Midterm Report 1

Team No. 10

Mariana Cave LIDAR Mapping System

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Abstract

Researchers at the Oceanography department at FSU are seeking help in the development of mapping technology to map out the dry-land portions of the Mariana Caves. The system must be small enough to fit on a manually controlled vehicle. The goal is to provide a three-dimensional representation of the dry portions of the cave with higher resolution and greater detail than previous efforts in mapping the area. According to our sponsors, if the time restrictions allow, we may move forward in the development of the manually controlled vehicle, which the mapping system will be mounted on.

Acknowledgements

We would like to express our deepest appreciation to Dr. Steven Kish and Mr. Bob Broedel whose support and guidance have allowed us to complete this report. We would also like to thank Dr. Victor DeBrunner, Dr. Shonda Bernadin, and Dr. Jerris Hooker for their suggestions on our project design.

1. Problem Statement

The purpose of this project is to create a portable cave-mapping device for freelance cavers. Cave mapping can be a very expensive undertaking. The most widely-used method involves the use of notepads and tape measure, and can be tedious and time consuming. There are also LiDAR devices on the market that are used to map caves. However, these products are very expensive, costing upwards of $20,000. Ultimately, we aim to make LiDAR cave-mapping devices more accessible by providing a DIY-style, open-source project that allows cavers to construct their own mapping devices at an affordable price.

2. Background Research

LIDAR

Figure 1: LIDAR LITE 3, *www.sparkfun.com*

LIDAR is a remote sensing technology often used for geographical mapping and surveying. The word LIDAR is an abbreviation for Light Imaging, Detection, And Ranging. LIDAR technology typically utilizes ultraviolet, visible, and near inferred light imaging in conjunction with GPS. LIDAR sensing methods employ light pulses to measure variable distances and other data along terrestrial surfaces. These systems, commonly mounted on aircrafts are useful in the mapping of broad areas with high accuracy and precision.

LIDAR is widely used in the fields of geodesy, meteorology, geology, atmospheric research, geography, and more. It is often used to create high-resolution maps because of its ability to target a very wide range of materials with very high resolution (typically around 30 cm resolution or better). Two main types of LIDAR systems are topographic, which uses near-infrared laser, and bathymetric, which uses a water-penetrating light to measure underwater areas.

The LIDAR-Lite Rangefinder is a compact and user-configurable optical distance sensor developed by Sparkfun and Garmin. Thanks to its compact size, it is optimized for use on drone and robot applications. It utilizes a 40-meter laser-based optical ranging sensor and boasts a low power consumption of less than 130mA while operating. Because of these features, the LIDAR-Lite is the optimal choice for a portable mapping technology.

Cave Mapping

Caves represent a unique and intriguing challenge for explorers and researchers alike because they are extremely difficult to get to. LANDSAT imagery, topographical mapping, and aerial photography often fail to even identify that a cave is present. As it is, caves provide an unparalleled opportunity for explorers and the scientific community to discover what is hidden in the depths of our planet.

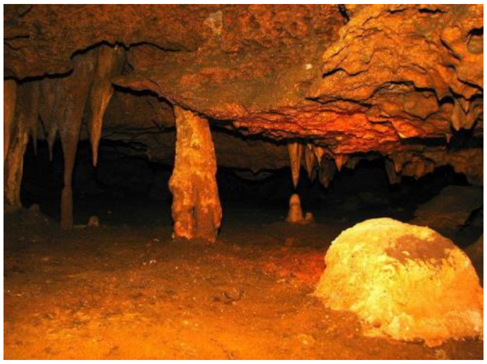

Figure 2: Cave in Florida Caverns State Park, *www.floridastateparks.org*

Cave mapping has traditionally consisted of choosing a centerline in a cave and taking a series of measurements from that centerline to the walls of the cave. The data would then be entered into a computer, which could produce a 2D/3D representation depending on the extent to which the researchers collected measurements. This approach usually requires a team of at least four people, and can take hours, days, or even weeks. In recent years, technology has allowed for quicker, more accurate mapping of caves using LIDAR, but the apparatuses can cost upwards of $50,000.

3. Needs Statement

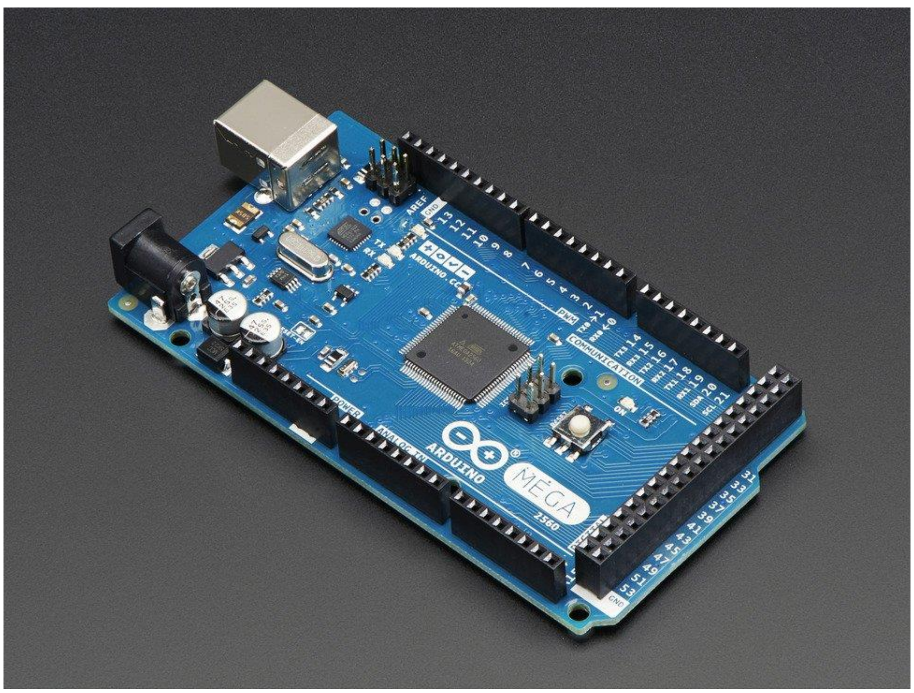

Figure 3: Arduino Mega 2560 R3, *www.arduino.com*

Traditional cave mapping can be costly, limiting participants to professionals. There exist some examples of simple mapping systems online using LIDAR and Arduino programming, but the resolution is typically low. Our client wants a high-resolution system, however our client is requesting a mapping system with much higher resolution and detail than these do-it-yourself approaches considering the extent of the resources that will be provided to us. Furthermore, this system must be small enough to mount on a vehicle, which will be sent into the caves.

Needs and Wants list

- High-resolution data encoding software
- Functional and stable mounting system (for mounting onto vehicle)
- Full rotational motion with micro-stepping abilities
- Small size (facilitates portability on a small vehicle)
- Durability (resistant to shock / damage from natural elements)
- Low cost (budget details TBD)

We need a compact, durable, high resolution LIDAR system that can be carried, or mounted, to accurately depict the inside walls of any cave system.

	High Resolution	Portable	Low Cost	Durable	Geometric Mean	Normalized Weight
High Resolution	1.00	2.00	3.00	4.00	1.78	0.30
Portable	0.50	1.00	2.00	3.00	1.59	0.27
Low Cost	0.33	0.50	1.00	2.00	1.39	0.23
Durable	0.25	0.33	0.50	1.00	1.20	0.20

Table 1: Needs Matrix for the LIDAR Mapping System

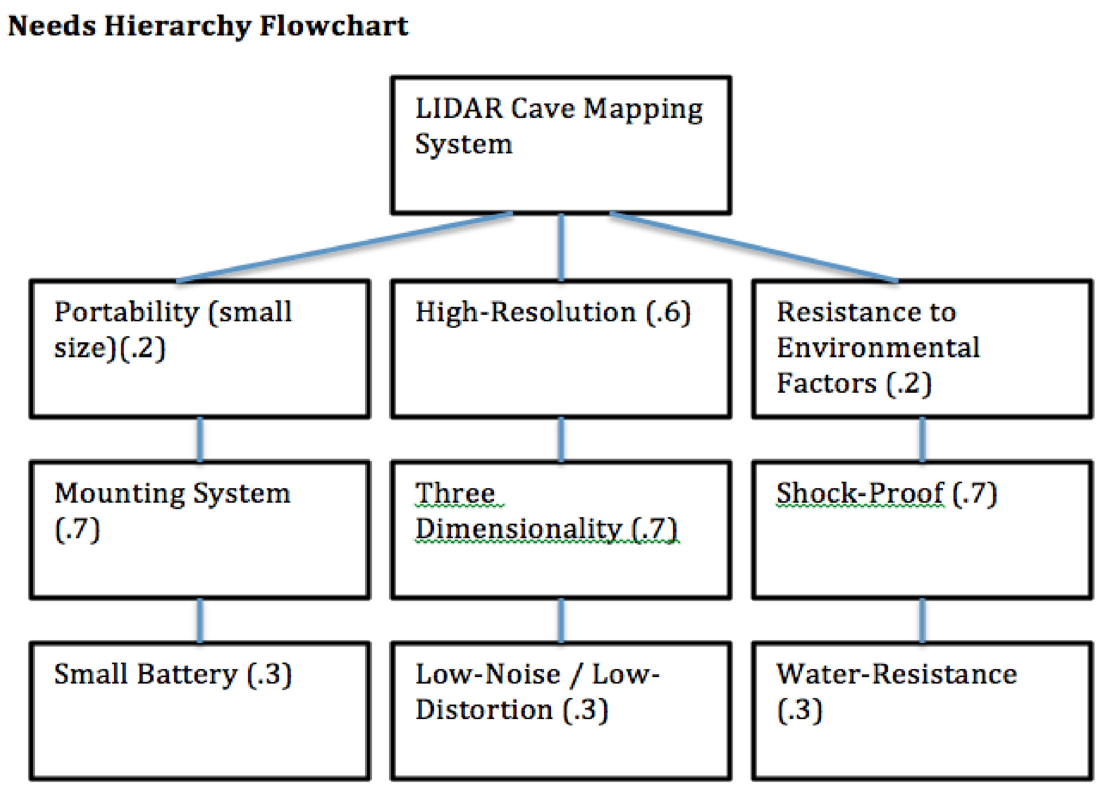

Figure 4: Needs Hierarchy Flowchart for LIDAR Mapping System,

4. Project Objectives and Goals

The goal of the LIDAR Mapping System is to create a durable, high-resolution device that can be easily deployed to map an above ground cavern. The device must be small enough to be carried into a cave and potentially mounted on an autonomous vehicle. The mounting system will be a quick connect/disconnect and will be rigid enough to stabilize the measuring device as it traverses over obstacles. The device will be in an enclosure making it resistant to the rugged and wet environments of caverns.

Once set in position, the device will run autonomously to capture measurements of the targeted area. To acquire reliable data, stepper motors will be used to change the angles of the measuring system in micro steps. Full rotational motion in the x, y and z plane will allow the device to accurately measure a targeted area. The data will be correlated to true north and a high-resolution 3D image of the cave will be created.

This device will be made with readily available parts to keep cost low while data encoding will ensure reliability. Inexpensive parts make upgrading or repairing the device easy. Batteries will be used to provide the system with ample power to perform measurements at multiple target areas. An automatic “off” feature will be added to reserve the batteries in dormant conditions. In case of a system failure, the data will be saved in memory to be exported when the system is retrieved.

5. Project Constraints

LIDAR device must be fully rotational in x, y, and z plane to map surrounding area up to a 40 meter range in each direction. It should be able to map up to 5cm in accuracy and convert the data into a 3D image. The total weight should be no more than three to five pounds. It should be easily portable and small in height, no more than 1.5 feet tall. It will need to rest firmly on the ground and have a waterproof case for when not in use.

The device must be operational in dark caves. It should operate with little initial user input, then run autonomously for the duration of the scan. There must be indicator lights to alert user if mapping is finished, running, or fails at any time during the run. The device must have enough battery power for at least one complete scan, preferably two. The total cost of the finished device should not exceed $500.

6. Deliverables

Project Planner

Plan | Actual | % Complete

Activity	DUE DATE	PLAN START	PLAN DURATION (Weeks)	ACTUAL START	ACTUAL DURATION	PERCENT COMPLETE
Code of Conduct	16-Sep	1	1	1	1	100%
Contact Sponsor		1	1	1	1	100%
Needs Assessment Draft	30-Sep	2	2	2	2	100%
Meet with Sponsors		2	1	2	1	100%
Midterm 1 Presentation	14-Oct	2	4	2	4	100%
Initial Web Page Design	21-Oct	5	1	5	1	100%
Midterm 1 Report	21-Oct	4	2	4	2	100%
Peer Evaluations	21-Oct	6	1	6	1	100%
Meet with Sponsors		6	4	6	4	50%
Begin Coding and Assembly		6	4	6	4	0%
Test LiDar with codes		6	4	6	4	0%
Midterm 2 Presentation	11/14 - 11/2	6	4	6	4	0%
Peer Evaluations	18-Nov	10	1	10	1	0%
Update Website		5	6	5	6	0%
*Test LiDar System in Cave		10	3	10	3	0%
Final Web Page Design	22-Nov	11	1	11	1	0%
*Test LiDar System in Cave		11	2	11	2	0%
Poster Presentation	1-Dec	12	1	12	1	0%
*Test LiDar System in Cave		12	1	12	1	0%
Final Report	5-Dec	13	1	13	1	0%

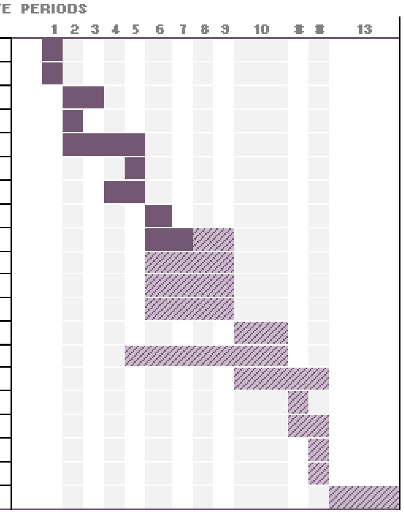

Figure 5: Project Gant Chart

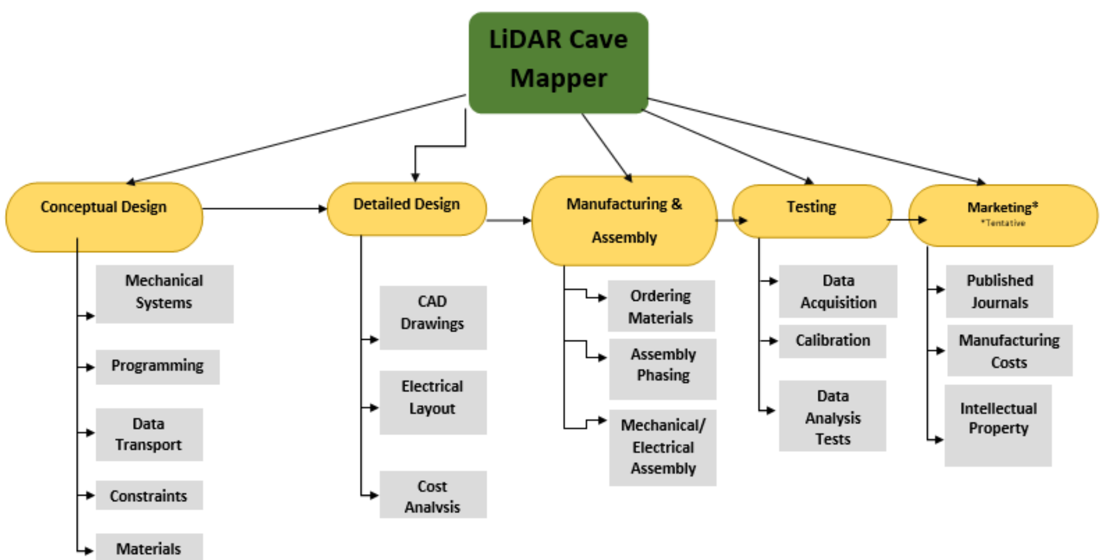

Figure 6: Project flow chart

7. Assign Resources

The project manager, Alisha Hunt, will delegate to both ME and ECE leads as needed. She will oversee general project deadlines and keep contact between project sponsors and our design group. She is also responsible for accounting for the LIDAR mapper device timing. She must calculate the total run time of the device based on a per/sample point time estimate.

The lead ECE, James Oliveros, will be responsible for dividing and delegating the ECE work amongst electrical and computer engineers within the group. He is personally responsible for the memory management of the LIDAR mapper device. This means calculating the memory usage per mapping point and then total usage of data. On this project all of the electrical and computer engineers will be partly responsible for coding the microprocessor. When it comes time to code, James will have to delegate this work.

The lead ME, Spencer Day, will be responsible for dividing and delegating the mechanical work within the group. With the assistance of Hunter he will design the concept frames and wiring/physical layout of the device.

The financial advisor, Cesar Rivas, will be responsible for budgeting and cost comparison. Since the team does not directly manage funds for this project, these will be based on publicly available cost data and estimated taxes/shipping.

The webmaster, Hunter Hayden, will be responsible for upkeep of the website. Website should contain general information about our project and team. It may also contain documents from presentations or reports compiled by the group.

The power engineer, Jake Ogburn, will be responsible for calculating power consumption of the device. This includes the individual consumption of various sensors and the microprocessor. He must be sure that consumption is within the constraints of the batteries.

8. Product Specifications

A. Design Spec

The hardware components of the LIDAR system design include one LIDAR Lite v3 module, an Arduino mega 2560 microcontroller, two stepper motors (one for vertical motion and one for horizontal motion), two stepper motor drivers, one Sparkfun inertial measurement unit, batteries, external memory data storage via SD card, and status LEDs. The status LEDs will be used for error checking and notifying the user of issues during the data acquisition process. The inertial measurement unit includes an embedded Accelerometer, Magnetometer and Gyroscope for orientation purposes. The Arduino microcontroller was selected for its ease-of-use, and open-source modular nature.

The software for the LIDAR system will be developed on the Arduino integrated development environment. Since the Arduino IDE is freeware, and it supports C and C++, our software will be open-source and easily modifiable for future iterations of design. Data from the LIDAR module will be collected and stored in local memory as a series of arrays including data for distance, orientation, and light measurements. This will be implemented into the AutoCAD part of the software design for the development of three-dimensional cave models.

Power will be supplied to the device by two separate battery systems. The total current consumption of the measure system is below 5 amps. The two stepper motors require the majority of the power and will need to be supplied a constant current to uphold the rotational movement with the required torque. A series of batteries with at least a 12 volt and a 13 amp-hour rating will be use to provide both motors continuous power for approximately 4 hours. Additional batteries with at least 5 amp-hours will be used to supply power to the Arduino microprocessor, the LIDAR Lite3, and the motor driver. The Arduino Mega has an onboard power supply, which will be used to power the IMU device. The two power systems will be small enough to remain portable while supplying ample power to the device to last over 4 hours. The batteries will also be removable for easy replacement.

B. Performance Spec

The operation range of the LIDAR mapping system will be the maximum distance of the LIDAR Lite v3 module, which is the distance of 40 meters. The system will have the precision of at least 5cm at 40m, its maximum distance. It will be able to gather distance data at this level of accuracy and feed it into AutoCAD mapping software to develop a three-dimensional representation of the surrounding cave area.

The operator of the system would begin the surveying process by placing the system on a stable section of the cave floor. They would then adjust the system such that the LIDAR Lite module is level to the horizontal plane. The LIDAR system will also have an error-detection feature which will contact the user remotely if there are any problems during the data collection process. Data acquisition at a particular point is projected to take around two hours, though this time estimation may vary during the developmental process. Therefore, the battery life of the LIDAR system should be able to span the time it takes to perform two points of data acquisition, which is about 4 hours.

According to the LIDAR Lite V3 specifications, distance measurements will be read in as two byte strings of data. In a worst-case scenario for data acquisition, the LIDAR design would be reading a data point at every increment on each respective stepper motor on the horizontal and vertical axes. Because each stepper motor has 200 steps, a worst-case-scenario run (taking in the most data points possible) would yield 40,000 data points. At two bytes each, this takes up 80,000 bytes or 80 kB of data. Ideally, the system would be able to collect data for two locations at a time, so the maximum amount of memory necessary for two runs would be 160 kB. This figure is significantly less than the available flash memory on the Arduino Mega 2560 R3. Although this figure does not account for the memory required for the program itself, it appears that the on-board flash memory is sufficient for the maximum load of data and that the Arduino Mega 2560 should have adequate data storage capabilities for the purposes of the Cave Mapper design.

9. Conceptual Design

The conceptual designs for this system have two main parts, the mechanical system used to maneuver the LIDAR, and the electrical computer system, used to record, process and export the data. Ideally, the mechanical system will operate with minimum moving parts while covering maximum scanned surface area. The computer system will preferably use as little memory as possible in the best possible resolution.

Preliminary mechanical designs consisted of three concepts. Because a LIDAR has not yet been acquired, physical tests have not been run in order to assure free movement of the LIDAR. These tests will take place in the coming weeks.

Concept 1

Concept 1 can be seen in Figure 5 below. This design runs on two stepper motors, one underneath the base and one on the side of the LIDAR base. When resolution calculations are calculated, the bottom motor will be programed to turn a certain degree in the X-Z direction and then pause. During this pause, the top motor will rotate the LIDAR its full range of motion at one time while it collects data points. This pattern will continue until the base motor rotates its full range and then the system will be moved and the process will be started over. At most, this design will have a view of 270° with a 90° section blind on the floor of the cave. This concept, like all concepts at this stage in the design process, has not considered the wiring and how the design will react to the various degrees of rotation. Therefore, hands-on testing is required. Concept 1 also leaves the LIDAR exposed to environmental factors and will need some level of protection.

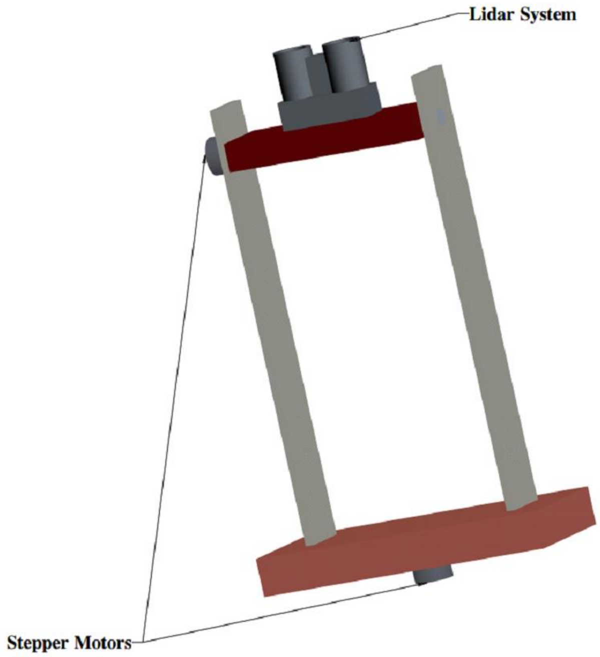

Figure 7: Rendered model of mechanical concept 1.

Concept 2

Concept 2 can be seen in Figure 6 below. This mechanical system is very similar to concept 1 however the LIDAR is fixed to the base and a mirror is on the bottom of the rotating piece on the top. In this case, the LIDAR can only "see" 180°, 90° on the left and 90° on the right. The mirror base blocks the area directly above the LIDAR and the LIDAR itself blocks the reflection directly below the device. Mirrors also pose an issue in of themselves because they need to be perfectly pure in order to give an accurate reading. Any scratches, dust, dirt, or scuffs will alter the readings because the LIDAR beam will not make it to its intended target. Unlike Concept 1, the LIDAR is protected to an extent and will only need minimum protection outside of this. This is countered by the extra protection the mirror now needs because any damage to the mirror will make the system inoperable.

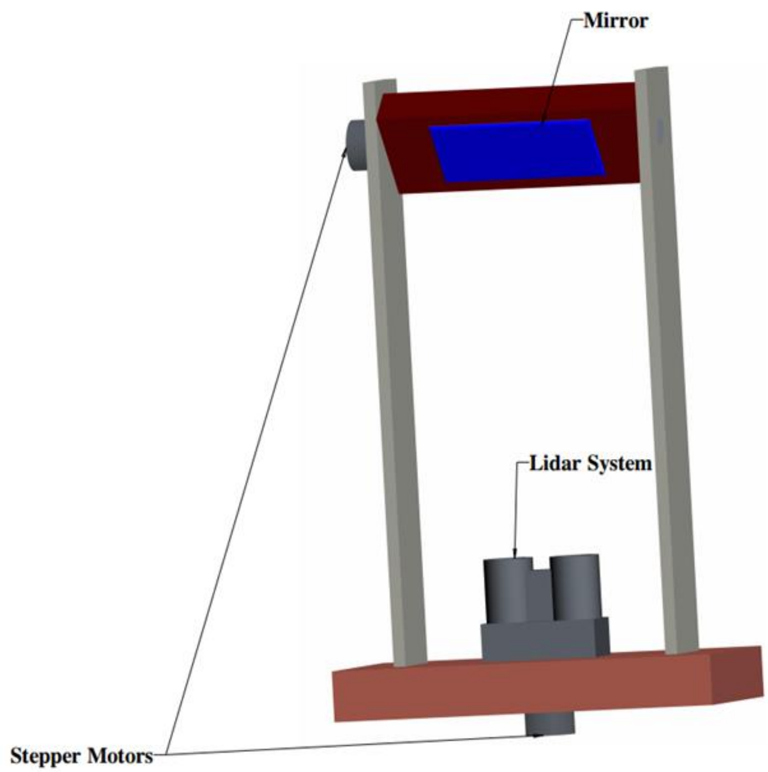

Figure 8: Rendered model of mechanical concept 2.

Concept 3

Concept 3 is a very different design than concepts 1 and 2. Figure 7 shows a 2-motor driven system that theoretically has a 360° field of view with a small blind spot directly below the tripod. The red stepper motor will rotate in the same motion as concepts 1 and 2 while the green stepper motor rotates 360° in between red steps. This will build a full picture of the entire cave surrounding the tripod. Concept 3 will be susceptible to the biggest problems due to tangling wires. If wires do become an issue, the most likely course of action will be to limit the rotational distance of the green motor, which would also limit the field of view. This again will be handled when physical tests can be run and problems can be corrected. Another issue with this design is the vulnerable state of the LIDAR and the potential issues that will be presented by the device being extended out in the open.

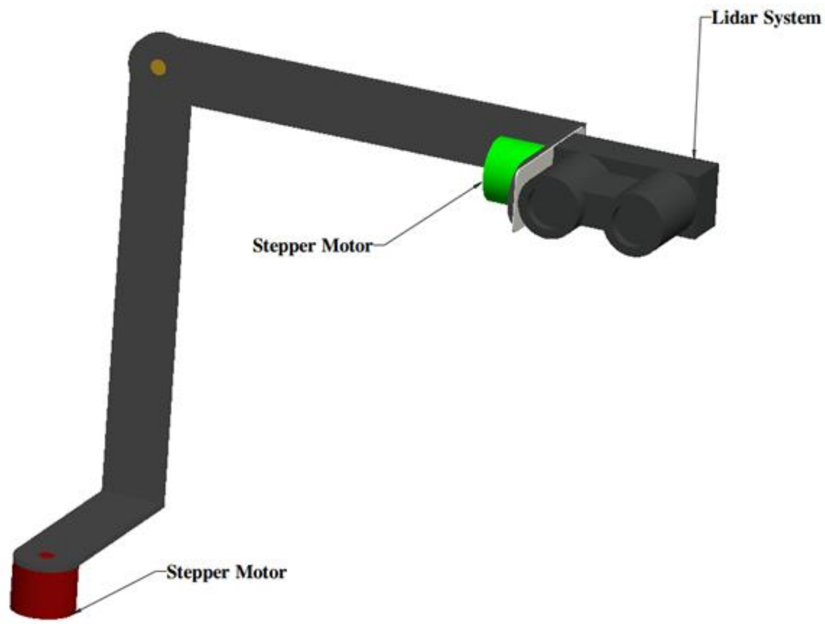

Figure 9: Rendered model of mechanical concept 3.

10. Conclusion

Cave mapping has been a specialized field utilizing expensive technology only few people can afford to use. Our LIDAR Cave Mapping System aims to provide an inexpensive, portable, and reliable device, easily obtainable to all cave-mappers. The open source project will allow cavers to construct their own LIDAR Cave Mapping system for around $500.00. Using this device, the user will be able to place the LIDAR system in a cave, initiate scanning, and scan the entire area within a couple of hours.

During the early stages of the design process, 3 potential designs were created. However, it has been decided that concept 3 has been eliminated due to flaws in the design. The design will be finalized within the next week, and materials and components will be ordered soon after that. The necessary code modules have been divided between the non-mechanical members of the group. A rough estimate for required power has been calculated, and the necessary batteries and voltage-regulation components will also be ordered within the next week. The prototyping and testing stage will begin within the next couple weeks.

11. References

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