

Halloween Guillotine Project



Project summary

I'd seen a lot of guillotine Halloween props, but I wanted to design one that had a more theatrical element to it. The basic idea was for the blade to raise on its own (as opposed to the traditional manual raise) and for the head to get chopped off and fall. I also wanted full automation for resetting, so there would be no human involvement on game day. Motion would be detected, the blade would fall, head gets chopped off, and after people leave, everything would reset, ready to scare the next victim.

Design Challenge

I had laid out some basic constraints/requirements for what I wanted this year:

1. Aesthetics! It needs to look good
2. Fully synchronized subsystems
3. Reliable and durable for hundreds of runs throughout the night
 - a. Fail safe and reset mechanisms
 - b. Strong structure
4. Smooth movement: no clanky or unrealistic blade or head physics
5. Modularity: every subsystem should be easy to replace in case of failure, not locked around others
6. Safety: last year I had some issues with some kids getting really close to the box, and this year I wanted to ensure nothing could harm onlookers
7. Salvageable: since I take apart these things after Halloween, I'd like to keep it easy to move and take apart so I can repurpose materials and electronics for future projects

Initial Brainstorming

Below are some images that I took inspiration from when brainstorming





Early in ideation, I took a look at existing Halloween props and guillotine replicas on google and YouTube to understand motion, structure, and how they shaped audience perception. The inspirations shown here helped me form some baseline ideas for what I wanted/didn't want:

- **Common likes:**

- Tall, open wooden frames created grand silhouettes visible from a distance.
- Gravity-driven blade physics felt way more convincing when motion was fast and unobstructed.

- **Dislikes / What I avoided:**

- Some of the ones that were fully motor driven on the descent felt kind of robotic and lame.
- Some props used heavy or sharp blades and labeled them as “functional”, which looked cool but introduced real risk... this conflicted with my safety-first constraint.
- Certain builds felt **clunky or noisy during resets**, breaking the illusion and making motion feel overly robotic instead of dramatic.

- Frames with a high center of mass looked really unstable. Some of the builds were visibly rocking as the blade went up or when someone simply touched it.
- **Takeaways applied to my design:**
 - Use **lightweight building materials (pine wood maybe), non-sharp materials** (foam/PLA) for impact parts to maintain illusion without harm.
 - Have all moving components be as quiet as possible to uphold the illusion
 - Keep the structure wide-based and stable, hiding actuation hardware inside the structure while preserving a clean exterior. Some sort of stain or paint would do nicely to give it a nice finish.

Subsystem brainstorming

Motor selection:

- Stepper motors would fit my need best, as they offer a good amount of speed and torque, but shine from an accuracy standpoint. DC motors are fast and can have good torque, but in order to attain precision, I would need to use something like an O-drive. Servos are too slow and are limited to 180 degrees of movement, and therefore also do not work.
- For the blade raise mechanism, I came up with a few ideas on how I could have motor controlled ascent but free-fall on the way down.

- Power Take Off: by using an electromagnetic solenoid or linear actuator, I could shift the gears out of place to allow for the driving gear to slip in and out of meshing to allow for both freefall and powered ascent.



- Pros:
 - Long travel and reset possible with one actuator path
 - Descent is fully gravity-driven, looks natural
 - Easy to trigger electronically (solenoid/linear actuator)
- Cons:
 - More mechanical parts = more alignment tolerance issues
 - Can be noisy during gear shift + not shift at all! :D

- Needs guarding to avoid accessible pinch points
- Slip gear mechanism (similar to the intermittent Geneva mechanism, but with more actual rotation): By cutting off teeth from a section of the gear, it is able to drive the driven gear for most of the driving gear's rotation, but also allow for freefall as it slips



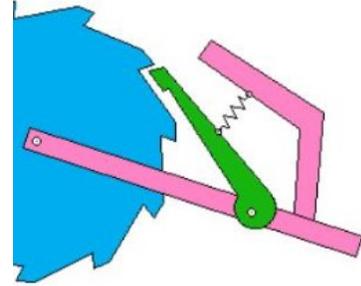
- Pros:
 - Simple to fabricate and iterate (laser/3D print friendly)
 - Inherent mechanical forgiveness protects drivetrain
 - No direction reversal needed for free-fall
- Cons:
 - Timing window is fixed by tooth gap, less runtime-tunable
 - Wear concentrates at tooth edges
 - Harder to auto-home if slip region is large

- One-way clutch or freewheel mechanism: By putting a one-way bearing sprag clutch or like a bike freewheel between the motor and the lift spool, the system can transmit torque only in the lift direction. This provides powered ascent when the motor spins the “engage” direction and free-fall descent when the blade pulls the spool the opposite direction and the clutch overruns (disengages automatically), letting the spool spin freely so the blade can drop under gravity.



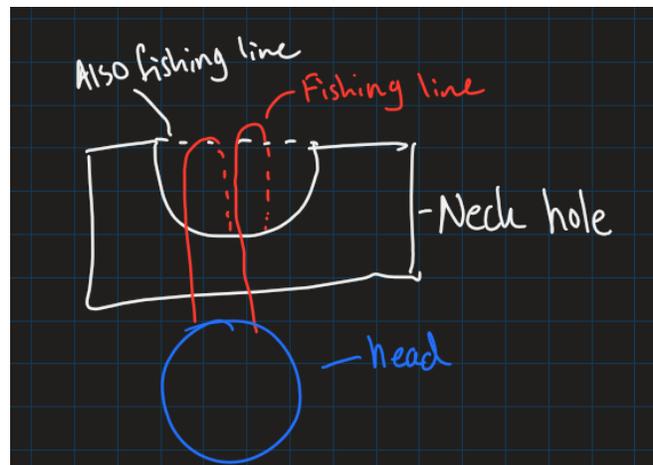
- Pros:
 - Cleanest kinematics: no release timing logic needed
 - Very reliable for repeated autonomous cycles
 - Quiet priming; zero backlash during lift
- Cons:
 - Clicking.
 - Can overspeed if load is heavy and unbraked
 - Harder to 3D print (usually bought components and salvaging from bike may be too big and expensive)
- Ratchet + pawl release: By using a ratchet wheel on the lift spool and a spring-loaded pawl, the motor can lift while the mechanism prevents back-

driving, then a small actuator can release it instantly for a drop. This is similar to PTO but a little more compact



- Pros:
 - Strong intentional lock during lift, high safety confidence
 - Release stroke is extremely fast and crisp
 - Easy to fabricate and test standalone
- Cons:
 - Clicking.
 - Needs a spring or secondary force to ensure consistent re-engagement
 - Requires deliberate reset sequencing after each drop -> slow
- Ultimately, I chose the slip tooth mechanism because it is also by far the easiest to customize and 3D print in a hobby making context. A close contender was the one-way clutch, but designing one of them from scratch is a pain.

- For the head drop mechanism, I decided to go with the exact same mechanism, having it hidden behind the basket as opposed to at the top though. To preserve the illusion, I didn't want to have any pulleys mounted inside the neck hole, so instead I decided to use a piece of fishing line as a sort of invisible pulley



- I wanted to have some sort of theatrics as well, and so I decided to have some individually addressable LED strips to provide a more smooth set of effects. As I am already comfortable working with the WS2812B 5v LEDs I just decided to use WS2815 12v strips to reduce the overall current requirement.
- For sound I took apart some old speakers I had lying around and used a DF3 module to store and select MP3 files using the Arduino
- For control I decided to use an Arduino uno microcontroller just because I had a couple on hand.

Design Phase

I CADed out a first iteration of the guillotine just to get an idea of what the footprint would look like.



I also added an abnormally large topper in order to house and conceal the winch system. I realized that this would make the entire thing pretty heavy so this helps a bit with that, but I still need to work on making the base extremely stable as I just made the center of mass way higher.

I added a carriage for the blade itself to make it more stable and give it more weight. I decided to make the blade itself out of foam in order to keep it safe for display, but the carriage, which couldn't come in contact with anyone, could be made out of a stronger wood.

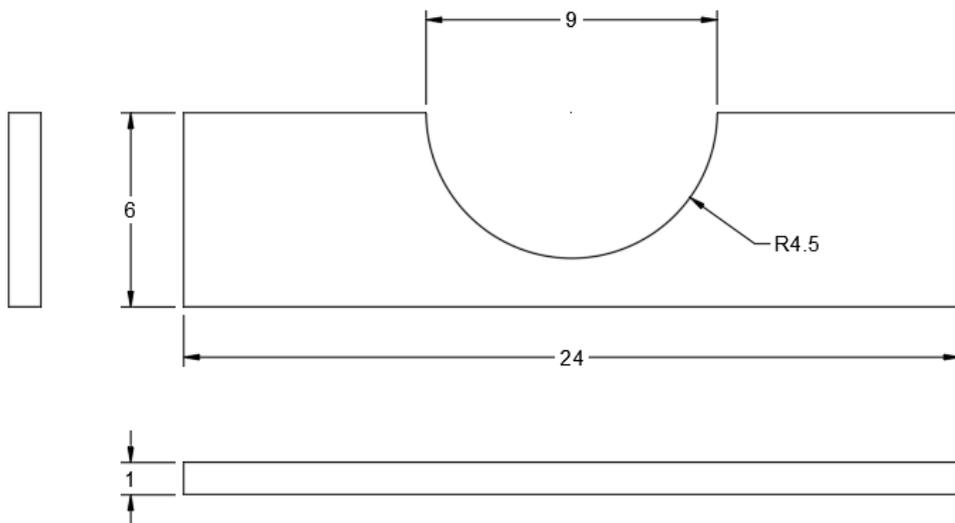
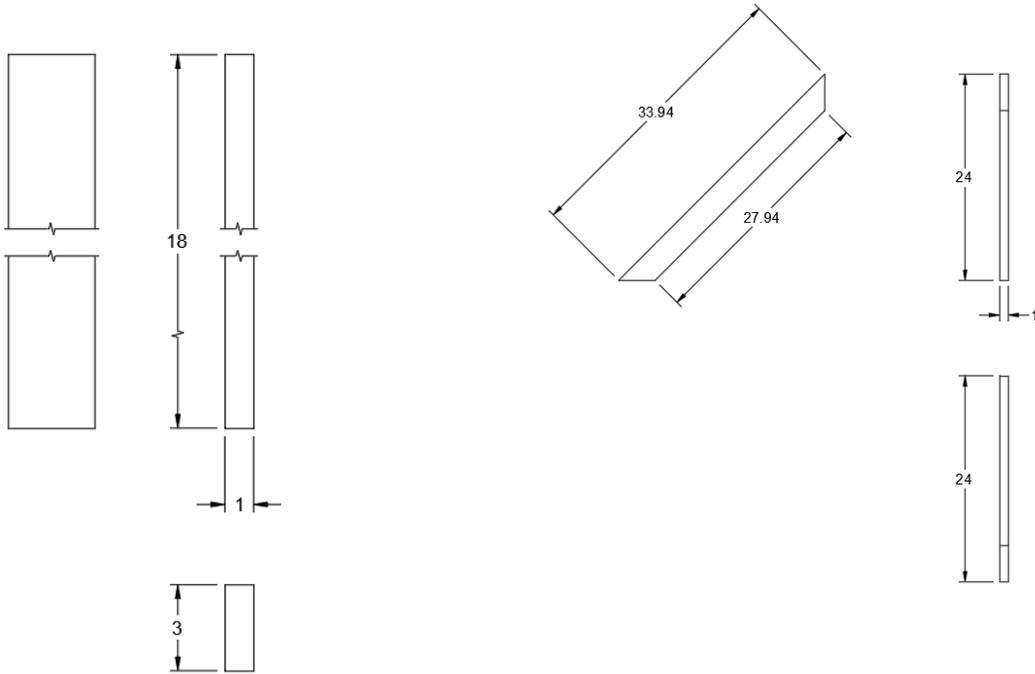
I decided that I wanted to conceal all of the electronics and wires on the underside of the table bench thing, so that aesthetically the exterior looks nice and clean.



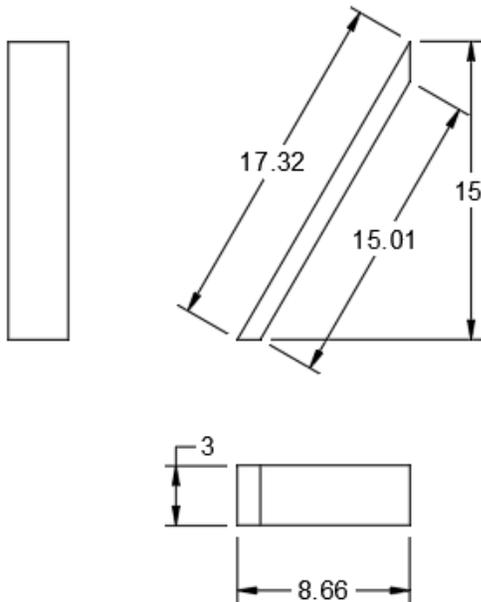
After I had a clear idea of what the entire system was going to look like at a high level, I made a more detailed CAD model comprised of the exact dimensioned wood cuts. This is also when I drastically reduced the height of the thing to make it more manageable to build (12 feet to 8 feet tall). I added side supports to ensure it wouldn't topple over and made the design a little sleeker for weight.

Build

I decided to work with 1x3 boards for the most part, providing ample strength for not a lot of weight. These are the cut diagrams I made so I could get the wood cutting out of the way for the preliminary build:



These made life easy while cutting because especially with the angle cuts, getting accurate dimensions was tough. I

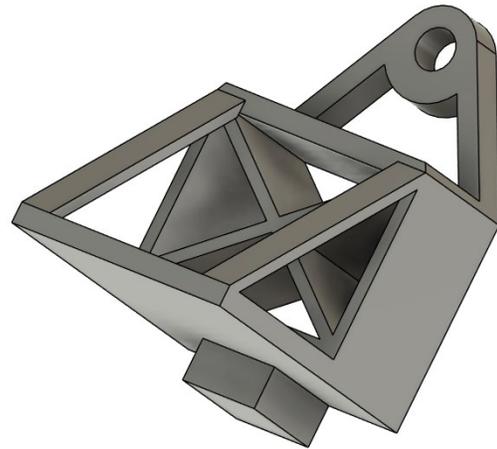
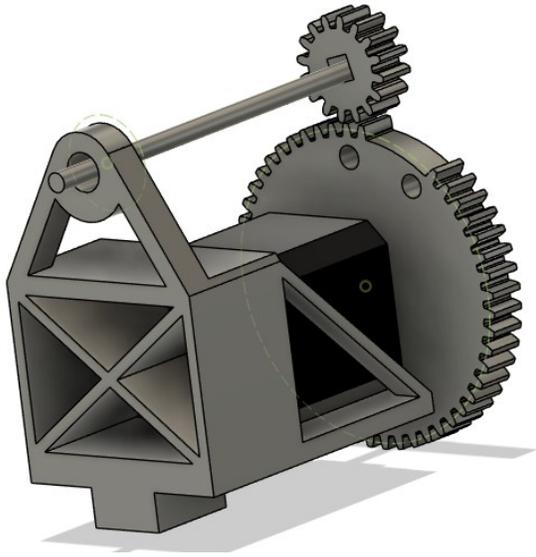


made these cuts using a jigsaw and drew two parallel angled lines, one as a reference to align the jigsaw and the second to ensure the cut was going in the right trajectory. Pictured



on the left is where that came in particularly useful, as I was able to measure the top and the bottom lengths to ensure the 45 degree angle was good.

I designed these mounts to fit into the channel groove so they wouldn't come out, the hole at the top for the ¼" axel and the middle to mount the motor.



On the left is what the assembled system looked like with all the 3D printed parts in place.

Coding

<https://github.com/avnish-site/Guillotine>

Code and comments are all documented above.

Problems

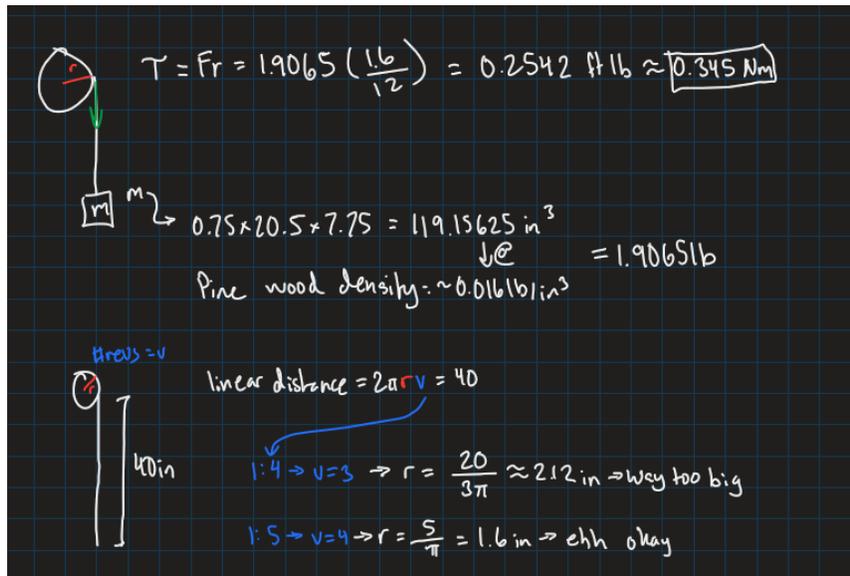
Oh boy there were a lot.

1. Motor didn't have nearly enough torque

Despite doing the calculations for the torque that the motor would need, the actual amount was way greater, and it was much harder to lift than expected. As a

result, the motor did not have enough dynamic torque to lift the blade carriage, so I replaced the wood piece with a foam board cut out of a trifold board instead. This worked great.

2. Heavy misalignment in the two pillars due to heavy wood warping and poor manual alignment during build. When erecting the pillars that the blade had to fall through for the first time, The channels were so heavily misaligned that the blade carriage wasn't even able to freefall through it. This demanded the need for drastically more horizontal supports to tension it back into alignment. Additionally, relating to #1, I forgot that the pulleys would not be pulling straight up and rather be pulling at an angle, introducing an extra force of friction with the interaction between the blade and the channels and also the angle at which the torque was being applied.
3. Because at the high speeds, stepper motors need pulses to be sent at 100 microsecond intervals, it takes up a lot of the Arduino board's CPU. Because of this, creating smooth animations with the lights caused both to start stuttering. To solve this, I decided to use two Arduinos, hooked up together via the 6th digital pin to communicate. The board controlling the motors was the "Master" and the one controlling lights was the "Slave". I created a case rotation in the code so that every time the slave Arduino received a high state on the 6th pin, it would know to trigger the next effect in line.



- Slip gear not working too well due to the long linear distance that the rope needed to be pulled: the

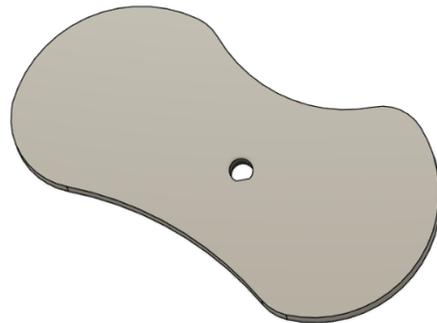
Free fall:
 $\Delta y = 2l \rightarrow @ a = 9.8$
 $\Delta y = \frac{1}{2}at^2$
 $t = \sqrt{\frac{2y}{a}} = \sqrt{\frac{2(2l)}{9.8}} = 2.069 \text{ seconds}$

Direct:
 $\Delta y @ v = 400 \text{ steps/rev}, 400 \text{ microsec/step} \rightarrow 160000 \text{ microsec} = 0.16 \text{ sec/rev} \rightarrow 6 \text{ rev} = 0.96 \text{ sec}$

downside to a slip gear is that all movement must come from a little under one revolution of the driving gear. This means that in order to pull a distance of 3 feet, even with a pulley as big as 3 inches in diameter, the gear ratio was absurdly high, losing a lot of torque in the process. For the head reset mechanism therefore, I decided to just direct drive it by printing an adapter. I had to make sure that the motor at max speed would be able to spin the distance faster than gravity to preserve the illusion of freefall:

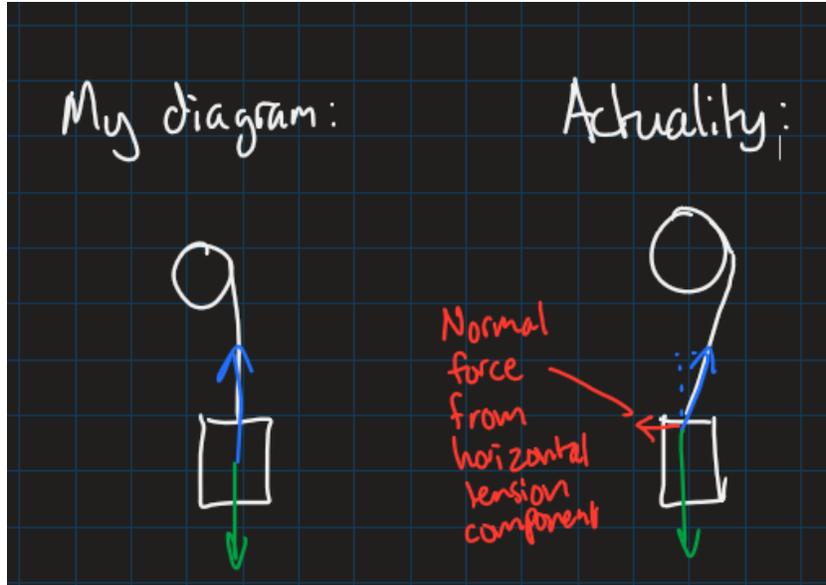
Takeaways/improvements for next year:

- I wanted to add a thrash mechanism to make the man look like he was violently trying to escape, but I ran out of time before game day. It was meant to be an oddly shaped cam mounted to the shoulder blades of the prop, allowing for a jerky, eccentric movement by spinning the stepper motor at a moderate RPM. After discovering how poorly the motors handled external vibration, I'm not entirely sure this would have worked in the first place. For next year's prop, I think that focusing more on delivery would work well to set the stage and add to theatrics.
- Account for heavy friction... I almost had to redesign the raising mechanism because the motor could not provide enough torque to lift the system at the gear ration that I needed it to work at. One major thing that I want to make sure I remember is to recheck how moving systems are applying forces on each other, because one thing that I overlooked at the beginning was the fact that the pulleys would not be pulling directly upward on the blade carriage, and rather pulling at an



angle. This introduces a kinetic friction due to a component of the tension force being perpendicular to the displacement, and subsequently reduces the component of the tension force actually pulling the carriage upward. Obviously this was something I

missed on the first prototype, but I'd like to be a little more intentional about scanning for such details here on out.



Overall a very fun project to work on. My biggest regret, as with many things is not starting earlier. As always, I'm already looking forward to next year!