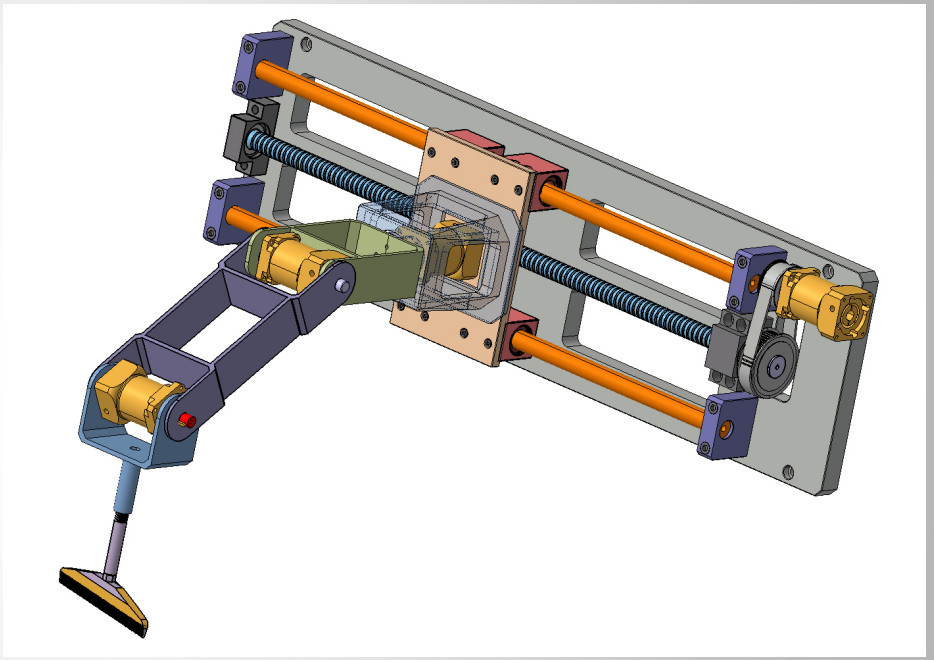
Intro

The DRUNK Robot

Dusting Robot Using Nice Kinematics



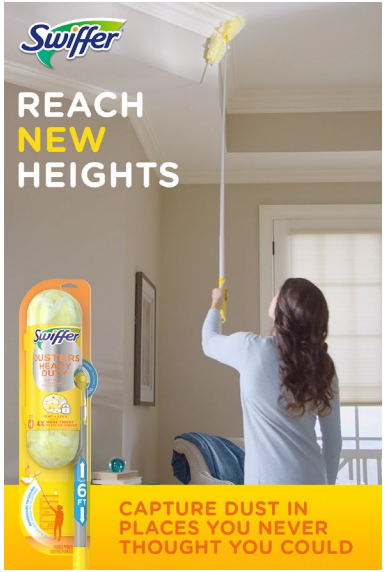
Team 11: Alex Gaal, Austin Tang, Haochen Yin, Tom Wang

Motivation

- Wiping down surfaces is annoying
- Wiping hard -to-reach surfaces is super annoying
  - Ceiling, high shelves, etc.

Motivation

Current solutions are…

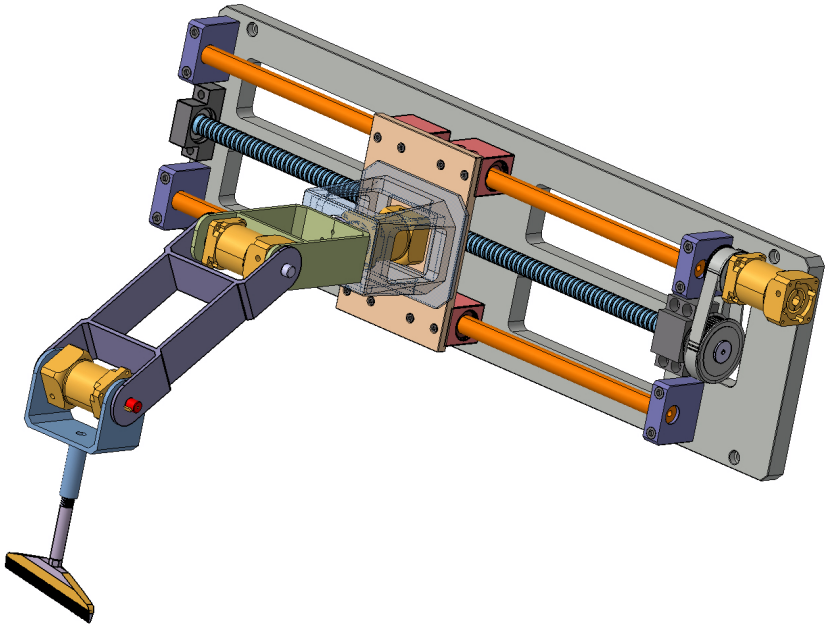


...pretty lame

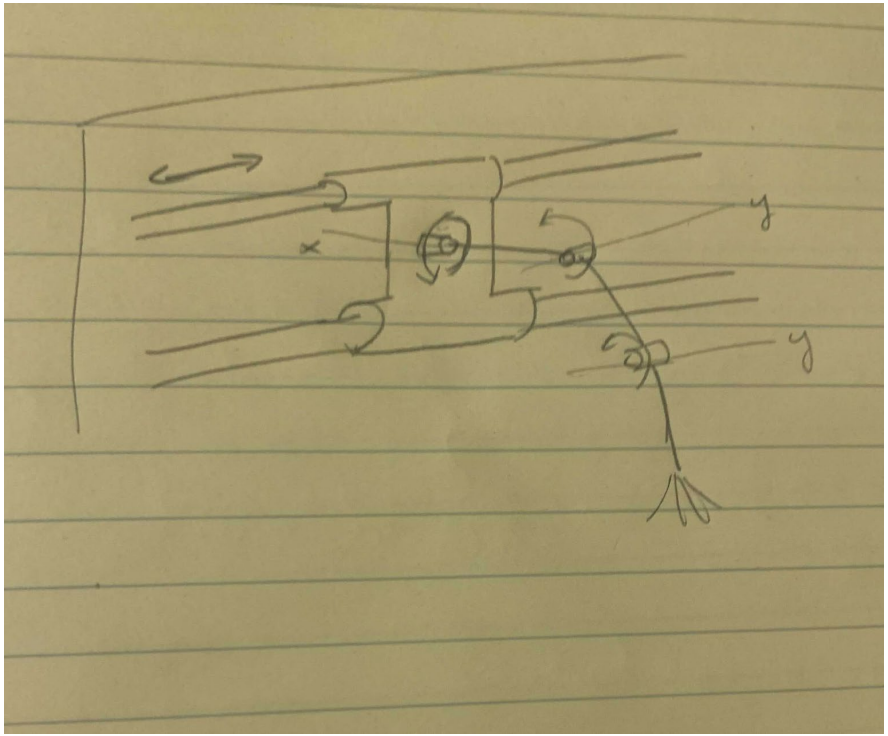
Our Solution

DRUNK

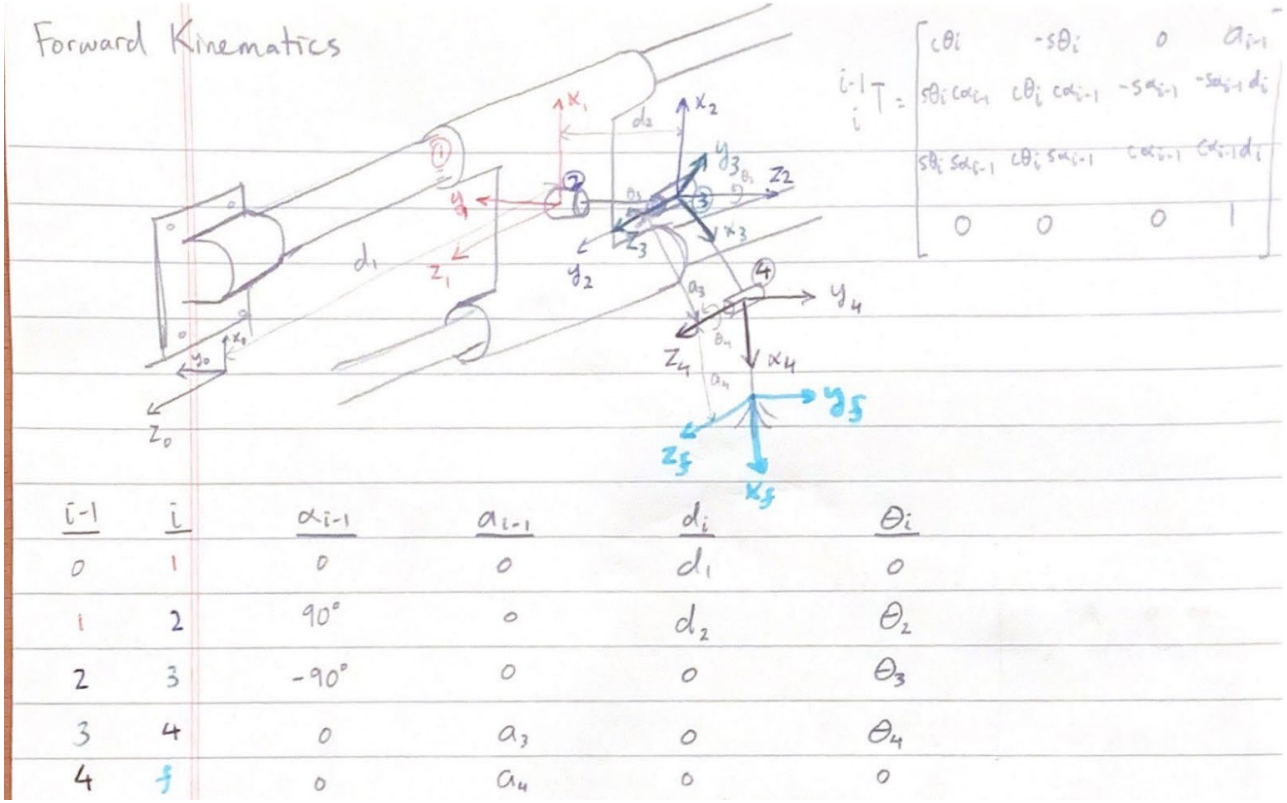
- P-R-R-R
- Mounted on a wall near ceiling
- Interchangeable end effectors
- Cleans high shelves, ceiling, walls



Preliminary Sketch

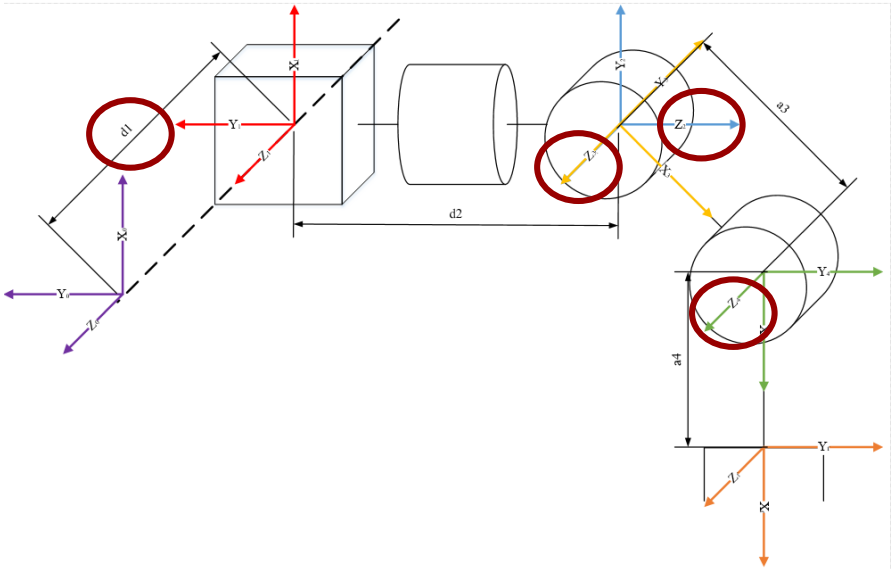


Forward Kinematics



$i-1$	i	α_{i-1}	a_{i-1}	d_i	θ_i
0	1	0	0	d_1	0
1	2	90°	0	d_2	θ_2
2	3	-90°	0	0	θ_3
3	4	0	a_3	0	θ_4
4	f	0	a_4	0	0

Forward Kinematics

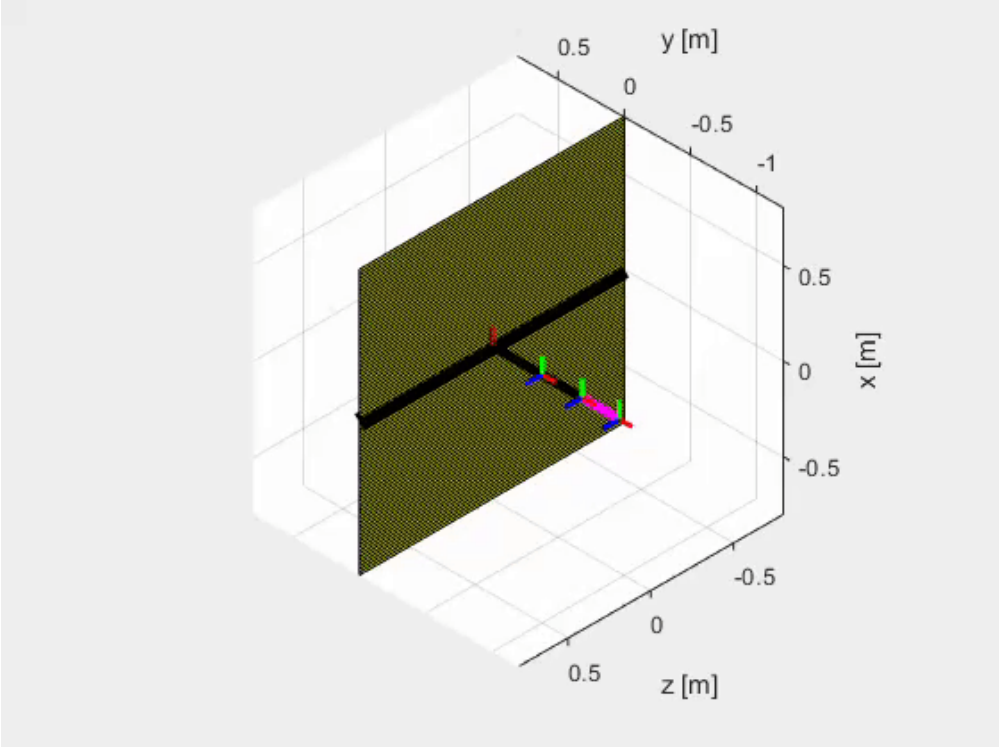


$i-1$	i	α_{i-1}	a_{i-1}	d_i	θ_i
0	1	0	0	d_1	0
1	2	90°	0	d_2	θ_2
2	3	−90°	0	0	θ_3
3	4	0	a_3	0	θ_4
4	f	0	a_4	0	0

$$ {}^{0}_{f}T = {}^{0}_{1}T\,{}^{1}_{2}T\,{}^{2}_{3}T\,{}^{3}_{4}T\,{}^{4}_{f}T = \begin{bmatrix} c_2c_{34} & -c_2s_{34} & -s_2 & a_4c_2c_{34}+a_3c_2c_3 \\ s_{34} & c_{34} & 0 & a_4s_{34}+a_3s_s-d_2 \\ s_2c_{34} & -s_2s_{34} & s_2 & a_4s_2c_{34}+d_1+a_3s_2c_3 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

Forward Kinematics

A Little Demo of our Forward Kinematics by changing each joint variables



Joint Variables: [d1, theta2, theta3, theta4]

Inverse Kinematics

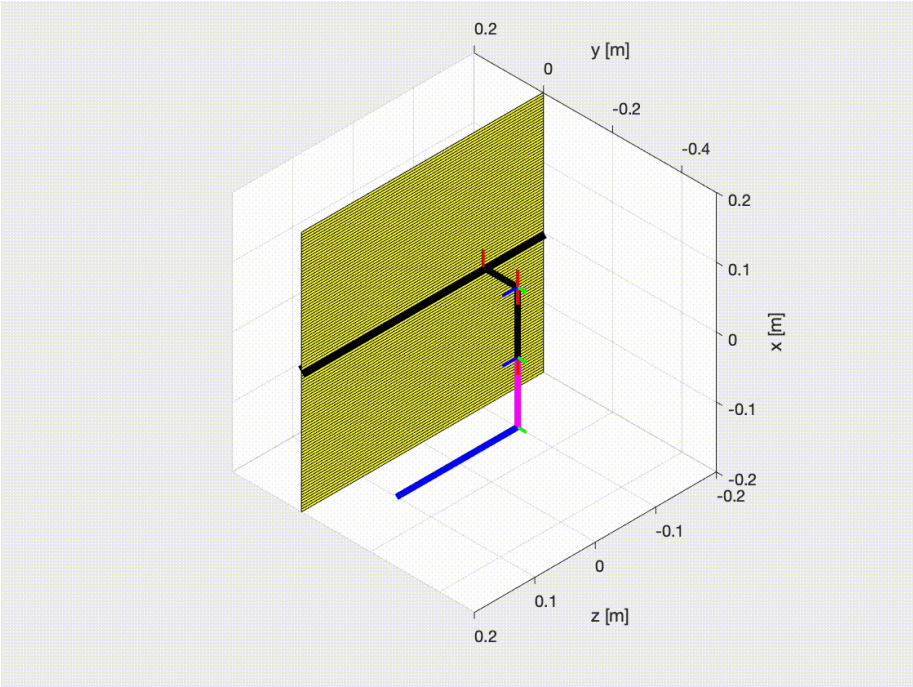
Given ${}^{0}_{f}T = \begin{bmatrix} r_{11} & r_{12} & r_{13} & p_x \\ r_{21} & r_{22} & r_{23} & p_y \\ r_{31} & r_{32} & r_{33} & p_z \\ 0 & 0 & 0 & 1 \end{bmatrix}$

$$\begin{cases} d_1 = p_z + \dfrac{p_z r_{13}}{r_{33}} \\ \theta_2 = A\tan 2\left(-r_{13}, r_{33}\right) \\ \theta_3 = A\tan 2\left[\left(p_y - a_4 r_{21} + d_2\right) r_{33}, p_x - a_4 r_{33} r_{22}\right] \\ \theta_4 = A\tan 2\left(r_{21}, r_{22}\right) - A\tan 2\left[\left(p_y - a_4 r_{21} + d_2\right) r_{33}, p_x - a_4 r_{33} r_{22}\right] \end{cases}$$

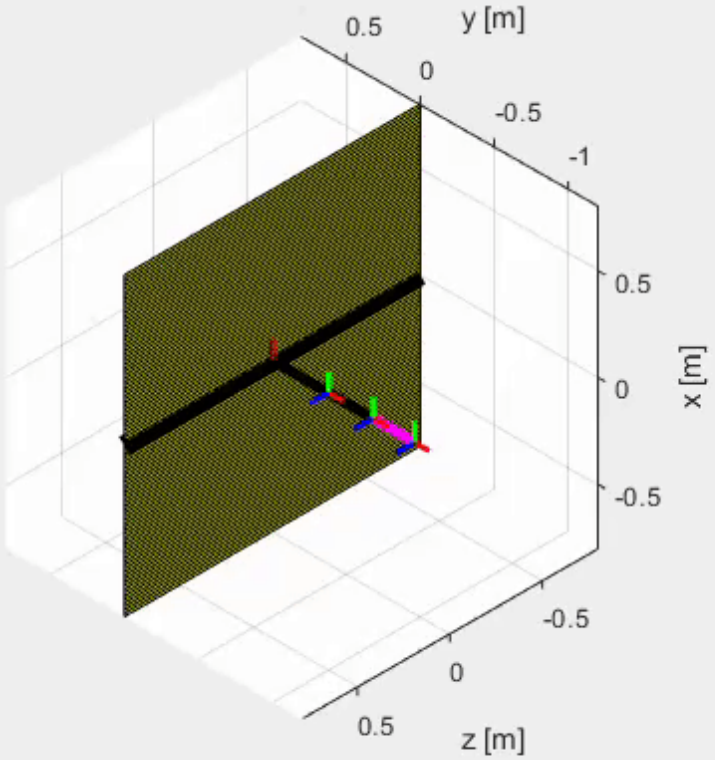
Inverse Kinematics

- First, we tested inverse kinematics with a straight line trajectory and constant orientation

- However, we wanted to create a more complicated trajectory using our inverse kinematics that shows the use of all of the joints...



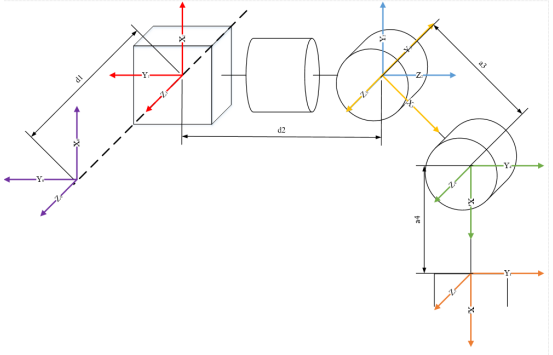
Inverse Kinematics



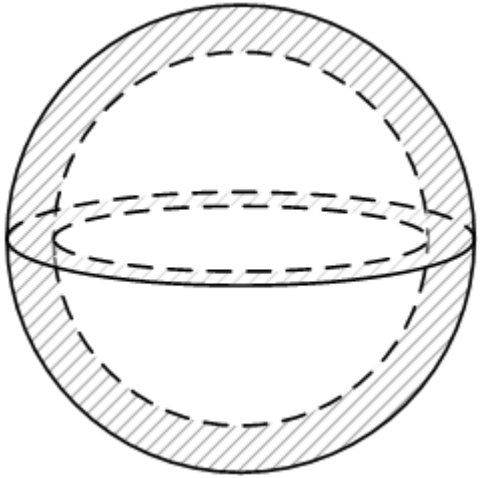
- Remember the more complicated trajectory from 2 slides ago using only the forward kinematics? We were able to reproduce the same animation using the inverse kinematics this time to prove that our inverse kinematics works!

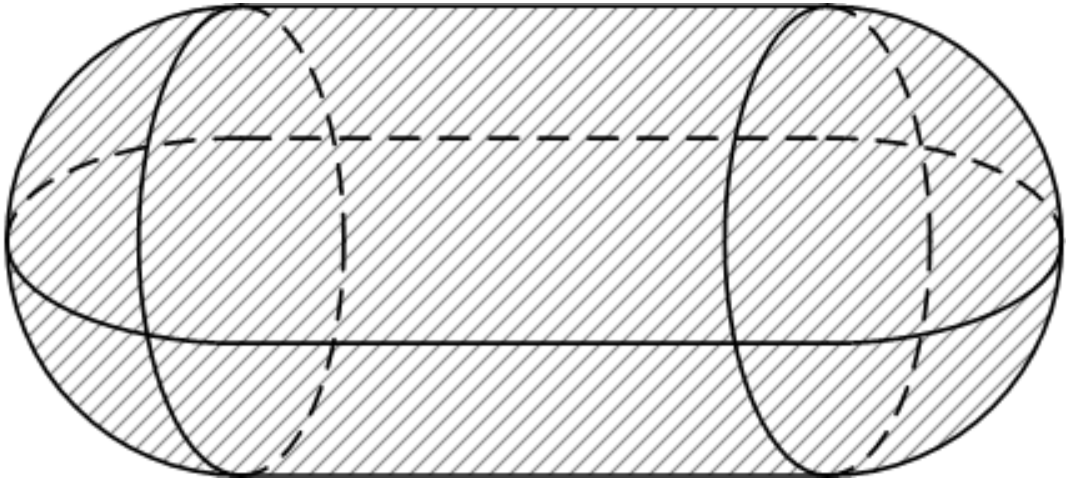
- Now, the challenge is finding more trajectories that may be more suitable to the dusting task that are within our workspace...

Workspace without limitation



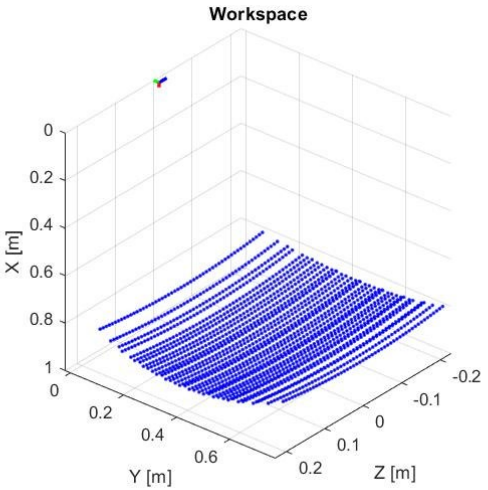
Reachable Workspace:

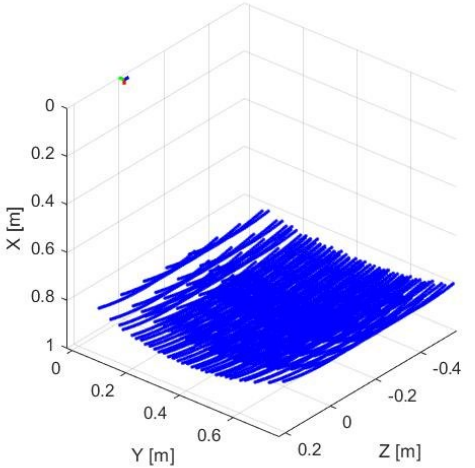




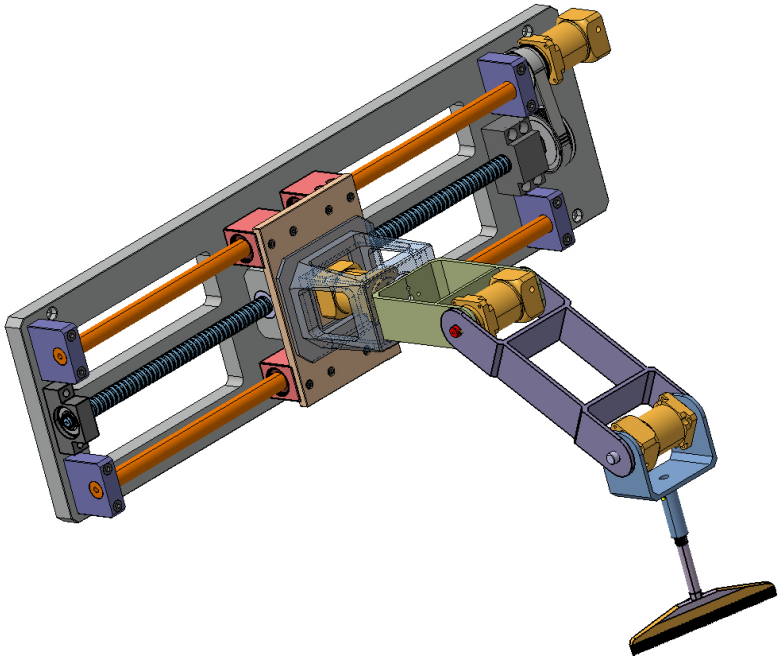
Dexterous Workspace: No.

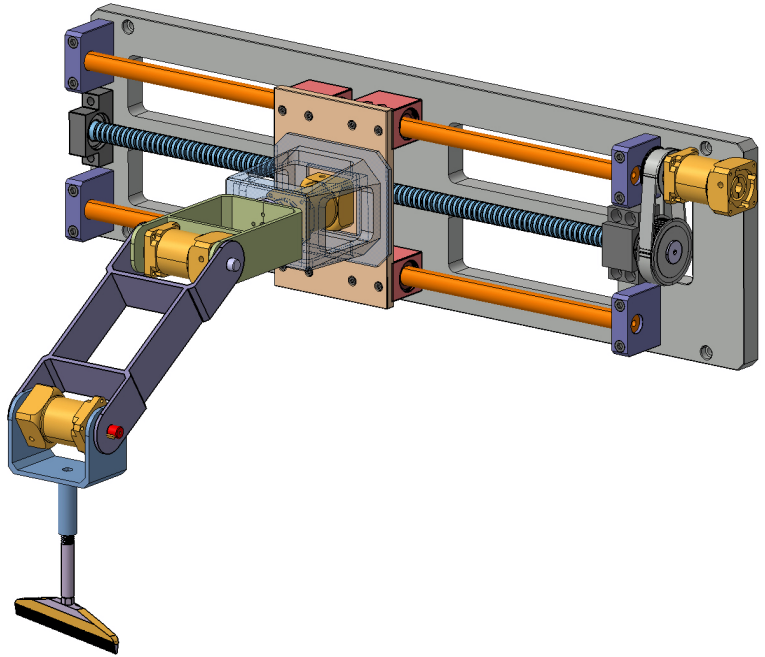
Workspace with limitation



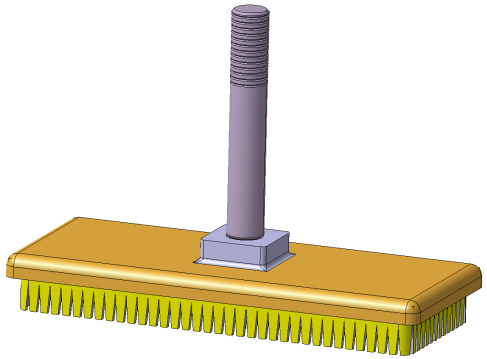


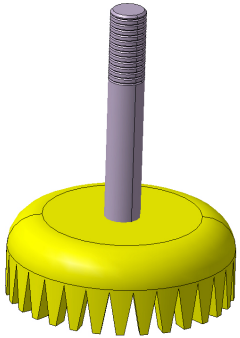
CAD Desig

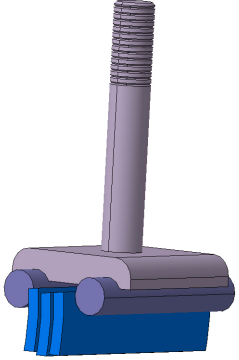


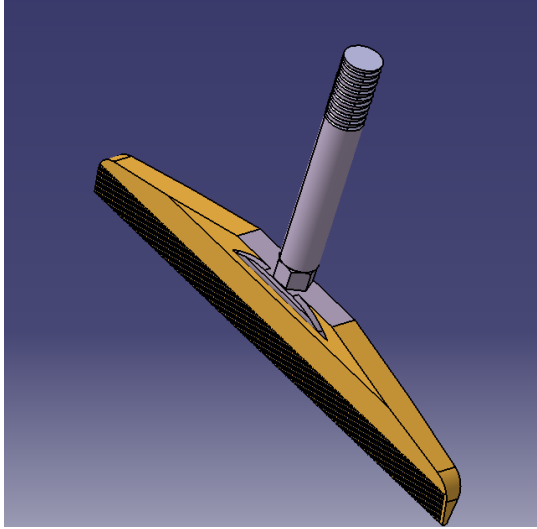


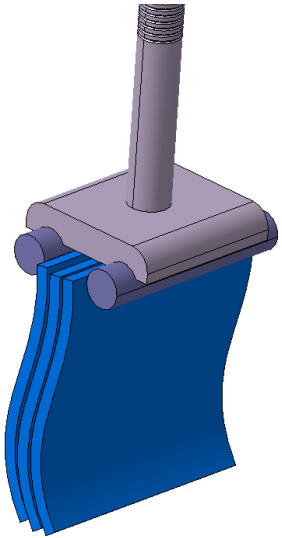
Replaceable End Eff

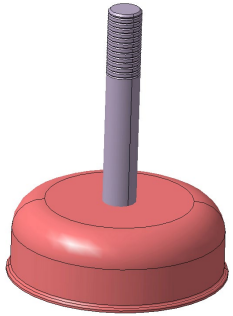


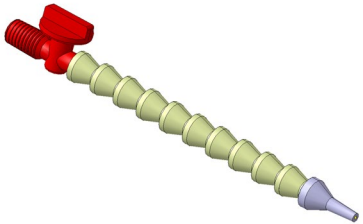


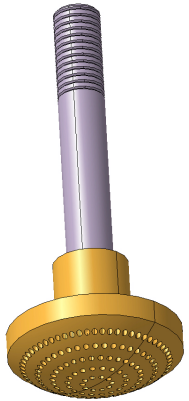






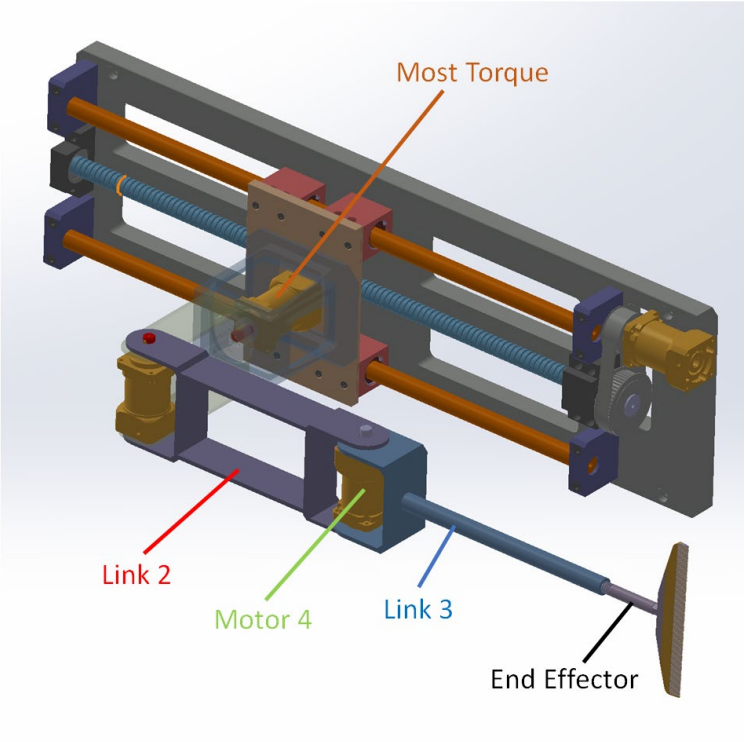




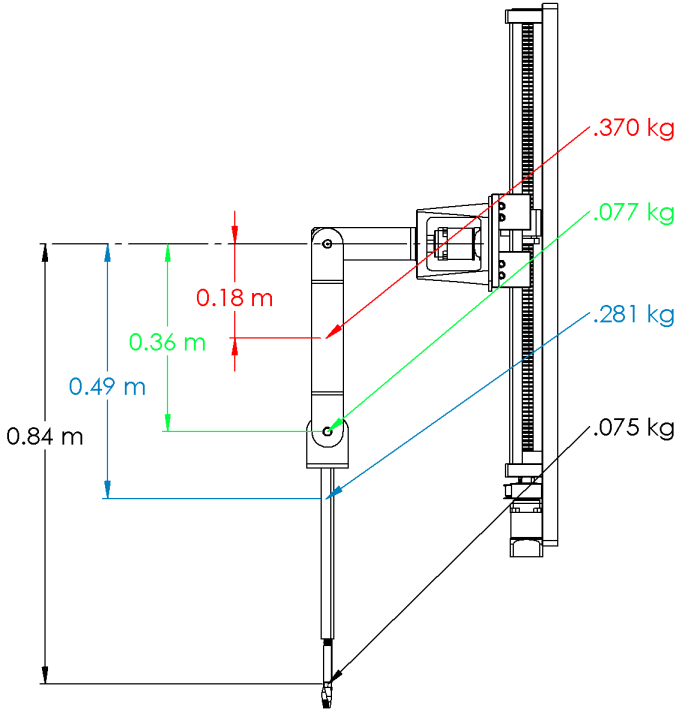


Static Force Analysis

- Put arm in its most “mechanically - disadvantaged” position
- Calculate torque on motor experiencing the greatest torque
- Compare to stall torque of motor



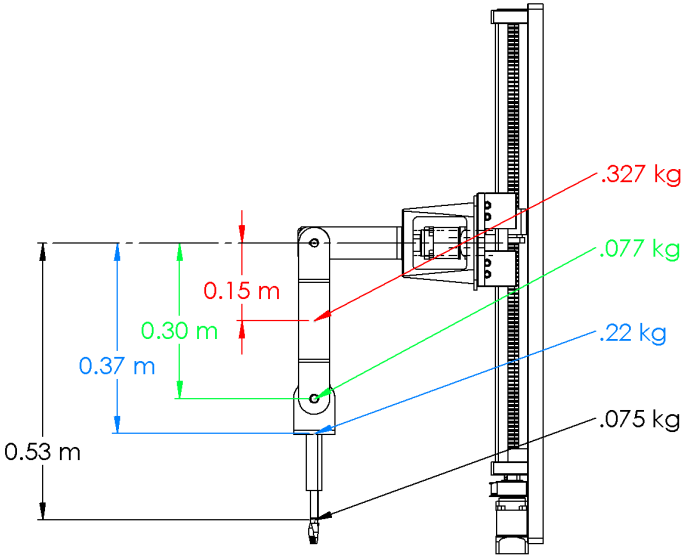
Force Analysis: Original



Component	M (N-m)
Link 2	0.653
Motor 4	0.272
Link 3	1.345
End Effector	0.621

Total M = 2.891 N -m > 2.5 N-m stall torque

Force Analysis Redesign



Component	M (N-m)
Link 2	0.481
Motor 4	0.227
Link 3	0.792
End Effector	0.393

Total M = 1.893 N -m < 2.5 N-m stall torque

What's Left?

- Create simulation for desired trajectory
- Secure funding

Thank You

Questions?