The Artemis Project

Lunar Regolith Excavator Student Competition
ME Team #8 / ECE Team #1

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NASA Lunabotics Mining Competition

- Purpose
  - Primary- educate students
  - Secondary- lunar excavation

Guidelines

- Maximum excavation hardware mass:
  - 80 kilograms
- Maximum power supply voltage:
  - 40 Volts
- Maximum power supply current:
  - 15 Amps
- Maximum setup/takedown time:
  - 10 minutes
- Maximum operation time:
  - 30 minutes
- Minimum excavated regolith mass:
  - 150 kilograms
- Minimum communication delay:
  - 2.0 seconds
- Maximum communication bandwidth:
  - 1.0 Megabits per second
- Max hardware width/length:
  - 1.3 meters
- Max hardware height:
  - 2.4 meters

Sub-Systems

- Excavation
- Locomotion
- Obstacles

- Power Supply
- Microcontroller and Communications
- Navigation

EXCAVATION METHODS

EXCAVATION METHODS

Bucket-wheel

- Current Applications:
  - -Surface mining excavation
- Design:
  - -Bucket-wheel excavates regolith
  - -Regolith is transported to collection bin via conveyor belt within connecting arm
- Pros:
  - -Uniform excavation
  - -High efficiency
  - -Good scalability
  - -Excellent controllability
  - -Proven design
- Cons:
  - -Few off-the-shelf parts available
  - -Works best for soft soil (large objects pose a problem)

EXCAVATION METHODS

<u>Split Inward V-plow</u>

•Current Applications:

-Commonly used for the clearing of debris from roadways

•Design:

-Blades angled inward

-Separation between blades "funnels" the regolith

-Conveyor belt transports regolith to collection bin

•Pros:

-Simple design (1 dof)

-Low cost

-Ease of fabrication

-Uniform excavation

•Cons:

-Unproven design

-High power requirement

-Effectiveness directly tied to performance of drive system

EXCAVATION METHODS

Backhoe

•Current Applications:
- -General usage excavation equipment (primarily digging)

•Design:
- -Consist of a two-part articulating arm with a bucket attached to the end
- -Bucket is forced into soil and drawn toward the vehicle during excavation

•Pros:
- -Proven design
- -Low cost

•Cons:
- -Slow excavation rate
- -Difficult controls
- -Low volume bucket

EXCAVATION METHODS

Paddle belt

•Current Applications:

-Used in excavation as a means of material transport

•Design:

-Works under the same principle as bucket-chain. Paddles excavate and transport regolith

•Pros:

-Uniform excavation

-Relatively basic design

-Variable speed capability

-Only one motor necessary

•Cons:

-Unproven excavation method

-Few off-the-shelf parts available

EXCAVATION METHODS

<u>Front Loader</u>

•Current Applications:

-Used in construction to as a material loader

•Design:

-Consist of large volume bucket attached to the vehicle via one or more arms

•Pros:

-Proven design

-Large volume

-Low cost

-Good controllability

-Low maintenance

•Cons:

-Excavation rate directly tied to performance of locomotion

-Few off-the-shelf parts available

Excavation Methods

<u>Bucket Chain</u>

Current Applications:

- Canal dredging and large scale material handling

Method of Operation:

- Buckets attached to a belt remove material and deposit it directly into a bin

Pros:

- Eliminates separate conveyor
- Less post-excavation material loss

Cons:

- High inertia
- High power requirements

Excavation Methods

Clamshell

Current Applications:

- Limited access material removal

Method of Operation:

- Hydraulic cylinder closes buckets to remove material

Pros:

- Operates in small areas
- Does not affect platform position

Cons:

- Requires high downward force
- Difficult to control over large area

Excavation Methods

<u>Powered Brushes</u>

Current Application:

- Street sweepers

Method of Operation:

- Circular and cylindrical brushes rotate to move material in the desired direction

Pros:

- Easy to control
- Simple to implement

Cons:

- Creates large amounts of dust
- Only works for loose surface material

Excavation Methods

<u>Boring</u>

Current Applications:

- Creating tunnels through rock, installing utility lines

Method of Operation:

- Grind material off rock face and transport backward to remove

Pros:

- Groundbreaking application of technology

Cons:

- Need solid/semi-solid material
- Overly complex

OBSTACLES

Obstacles

•Rocks

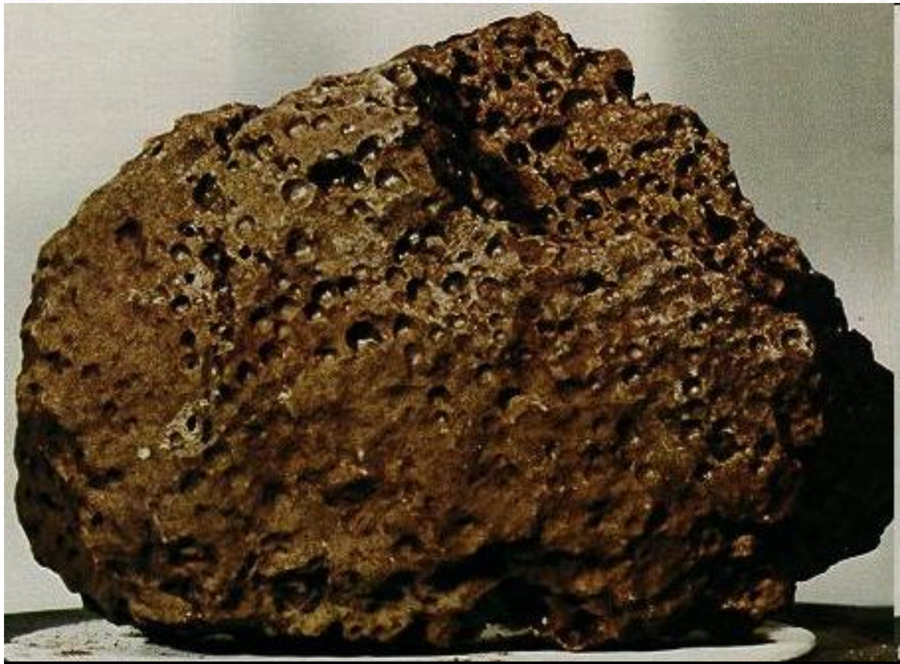
-4 total

-20 to 30 cm in diameter

-Approximate mass of 7 to 10 kg

-Placed randomly

-Minimum difference between any two rocks is 40 cm



Rock Handling Methods

<u>Bumper/Pilot/Angled Plow</u>

Current Applications:

- Go-karts, automobiles, trains, snowplows

Method of Operation:

- Shield fragile parts from direct impact
- Use angular force to move objects out of vehicle path

Pros:

- Inexpensive
- Simple to fabricate and implement

Cons:

- Adds mass
- Drag on drivetrain

Rock Handling Methods

Post-excavation

Current Application:

- Sorting machines, quality control

Method of Operation:

- Ignoring – excavate the rock directly into the dump bin
- Conveyor rejection/Bin screening – prevent the rock from entering the bin

Pros:

- Easy to implement
- No moving parts

Cons:

- May hurt weight capacity of robot
- Requires overpowered conveyor system

Rock Handling Methods

<u>Catapult</u>

Current Applications:

- Recreation, historical reenactment

Method of Operation:

- Using spring loaded launcher, forcefully ejec

Pros:

- Permanently solves rock problem

Cons:

- Complex
- Hazardous to humans

Locomotion Subsystem Requirements

- Speed
- Traction
- Maneuverability
- Stability
- Power
- Simplicity
- Maintenance
- Dust Resistance

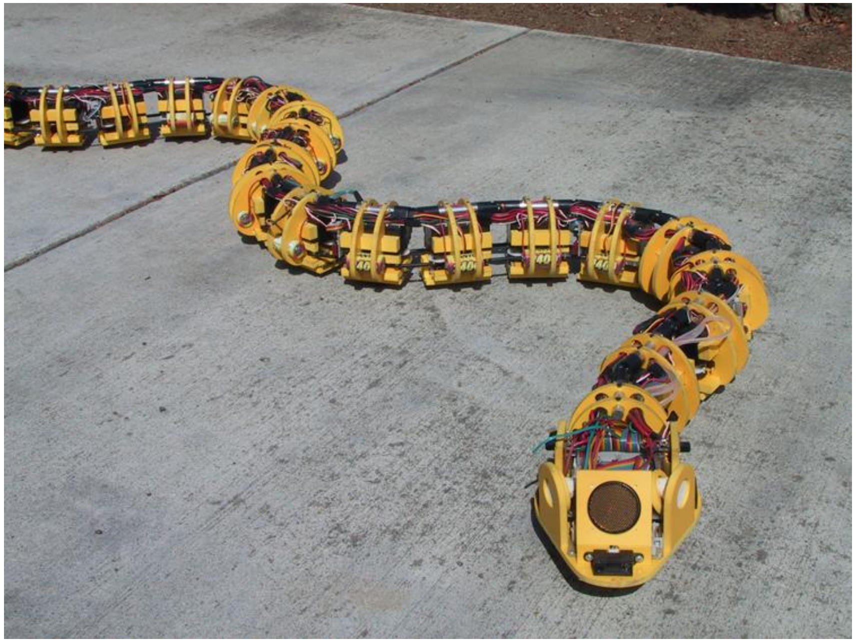
Concept Generation

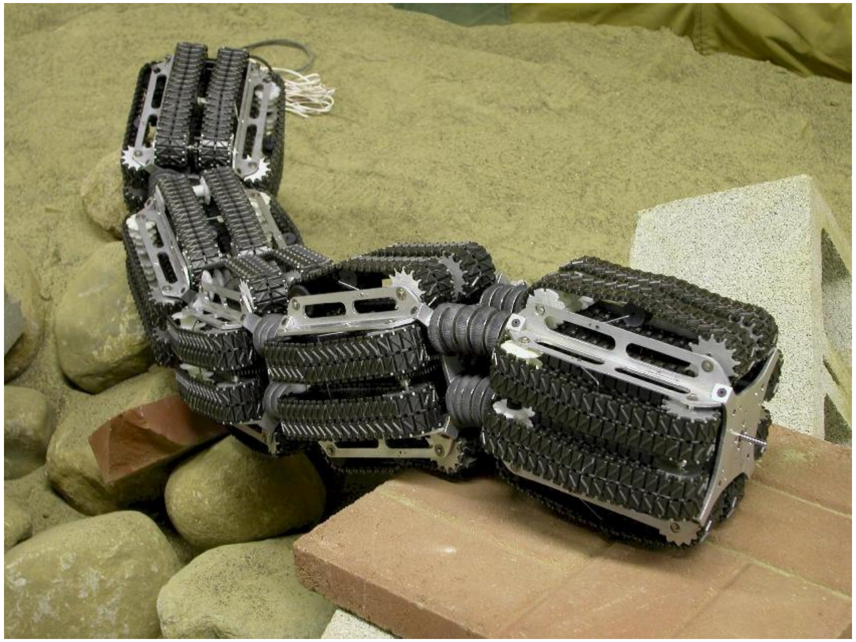
- Locomotion
  - Legged Locomotion
    - C-Legs
    - Piston-Compliant Legs
  - Wheeled Locomotion
    - 4 Wheels
    - 6 Wheels
  - Tracked Locomotion
    - Tracks
    - Tracks with integrated excavation equipment (buckets)
  - Other Locomotion
    - "Earth Worm" – digs through dirt while "eating"

Legged Locomotion

Wheeled Locomotion

The Worm





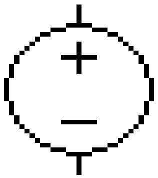
Tracked Locomotion

Final Selection

- Standard Tracks
  - Provide traction, maneuverability, stability
  - Proper motors provide speed

Power Regulation

Source Options:



I. Use 40V/15A source delivered by tether (unconfirmed)

II. Implement a battery pack

III. Combination of the tether source and a battery pack

Power Distribution Options:

I. Design one power electronic circuit

II. Use multiple circuits for powering specific devices

Battery Options

<u>I. Lead Acid</u>

-Inexpensive but large and heavy

-High current output

Optimal choice if limiting factor is money.

<u>II. Lithium-Ion</u>

-Expensive but lightweight

-Fast charge with zero memory effect

Optimal choice if limiting factor is weight.

<u>III. Lithium – Polymer</u>

-High current output

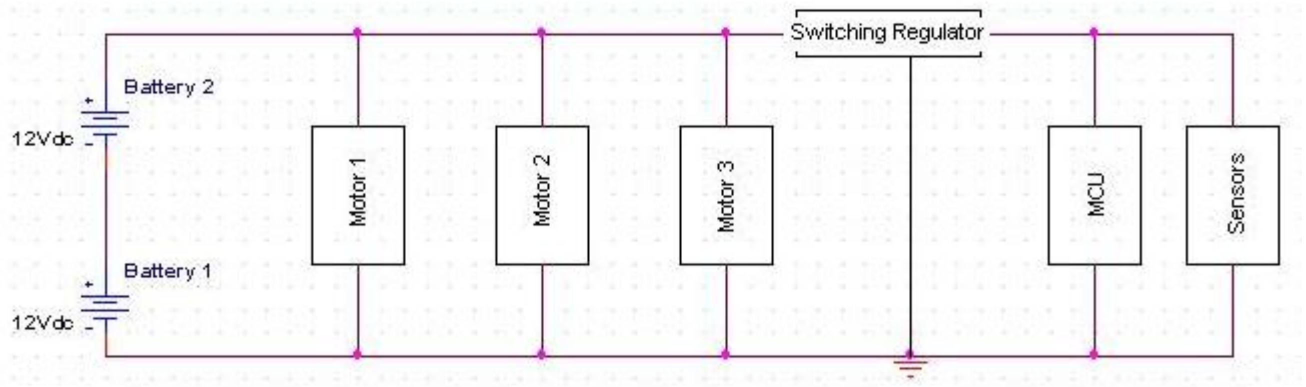
-Lightweight but expensive

-Lower energy density

Optimal choice if limiting factor is weight with maximal current desired

specific battery output parameters ultimately depends on required power of motors.

General Power Distribution Circuit (Low Cost):



- Two (or more) 12V DC sources connected in series

- Switching regulator to step down the voltage (~ 7V)

- Multiple switching regulators can be implemented if necessary

-Optimal choice so long as money is the greatest limiting factor

Conceptual "Next-Step" Procedures

1. Verify money is the greatest limiting factor

2. Obtain motor requirements to appropriately select source parameters

3. Research and implement safety features (diodes, capacitors, fuses)

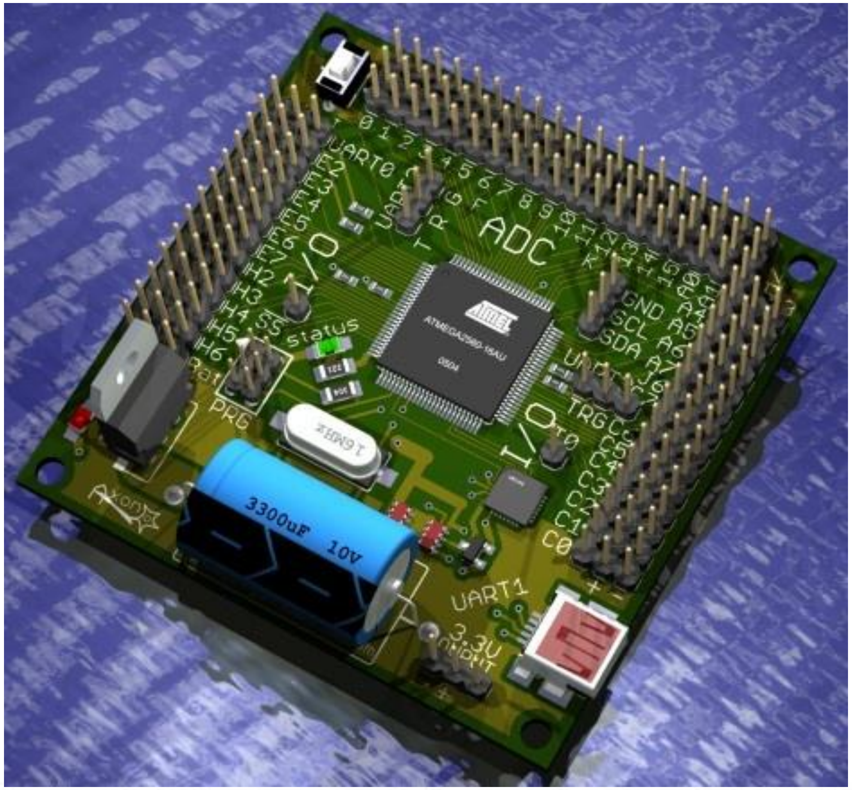
4. Simulate and test.

Microcontroller Pros/Cons

- FPGAs
  - Very fast, Tons of I/O, Can do many different things at once
  - Harder to program and debug, Would need most of the functions already implemented on a µC, No analog inputs
- 8-bit µC (ex. AVR ATMEGA)
  - “Easy” to program, Good low level functions, Very popular with robotics tons of support, Plenty of development boards,
  - Slower especially with FP, Limited amount of memory
- 32-bit µC (ex. AVR32, ARM7)
  - Faster and more memory than 8-bit, Can run OS, More I/O pins, Built in higher level functions(LCD, Image processing),
  - More complicated and expensive than 8-bit, Less selection of lower level functions, Fewer boards available, Most aren't TTL

Microcontroller Selection

- Decided on 8-bit. Most likely the Axon (AVR ATMEGA 640)
- An FPGA would take far too long to get working
- Low level functions far more important for motor control and sensor reading
- Program shouldn't be complicated so extra speed isn't needed
- Tons of examples/tutorials on
- to use them
- Used a similar chip before

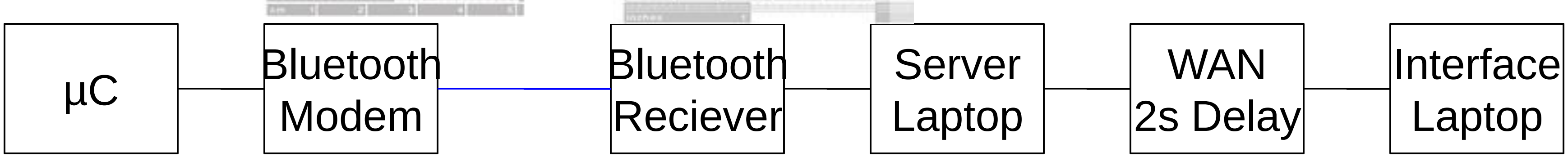


Telerobotics Interface

- Wired vs. Wireless
  - Ethernet is simpler but cable gets tangled
  - Wireless is more expensive, complicated but no cable
- Power tether supplied: Wired, No power tether: Wireless
- Types of Wireless available:
- Zigbee
  - Slow speeds, <250kb/s, 10m range, Low power, More for communication between sensors
- Bluetooth
  - Faster 1-3Mb/s, 10-100m range, Medium power, Acts as Wireless serial connection
- WiFi 802.11
  - Very fast 54Mb/s, 50-100m range, Highest power, High complexity

Communication System

- Max bandwidth is 1Mb/s so zigbee is too slow
- The bottleneck is the µC serial connection to the modem of ~ 1Mb/s
- Bluetooth is cheaper and seems to have a simpler interface
- A PC receives data from µC and acts as a server through the delay
- The server laptop can also be used for additional processing power



Navigation/Sensors Subsystem Requirements

The excavating robotic device must have the ability to move about the course freely and return to its starting position throughout the competition; as well as calculating the amount of regolith collected. To do so the device will need navigational sensors that have the ability to

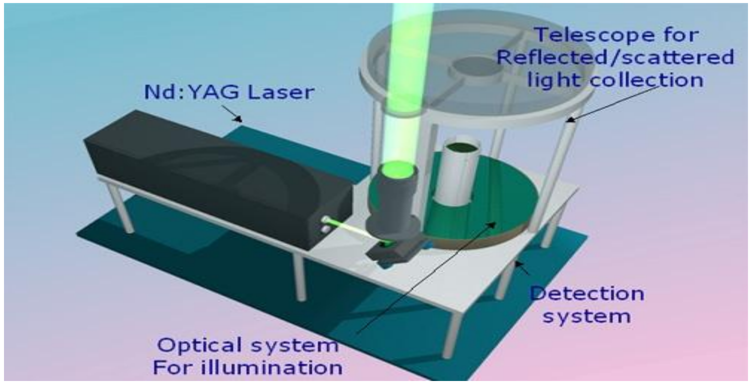
- Measure speed
- Distance
- Position
- Mass measurements.

Concept Generation

- Types of Sensors

  - Position, angle, displacement, distance, speed, acceleration

  - Acoustic, sound, & vibration
  - Navigation instruments
  - Optical, light, imaging



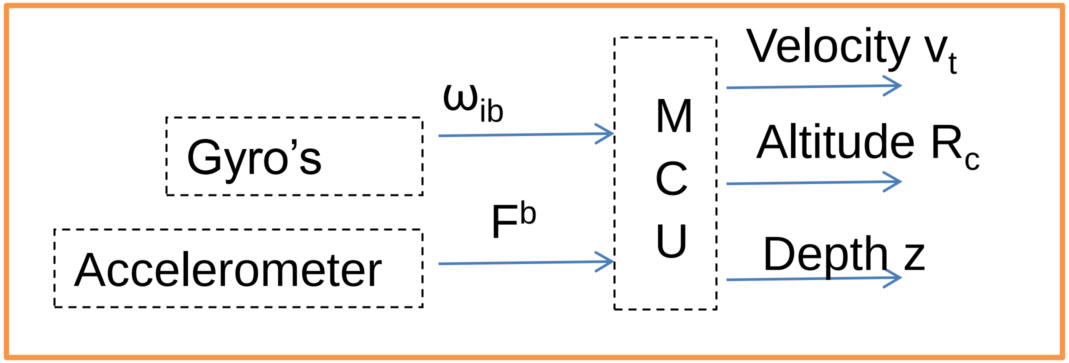
Concept Generation

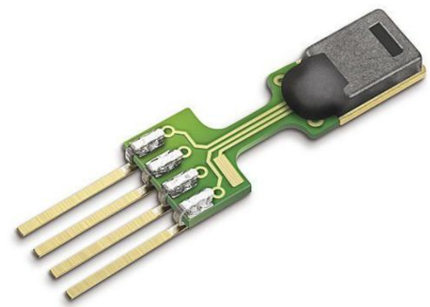
- Types of Sensors
  - Proximity, presence
  - Electric current, magnetic, radio, voltage
  - Pressure, force, density, level
  - Environment, weather




Navigational and Weight Sensor(s)

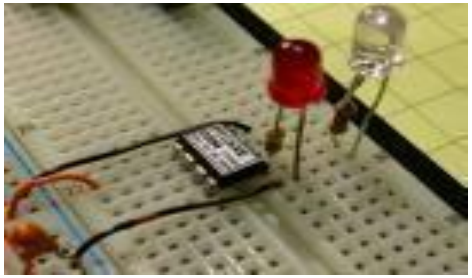
- Inertial Sensor





- Relative Sensor

- Beacon Sensors



- Weight Sensor(s)

Conclusion

- V-plow
- Track
- 2 DC motors
- MCU

- Inertial Sensor
- Digital Scale
- Current Sensor
- Beacons

- At this time are there any questions?