Farmbot

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12/8/16

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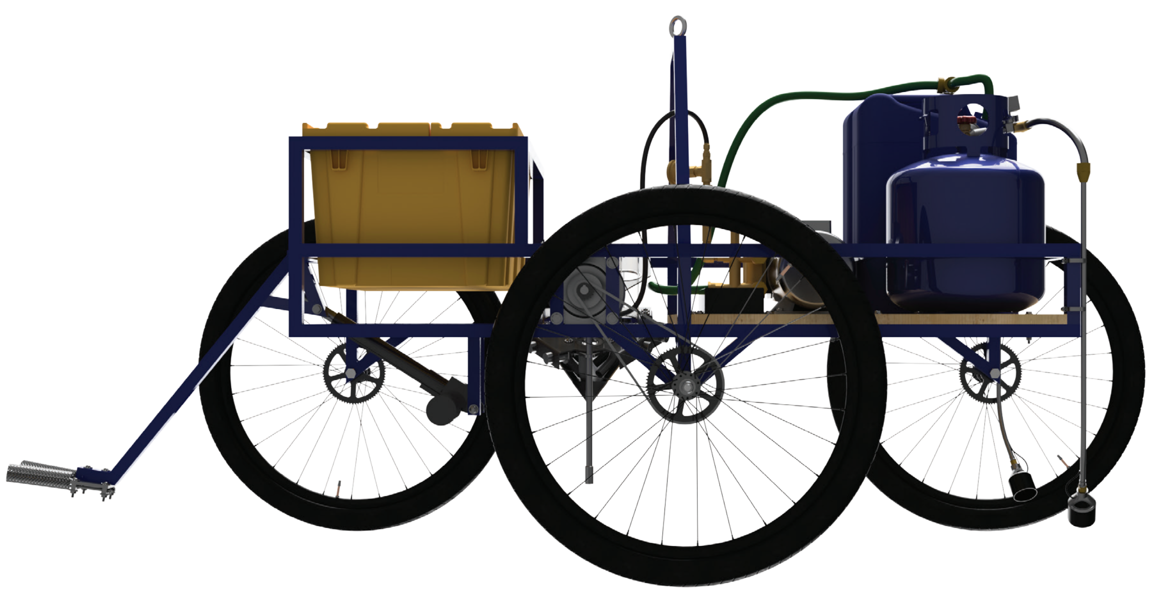
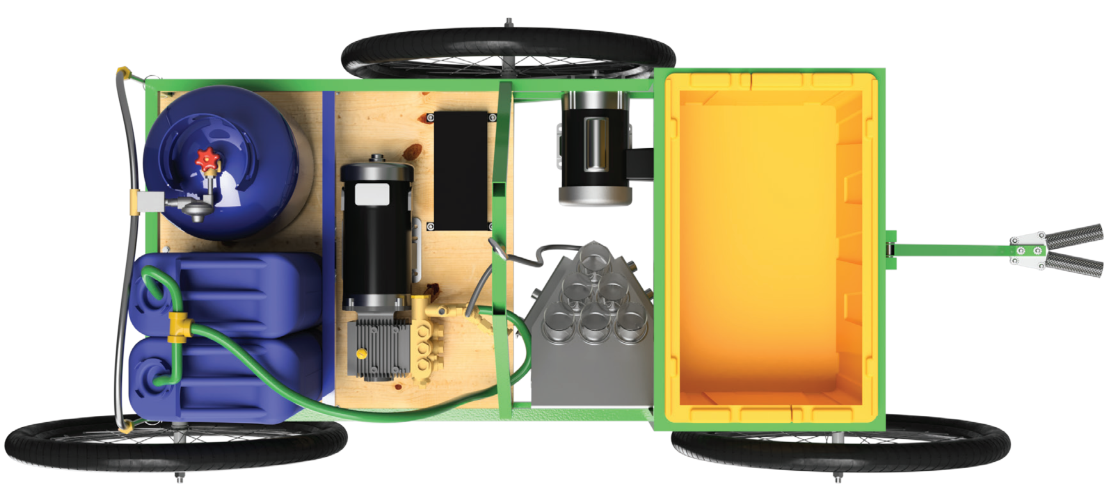


Executive Summary

Our farmbot takes a unique “spin” on CNC farming. Instead of a traditional X-Y gantry for accessing all the points in a plot of land, we opted for a spiral layout of plants. Moving a cart in a spiral is eaily acheived by having a cart wrap/unwrap itself around a central post. The major motivator for this arrangement was to make an inexpensive “gantry” by decentralizing the weight of our structure. Because the chassis of our farmbot is all that needs to move around (as opposed to a massive steel gantry) we could create a simple and lightweight method of tending a plot. Furthermore, to address the need to keep price low, we opted to reduce complexity and number of parts as much as possible. And with the parts that we created, we made sure that they could all be made with the resources available in an agricultural setting, albeit an agricultural setting with access to a half-decent shop.

Our farmbot is composed of a 5 major subassemblies that are modular and interchangeable based on a farmer’s specific need. The selection of subassemblies that we included on the farmbot include: a seeder, a waterer, a weeder, and a harvester. The seeder uses hydroseeding to plant seeds with water pressure. Because this includes a water displacement apparatus, it doubles as our waterer. To weed, we use an environmentally friendly propane burning technique that is already commonplace in agriculture. The harvester passively grabs plants and puts them into a tub on the chassis for later collection.



General Design

We were tasked with creating a “FarmBot”: a robotic system that can plant, cultivate, and harvest crops. Our design was created in response to a specific set of design constraints. From there we were inspired to pursue a non-traditional CNC planting configuration, namely a spiral. Our final assembly can be broken down into five major subassemblies: post, chassis, seeder/waterer, weeder, and harvester. What follows is a brief overview of each of these sections with more detailed design descriptions later in the report.

Constraints

Look awesome	Looks fabulous
Cost less than $2000	Costs $1553.74
Cultivate a plot of 250 square feet	Easily reaches 675 square feet
Be powered by 120VAC	Yes
Contain Olin logo	Yes
Be safe	We designed our apperatus to be light weight and slow moving. Furthermore, all of our dangerous components (transmission/seed-er) are internal and shielded by the chassis.
Survive the environment	All of our parts are designed to be rugged and durable with special attention being paid to replacability and ease of maintenance.
Entrance viewers	Our unique take on “one axis” CNC will impress and inspire

Inspiration

The guiding force for this project was the extremely low budget constraint that we were given for the size of plot that we were tasked with cultivating. In response, our team brain stormed ways to keep costs low while keeping a large cultivation area. Here is our logic:

1. Cost is proportional to weight

2

We can decrease weight by reducing the aspect ratio of our plot. The gantry that needs to access any point in a rectangle can weigh less if the gantry is skinny and simply rolls a longer distance along the ground.

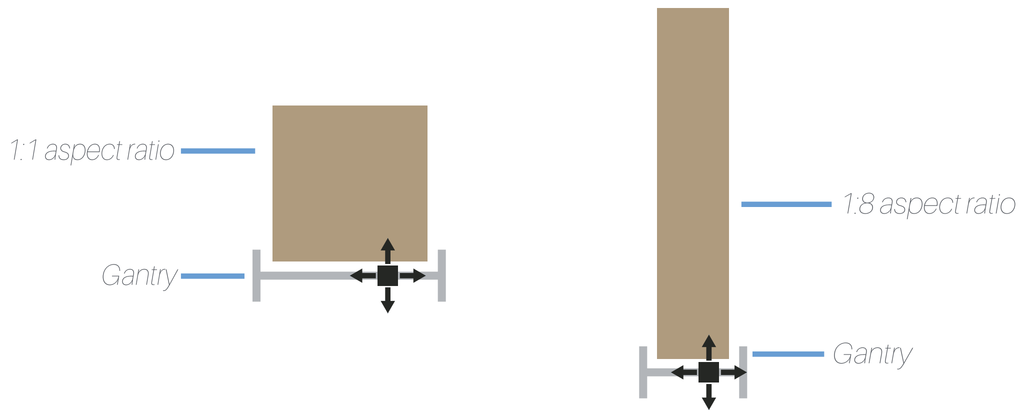


Figure 1: The left farmbot necessarily weighs more than the right farmbot due to the aspect ratios of the plot

3

The logical extreme of this aspect ratio reduction is a line where a small "gantry" (essentially just a cart) rolls down a long row.

4

Having a 350'x1' garden is inconvenient, but it can be made more compact by spiraling it inward along an Archimedean spiral. Such a figure is easily constructed by tethering our cart chassis to a post and having it wind itself in or out to access any point in the plot. This proposition also provides a whole host of benefits such as: our plot size is easily augmented by increasing the tether length, position within our plot is reached with a single motor, and resolution is adjustable from the diameter of the internal post. Furthermore, our design is mobile. If needed, one can simply plant an additional post and use the same machine to cultivate a separate plot without the need for heavy moving machinery and equipment.

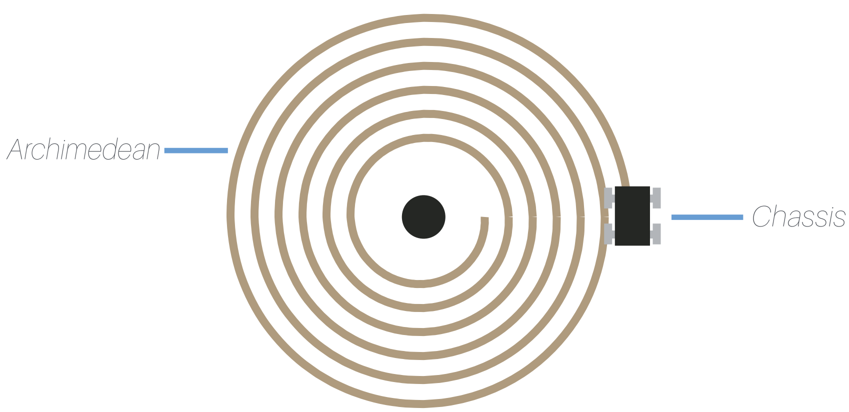


Figure 2: By spiraling inward, we can keep our farmbot lightweight but still cultivate a large plot.

Chassis

Two key issues that as a design team we had to alway keep in mind were cost and robustness. These were especially hard to satisfy as it is hard to maintain strength when minimizing costs. However we believe that the platform that the chassis provides was a great compromise between both variables. For us as a team it was also really important to keep the chassis as as simple as possible so that farmers would be able to fabricate the entire thing on site from tube stock.

The design seen above is a welded construction made out of 1 in SQ x 0.065 A5130 Mild Steel tube. We leveraged the use of tubes as muchas possible for mounting in order to eliminate the need to have milled or waterjet parts that would make it harder for the farmer to repair on site without specialized equipment. The chassis is powdercoated in our design (though it can also be spray painted) in order to protect the tubes from the environment, this in addition to proper storage over the winter would ensure longevity for the robot.

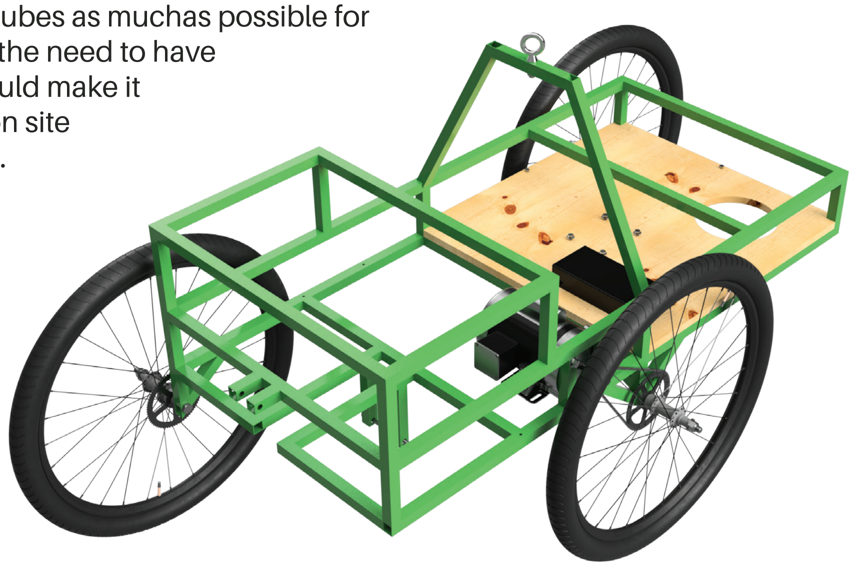


Figure 3

Seeder

The seeder was inspired by hydroseeding and power washing - two high-pressure water-driven systems. It is driven by a compressor that forces water through a high-presssure tube, and delivers seeds to the jet stream via six independantly actuated seed canisters. These canisters are opened and closed with solenoids. It's fundamentally based on three base plates made of either aluminum or steel that fully retain the system and enable eas of mounting to the chassis.

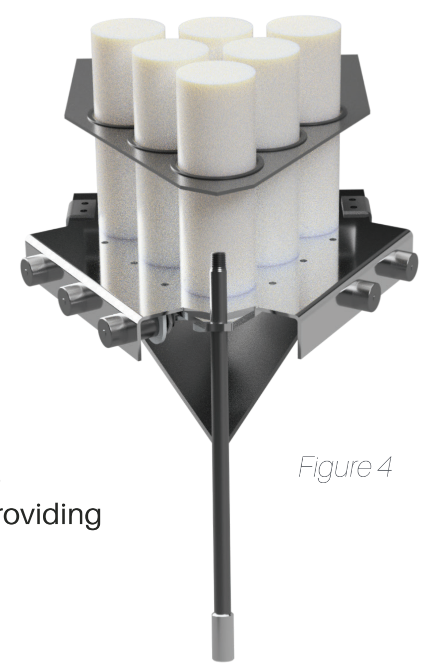


Figure 4

Water

As the seeder is capable fo spaying just water. We are using the same mechanism run at a signiifcantly lower pressure to water our crops. Providing super precise and efficient water distrobution.

Harvester

The harvester uses two knurled aluminum cams to passively grasp plant stalks. This mechanism was inspired by jumar mechanisms which allow climbers to clamp onto rope when it is moving in one direction and allow the rope to pass through easily in the other. Similarly, the pair of cams are mounted on off-axis axles which culminates in their spacing decreasing as they rotate inwards. This motion lets our harvester hold on tightly to plants when uprooting them, but when force is applied in the opposite direction, the plants are able to slip free. Such a loading scenario occurs when the harvester is rotated upwards to dump the plant material into a tub located on the chassis. Because safety was a concern, it is significant to note that the harvester grasps plants passively which means any sentient being would easily be able to free themselves from the cams without harm. Also, the harvester subassembly meets the requirement of being cheap because it is made from few parts and all of which are inexpensive and easily replaced.

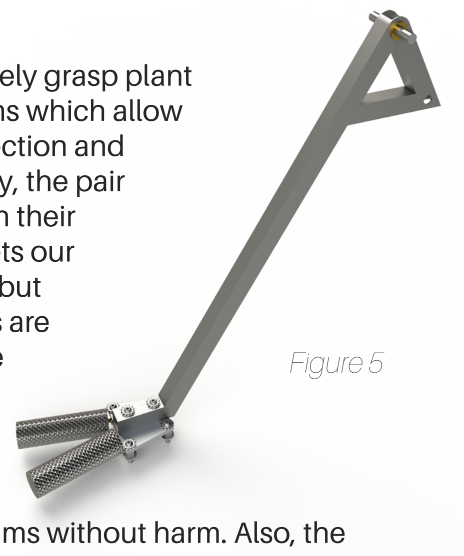


Figure 5

Weeder

Seeking to ruduce the amount of cost and complexity of our system for weeing we chose to use a pair of propane torches. We chose this for a number of reasons. First, propane torches are a very enviromentally friendsly way of managing weeds. It does not disrupt the soil, it just wilts the weeds and keeps all the nutrients in the soil. It also allows for no need of pesticides and reduces the need for fertilizer.

The weeder has nomoving parts. This means that there fewer points of failure. Making the system incredibly durable and reliable. Further all of the parts can be bought off of the shelf. This makes it very cheap and easy to build pretty much anywhere. Also, it makes it a lot easier to repair as if anything breaks it can easily be replaced for very little work.

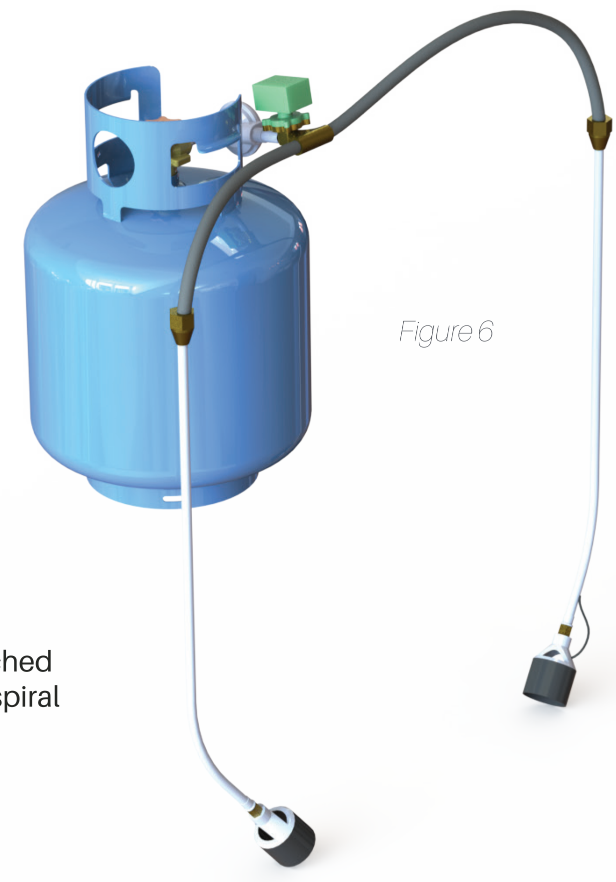


Figure 6

Post

The post is used as a center point to ground the farmbot and provide its path of motion. It is a simple cylindrical design that is made out of concrete so that it can be poured directly into the ground using a cement tube. At the top of the post there is a fixed spool that the farmbot is attached to by a cable, this leads the farmbot to move in a spiral path towards the center maximizing use of land.

BOM

DESCRIPTION	QTY	PRICE	TOTAL
CHASSIS WELDMENTS - 1x1 065 Tube per foot	64.12768333	2.20375	141.3213821
91280A806_MED-STRG ZINC-PLTD STL CAP SCREW - CLASS 8.8 (1)	3	3.39	10.17
99908A105_NYLON-INSERT NONMARRING FLANGE LOCKNUT	1	0.871	0.871
29 IN BIKE WHEEL	3	30	90
3014T118_STL EYEBOLT W SHLDR - FOR LIFTING	1	7.44	7.44
94945A225_GRADE 8 STEEL THIN NYLON-INSERT LOCKNUT (1)	3	1.138	3.414
1 HP Agricultural Farm Duty Motor	1	159.99	159.99
Motor Bolt -Grade 8 Steel, 7/16"-14 Thread Size, 2-3/4" Long	4	0.913	3.652
Zinc-Plated Steel Internal-Tooth Lock Washer 7/16th	4	0.0813	0.3252
Zinc Yellow-Chromate Plated Grade 8 Steel Washer for 7/16th	4	0.1796	0.7184
Sprocket 25H - 72 Tooth, Rear - Cag / Pocket Bike, ATV, Dirt Bike, 47cc/49cc	1	12.95	12.95
Finished-Bore Sprocket for ANSI Roller Chain for #25 Chain, 1/4" Pitch, 17 Teeth	1	10.63	10.63
Motor Key - Square 3/16"	1	1.84	1.84
Zinc-Plated Steel Slotted Spring Pin 3/16" Diameter, 1" Length	1	0.0696	0.0696
Zinc Yellow-Chromate Plated Hex Head Screw Grade 8 Steel, 5/16"-18 Thread Size, 2" Long, Fully Threaded	1	0.884	0.884
316 Stainless Steel Washer for 5/16" Screw Size, 0.344" ID, 0.75" OD	1	0.1118	0.1118
High-Strength Steel Nylon-Insert Locknut Grade 8, Zinc Yellow-Chromate Plated, 5/16"-18 Thread Size	1	0.184	0.184
Zinc Yellow-Chromate Plated Hex Head Screw Grade 8 Steel, 3/8"-16 Thread Size, 5-3/4" Long	4	2.27	9.08
Zinc Yellow-Chromate Plated Hex Head Screw Grade 8 Steel, 1/4"-20 Thread Size, 2-1/2" Long, Fully Threaded	3	0.727	2.181
High-Strength Steel Nylon-Insert Locknut Grade 8, Zinc Yellow-Chromate Plated, 1/4"-20 Thread Size	3	0.1372	0.4116
Straight Line Dyneema 65' Main Line	1	6.72	6.72
Black Box of electronics controls	1	200	200
Roller Chain ANSI Number 25, 1/4" Pitch	1	15.42	15.42
SQUEEZE BOTTLE	1	12.88	12.88
BASE PLATE	1	29.99	29.99
8507K11	1	8.8	8.8
SOLENOID	4	19.98	79.92
aluminum sheet 1/8in	522	0.06130268199	32
FM-Approved Low-Pressure Iron Pipe Fitting Tee Connector, 1/2 NPT Female	1	6.36	6.36
steel sheet 1/8 in	359	0.04456824513	16
Bin for them veggies	1	7.58	7.58
Arm weldment	1	2.87	2.87
Tong axle	1	2.25	2.25
Spacer (wide) for bushings	2	7.36	14.72
knurled alluminum tong	2	19.75	39.5
linear actuator housing	1	120	120
axel	1	2.12	2.12
Zinc Yellow-Chromate Plated Grade 8 Steel Washer for 3/8in bolt	21	0.1144	2.4024
Zinc Yellow-Chromate Plated Hex Head Screw 3/8 x 2.25	21	0.829	17.409
High-Strength Steel Nylon-Insert Locknut - 3/8 - 16	21	0.201	4.221
Propane Torch with Push Button Igniter	2	29.99	59.98
Worm-Drive Clamps for Firm Hose and Tube (10 Pack)	4	6.74	26.96
Greenworks 1,800-PSI 1.1-GPM Cold Water Electric Pressure Washer	1	159	159
5 Gal 20L Jerry Can Gasoline Gas Fuel Can Emergency Backup Gas Caddy T	2	34.99	69.98
Valve Connector	1	70	70
Brass gas line t joing	1	$7.97	$7.97
Concrete Post	1	$16.60	$16.60
Spool	1	$21.02	$21.02
Bolt	1	$11.05	$11.05
Nut	1	$3.14	$3.14
Lock Washer	1	0.641	0.641
20 Lbs Propane Tank	1	29.99	29.99
		Total =	**1553.737382**

Harvester

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Inspiration

The harvester mechanism was inspired by the action of a jumar mechanism which allows climbers to ascend ropes safely. The key feature is a "one-way" cleat that allows rope to pass through in one direction easily but then grips it tightly in the other direction in a way that increases in force the more that the rope is pulled.

Figure 7: The locking "jumar" mechanism employed by climbers to grip rope in one direction and let it slide in the other.

For ease of fabrication, we decided to use knurled aluminum cylinders as the cams that would make contact with the stems of the plants (instead of the toothed jaw in a jumar). We think that because plants have rough stalks, a sharp knurling surface finish will be enough to engage the pinching action of our harvester mechanism. Because most plants have a stalk/stem structure, we believe that we can harvest anything we can get the cams around.

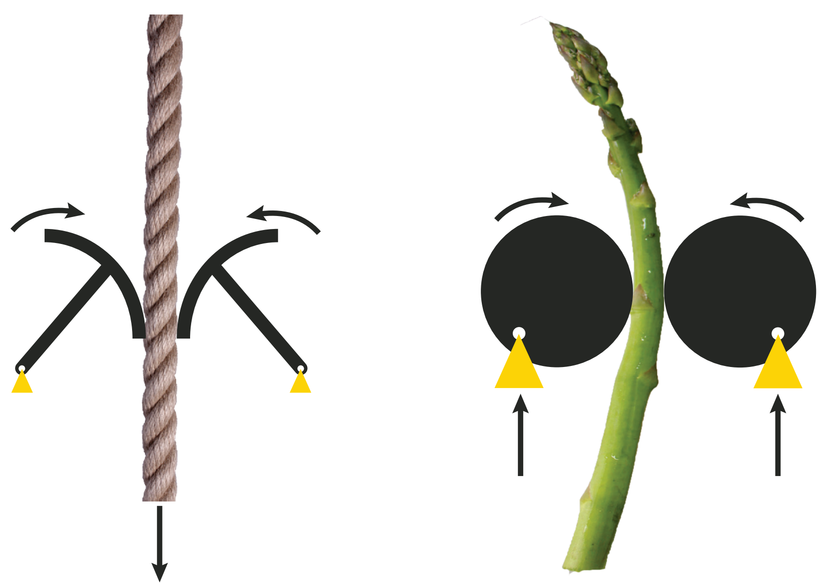

Figure 8: The rope mechanism on the left uses the downward force of the rope to force the jaws closed. Similarly, our mechanism uses the upward force of the harvester to roll the twin cams inward to grasp the plant

Design Decisions

In order to grasp a variety of plant stalk diameters, we opted to mount the cylindrical cams with an inter-axial angle of 24 degrees. This means our harvester can grasp any plant stalk that is less than 2.5” in diameter. At the upper end of the spectrum, the root of lettuce heads can run in the 1-2” range and so are comfortably below our max.

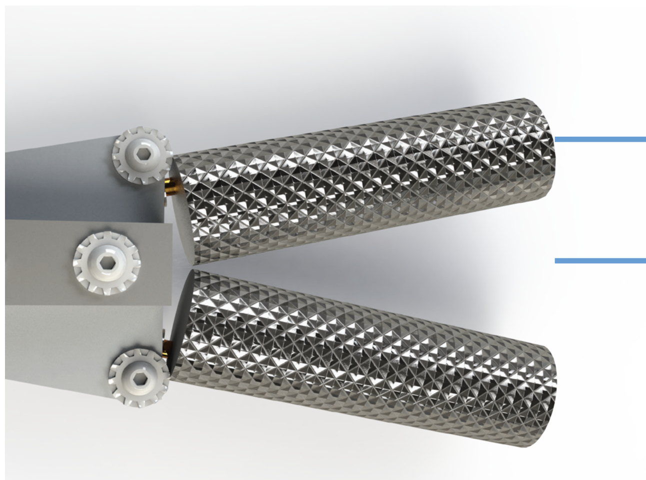

Figure 9: The angled cams with knurled surface finish are the components that physically grasp the plants we are harvesting. Especially important is the inter-axial angle that allows for variable plant diameter

Each of the knurled aluminum cams is mounted along an axis that is offset from the center by .5” so as to cause the gap between the cams to effectively decrease as they rotate inwards and grip the plant. Specifically, the cams are pressed onto .25” brass rods which in turn are passed through two bushings a piece and secured with retaining rings. Oil embedded bushing were used instead of ball-bearings because we are working in the dirt and aren’t expecting these rods to rotate at high RPM

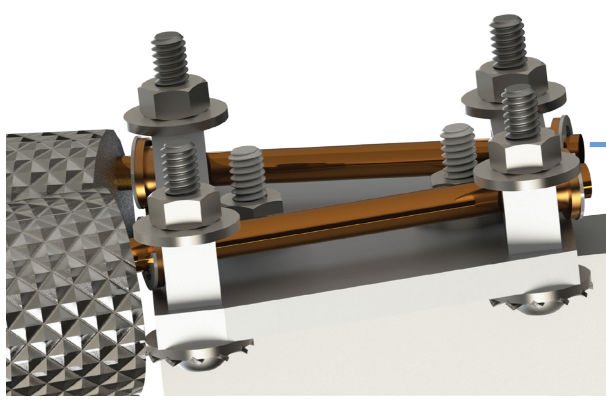

Figure 10: This view shows the underside of the assembly that constrains the axels responsible for allowing the cams to rotate. Pictured above are the flanged bushings, the retaining rings, and the various fixturing elements that hold the subassembly together

But grabbing a plant is just the first half of the battle: once we have it, we need to drop it into some collection receptacle which is in our case a plastic bin. This is achieved by actuating the harvester arm up in a circle (whose center is on the front of the chassis). At the peak of this extension, the weight of the plant drops itself from the tongs and into the bin. When the harvester arm resets, the cylindrical cams fall back to their initial positions as well due to their off-center weighting. The entirety of the harvesting motion is achieved with a single linear actuator (more on the specs of this component in the power section).

Transmission

The harvester is predominately one long lever arm that extends from the chassis to the ground where it can pick up plants and lift them into a tub on the chassis. We reckon that 20 pounds of force is more than sufficient to lift any plant out of well aerated soil. The fulcrum of the system is fixed at the end of the chassis and the applied force is somewhere along the arm. When designing this part, we fixed the location of the application of force (where the linear actuator interfaces with the harvester arm) and then spec'ed the strength of the actuator accordingly.

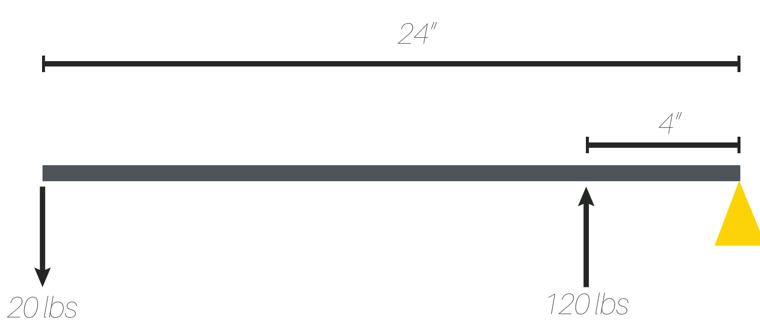

Figure 11: this is an abstraction of our harvester arm with the "weight" of harvesting a plant on the far left (20lbs) and the anticipated force of the actuator on the right (120lbs).

Despite the concentration of stress, the part still exhibits a factor of safety of 2.6 which is more than enough for our application. In fact, if a part were to fail, this would be a good mechanical fuse as these rods are cheap and failure here would likely be a slow “bending out of shape” rather than the explosive buckling that would occur elsewhere in the harvester assembly.

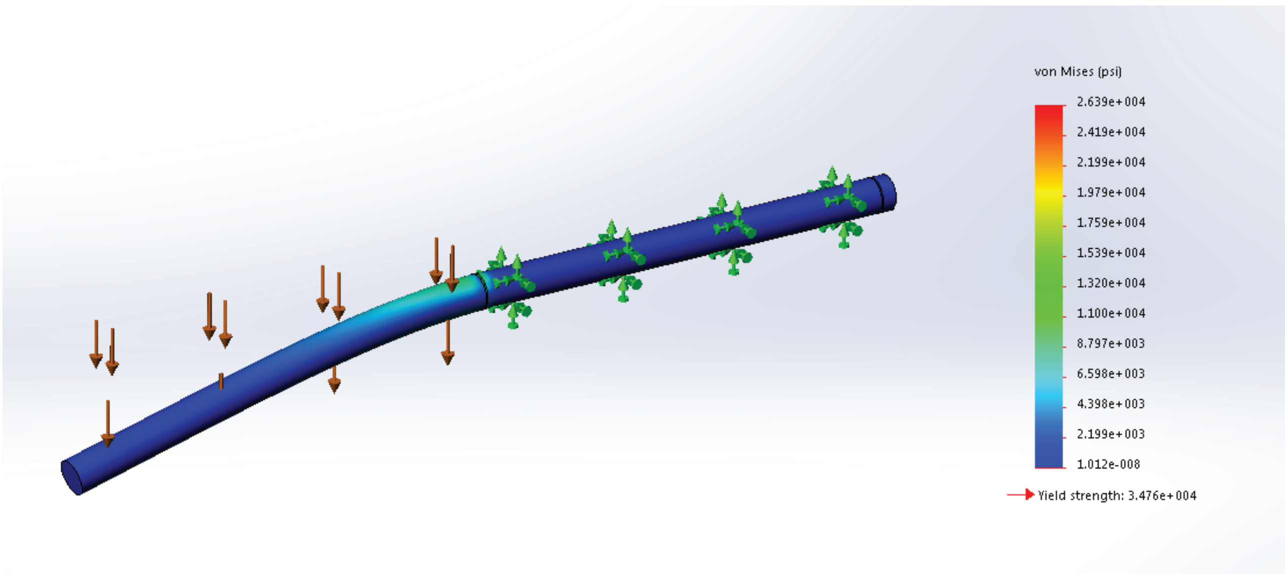

Figure 14: This is the axel that holds the knurled cams and is responsible for supporting the load of lifting a plant. While this part is strong enough to do so, if it were to break it is cheap and easy to replace.

Structure

The length of the lever arm is made of square steel tube because it is cheap and easy to work with. The specific gauge/dimensions were decided based on instinct derived from previous experience, but it is always important to check these assumptions analytically. Now that we have decided on the power and transmission, we used SolidWorks' powerful FEA simulation tools and found that our structure has a factor of safety of 7.58 at its lowest.

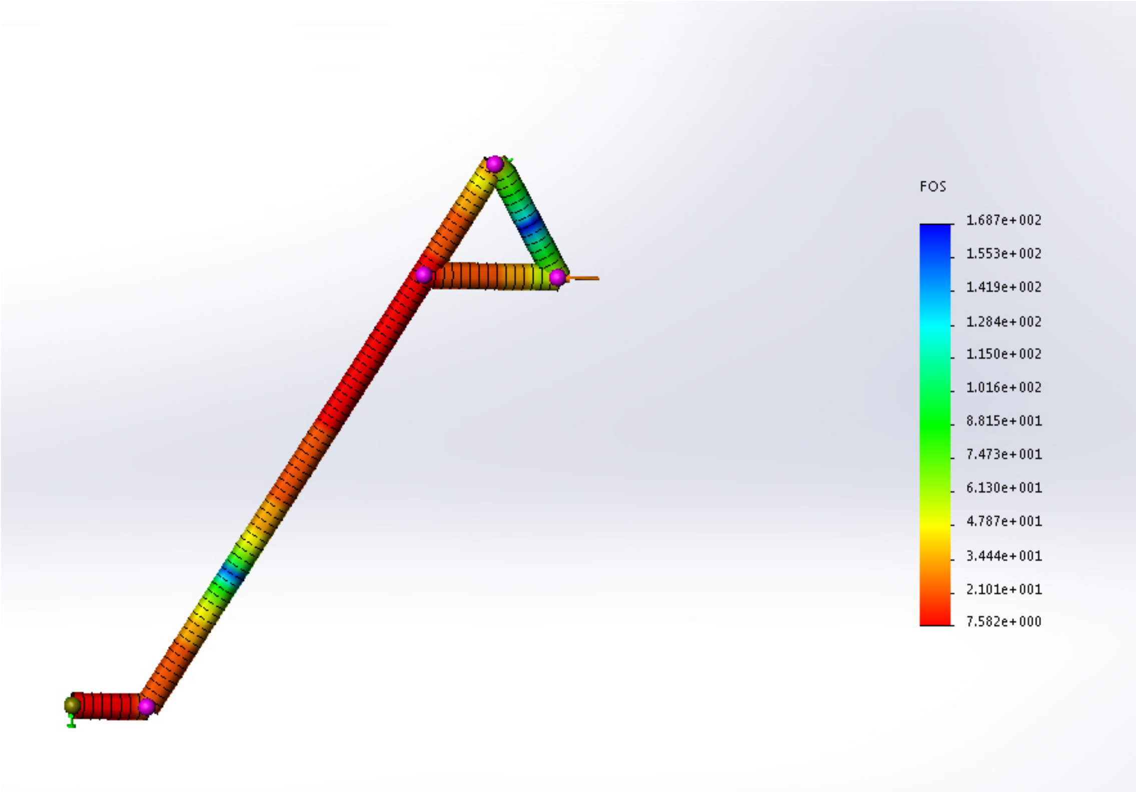

Figure 13: Here we see the FEA for the weldment that makes up the majority of the harvester arm. Stress is spread over the length of the arm and even at its worst, the FOS is greater than 7.

The other location where we could expect failure would be the rods that support the knurled cam tongs. When subjected to ten pounds of force downward, for a total of twenty supported pounds when considered in tandem, they deform as expected with stress concentrations at the locations of the retaining rings.

The location of force application, and therefore the lever arm transmission ratio, was influenced by the pragmatic constraints of commercially available actuators whose throws are mechanically limited.

Power

With the above lever arm, power is transmitted from the linear actuator to the cams and then to the plant. In order to calculate the power we required, we used the lever arm ratio to estimate the amount of force needed to harvest. From these calculations, we arrived at a value of 120 pounds of force needed at the point of the upward force. For a comfortable safety margin, we decided on an actuator that is designed to deliver up to 900 pounds of force.

Figure 12: the harvester is motorized with a linear actuator. The one we spec'ed for this application can supply more than five times the anticipated force which will let us pick even the most stubborn plants.

This component could be changed out later in favor of a faster actuator, but this iteration focused on providing more than enough force at a slow speed with the assumption that our machine can run 24/7. Such a change in internal gearing of the actuator is relatively cheap and could provide useful insight in later iterations of this project.