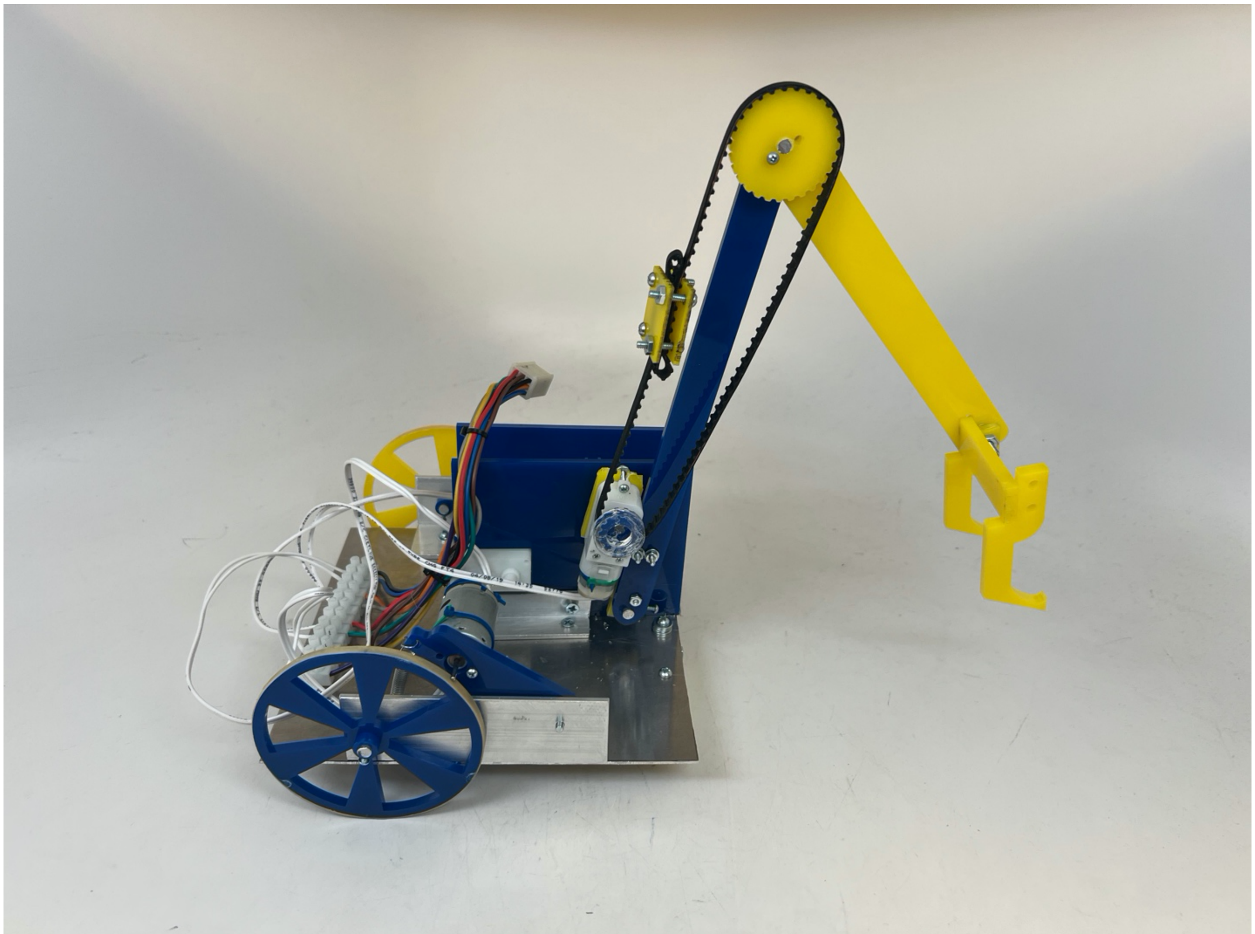
Joseph Pallan
Section: A04



Overview:

Our robot consists of three powered components. A friction driven set of wheels, a bottom arm with 2-joint linkage and a timing belt driven top arm. This report will cover the maximum velocity for the robot to actuate the bottom arm by conducting a speed analysis of the bottom arm geared motor using power.

Component Description:

The gearbox and bottom arm is placed in the center of the robot for reduced parallax errors while being driven.

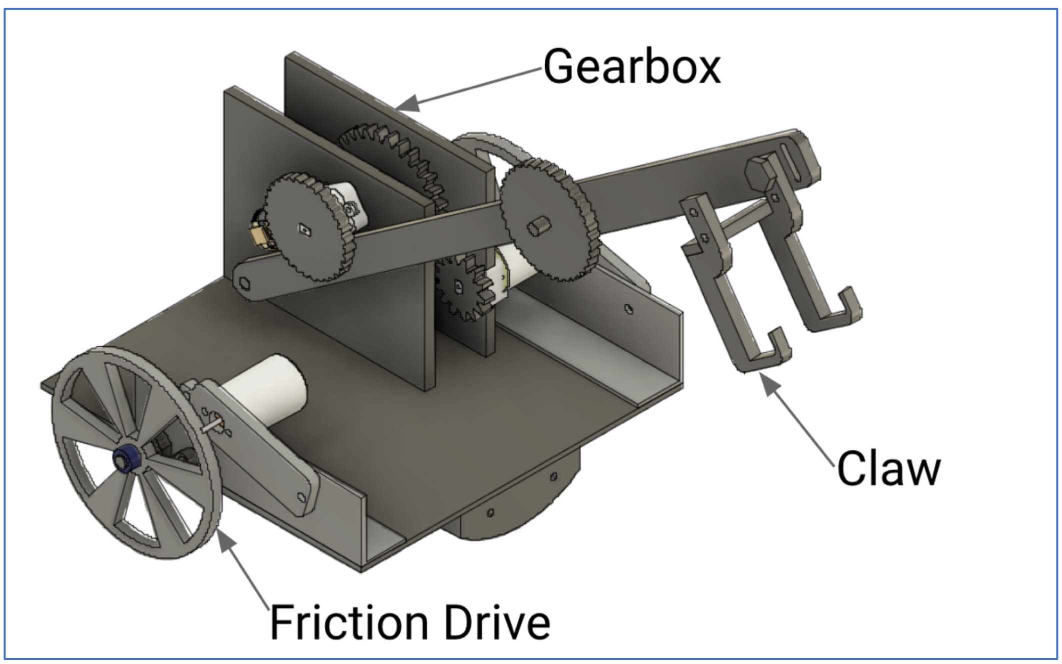


Figure 1) Isometric NE View of robot. Indicating powered components.

Figure 2 highlights the entire bottom arm sub assembly. The geared motor attached on the right-hand side of the figure is connected to the first set of gears.

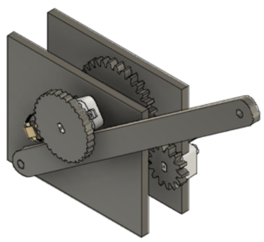


Figure 2) Isometric NE View of gearbox. Bottom arm attached for reference.

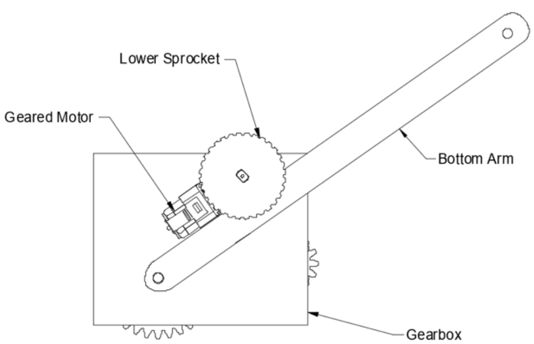


Figure 3) Front View of Gearbox.

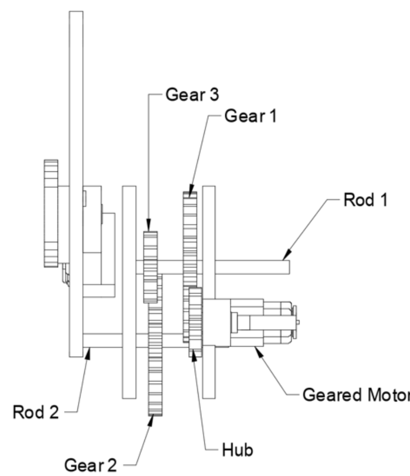


Figure 4) Right view of Gearbox

The functional requirements of the bottom arm that need to be met with a speed analysis using power are:

- Robot must move bottom arm from horizontal position to vertical position (90 degrees).
- Robot must lift arm within 1 second to allow enough time to lift / drop every box (6) on playing field.

Analysis of Powered Bottom Arm:

We're going to learn the maximum velocity of the bottom arm. This will let us find the time taken for the bottom arm to move from its lowest position to highest needed.

Assumptions:

- No friction: there is no friction at the pivot points of the geared motor and hub it attaches to. (optimistic)
- Point masses: masses are concentrated at points. The entire weight of the arm (claw, top and bottom arm, timing belt, etc.) will be considered as a point mass. (optimistic)
- Max Power: the motor always operates at max power. (optimistic)
- Exact clearances: components have exact clearances to operate without any parasitic losses. (optimistic)

Free body Diagram representing analysis:

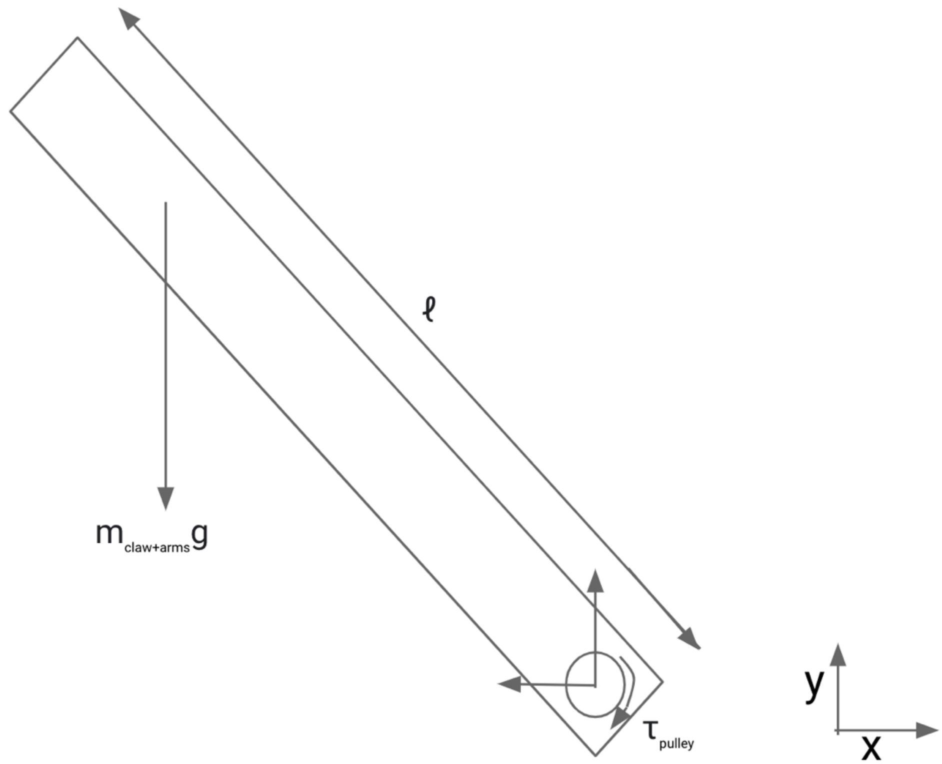


Figure 5) Free Body Diagram of Bottom Arm

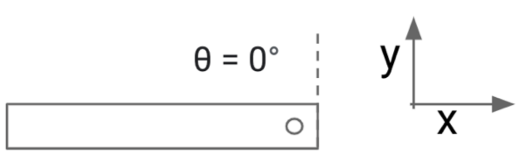


Figure 6) Bottom Arm at Horizontal Position.

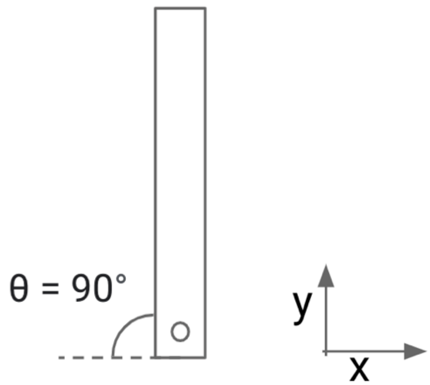


Figure 7) Bottom Arm at Vertical Position. Analysis finds maximum speed at which arm can reach this position by measuring time taken

Calculating speed using timing analysis:

We measured the time taken for the robot to lift its arm from a fully horizontal position to fully vertical position multiple times to achieve a reliable time taken. The radius of the arm was eight inches, allowing us to find the linear speed using its angular velocity.

Speed using Power Analysis:

The Energy to move the arm can be attributed to the equation for rotational kinetic energy

$$E = \frac{1}{2} I\omega^2$$

Where the inertia is approximated as a point mass ($I = m_{arm}l^2$) and ω is the angular velocity as given by $\omega = \frac{\Delta\theta}{t}$

Power is given by

$$P = E/t$$

Combining all the equations and solving for t, we obtain

$$t = \sqrt[3]{\frac{\frac{1}{2} m_{arm} l^2 \Delta\theta^2}{2P}} = 0.312s$$

Where:

m_{arm} = 340g	l = 0.3032m	$\Delta\theta$ = 90 deg = $\frac{\pi}{2}$	P = 0.56W

Power Conclusions:

The average measured time for the bottom arm was $t_{meas} = 0.62s$. This leads to a relatively large error of 49.7%. We believe that our assumption of where the center of mass was is the main reason for this discrepancy. Since the claw + bottom arm and all the other parts of the top arm subassembly such as sprockets and rods were heavy relative to the bottom arm itself, we should've placed the center of mass further away from the pivot point to give us a better estimate. Moreover, since the motor is not always operating at maximum power, it gives us an unrealistic speed estimate when calculating time taken.

If given the opportunity to redo this component, I'd have gone with a 4-bar linkage instead of our current 2 bar linkage. This would've let us have greater control of the arm and reduced the amount of flexion on it as we experienced. Overall, the robot was poorly designed in my opinion, we focused on short term success of fulfilling each week's requirement instead of trying to develop a good robot. I'm not sure how I could do this differently if I were to do it all again since we were at office hours 3-4 days a week and still couldn't design a robot able to score over 100 points. Perhaps a completely different design such as scissor lift, 4 bar linkage stationary robot.

Design Process Essay: Gearbox

The original design for the bottom arm had a laser cut hub that would directly attach to the bottom arm. Our analysis showed that the geared motor did indeed have enough torque on its own to lift the arm from its lowest position. However, upon the component being manufactured and tested, it showed that we were unable to hold the box in position during transit. This was an issue as the box would fall off the claw, or worse, of the playing field.

Our conceptual break-through was to add a Gearbox to the bottom arm subassembly. This would increase torque delivered to the bottom arm and thus proportionally reduce its angular velocity. In theory, it would work perfectly, however we did have issues with implementing it into our robot design. The gearbox needed a mount large enough to hold the large gear sizes we wanted to use. Therefore, to remain within the 10x10 inch size limit, we decided to create a cutout on our chassis (base plate) to reduce the distance at which the gearbox would occupy + reduce overall center of gravity of the robot. Moreover, in order to have a large enough gear reduction factor we wanted (4.5), we added two sets of shafts similar to a multi-gear reducing traditional gearbox. If we'd stuck with a simplified single shaft gearbox, it would've been enough to prevent the arm gliding down during transit. However, it would've remained difficult to control using the controls we were given.