IGVC
Intelligent Ground Vehicle Competition

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ME 4243 Fall 2007  Advisor: Brian Audiffred & Marcio de Queiroz  Sponsors: Various
Overview

• Introductory Video
• Prototype Design
  – Obstacle/Boundary Detection
  – Path Planning
  – Computer Processing
  – Chassis Design
  – Vehicle Integrity
• Safety, Cost, & Future Plans

Graphic aids courtesy of www.3dcontentcentral.com
Competition Overview
Prototype Design

• **Obstacle/Boundary Detection**
  • Information Acquisition
  • Image Processing
  • World Coordinate Transformation

• Path Planning
• Computer Processing
• Chassis Design
• Vehicle Integrity
Information Acquisition

- Elevated image from camera
- Obstacles detected with laser rangefinder
- Emergency distance sensors
Image Processing

Photo courtesy of www.igvc.org
Image Processing

Colors Identified
Image Processing

Green Removed
Image Processing

White Only
World Coordinate Transformation

- Pixel ↔ line in world coordinates
- LRF pinpoints obstacle
- Estimate obstacle depth
- Separate ground plane
  - Lines & potholes

Original photos courtesy of www.igvc.org
Prototype Design

- Obstacle/Boundary Detection
- **Path Planning**
  - Avoiding Obstacles
  - Intelligent Navigation
- Computer Processing
- Chassis Design
- Vehicle Integrity
Avoiding Obstacles

- Take 2D Overhead Image
  - Translate into obstacle map
  - Process into weighted grid
- Use A-Star Algorithm
  - Find lowest weight path
  - Option to add panorama
    - Multiple grids
- Two Modes
  - Planning & Following
Intelligent Navigation

• Visit Waypoints in Preplanned Order
  – Brute Force Algorithm

• Map Path to Center of Course
  – Find fence
  – Mark fence coordinates
  – Recalculate path
Prototype Design

- Obstacle/Boundary Detection
- Path Planning

- **Computer Processing**
  - Software Platform
  - Hardware Platform
  - Hardware/Software Flowchart

- Chassis Design
- Vehicle Integrity
Software Platform

- Linux OS
  - Customizable
    - Kernel features
    - Hardware access
  - Large open source code base
  - System, documentation & support are free
Hardware Platform

• Hardware Platform
  – Mini – ITX Motherboard
    • 6.75 in x 6.75 in
  – Video card nVidia 8800GT 512MB PCIe
    • GPU off loading using OpenVidia library
    • Fast & efficient
  – Core 2 Duo 1.66 – 1.8 GHz
    • True simultaneous multithreading
Hardware/Software Flowchart

- Hardware -
  - GPS -
  - Laser Range Finder -
  - Camera -
  - Em. Dist. Sensor -
  - Em. Stop -

- Software -
  - Nav. Path Planning -
  - Obstacle Detection -
  - Obstacle/Boundary Map -
  - Real Time Path Planning -
  - Motor Control -

- Hardware -
  - Motor Control Hardware -
  - INT -

- Process -
Prototype Design

• Obstacle/Boundary Detection
• Path Planning
• Computer Processing
• **Chassis Design**
  – Weight & Functionality
  – FEA Stress Analysis
  – Camera Mount
• Vehicle Integrity
Weight & Functionality

• Al-6061 (1” Square Tube)
  – Total weight≈29.18 lbs
  – Previous≈90lbs (304 steel)
  – 67% weight reduction

• Painted Steel Sheet
  – Weather proofing

Graphic aids courtesy of www.3dcontentcentral.com
Distributed Load - 1000 lbs
Max Stress - 0.83 ksi
Yield Strength - 7.99 ksi
Max Displacement - ~1 mm
Camera Mount

**Option 1**

Displacement - 8.21 mm

**Option 2**

Displacement - 3.4 mm

REDUCTION = 58.6%

Graphic aids courtesy of www.3dcontentcentral.com
Prototype Design

• Obstacle/Boundary Detection
• Path Planning
• Computer Processing
• Chassis Design
• **Vehicle Integrity**
  – Vibrations
  – Dynamic Stability
  – Heat Transfer
Vibrations

• Acceptable Camera Velocity < 10.6 in/sec
• Preliminary Tests
  – Gravel= 4-6 in/sec
  – Potholes/Bumps= 8-10 in/sec
• Vibration Reduction
  – Low pressure front tires
  – Pneumatic tires
  – Spring suspended caster

Graphic aids courtesy of www.3dcontentcentral.com
Dynamics

\[ \text{Center of Mass} \left( r_x, r_y, r_z \right) = (17.7", 7.3", 12.8") \]

\[ \text{Min. Stopping Time} = 1.18s \]

\[ \text{Min. Turning Radius} = 10" \]

Graphic aids courtesy of www.3dcontentcentral.com
Heat Transfer

- Relative Humidity < 85%
- Heat Decreases Humidity
- T < 122°F
- Fan cfm $\alpha$ Heat load

$$\Delta T = \frac{h_{sens}}{1.08 \times cfm}$$

- 5Watt $\rightarrow$ 3.16cfm
- 50Watt $\rightarrow$ 31.6cfm
Manufacturing

- Lock or Push-in Fasteners on Side Panels
- Bolt-on Motors & Camera Bracing
- TIG-Welded Frame (Al-4043 filler)
  - Pre- and post- weld heat treatment
  - Glass bead peening
  - Grind stress concentrations
  - AWS D1.2 as reference
Safety

• Mechanical Emergency Stop
  – Use “normally closed” button
• Wireless Emergency Stop
• Hardware Limited Speed
• Emergency Distance Sensors

Photo courtesy of www.arcadeshop.de
## Cost Breakdown

<table>
<thead>
<tr>
<th>Description</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser Rangefinder</td>
<td>$2700 (Purchased)</td>
</tr>
<tr>
<td>GPS</td>
<td>$3000 (Purchased)</td>
</tr>
<tr>
<td>Motors</td>
<td>$600 (Purchased)</td>
</tr>
<tr>
<td>Camera</td>
<td>$300 (Purchased)</td>
</tr>
<tr>
<td>Batteries &amp; Chargers</td>
<td>$500 (Purchased)</td>
</tr>
<tr>
<td>Motor Controllers &amp; Encoders</td>
<td>$700 (Purchased)</td>
</tr>
<tr>
<td>Testing Equipment</td>
<td>$1000 (Donated)</td>
</tr>
<tr>
<td>Computer</td>
<td>$1000</td>
</tr>
<tr>
<td>Frame Material, Wheels, Casters, Tires</td>
<td>$550</td>
</tr>
<tr>
<td>Miscellaneous Supplies</td>
<td>$100</td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
<td><strong>$10450 (Remaining costs=$1650)</strong></td>
</tr>
</tbody>
</table>
Future Plans

• Continue testing on images & vibration
• Complete fabrication of chassis & casters (Feb.)
• Complete incremental implementation (April)
  – Self awareness
  – Obstacle & line detection
  – Intelligent path planning
• 2008 IGVC Competition (May 30)
Semester Achievements

- Method for detection and mapping of obstacles
- Unique path planning algorithm
- Image processing load from CPU to GPU
- Modeled chassis (stress levels acceptable)
- Reduced chassis weight & maintained integrity
More Information

- Condensed Vision
- GPS and Compass Data
- Motor Controller Data
- Power Distribution
- Motors and Power
- FEA Natural Frequencies
- FEA Displacement
- Vibration Dampening Plots
- Dynamics
Image Processing

1. 
2. 
3. 
4. 

More Information
GPS and Compass

- CSI Wireless Vector GPS Compass
  - Differential correction for <1m position accuracy
  - Heading accuracy of .5 degrees
  - 10 Hz heading updates, 5 Hz position updates
  - NMEA 0183 communications interface over RS-232
  - Low power consumption
  - Waterproof housing
Motor Controller

- Roboteq AX3500
  - 2x60A Continuous output
  - Quadrature encoder support
  - RS-232 Control option
  - Programmable current & speed limitation
  - E-Stop input
  - Transistor temperature monitor
  - Joystick control through PC
Power Distribution

- Highest required power:
  - 15° incline at 5 mph
  - Friction coefficient ($f_r = 0.06$)
  - Max req. torque=38.4 ftlb

$$Power = \frac{Energy_{incline} - Energy_{friction}}{time}$$
Motors and Power

• 2 Motors:
  – NPC-T64
    • 24-36V DC
    • 235 Max RPM
    • 1.6 HP
    • 13 LBs each
    • Stall torque=68.75ftlb

• Battery Bank
  – 6x Sealed Lead Acid Batteries
  – 12V 21.0 Ah/battery
  – 4 – Motor, 1 Computer, 1 Spare
  – Series-Parallel Wiring for 24V 41 AH

<table>
<thead>
<tr>
<th>Tire Size</th>
<th>Max Speed</th>
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<tbody>
<tr>
<td>10”</td>
<td>7 MPH</td>
</tr>
<tr>
<td>12”</td>
<td>8.4 MPH</td>
</tr>
<tr>
<td>14”</td>
<td>9.8 MPH</td>
</tr>
</tbody>
</table>

More Information
FEA- Natural Frequencies

• Modes ⇒ Different Loads

<table>
<thead>
<tr>
<th>Mode No.</th>
<th>Frequency (Hertz)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>20.70</td>
</tr>
<tr>
<td>2</td>
<td>25.27</td>
</tr>
<tr>
<td>3</td>
<td>64.66</td>
</tr>
<tr>
<td>4</td>
<td>74.91</td>
</tr>
<tr>
<td>5</td>
<td>83.45</td>
</tr>
</tbody>
</table>

⇒ LOWEST

⇒ HIGHEST

*Tests show highest frequency peaks @17.5 Hz (0.14 in/sec)

More Information
Vibration Dampening

Natural Response of suspension system

\[ k = 58 \text{ kN/m} \]
\[ b = 200 \text{ kg/s} \]
Vibration Dampening

Forced Response of suspension under 10N sinusoidal input
Sponsorship

- Shell
  - DataPAC 1200 Handheld Vibration Monitor
- Metals Depot
  - Discounted 6061-Aluminum Tubing
- Polaris
  - SAE Discount on Polaris Parts

More Information
Dynamics

Minimum Turning Radius

![Graph showing the relationship between velocity and minimum turning radius.]

More Information

Graphic aids courtesy of www.3dcontentcentral.com
Max Displacement - ~1 mm