Holey-Moley!

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3. Abstract -

The idea of Holey-Moley is to create a tunneling robot capable of moving through loose soil. It will do this by angling the spinning drill bit until it reaches the predetermined ideal angle for the drill to dig into the soil. The robot will then drive forward, creating a groove in the soil that it will enter into. As the robot digs, it will use its magnetometer to keep drilling in the proper direction.

4. Executive Summary -

Holey-Moley is a tunneling robot that digs its way through loosely packed soil, clearing a path that could then be followed at a later time period. The robot body consists of three main segments: the main body, the drive base, and the drill bit. The drive base is a single aluminum plate with a set of treads on either side of the plate. The drill bit is the part of the robot used to tunnel through the soil. The main body houses all the electronics, batteries, sensors, and connects the segments together. The main body connects to the drill bit through a front-mounted DC motor, and connects to the drive base through the linear actuator system.

The linear actuator system is comprised of two miniature linear actuators that extend downwards and are lined up front-to-back. This formation allows for different configurations of extended actuators to angle the main body of the robot. By raising the front actuator and lowering the back actuator, the main body can be tilted upwards from the horizontal, and vice versa.

The electrical system is an Arduino Mega 2560 controller board, along with a custom plug-in board for the Arduino that houses the three motor controller boards and the XBee wireless communicator. The robot gets power from two 12V LiPo batteries: one for the Arduino and one for the motors.

The software for the robot is written in the Arduino environment, mostly based on C language code.

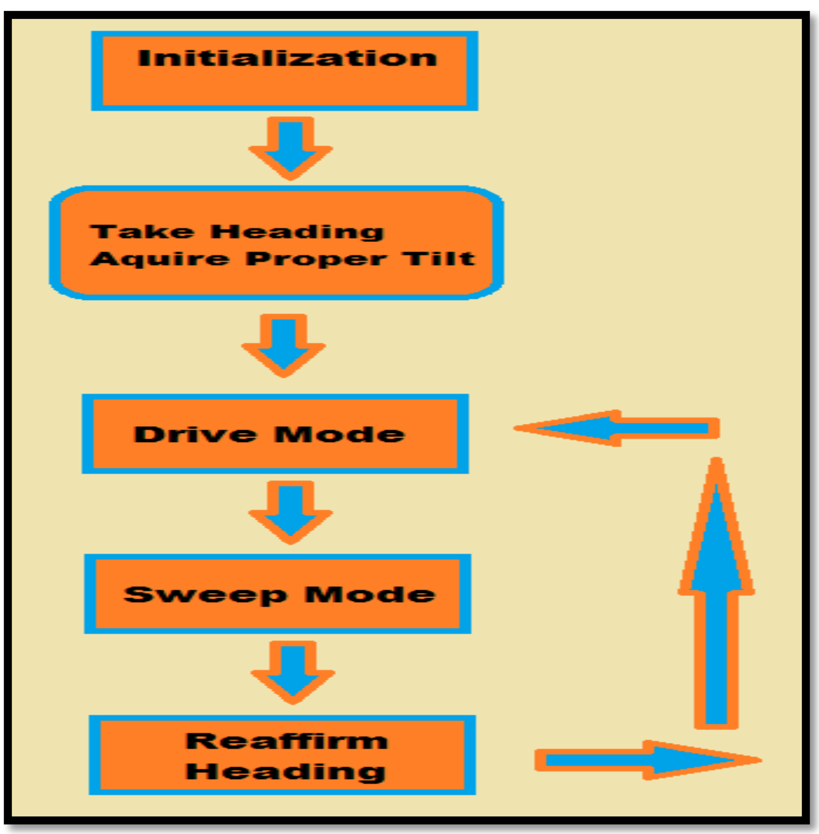
5. Introduction -

Robots have travelled the surface of the earth for well over four decades. In all that time however, very few have every shifted their way through the soil instead of on top of it. Holey-Moley now adds its name to that relatively short list.

Holey-Moley is a tunneling robot capable of digging through loose soil to reach its destination. Using the custom designed drilling bit, the linear actuator system to tilt the main body of the robot for easier digging, and its sensors (an accelerometer and magnetometer), this robot can create a path through the terrain that can later be followed and reinforced to create a permanent tunnel allowing for safe passage through the soil.

6. Integrated Systems -

Holey-Moley follows a simple thought process. Once placed in line with the soil it is intending to go through, Holey-Moley determines its orientation using a magnetometer, sets a proper digging angle using an accelerometer, and begins to travel along the orientation that was originally set. Should it get knocked off its path, the magnetometer will tell the robot how to adjust its course to get back on track. The magnetometer and accelerometer will also be used in having Holey-Moley do cleaning sweeps to remove excess dirt from its path.



7. Mobile Platform -

The mobile

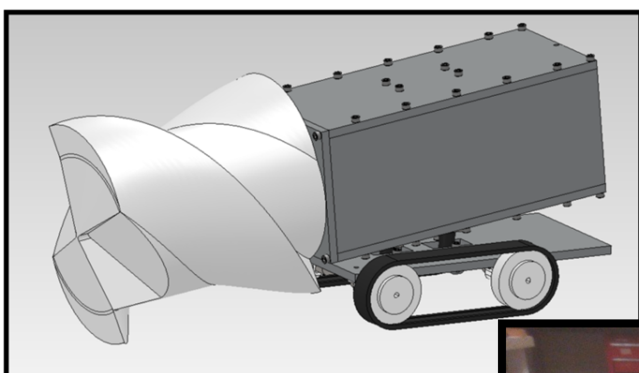
platform of this robot is built primarily out of aluminum, with a large, plastic drill bit. The drill bit was modeled after an End Mill bit, with a minor point added to the end in order to help facilitate digging once engaged with dirt of greater height than the robot's body.

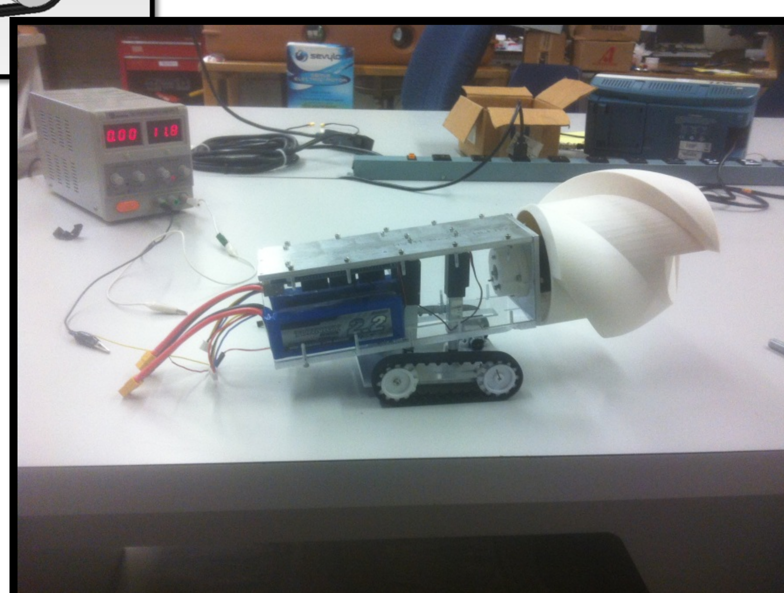
The main body is an aluminum box (the sides were later made out of clear plastic to see the internal workings of the robot). Manufacturing of the aluminum pieces was originally done in the machine shop located on campus, but due to the limited times the shop is available, more of the base had to be done outside of the machine shop. This limits the precision with which parts can be manufactured, but speeds up the manufacturing times.

A tread system was used to increase surface with the ground do that there is less chance of slipping.

The two linear actuators are used to angle the main body and drill in relation to the drive base. This allows the robot to change the angle of the path it's creating.

The drive motors were chosen due to their small size and extremely powerful torque. On the size wheel used for the treads, these motors put out approximately 15 lbs. of force each.





8. Actuation -

The actuators on the robot are two linear actuators, two micro geared motors, and a larger geared motor. The two linear actuators angle the drill, the micro geared motors drive the robot, and the large geared motor spins the drill bit.

9. Sensors -

The sensors used were an AXDL E8 2-axis accelerometer (to know the angle the robot is at while digging) and a MicroMag3 magnetometer (to keep the robot on line during the digging).

10. Behaviors -

The system for this robot will be run using an Arduino Mega 2560. This board was chosen for its ease of use and compact size. The behaviors of the robot will be controlled using this board.

The behaviors will follow a simple structure. First, the robot will run an “Initialization Phase,” during which an initial heading will be taken from the magnetometer. It is also in this phase where the drill with be tilted to the starting drilling angle.

From there, the robot enters "Drive Mode," where it will drive forward towards its destination. While in Drive Mode, the robot constantly checks the magnetometer to ensure it is aligned with its initial heading. Should it veer off course, the robot will immediately adjust itself to get back on its line.

Following Drive Mode, the robot goes to “Sweep Mode,” where it sweeps away excess dirt from the path it’s creating. This is done by using the magnetometer to sweep roughly 30 degrees to the left and right of the initial heading, thereby knocking the surrounding dirt farther away. The robot then realigns with the initial heading and enters Drive Mode again.

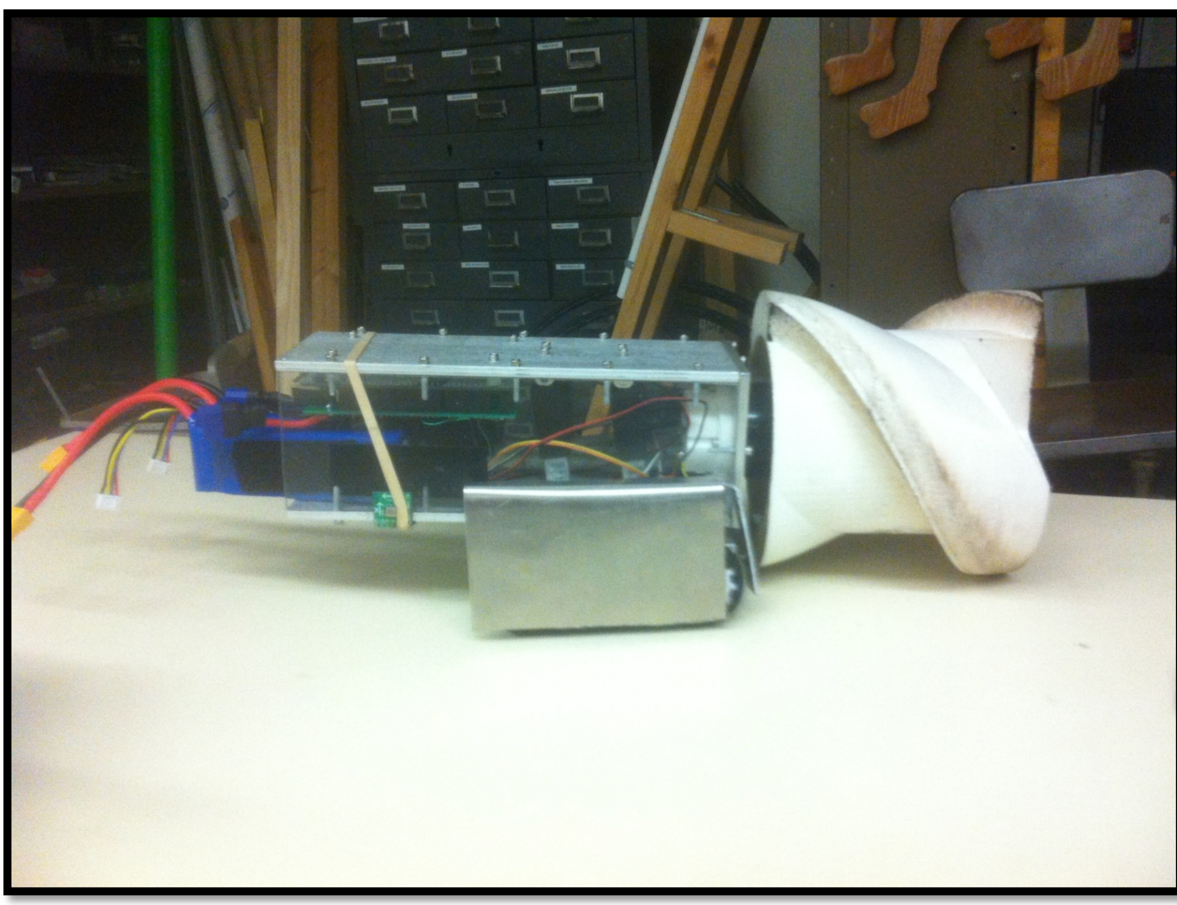
11. Experimental Layout & Results –

While testing, multiple problems were encountered that had been either unexpected or dismissed as more minor than they turned out to be.

The main problem was the lack of traction that the loose soil caused with the robot's drive system. This problem is due to the weight of the robot combined with the small surface area contacting the ground from the treads. While better at preventing the frame from sinking than regular wheels, the treads had another problem: the rubber track fell off the motors after moderate use.

To solve some of these issues, a sheet metal skirt was added around the sides of the tracks to keep excess dirt out. Slowing down the drive motors also helped to keep the treads in place and prevent slipping.

Another issue was that the robot would tip forward if not placed on a level surface. This was solved by creating a new bottom plate with more mass and shifting the batteries farther towards the back of the robot in order to move the center of mass.



12. Conclusion -

The conclusions that were drawn from this project were three-fold:

1) Traction is of vital importance
2) Things don't always go as planned
3) Digging is hard

Traction (or its lack-thereof), was the main hurdle that had to be addressed in this project. While the design was more than capable of moving the soil out of its path, the robot failed often due to the fact that it would lose traction halfway through digging and just mindlessly spin its wheels. This was eventually countered by the decision to change the environment the robot worked in to one with a more solid foothold and soil-based obstacles to go through.

The unexpected also claimed many hours of hard work. The fact that the slight slop created from the manufacturing process allowed certain elements of the mechanical design to drift outside of expected bounds and wreak havoc with the robot's performance until corrections were made. The fact that the robot, while light enough to stay above the soil initially, began to sink slightly the moment the drive wheels began to spin. This was fixed by the aforementioned change in environment.

Digging is just plain hard. The accelerometer and magnetometer are the only two sensors that were used, leaving a very limited view through which the robot can know about the world. The unfortunate part is, there aren't that many other sensors that would help significantly in this project. The main sensor that may have been useful would have been a camera positioned directly above the robot and looking down on its movements, and even this would be useless should the robot have fully immersed itself in the ground. There is a reason very few have attempted a tunneling robot.

13. Documentation -

Arduino Mega 2560 - http://arduino.cc/en/Main/ArduinoBoardMega2560

MicroMag3 -
http://www.sparkfun.com/datasheets/Sensors/MicroMag3%20Data%20Sheet.pdf

3-Axis Accelerometer ADXL E8 - https://www.sparkfun.com/products/9269

14. Appendices -

None