
Dr. Michael C. Murphy
IGVC - History and Description

• June 8-11, 2007 in Rochester, Michigan, hosted by Oakland University

• Autonomous Ground Vehicle Competition
  – Autonomous Challenge
  – Design Challenge
  – Navigation Challenge
Organization Chart

- Software
  - Control
  - Sensor
  - Vision

- Speed Control
  - Steering
  - E-Stop
  - Motor

- Traction
  - Body Material

- Recharging
  - Battery

- Frame

- Navigation
- Propulsion
- Power
Camera

• Requirements
  – Lane & Pothole Detection

• Part Specification
  – ImagingSource DFK 21F04 (Firewire)

• Orientation
  – 5.5’ high
  – Front of vehicle
  – Tilted downwards approx 60°
Rangefinder

- Requirements
  - Obstacle Detection

- Part Specification
  - SICK LMS 291 (RS-232)

- Orientation
  - 1’ high
  - Front of vehicle
  - Horizontal to ground

Image...
http://www.sick.com
GPS Unit

• Requirement
  – Give accurate position

• Magellan DG14 Sensor
  – Accuracy: 70 cm (with differential signal)
  – Interface: serial
  – Housing w/ prefabricated connections
  – NMEA protocol
Digital Compass

• Requirement
  – Give accurate heading

• KVH Azimuth 1000
  – Accuracy: 0.5 degree
  – Serial interface
  – NMEA protocol
Propulsion

• Motors Selection
  – Weight
  – Acceleration
  – Driving wheels
  – Wheel Radius
  – Coefficient of rolling friction
  – Linear and angular speed
Propulsion

OUTPUT SHAFT RPM vs LIN VEL
(r = 0.1524m = 6in)

Speed Limit = 5mph = 2.234m/s
Torque Required

![Graph showing torque vs vehicle weight with different coefficients of friction](image-url)
Torque Required

![Graph showing the relationship between torque (Tq) and vehicle weight (W) for a 17 degree incline with Ur COEFF = 0.06. The graph displays a linear increase in torque as weight increases.]
Propulsion

• The motor we selected is the NPC R-82
Propulsion

RPM vs. Torque

<table>
<thead>
<tr>
<th>RPM</th>
<th>Torque (N-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>1.2</td>
</tr>
<tr>
<td>130</td>
<td>6.4</td>
</tr>
<tr>
<td>150</td>
<td>11.6</td>
</tr>
<tr>
<td>170</td>
<td>17.4</td>
</tr>
<tr>
<td>190</td>
<td>22.3</td>
</tr>
<tr>
<td>210</td>
<td>27.9</td>
</tr>
<tr>
<td>230</td>
<td>32.9</td>
</tr>
<tr>
<td>250</td>
<td>38.0</td>
</tr>
<tr>
<td>270</td>
<td>43.1</td>
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<tr>
<td>290</td>
<td>48.2</td>
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</tbody>
</table>

Graph showing the decrease in RPM as the torque increases.
Propulsion

Current vs. Torque

![Graph showing the relationship between Current (amps) and Torque (N-m). The graph is a straight line with increasing Current as Torque increases.]
Motor Controller

• AX3500BP
  – Current Requirements
    • Motor current: 40 A
    • Max continuous controller current: 60 A
  – Serial-to-PWM converter
  – Controls both motors
  – Accepts feedback
  – PID control
Control Loop - Block Diagram

CPU -> AX3500BP -> Motor 1

Motor 2

CPU
Traction and Steering

• Requirements
  – Low cost
  – Reliability
  – Low weight
  – Low turning radius
  – Max speed of 5 mph
  – Stability
  – Good traction in grass and sand

• Solutions
  – Four wheels with rack and pinion steering
  – Track with differential steering
  – Wheels with differential steering (Chosen)
Traction and Steering
Power System Design

- Batteries
  - 6 Powersonic Sealed Lead-Acid Batteries
  - Calculated battery life = 3 Hours

- Charging
  - 2 Battery Tender Multibank Chargers

- Monitoring
  - Serial Voltmeter Software
Power System Layout

- 12V/24V Battery Bank for Sensing and Processing
  - Camera 12V 11.28W
  - Computer 12V 90W
  - Laser Range Finder 24V 20W
  - 24V Battery Bank for Motors
    - Motors 24V Variable Power

- Box for Electrical Wiring, Fuses, Converter, and Regulator
  - Digital Compass 12V 0.1W
  - GPS Unit 12V 3.7W

- Variable Power Box for Electrical Wiring, Fuses, Converter, and Regulator
Frame Design

**Material**
- Strength
- Elasticity (bending deflection)
- Cost
- Weight
- Weldability

**Design**
- Layout
- Dimension Requirements
- Water Resistance
- Center of Gravity
- Component Mounting
Frame Design

ANSI 1020

- Yield Strength ~ 51,000 psi
  - Maximum stress on vehicle is 4,700 psi
  - Lowest FOS = 10.7

- Cost Efficient

Coated Polyester

- Lightweight
- Breathable
- Inexpensive
Component Positioning
Component Positioning
Component Positioning
Component Positioning
Component Positioning
Component Positioning
FEA - Stress and Deformation

Maximum Stress = 4,700 psi
Average Stress = 2,300 psi
Maximum Deflection = 0.023 in
Average Deflection = 0.012 in
Processing

- Personal Computer
- GPU Acceleration
- OpenVIDIA Graphics Library
- C Programming Language
- Multithreading
Processing

Encoder → Motor Controller → Motor

GPS

Range finder

Computer

→ Monitor

→ Keyboard

Compass

Camera
Software Flow Chart

Initial State

Gather data

Camera
Rangeﬁnder
GPS Unit
Compass

Store Data

Get Direction

Move Vehicle
Navigation Algorithm

1. Gather data from sensors
2. Identify target directions
3. Process GPS coordinates
4. Determine heading correction
5. Send direction to motor controllers
Lane & Pothole Detection

- Capture image from camera
- Convert image to B/W
- Downscale image
- Detect white pixel chains
- Detect white pixel areas
- Determine direction
Obstacle Detection

• Get image from rangefinder
• Determine distance to obstacles
• Determine optimal direction
Emergency Stop

• RF Communication
  – 433MHz
  – 250ft

Transmitter

Receiver

E-Stop

Motors
## Budget

<table>
<thead>
<tr>
<th>Category</th>
<th>Part</th>
<th>Cost</th>
<th>Category Total</th>
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<tbody>
<tr>
<td><strong>Navigation</strong></td>
<td>LRF</td>
<td>6,000</td>
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<tr>
<td></td>
<td>Camera</td>
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<td>GPS</td>
<td>3,700</td>
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<td>Compass</td>
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<td>10,350</td>
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<td><strong>Power</strong></td>
<td>Batteries</td>
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<td><strong>Propulsion</strong></td>
<td>Wheels</td>
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<td>Motors</td>
<td>1,050</td>
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<td><strong>Frame</strong></td>
<td>Tubing</td>
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<td><strong>Processing</strong></td>
<td>On-Board CPU</td>
<td>1,185</td>
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<td>TOTAL</td>
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<tr>
<td></td>
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<td>~13,500</td>
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AGV - Past Competitions

Images...
http://www.igvc.org/photos.html
Summary

• Navigation
  – Camera
  – Laser rangefinder
  – Differential GPS Unit
  – Central Processing Unit

• Propulsion
  – DC motors
  – Wheels

• Power
  – Rechargeable efficient batteries

• Frame
  – Strong, light material
Questions / Suggestions

• Contact area experts

  – Navigation - Vision
  – Navigation - GPS
  – Propulsion
  – Propulsion
  – Power
  – Frame
  – Processing

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Sponsors: