Design of an Assistive Multi-Functional Gardening Robot

MECE E4602 Final Project

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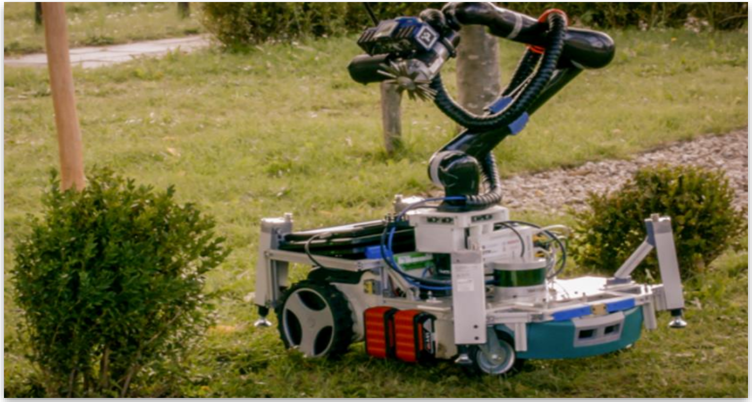
Problem Statement and Prior Research

Problem statement: With urban green spaces expanding, gardening is becoming approachable for more people, especially the elderly. Studies have shown large benefits in gardening, such as a decrease in cognitive decline. These individuals often lack the necessary mobility for certain tasks related to gardening however, and with these tasks come safety risks. Therefore, there is a need for assistive technology, such as an accessible, automated solution.

Prior research: Current hedge trimming robots on the market either focus on controlled environments or rely on complex, costly designs. We aim to address these issues.



TrimBot2020 (6 dof)

FarmBot

Solution Approach

Denavit–Hartenberg Table

Link	θ_i	d_i	α_i	a_i
1	θ_1^*	0	0	0
2	0	d_2^*	0	15.375”
3	θ_3^*	0	90°	11”
4	θ_4^*	0	0	7.325”

Jacobian

$$\begin{pmatrix} -\sigma_6 - a_2\sin(\theta_1) - \sigma_2 - \sigma_3 & 0 & -\sigma_6 - \sigma_2 - \sigma_3 & -a_4\cos(\theta_1+\theta_3)\sin(\theta_4) - a_4\sin(\theta_1+\theta_3)\cos(\alpha_3)\cos(\theta_4) \\ \sigma_5 + a_2\cos(\theta_1) + \sigma_4 - \sigma_1 & 0 & \sigma_5 + \sigma_4 - \sigma_1 & a_4\cos(\theta_1+\theta_3)\cos(\alpha_3)\cos(\theta_4) - a_4\sin(\theta_1+\theta_3)\sin(\theta_4) \\ 0 & 1 & 0 & a_4\sin(\alpha_3)\cos(\theta_4) \\ 0 & 0 & 0 & \sin(\theta_1+\theta_3)\sin(\alpha_3) \\ 0 & 0 & 0 & -\cos(\theta_1+\theta_3)\sin(\alpha_3) \\ 1 & 0 & 1 & \cos(\alpha_3) \end{pmatrix}$$

$$\sigma_1 = a_4\sin(\theta_4)\left(\frac{\sin(\alpha_3+\theta_1+\theta_3)}{2} + \frac{\sin(\theta_1-\alpha_3+\theta_3)}{2}\right)$$

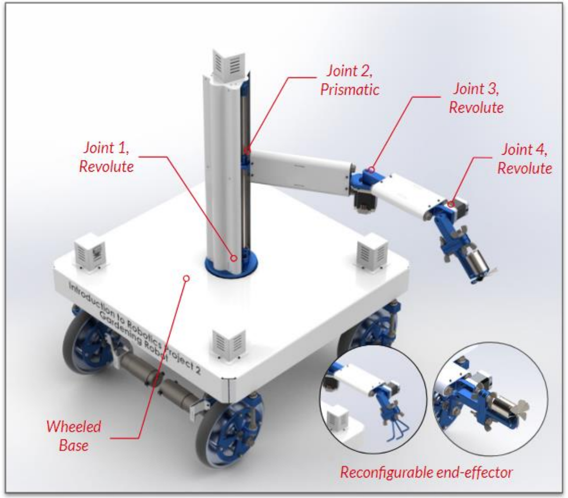
$$\sigma_2 = a_4\sin(\theta_4)\left(\frac{\cos(\alpha_3+\theta_1+\theta_3)}{2} + \frac{\cos(\theta_1-\alpha_3+\theta_3)}{2}\right)$$

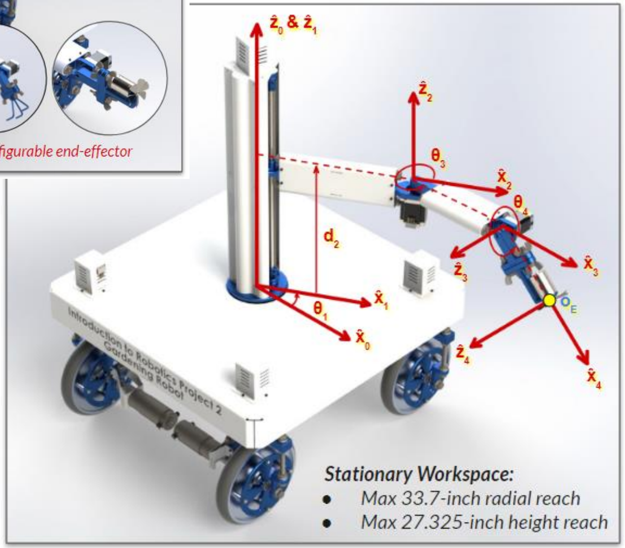
$$\sigma_3 = a_4\sin(\theta_1+\theta_3)\cos(\theta_4)$$

$$\sigma_4 = a_4\cos(\theta_1+\theta_3)\cos(\theta_4)$$

$$\sigma_5 = a_3\cos(\theta_1+\theta_3)$$

$$\sigma_6 = a_3\sin(\theta_1+\theta_3)$$





Results - Kinematics & Trajectory Planning

Inverse Kinematic Equations

$$a_2cos(\theta_1) + (a_3 + a_4cos(\theta_4))cos(\theta_1 + \theta_3) = x$$

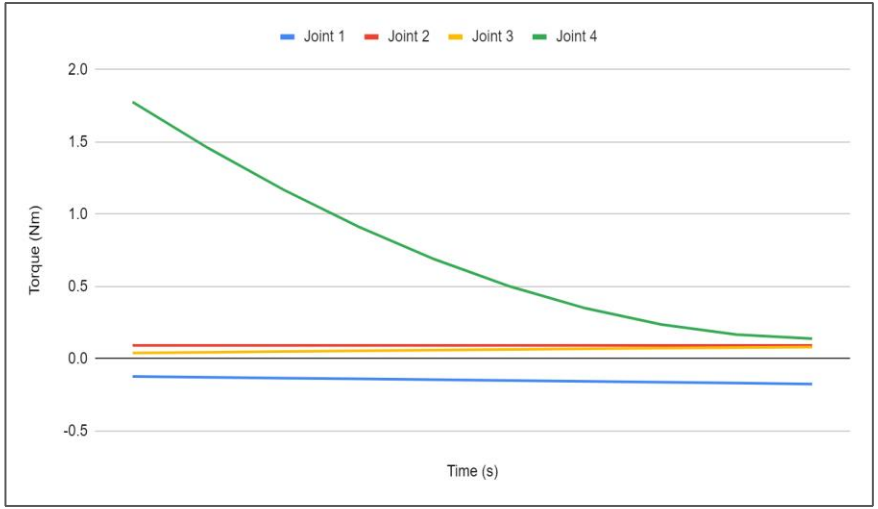
$$a_2sin(\theta_1) + (a_3 + a_4cos(\theta_4))sin(\theta_1 + \theta_3) = y$$

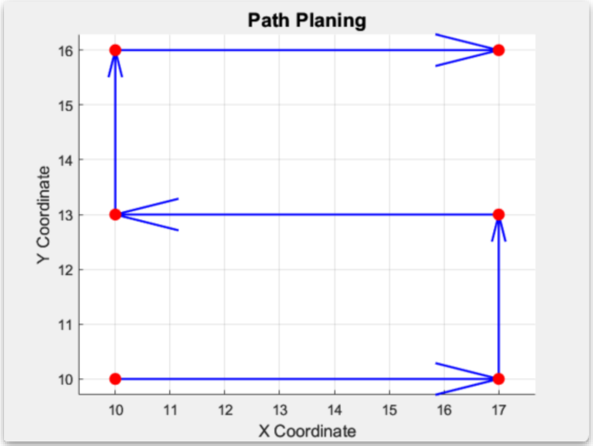
$$d_2 + a_4 * sin(\theta_4) = z$$

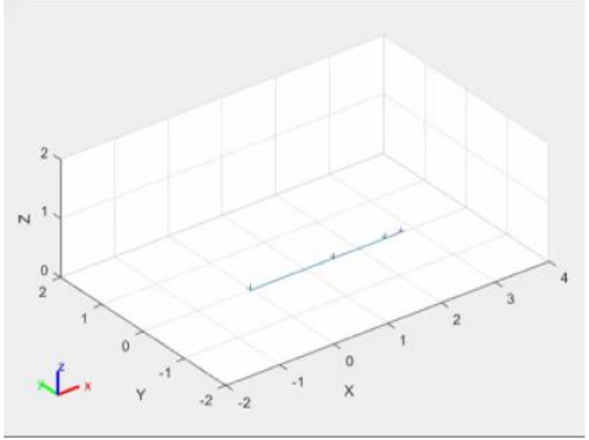
Joint Trajectory Function Selection

$$q(t) = a_0 + a_1t + a_2t^2 + a_3t^3$$

$$q(t) = q_0 + \dot{q}_0t + \frac{3(q_f - q_0) - (2\dot{q}_0 + \dot{q}_f)t_f}{t_f^2}t^2 + \frac{2(q_0 - q_f) + (\dot{q}_0 + \dot{q}_f)t_f}{t_f^3}t^3$$







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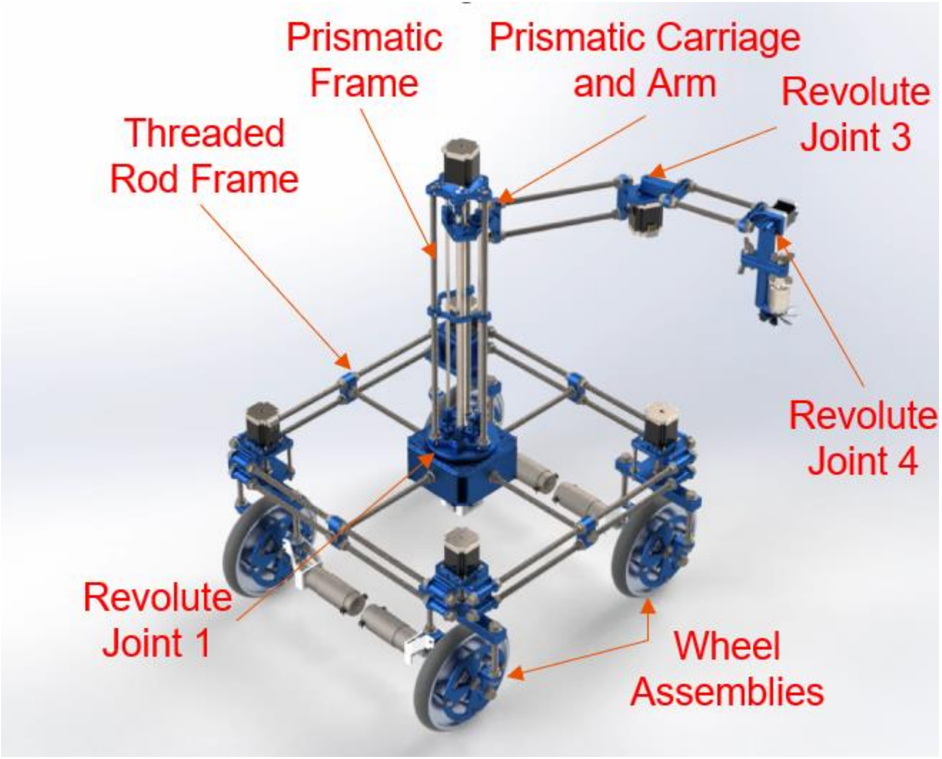
Results - Inputting MATLAB data into SolidWorks

Joints 1 and 2 Data in SolidWorks, showing displacement, velocity, acceleration, and jerk graphs.



3D render of SolidWorks model with motion simulation using MATLAB rectilinear path data points

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Conclusion & Future Extensions

We have completed the design and analysis of a 4 DOF assistive robot. It includes:

- An RPRR arm on a wheeled base with large range of motion
- Easily interchangeable heads
- Full path control with inverse and forward kinematics solved
- Torque control for safety and reliability

Areas for future improvement and extension include:

- Increasing the number of degrees of freedom of the arm
- Including machine vision for increased safety and object awareness