Concept Generation

EML 4551C – Senior Design – Fall 2011 Deliverable

Team # 15

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Table of Contents

Introduction

The mission of the 2011-2012 NASA Lunabotics Competition is to create a robot that is either autonomous or controlled by a WiFi signal, which is also capable of traversing and excavating from a simulated lunar surface. The team will complete this by creating a hexapedal robot based on the RHex family of robots. The main benefit of this design is the ability to easily overcome various obstacles such as rocks and craters. Previous competition teams have succeeded with more traditional wheel based design, but have struggled with navigating the obstacles. The excavation system for the robot has to overcome difficulties including being a strong enough to haul substantial payloads (5kg), while keeping the robot at minimum weight with a maximum height of 0.75m at start. There are plenty of real world examples of excavation system to consider for the robot, but the challenge is applying excavating principles utilized on earth to a lunar robot and on a legged platform.

Last year's senior design team built the Hexcavator platform, but was unable to complete the design. The completed portion of the platform is shown below in Figure 1; the platform has a frame, motors, legs, leg attachments and a few other minor components. It has no control system and no excavation system. The goal for this year is to finish last year's design by making it operational and develop an effective excavation system.

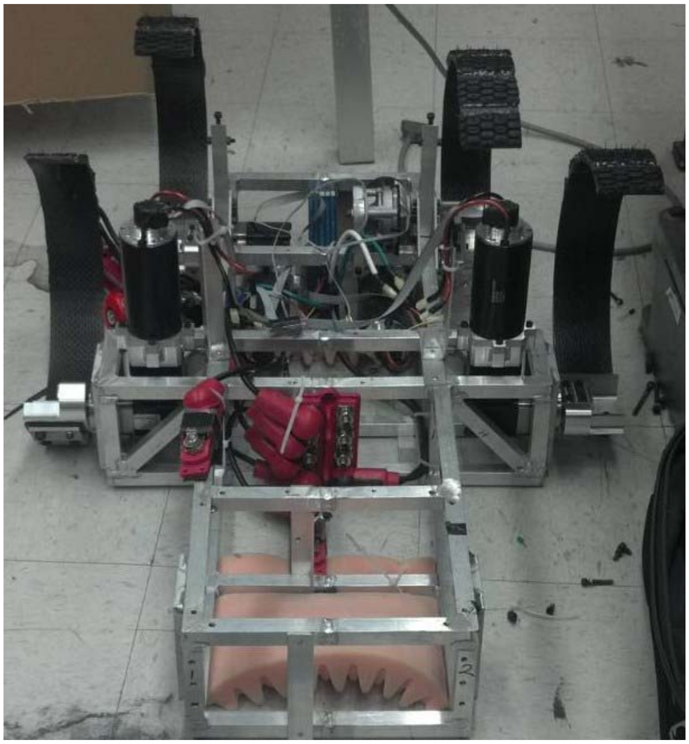

Figure 1: The platform last year's team designed.

Existing Technology

There are several types of modern excavation systems but none are designed specifically for moon excavation. The most common type of excavation systems are the compact excavator, the dragline excavator and the long reach excavator. They all have pros that would be useful for the excavation, but some have large downsides that would make them less than optimal for Hexcavator.

The compact excavator is one of the smallest of the family of excavators, in Figure 2[2]. This style of excavation is used for small scale digging, such as ditches. The swing arm moves independently from the boom swing. This means the design can extend its reach and also fold up to take up less space.

The compact excavator has many aspects that could be applied to the Hexcavator project. The claw would need to be strong enough to loosen and collect compacted regolith. One of the biggest constraints of the project is the starting dimensions. The compact excavator is meant to fold up when it isn't in use and then extend to full size when ready. However, there are some major drawbacks of this design. When the arm is fully extended and the claw is filled with regolith, the center of mass changes considerably, which could cause stability problems with Hexcavator. This design is also very complex and requires multiple actuators for movement.

Figure 2: A Kobota compact excavator[2].

Figure 3: Dragline Excavator[3].

The dragline excavator is another type of excavation system which is commonly used in mining, shown in Figure 3[3]. The system works by dropping the dragline bucket on the surface and pulling it closer with the drag rope. This loosens and gathers the topsoil simultaneously. The hoist rope allows the dragline bucket to achieve great depths, where humans could not safely work.

The dragline excavator's largest upside is that it has the ability to gather and loosen regolith simultaneously. Unfortunately, the swing arm is so tall that it is difficult to implement this design while maintaining the maximum starting height of 0.75m. Additionally, this style of excavation is used mainly for mining from an existing hole. While there are some craters on the moon, additional machinery would be needed to create a hole appropriate for a dragline excavator.

A third type of excavator is the long reach which is a system primarily used for demolition, shown in Figure 4[4]. The main difference from its digging counterpart is the length of the boom arm. The length allows the arm to reach greater heights, allowing it to destroy taller buildings.

This design would optimal for loosening the compacted regolith in the competition, but that is one of the few benefits of it. With its longer boom arm, the storing of the regolith would be much easier since it could easily make it into the bin. However, this design has two major flaws. The first is the height. Since the competition has a maximum height of 0.75m at the start, and a 1.5m length, the long reach excavator would need to be scaled down for competition. The second is again the need for many actuators needed to articulate the arm.

Figure 4: A long reach excavator being used to demolish an office building in Rosslyn, Virgina[4].

The previous team designed the original Hexcavator, however due to poor time management and an onboard fire prior to the competition, the team chose to use the robot Artemis to compete, shown in Figure 5. Artemis competed in the first Lunabotics competition in 2010. It utilizes a gear driven tread for locomotion and is top heavy. When Artemis emptied its payload, it had a tendency to tip over and was not able to stand itself back up. The tracks on Artemis would pick up regolith during locomotion, adding additional weight and inhibiting movement. The Hexcavator would solve this problem by using legs; there aren't very many small spaces for excess regolith to accumulate so it would not hinder movement.

Figure 5: Artemis is the robotic platform designed for the 2010 NASA Lunabotics Competition by the FAMU/FSU College of Engineering.

Figure 6: The winner of the 2011 NASA Lunabotics Competition.

For the 2011 competition the winning robot was from Laurentian University[1] from Sudbury, Ontario, Canada. Their design had a dedicated excavating bucket chain, a central hopper, and a dedicated removal bucket chain as well as a belt that ran the length of the hopper to move material towards the removal bucket chain, shown in Figure 6. Additionally, last year's winning robot had a wheel base with added traction, instead of a smooth wheel. This added to their mobility because it was able to move through the course without accumulating regolith in crevices. This design did work well but would not be allowed in competition this year due to new size constraints.

Concept #1: Rotating Drum Excavation

Shown in Figure 7 is a rendering of an excavation design that will use a rotating drum with cutouts that will both dislodge and collect the regolith. The regolith will then be stored in the drum for transportation across the lunar competition arena. While the drum is rotating forward it will collect the regolith and when the rotation is reversed it will empty. The drum will be mounted on a four-bar linkage that will be used to lower the drum to the lunar surface, and then the four-bar will be used to raise the drum to the level of the collection area.

This design is appealing because it is relatively simple in operation. The drum would not require an encoder to determine its position because it is just a simple on off operation. The four-bar that the drum is mounted on to would also not need an encoder, this is because of the cameras monitoring the competition are available to the operator of the robot. The draw backs of the system would be in manufacturing. It would be difficult to make the drum due to its complex shape. The four-bar is considerably easier to produce.

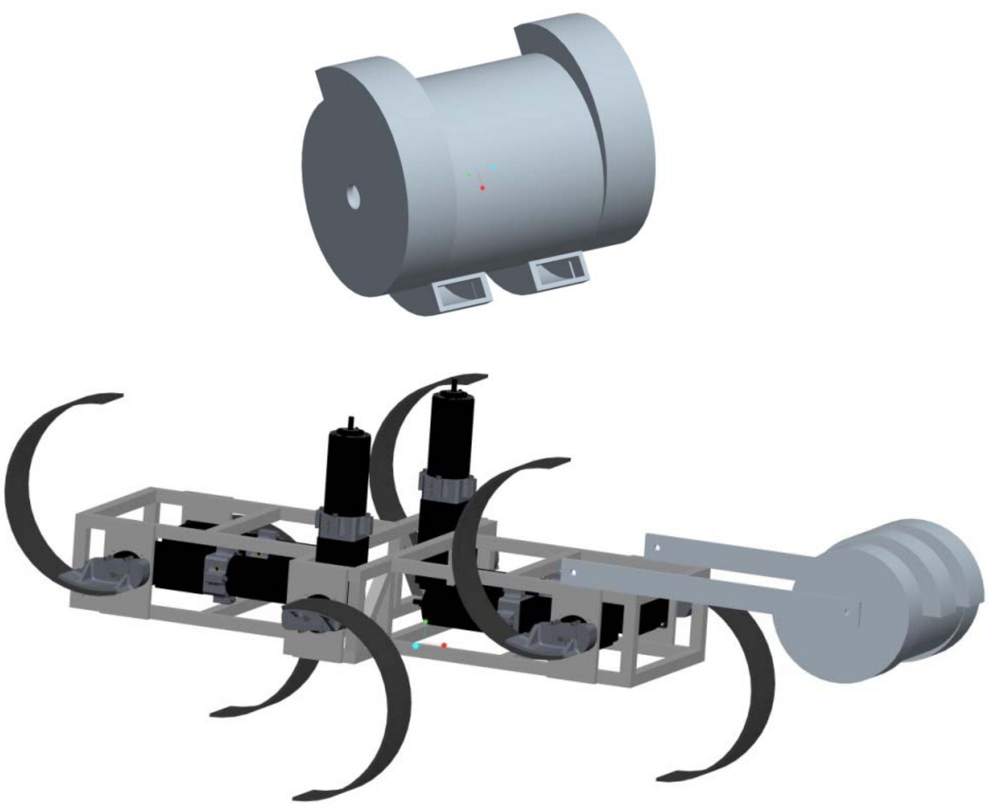

Figure 7: The top picture shows a close-up image of the excavation mechanism. It is a rotating drum that collects regolith when positioned on the ground. Then it rotates the opposite way to release the regolith into the LunaBin. It would be narrow enough to carry in between the legs, and will be capable of being lifted up to the center of the robot when containing regolith so it will not alter the center of mass outside of the vertical plane.

Concept #2: Screw Jack

The second design which will be considered for implementation on the current Hexcavator is a relatively simple design involving a shovel head and extending mechanism, a prototype is shown below in Figure 8. This shovel can either be bought or manufactured in house, and will then be welded to an arm attachment. This arm attachment will be a two part system. The instrument in which the shovel head will be attached will be called the “inner arm” because it will be able to translate in and out of a slightly bigger, longer part called the “outer arm.” This smaller arm attachment will be half the length of the piece that it will be translate in and out of. Attached to the other side of the “inner arm” will be a worm gear that will act as the extender for the inner arm. This will be fixed to a gear that will turn via motor actuation to either make the inner arm extend out or contract in. The worm gear length will be no longer than half of the length of the outer arm. This will be done to ensure that all moving parts stay housed within the other arm attachment to decrease the likelihood of problems due to regolith material build up. The entire arm mechanism will have one-dimensional rotational mobility via another actuator that will translate the system upwards and downwards. This will allow Hexcavator to be able to pick up and deposit the regolith material. The arm will be translated downward to some predetermined length so that the robot will be able to excavate from the test section surface. The upward actuation of the arm will be used to bring the shovel head to a horizontal equilibrium as well as deposit the material into the testing LunaBin. An additional actuator may need to be used to dump the material. However the preferred method would be to disturb the material using the motion of the other actuators.

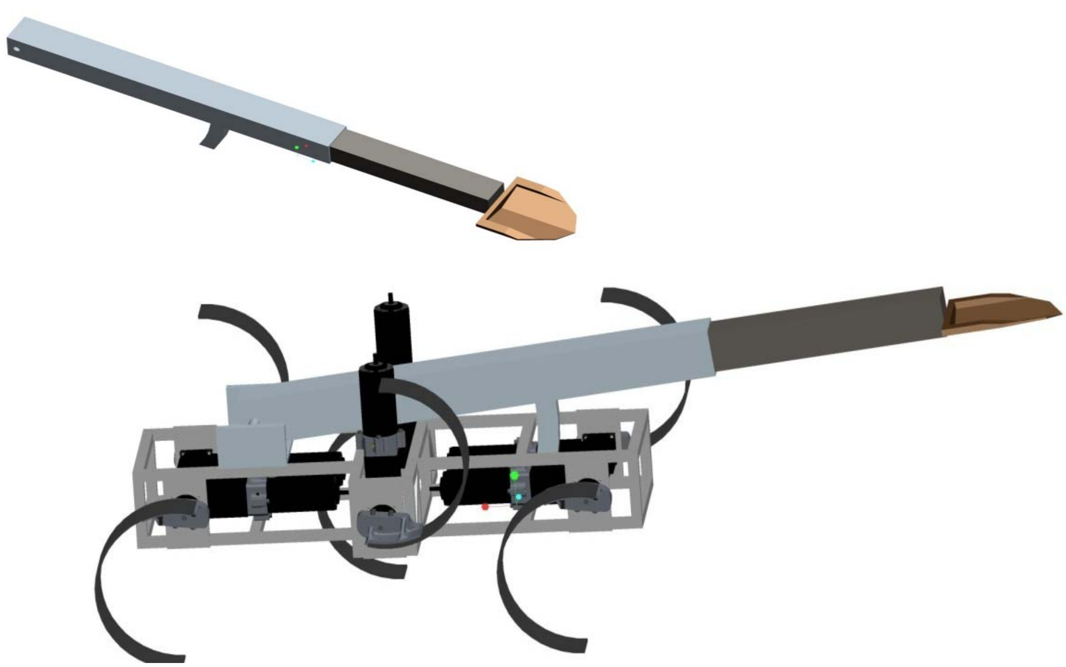

Figure 8: The top image is a close up of the excavation mechanism. It utilizes a shovel to cut thought the compacted regolith. Since it has an extendable arm it can reach both the ground and the LunaBin.

Concept #3: Auger

Figure 9 demonstrates a design that would use an auger to collect the lunar regolith, and release it into a bucket. When the augur rotates, it would circulate regolith into the collection bin. After the robot is done excavating, it would carry the regolith in this bin. When the robot reaches the LunaBin, the collection bin would raise up and deposit the regolith by inverting the collection bin. The bin would be connected to the frame using a four bar mechanism. However, the collection bin would not be capable of a large payload capacity because it would significantly affect the locomotion of the robot. The four bar mechanism would also have to be very long because the LunaBin is 1.65m from the ground, and the Hexcavator currently stands at 0.75m. However this system would be very complicated to build. Additionally, an auger mechanism is unprecedented in lunar excavation. Since regolith is a very dense, adhesive substrate, the effectiveness of the auger for collecting material is unknown. This system is would be very simple from an electronics stand point. It would not require an encoder or position control, it would simply need a motor to drive the four bar and the auger.

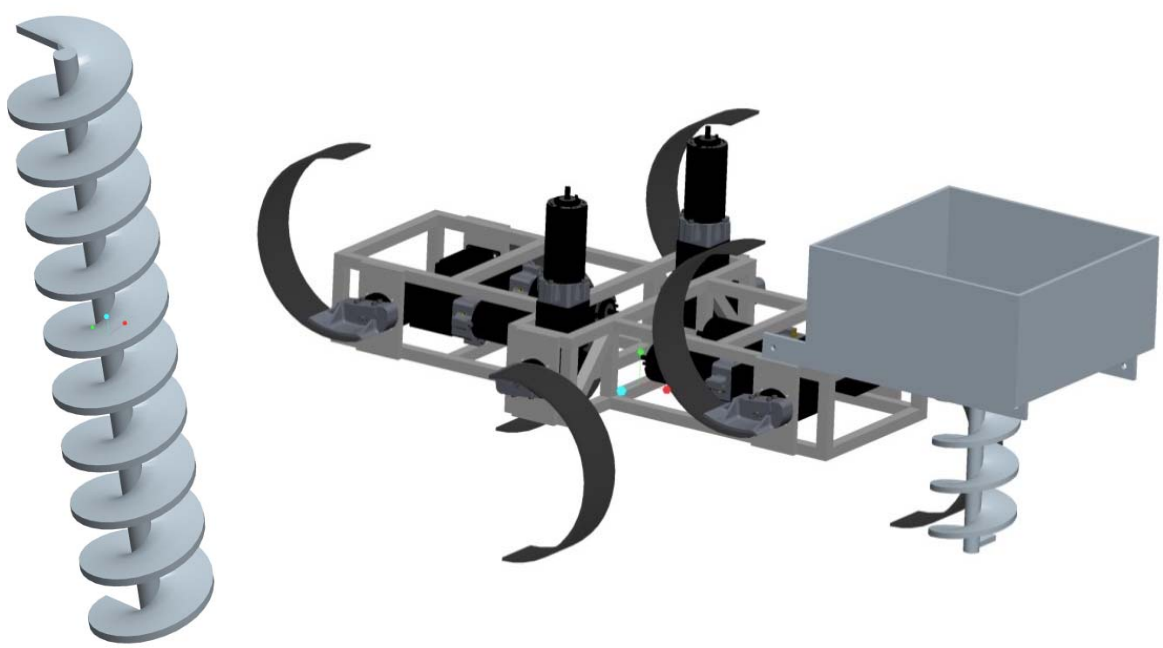

Figure 9: (Left) A close up image of an Auger design. It would rotate in order to collect regolith. (Right) The collection bin would retain the excavated regolith. The auger would directly transmit the excavated regolith in this bin. The design is attached with a four bar mechanism.

Concept #4: Shovel and Dump Bucket

This concept is based off last year's design for an excavation system, shown in Figure 10. It utilizes a belt driven shovel to excavate the regolith. Then the shovel will put the sand into the dump bucket, which uses pulleys to guide it up the height of the Lunabin. Then the dump bucket deposits the excavated regolith into the Lunabin. The advantages of this design are that it is fairly simple to attach to the existing frame. Also, pulleys and belts are commercially available in a variety of sizes, making it simple to purchase materials. The attachment mechanisms are very simplistic in design and would be very easy to construct. The disadvantages are that it will be costly to integrate the drive mechanisms for these pulleys. Additionally, the cost of materials will be very high, and probably add a significant amount of weight. The pulleys would also be a challenge because previous year's experience has indicated that the regolith can get into the cracks and hinder the performance of the pulleys. Finally, the linkage would need to be able to fold down onto the robot when not in use since there are starting height restrictions on the robot.

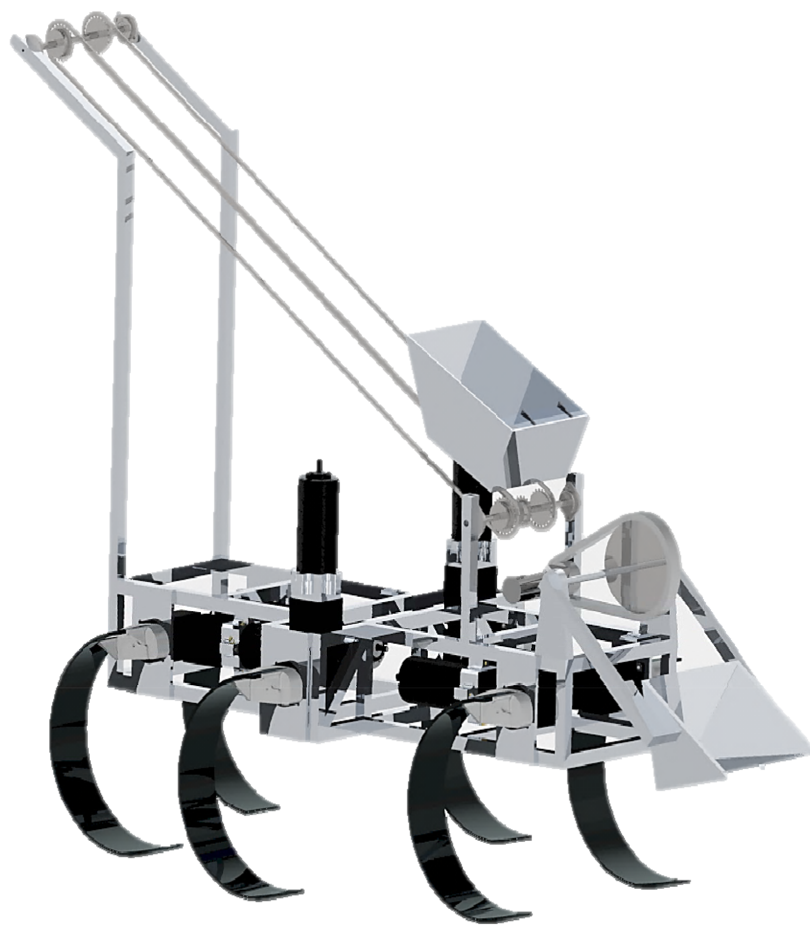

Figure 10: This design uses two pulley systems. The front one drives the excavation shovel which would cut into the compacted regolith. When it excavates some, it then deposits the collected regolith into the bin. When the robot reaches the collection bin, the bucket raises up (using the pulley system on the top left of the diagram) to release the regolith.

Conclusion

The major challenges which will need to be addressed by the final excavation design are maximum payload capacity, minimum weight increase to the Hexcavator platform, able to cut through compacted regolith, resistant and uninfluenced by the regolith (which is a very dense, adhesive material), cost-effectiveness and minimal impact on the locomotion capabilities of the robot. The minimal impact on the locomotion will be the most challenging of these constraints. The center of mass shifts with the robot's motion (it walks in an alternating tri-pod gait), which will be especially critical when the robot is navigating the competition obstacles. If the excavation system is too front heavy it could hinder the robots capability to traverse back to the LunaBin, however counter weights will be counter productive since the competition deducts points for weight. Another concern to be addressed will be stability when excavating the regolith. The current concept for maintaining stability is to kneel the front legs of the robot while excavating, then stand up after its excavation is complete. All of the conceptual designs presented have advantages and disadvantages. Further research, and more in-depth designs will be conducted before the final design for excavation is chosen. Currently, last year's senior design team control scheme for electronics is the chosen method for controlling the robots locomotion.

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