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Study of G-Bot

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***Abstract:** This study aims to improve the performance of the vine robot to allow for its movement into hard materials by innovating on a setup that can help it to move through hard materials like rocky terrain, caves, man made covers, etc. increasing its area of use to almost all drilling and surveying activities happening in the industry today and will the time and resources of many of our customers if we succeed in this endeavor. Vine Robots are soft continuum robots design with low-cost fabrication in mind and for the navigation of difficult environments. Unlike traditional robots, which move through surface contact to walk or run, the vine robot relies on growth for movement. Much like a vine and other plants, the robot has a grounded root, or "base," and can continually grow as it expands to add material at its tip. Vine robots can be easily assembled and programmed by novices while also having the option to perform complex tasks. They allow users to either pre-program or control the growing robot in real-time as it navigates the environment. You can expect the robot to:*

- ***Traverse rough, sticky, and sharp terrain***
- ***Grow 100 times its original length***
- ***Enter gaps one-fourth its original size***
- ***Climb vertically***
- ***Transport fluids***

As a result, potential applications for the Vine Robot include search and rescue (such as searching for people in a collapsed building), deployable structures (like helical antennas), and medical procedures.

I. INTRODUCTION

Researchers are developing a new class of continuum robots characterized by tip extension, significant length change, and directional control. In this article, we call these vine robots because of their similarity to plants in their growth-trailing behavior. Due to their growth-based movement, vine robots are well suited for navigation and exploration in cluttered environments. Until now, however, they have not been deployed outside the lab. There are three features that are key for successful deployment in the field. First is portability. Second is the ability to be guided over long enough distances to be useful for navigation. Third is intuitive human-in-the loop teleoperation, which enables movement in unknown and dynamic environments.

There are various potential robotic applications in which nondestructive exploration of small spaces remains challenging for existing robot design, including inspection [1], search and rescue [2], medicine [3], and archeology [4]. Vine robots can potentially fill this need for robots able to move in highly constrained environments.

A. Problem Statement

To come up with a mechanism that allows the vine robot to move through all soil conditions. To increase its usable range and improve movement through relatively harder materials.

B. Objectives

1) To be able to drill into harder materials
2) To maintain all other functionalities like steering, and vision.
3) To improve the fabric to withstand the high temperatures during this operation

C. Scope Of Study

This study will touch on the following aspects of the curriculum:

1) Drilling: To understand and implement an optimized drill head.
2) Material Science: To select a strong, robust and heat resistant material for its body.
3) Pneumatics: To make all the pneumatic circuits for the pressure variations in the robot body.
4) Embedded Circuits: To control the pneumatic circuits and provide a GUI to the user for clarity.

5) *Data Acquisition:* To gather information like drill head temperature, fabric temperature, location of the head, image signal to the user, etc.

D. *Methodology*

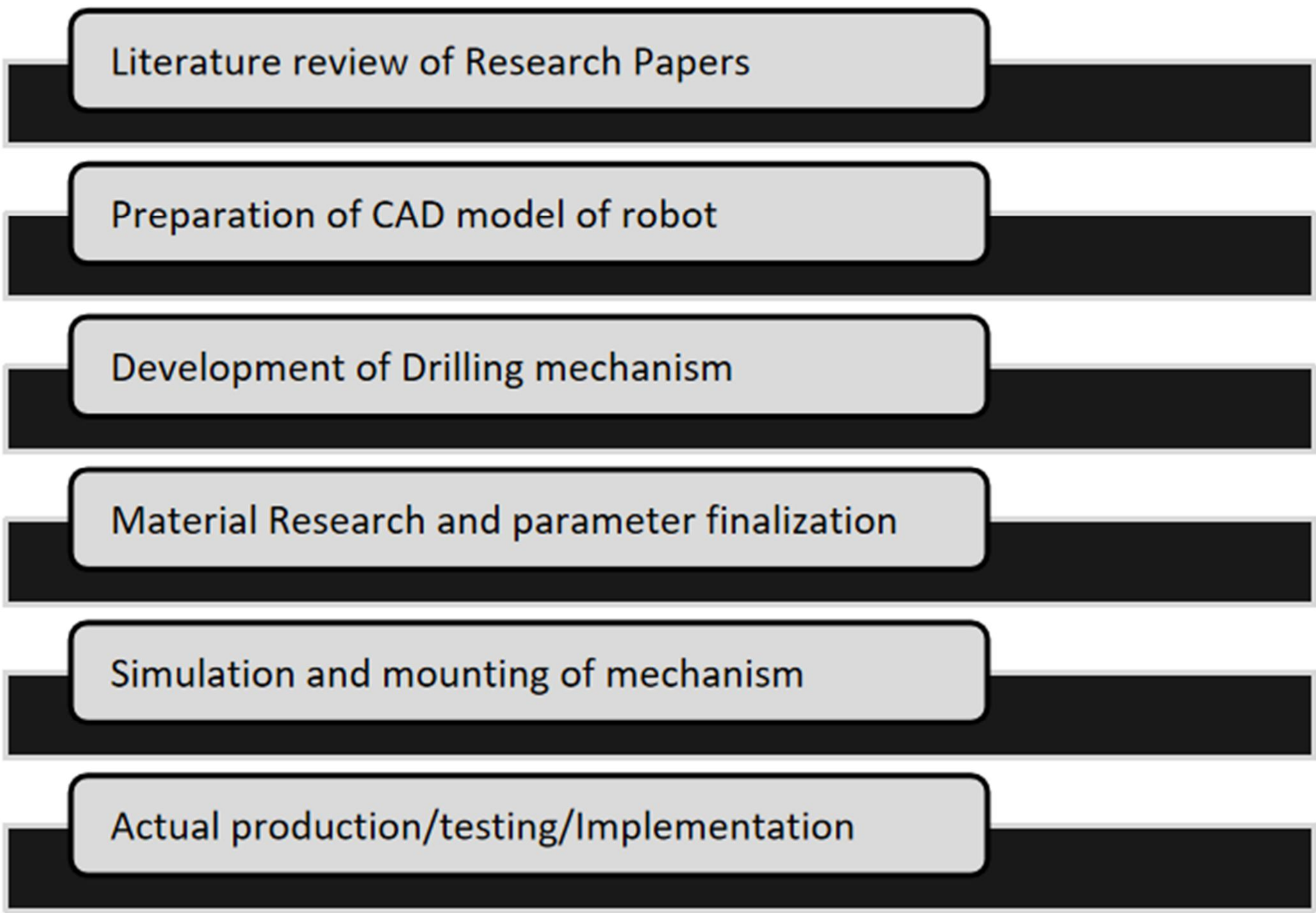

Figure 1 Methodology

II. WHAT IS A VINE ROBOT?

Vine Robots are soft continuum robots design with low-cost fabrication in mind and for the navigation of difficult environments. Unlike traditional robots, which move through surface contact to walk or run, the vine robot relies on growth for movement. Much like a vine and other plants, the robot has a grounded root, or "base," and can continually grow as it expands to add material at its tip. Vine robots can be easily assembled and programmed by novices while also having the option to perform complex tasks. They allow users to either pre-program or control the growing robot in real-time as it navigates the environment. You can expect the robot to:

1) Traverse rough, sticky, and sharp terrain
2) Grow 100 times its original length
3) Enter gaps one-fourth its original size
4) Climb vertically
5) Transport fluids

As a result, potential applications for the Vine Robot include search and rescue (such as searching for people in a collapsed building), deployable structures (like helical antennas), and medical procedures

A. Literature Review

Basic Principle and Working of Vine Robot Vine Robots are soft continuum robots design with low-cost fabrication in mind and for the navigation of difficult environments.

The vine robot is grounded through a base station, where the unused length of robot material is stored until required.

Once a fluid is used to pressurize the base, the inner chamber's pressure enables forward growth through lengthening at the tip.

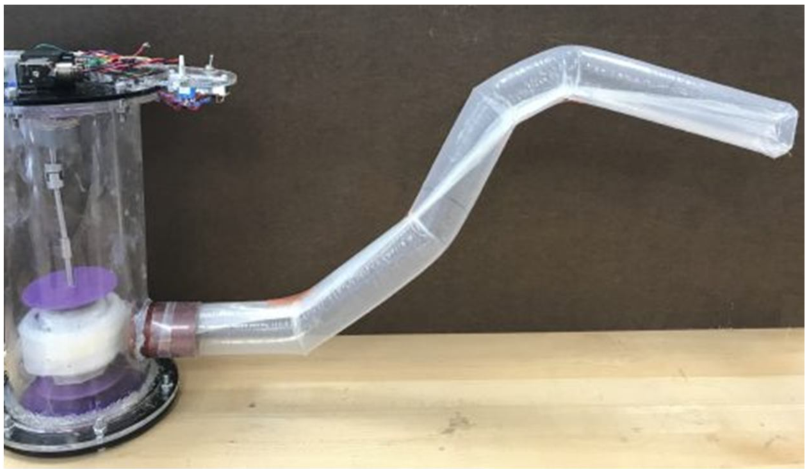

Figure 1 Growth

It is important to note that unlike snakes and earthworms, the robot does not slide as it grows; it has no movement relative to its surroundings.

As a result, it is able to move through the environment with ease, especially in constrained environments where friction would have normally hindered movement in a sliding robot.

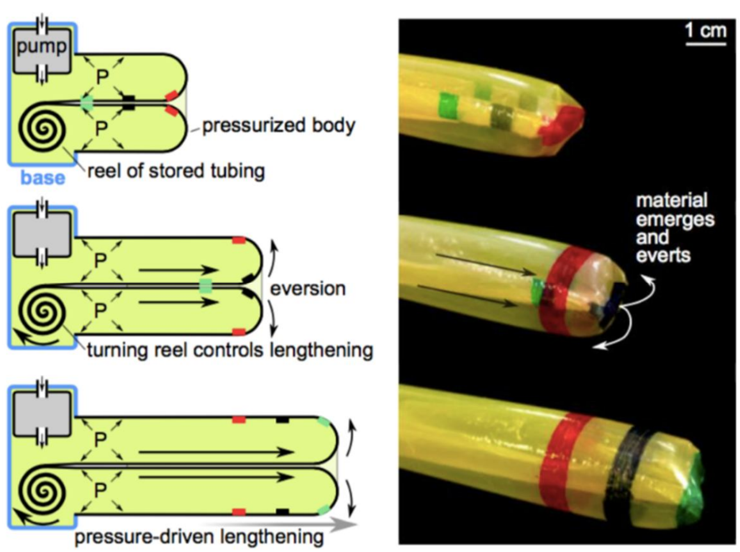

Figure 3 Growth and Eversion

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Eversion refers to the process of turning the tubular roll of plastic — the body of the vine robot inside-out as the robot grows . Vine robot growth is primarily pressure-driven. This means that pressure enables the turning inside-out of the plastic by "pushing" material out during actuation. Prior to launching the robot, the unused material is stored in a spool within the base station.

Create enough pressure and the inverted tubing will inflate to form a cylinder. Increase the pressure and the robot will begin lengthening as the spool unwinds and material everts, or turns inside out.

In models that include robot retraction, the spool is motorized to rewind material into the spool but may also be used to restrict growth to a particular rate.

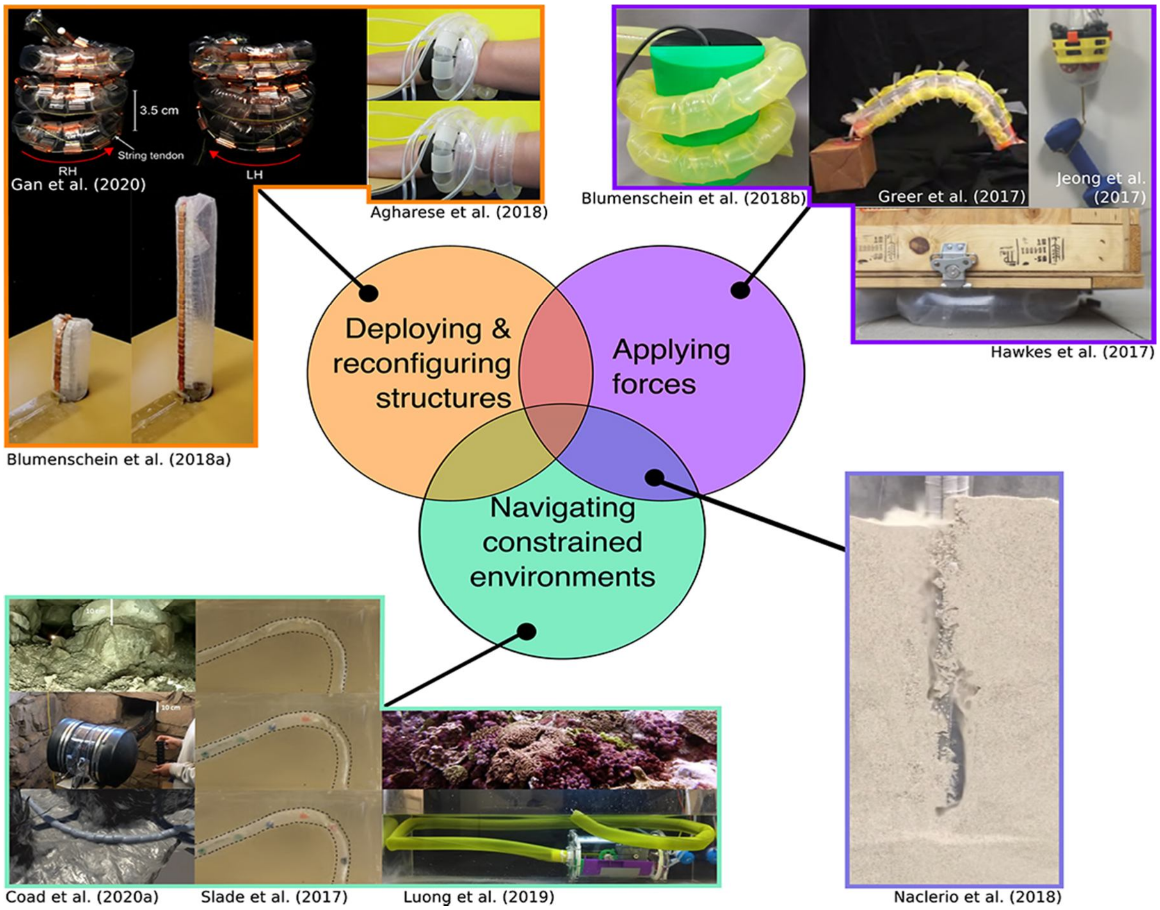

Figure 4 Current Advancement in Field

TABLE

Research Paper	Author	Findings
Design, Teleoperation, and Deployment for Navigation and Exploration	By Margaret M. Coad, Laura H. Blumenschein, Sadie Cutler, Javier A. Reyna Zepeda, Nicholas D. Naclerio, Haitham El-Hussieny, Usman Mehmood, Jee-Hwan Ryu, Elliot W. Hawkes, and Allison M. Okamura	A vine robot is designed, constructed and it's performance is analyzed, length is measured. This was achieved by assembling the required components of definite specifications according to the layout.

Robust navigation of a soft growing robot by exploiting contact with the environment	By Joseph D Greer , Laura H Blumenschein, Ron Alterovitz, Elliot W Hawkes and Allison M Okamura	A robot moving through a cluttered environment will interact with obstacles and that interaction is used for navigating the soft growing robot to a particular destination
Retraction of Soft Growing Robots Without Buckling	By Margaret M. Coad , Rachel P. Thomasson, Laura H. Blumenschein , Nathan S. Usevitch ,Elliot W. Hawkes , and Allison M. Okamura	When buckling and inversion occur during retraction for pneumatically everting soft robots. A key takeaway from the model is that buckling due to retraction forces cannot occur if the robot body length between the force grounding point and the robot tip is zero. So a retraction device is made up on this keysight for buckling free retraction.
Pneumatic Reel Actuator: Design, Modeling, and Implementation	By Zachary M. Hammond, Nathan S. Usevitch, Elliot W. Hawkes, and Sean Follmer	A pneumatic linear actuator that is highly extensible, lightweight, capable of perating under presure and tension is designed, modelled and it’s performance is analyzed. Also small scale applications of this are implemented and large scale applications are proposed.
Obstacle-Aided Navigation of a Soft Growing Robot	By Joseph D. Greer , Laura H. Blumenschein, Allison M. Okamura, and Elliot W. Hawkes	Interactions with obstacles can consolidate many possible paths down to a single desired path and these interactions can direct the robot to locations not on a straight line path from its starting point to a desired destination
A Tip Mount for Transporting Sensors and Tools using Soft Growing Robots	BY Sang-Goo Jeong, Margaret M. Coad, Laura H. Blumenschein, Ming Luo1,Usman Mehmood, Ji Hun Kim, Allison M. Okamura and Jee-Hwan Ryu	Designed a novel tip mount for transporting sensors and tools with soft growing robots that overcomes some limitations of previous tip mount designs and is able for the first time to exert significant pulling force on the environment while retracting, as well as to retrieve and deliver objects.

Table 1 Literature Review Summary

III. DESIGN

The design of vine robot is already well known, and a standard methodology has already been formulated hence, we referred the same methodology.

A. Soft Robot Body Design

The soft body of the vine robot is made of four airtight tubes that are flexible but not stretchable: one central main body tube and three smaller actuator tubes placed around the main body tube. Growth is achieved by pressurizing the main body tube. One end of the main body tube is fixed to an opening in a rigid pressure vessel. The other end of the tube is folded inside itself and wrapped around a spool inside the pressure vessel. This allows along length of robot body material to be stored in a compact space. Pressurizing the pressure vessel, and thus the main body tube, while allowing the body material to unroll from the spool causes the robot body to elongate from the tip. Thin, airtight plastic was chosen for the competition robot body, because it could be purchased in a tube shape, which allowed rapid prototyping and manufacturing. Thin, air tight fabric was chosen for the archaeological exploration robot body, because a more durable material was needed to with stand repeated use in the abrasive environment of the tunnels. Both materials are lightweight to allow the robot body to support its own weight. The soft robot body length was chosen to be just long enough to complete the competition course or to achieve useful exploration at the archaeological site. The soft robot body diameter was chosen to be large enough to allow growth at a low pressure [17] but small enough for the air compressor to quickly fill the robot body’s increasing volume during growth. The diameter of the archaeology robot was slightly larger because the additional thickness of the fabric meant that a larger diameter was needed to grow at the same pressure.

B. Base Station Design

Control of the vine robot body’s motion is enabled by the mechanical, electrical, and pneumatic components of the base station. The robot bases a cylindrical pressure vessel made by enclosing a large acrylic cylinder with two end caps, is used to store the un deployed robot body material on a spool. A second, smaller cylinder is fixed inside a hole in the large cylinder using hot glue, and the base of the main body tube of the vine robot is clamped to this smaller cylinder to create an airtight seal. To allow the robot body to grow to full length and still be pulled back after deployment, the distal end of the main body tube is attached to a string the length of the robot body. The string is tied to the spool in the base. The spool is driven by a motor with an encoder which allows controlled release of the robot body material during growth and assists with retraction of the robot body material back into the base.
The length of the robot base was chosen to contain the motor and spool assembly, and the diameter of the base was chosen to contain the rolled up soft robot body. The base for the archaeological exploration needed to be larger in diameter than the base for the competition to store the thicker, soft robot body material. In addition to the robot base, the base station includes pressure regulators, control circuitry, an air compressor, and a solenoid valve. Control of the air pressure in the four tubes of the robot body is achieved using four closed-loop pressure regulator An Arduino Uno signal-conditioning circuitry, and a motor driver control the voltages sent to the motor and pressure regulators. A portable air compressor provides a continuous supply of compressed air to the system

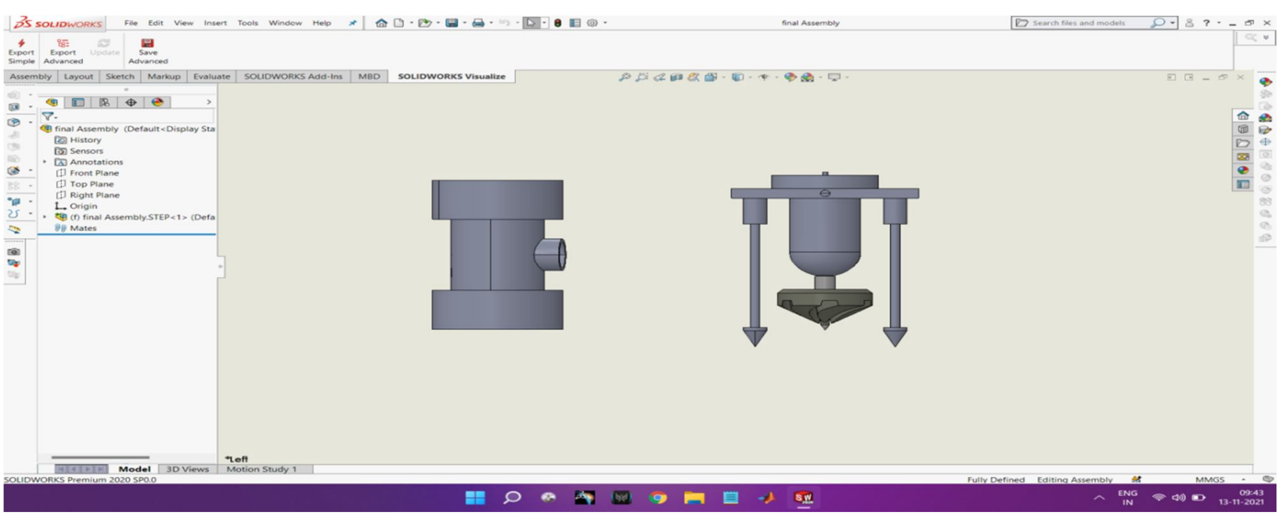

Figure 5 CAD assembly

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C. Design of Drilling Setup

The drilling setup was the main component of the overall setup hence its design was the most critical, The design was focused around having enough strength to hold the drilling head straight and also bear the pulling load of the robot once it starts moving inside the material hence a 4 pillar design was done to make sure that the support area for the robot was enough and also to allow for increased space around the drilling head to improve access to the area.

Clearances from the body of the robot were also maintained to avoid damage to the fabric of the robot and also to reduce resistance to movement which would reduce the overall pressure requirements of the robot

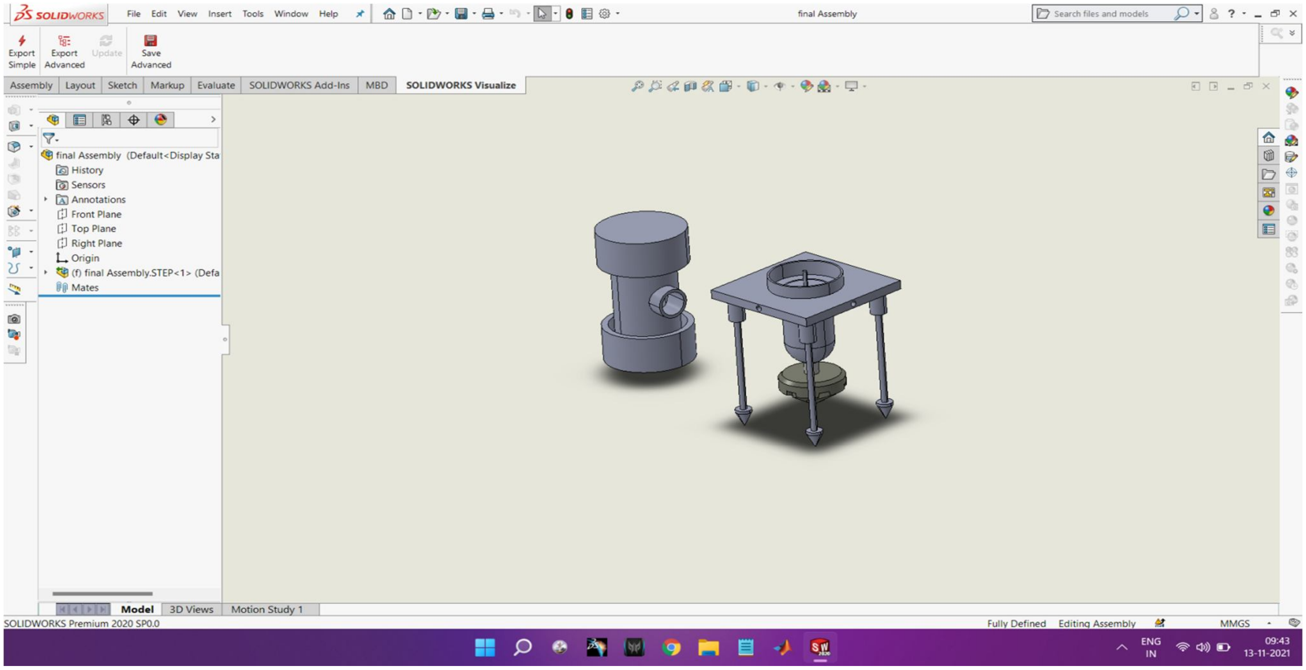

Figure 2 CAD Assembly-2

IV. CASE STUDY

Three locations were chosen to be explored by the vine robot due to their interest to the archeology community, difficulty to explore through other means, expected length (fewerthan 10 m from a human-sized entry way), and ease of setting up the vine robot at the entrance. Overall, the robot was able to achieve access inside all three of the targeted locations and take video that could not have been recorded otherwise. In Location 1, the robot was able to navigate past a rock blockage. In Location 2, the robot was able to round a 90° turn In Location 3, the robot was able to grow upwards into a vertical shaft. The robot grew approximately 6, 5, and 3 m into each tunnel, respectively. The challenges during this deployment of the robot were artificially slow growth speed, lack of actuator robustness, lack of shape morphing at the robot tip, inability to shorten the robot once grown, and difficulty maintaining situational awareness. First, growth was slower than it could have been because the length and narrowness of the chosen pressure tubing led to a significant unsensed pressure drop between the closed-loop pressure regulators and the soft robot body. Second, the heat seals on the actuators tended to pop open after repeated use, leading to leaks and an inability to curve the robot body. This was later improved by stapling over the heat seals and taping over the staples. Third, while the rigid camera cap at the robot tip enabled mounting and protected the camera, it also inhibited the vine robot’s natural ability to pass along walls and squeeze through narrow apertures. This led to the need to push the robot forward from the base at some points. Fourth, due to the robot’s natural tendency to buckle rather than reverse growth when the motor is run in the retraction direction, it was impossible to retract the robot while in the tunnels, resulting in the need to pull the robot back from the base to undo wrong turns and remove the robot after deployment. Fifth, challenges with situational awareness came from teleoperating the robot based only on the image from the tip camera. Because the tip of the robot body sometimes rolled relative to its base, changing the alignment of the camera image with gravity, the mental mapping between the bending directions of the joystick and the world-grounded directions in the tunnels was not always intuitive. Also, it was difficult to maintain an understanding of how far and in what direction the robot tip had gone, leading to confusion about the state of the robot and its environment. Even with these challenges, the vine robot gained access inside all three tunnels and recorded video in locations not previously observed by the archeology team.

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Figure 7 Case Sudy

V. CONCLUSION

The cad model of the vine robot was successfully carried out. As the vine robots could not drill through hard surfaces, we were able to come up with a drilling mechanism that can allow the vine robot to move through any soil condition. All other functionalities such as steering, and vision were maintained. This new mechanism can be useful in archaeological and mining sectors.

A. Applications of Vine Robot

1) Deploying and reconfiguring structures.
2) Navigating constrained environments
3) Applying forces on the environment

B. Drawbacks of Vine Robot

1) Drilling capacity.
2) Currently, the system has limit on the materials that it can drill through, however if scaled up, it has the potential pf making the robot virtually unstoppable if the proper drilling setup is constructed

C. Future Scope

The next step pf this project ie., Project stage 2 will be focused on the manufacturing, testing and finalization of the setup proposed above, flexibility has been kept accommodating any design changes that may occur in the testing and validation phase of this project.

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