2011 Summer Space Grant: Hovercraft Planetary Rover

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Project Goals & Mission

- New approach to planetary rover: non-wheeled
- Design/build a hovercraft for planetary exploration capable of autonomous navigation and wireless communication
  - < 4 pounds
  - $1,000 budget
Potential Application - Titan

- Component of the Titan Saturn System Mission (TSSM)
  - Current mission: hot air balloon drops a lake lander on Titan, Saturn’s largest moon with an atmosphere similar to Earth
  - Hovercraft rover could be integrated into the lake lander and activate its exploratory mission once the lander reaches the methane seas of Titan
Hovercraft Advantages

- Lightweight
- Low friction movement, thus minimal energy requirements
- Moves over different terrains; water, sand, rough dirt, etc.
  - Overcome obstacles that permanently grounded the “Spirit” Mars rover

Hovercraft Disadvantages

- Atmospheric limitations
- Autonomous guidance
- Wind
Key Components

Mechanical
- Lift Fans
- Thrust Fans
- Skirt
- Body Shape

Electrical
- Arduino
- Xbee and GPS
- Sensors – Temperature, Pressure, Humidity
Hovercraft Components

**SKIRTS**
- Bag Skirt
- Finger Skirt

**HOVER GAP**
*Most important*  Allows for movement with minimal friction

**BODY SHAPE**
- *Maximize Area vs. Perimeter Ratio*
- Larger area= increased payload capacity for given static pressure of lift fan(s)
- Smaller perimeter= larger hover gap= increased ability to travel over rocks/obstructions

**THRUST MOTION**
- Dual Fan rotation control
- Rudders/ servo motor
Initial Hovercraft Prototype

Body: “D” shaped (single lift fan)

Skirt: Inflated bag skirt

Thrust: Dual fan

Advantages: Great payload lift

Disadvantages: No hover gap, excess skirt friction, low area to perimeter ratio, extremely difficult skirt attachment
Final Hovercraft Design

Body: Circular (dual lift fans)

Skirt: Hanging Perimeter skirt w/ extension

Thrust: Dual fan

Advantages: Good payload lift, large hover gap, no drag, high area to perimeter ratio, simple skirt design and fabrication.

Disadvantages: Very sensitive to weight placement affecting the overall balance and motion.
Final Specifications

- 6600 mA-hr 11.1-Volt Li-Ion battery
  - Runs craft for 1 hour

- Two 12-Volt Lift Fans
  - 90 x 90 mm computer fans
  - 55 CFM each (at pressure)
  - 0.65 in/H₂O pressure

- Two 3.3-Volt Thrust Fans

- Current weight = 3.2 pounds
  - Additional sensors and circuitry would be added depending on the atmospheric pressure and gravitational pull of planet/moon
Circuitry

Double sided custom printed circuit board
- Front circuit for sensors

Back custom printed circuit board
- Thrust fans, voltage regulators
Guidance and Programming

- The thrust fans rely on a PID controlled by the Arduino Uno. An Xbee was implemented for wireless communication and data collection.
Data Collection

- Graphical display in LabView
  - Displays humidity, temperature, pressure, compass, and GPS location on Google Map.
  - User friendly
  - Manual / Autonomous Controls
Testing Process

- Step 1
  - Overcoming the “natural” torque caused by rotation of the lift fans
PID control system
Proportional-Integral-Derivative

INPUT (compass heading) → OUTPUT (Thrust fan) → PLOT (compass heading over time)

Adjust Kd → Overshoot? 
Adjust Kp → Slow Response? 
Adjust Ki → Large Steady State Error?

Compass Heading (degrees)

Output $\text{PID} = (K_p \cdot e) + \left( K_i \int e \, dt \right) + \left[ K_d \frac{d}{dt} e \right]$

Figure 1. Ideal PID output
Figure 2. Experimental PID output for Hovercraft Heading of South (180 degrees)
Testing Process

- **Step 2**
  - Maintain compass heading on PID rig
  - Weight balance device
Testing Process

- Step 3
  - Forward Motion (on a flat, smooth surface)
Final Results

Hovercraft was selected for televised demonstration on Discovery Channel Canada’s **DailyPlanet**.
Final Results

- Successful tests:
  - Dirt w/ rocks & twigs
  - Pavement
  - Puddles of water
  - Fine sand
Final Results

- Unsuccessful tests
  - Uneven surfaces
  - Bodies of Water
Future Ideas

- Camera and Additional Sensors
  - Better documentation of journey and more useful data
- Obstacle avoidance
  - Proximity or ultrasonic sensors
- Power regeneration
  - Solar Panels
Project Conclusion

- Unforeseen problems
  - Sensitivity of balance affecting the direction of motion
  - Complications with skirt design and required lift

- Lessons learned:
  - Testing phase is very important
    - Prototyping helps discover problems & solutions
  - Coding can become complicated
  - Leave room for adaptability
Questions?

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