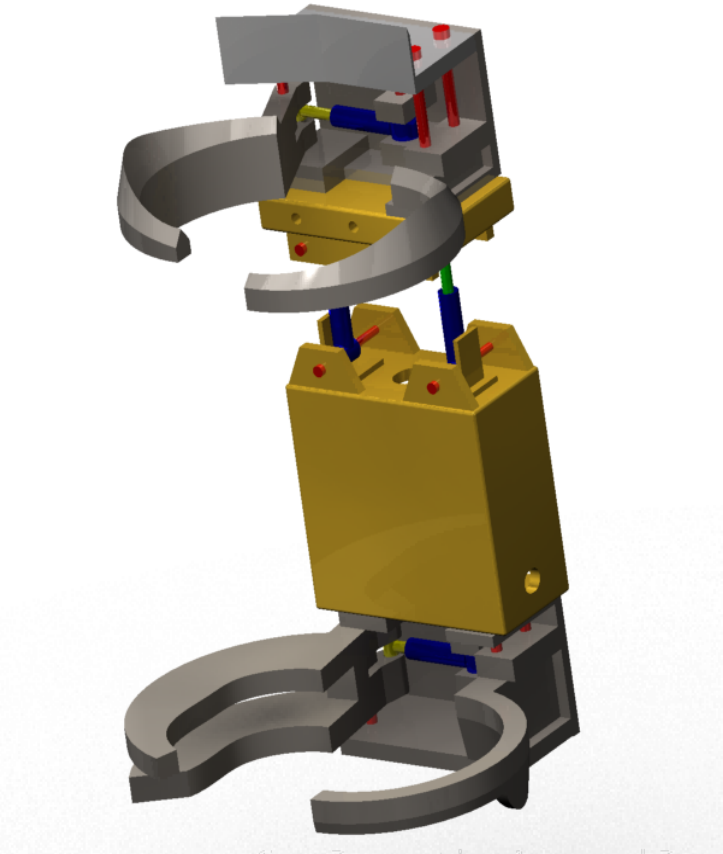
TREE LIMBING AND HARVESTING ROV

Introducing "The Bear"



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Abstract

Tree harvesting practices create great risk to human safety and damage to surroundings. For example, many trees have fallen on cables, nearby houses, and people. In addition, harvesting trees is expensive to the average consumer due to the dangers that arise. Our team is engineering a machine that can climb and de-limb a tree. Part of this project will include initial design work to implement the feature of sectioning a tree but is not a priority within the project scope. A worker will control this machine at a safe distance, to avoid falling limbs. The machine's name, The Bear, comes from the way it climbs a tree like a bear. A Hydraulics system powers The Bear, which consists of two clamps to grip the tree trunk. The top clamp acts as the bear arms and the bottom clamp acts as the bear legs. The Bear climbs up the tree, using these two clamps. The top clamp has a de-limbing blade to remove limbs as the device climbs. As The Bear reaches the top of the tree, it will begin to section the tree from the top as it climbs down. Once again design work on the sectioning procedure will not be a focus throughout this project. The project sponsor Mr. Jeff Phipps, assisted in funding for equipment and materials as well as feedback during the progression of The Bear. Florida State University professors Dr. McConomy and Dr. Clark for the mechanical engineering department also provided mentorship and advice for the final design of The Bear.

Introduction

To cut down a tree today, there are two methods that are in practice. The first is a human operated machine, called a total tree harvester, and is seen in figure 1. While this method is safe and easy, it is incredibly expensive and many times the machine is too large to fit into residential neighborhoods. The second method is someone climbing the tree to cut it down in sections. This can be seen in figure 2. This is the method that is common practice for tree harvesting in urban environments. While not as expensive as method 1, method 2 can still be very expensive due to the dangers and difficulties of the workers. Workers in the lumber industry have a 3 times higher fatality rate than the average US worker [1].


Figure 1 (left). Tree harvester cutting down trees.
Figure 2 (right). Worker unsafely using chainsaw to de-limb the tree

As you can see, there is a need in the market for a way to cut down a tree in an urban environment that is safe, easy, efficient, and cheap. Our sponsor, Jeff Phipps, realized this and gave us the task of creating a third method that would resolve these issues. His goal for us was to create a remotely operated vehicle (ROV) that could climb a tree, de-limb it on its way up, and section the tree on its descent.

Methods

Functional Methods

- **Secure to tree:** Target values were assigned for the minimum and maximum opening width, maximum clamping pressure, and minimum clamping force to climb and de-limb a tree. After researching dimensions loblolly of pine trees in the southeast United States, 25 inches was about the average diameter found. The reason for researching properties of a loblolly pine is because it's a commonly found pine tree in southeast United States and chosen as our target tree. The following list are different systems that could possibly secure the ROV to a tree.
    - *Hydraulics:* The benefits of the hydraulics is its capability to exert a large force output for its weight, while maintaining the force constant. However, since fluids are used to maintain the force, there is a chance of fluids leaking. If the fluids leak, a loss of pressure will occur. Another disadvantage to hydraulics is the extra parts. Pump, lines, and the fluids themselves would all have to be either carried by the ROV, adding to its payload or the pump and fluids would be stored separately, which results in the fluids having to overcome gravity to reach the ROV.

- **Climb Tree:** the ROV must be able to climb the tree once it removes a set of limbs. A target that was discussed was the climbing rate. This provides a comfortable speed that is considered safe without risking any potential harmful events and shows the ROV running efficiently.
    - *Climbing motion - Prismatic joint/ hydraulic cylinders:* For a prismatic guide, the top and bottom sections of the ROV would be attached by the hydraulic cylinders that act as a prismatic joint. This would reduce the stress on the ROV. The climbing motion of the ROV will result in a bear-hug manner where the hydraulic cylinders will push up or down one part of the machine, as the other holds on to tree.
    - **Delimb Tree:** The precision of the delimbing tool, or how close to the tree the removal must be is determined. The delimbing precision must result in a small enough obstacle for the ROV to climb over and delimb the next branch. The amount of force necessary to delimb a tree is important since it varies based on the branch diameter. A target for the minimum and maximum diameter of the limbs that will be detached was assigned to be 1 and 5 inches, respectively. This was determined by researching the average diameters of branches of pine trees.
    - *Shear:* Shearing is an efficient delimbing method because it results in the least amount of moving parts compared to other methods. The mechanism wraps around the tree and shear any limbs in that range when pushing upward. Shearing though requires large amounts of force.
- **Control ROV:** a link must be formed connecting the user to the ROV controlling the de-limbing and climbing operation. A target distance must be met between the controller and the ROV to ensure a safe work area to operate the machine.
    - *Xbee:* Device used to receive radio signal and transmit the signal to the main board. Is compatible with an arduino board that can connected within the ROV.
    - *Controller (gamepad):* an xbox controller consisting of multiple buttons, two triggers, and a joystick that is used to send signals that the Xbee will receive and transmit to the arduino board

Results and Discussion

Targets:

The prototype that we are creating has targets scaled down by about half in order to create a proof of concept model. These scaled down targets can be seen in table 1. The targets were scaled down to give us a more realistic timeline as well as create a prototype with weaker forces.

Table 1. Scaled down targets

Force to Shear Limbs	1800 lbf
Weight	70 lb
Opening Width of Clamps	12-16 in
Min. Clamp Force to Climb	100 lbf
Min. Clamp Force to Shear	1900 lbf
Limb Diameter	1-2 in

Design:

The final design uses two clamping mechanisms connected through a prismatic joint in order to move up and down and shear the limbs of the tree. The clamps and the movement of the prismatic joints are accomplished through hydraulics to generate enough pressure to hold to the tree and cut the limb. The limbing is done through shear force. The process involves the bottom clamp being held in place while the upper clamp would channel up transferring the force and impacting the branches causing them to shear off the tree. The climbing is accomplished in a similar way. After the top clamp fully extends, it then secures around the tree while the bottom clamp opens and channels up contracting the hydraulic arm to its initial position. The bottom clamp once again secures itself around the tree. After de-limbing the tree, the ROV would come back down and a chainsaw would be attached at the top. This chainsaw will be used to section the tree from top to bottom.

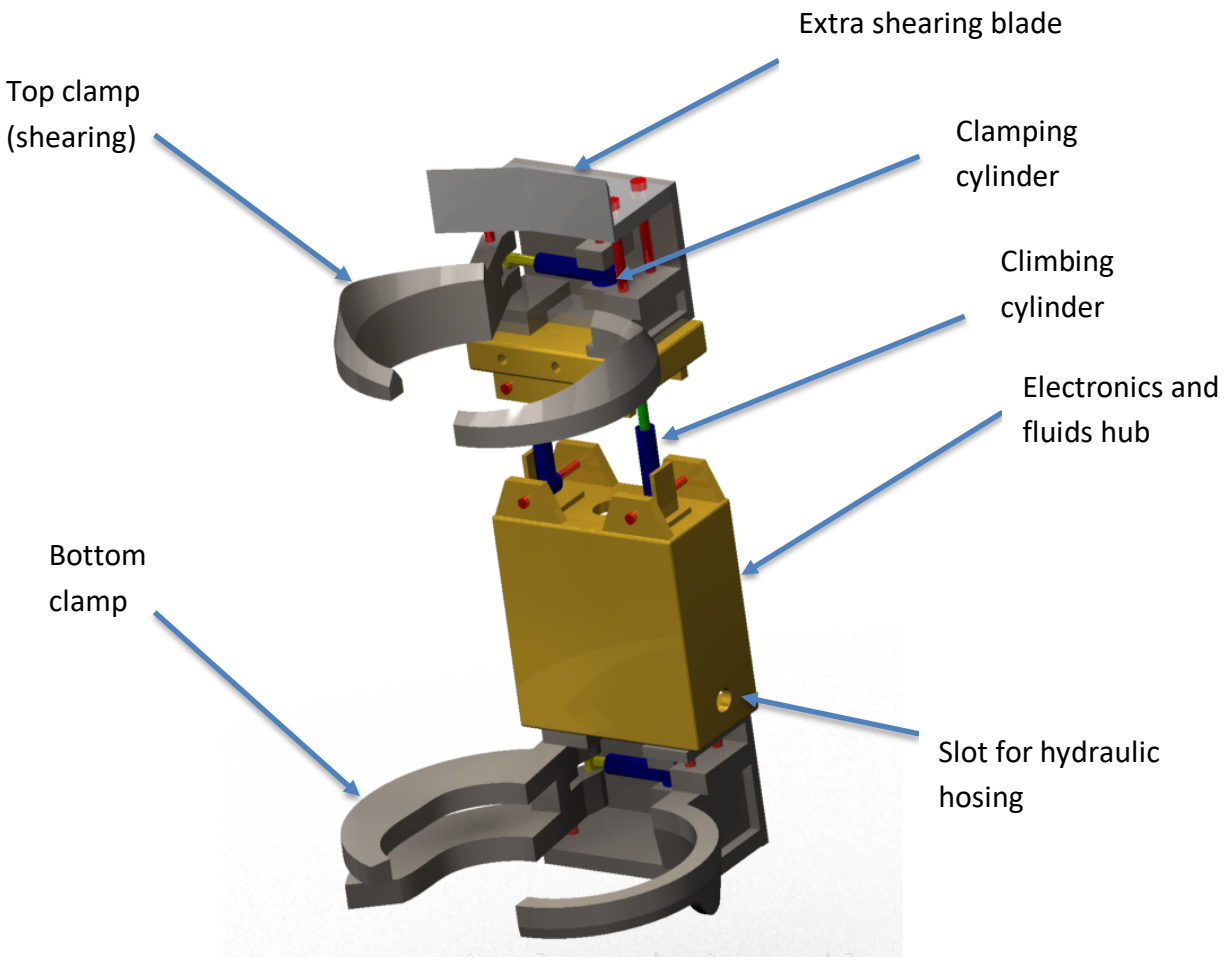

Figure 3. The Bear

Bill of Materials:

- 4 HP gas engine
- Hydraulic pump
- Oil reservoir tank
- Hydraulic cylinders
- Hydraulic hose lines
- Hydraulic fittings
- Hydraulic solenoid valves
- Hydraulic relief valves
- Valve manifold
- Machine parts
- Fasteners
- CPU arduino board
- XBee adapter
- Xbox controller

Building and Testing:

Pre-building

- Ensure that all parts given to us by the sponsor are in working order
- Check if ordered parts fit
  - Hosing, fittings, hydraulic cylinders
- Crimp fittings onto hosing

Preliminary Testing

- Check that engine, pump, solenoid, and valve manifold work
- Hydraulic unit set up ensuring the unit as a whole could move more than one cylinder
  - Ensure no leaks
- Force analysis on individual cylinders
- Test electronics
  - Ensuring that that Arduino Board, XBee, and controller worked in accordance

Initial Assembly

- Ensure that all clamps output the correct force
- Check that climbing cylinders are outputting correct force
- Check that electronics work for assembly and can control clamps and cylinders

Full Assembly (attached to tree)

- Check that ROV clamps to tree and cylinders are in working order
- Complete a full cycle (climb and delimb)

Conclusion

Tree removal has always been a common practice for the timber and deforestation industry. It has greatly improved with the help of heavy machinery known as tree harvesters. Though these machines work effectively and can prepare tree logs quickly, they are expensive and large which is difficult in the urban environments. The idea is to remove a tree before it causes potential damage to pedestrians or their property. The goal for this project was to design and build an ROV that is portable and effective at delimbing trees. Due to limited time

and funding, the tree removal part of the design was kept in mind but not part of the project scope.

After researching different tree harvesting machines, inspiration for the design came from a stroke tree harvester. This harvester uses a clamping mechanism to climb and is powered only by hydraulics. The Bear design was engineered based on the collaboration of multiple team members and through engineering analysis. The Bear was built after multiple tests were done on the hydraulic and electric controls. Having successful results during final test stages, The Bear is set for future improvements and potential job opportunities. This project was successful with help of advisors, professors, and the sponsors that participated with the funding and inception of the idea to solve common problems in the world.

Future Work

Finishing observations were done to better prepare future groups who will continue the work on the tree removal process. The scope will expand and focus on how the ROV will cut down trees. The Bear was designed to be easily assembled and disassembled giving it a customizable component which also helps keep the machine lightweight and portable. An attaching mount was kept in mind when designing the ROV so that a possible cutting tool can be attached and used to section off levels of the tree once it has reached the assigned height. We have prepared a section with possible solutions for the removal process of the tree that can assist future groups in the right direction.

References

[1] Gollan, J. (2016, April 21). Tree trimming deaths alarm federal officials and industry insiders. Retrieved October 15,2017, from http://www.revealnews.org/blog/tree-trimming-deaths-alarm-federal-officials-and-industry-insiders/.