Contact Bridge Inspection: Using Drones to Improve Infrastructure

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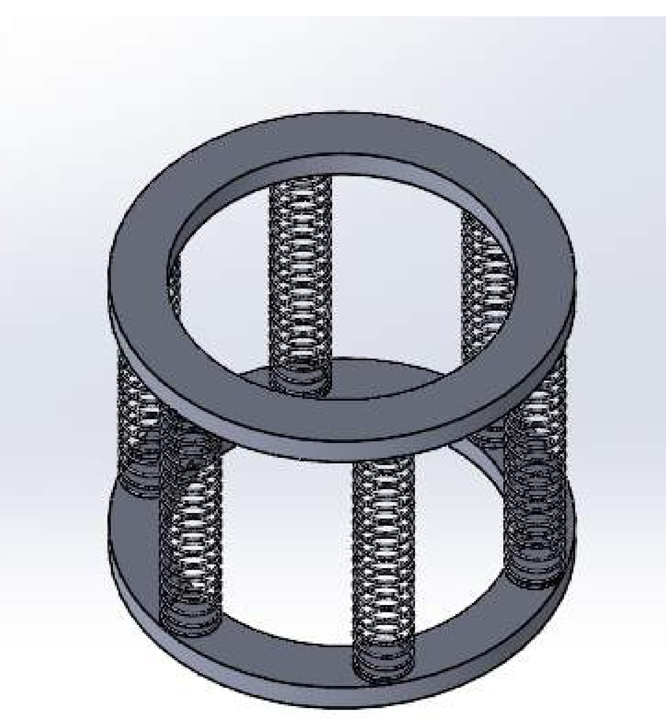
Why use drones for bridge inspection?

With over 25,000 bridges owned by the state of Pennsylvania, it takes a lot of time and money to inspect and maintain bridges. Introducing ank unmanned aerial vehicle (UAV) into the process of inspection will make it faster and cheaper.

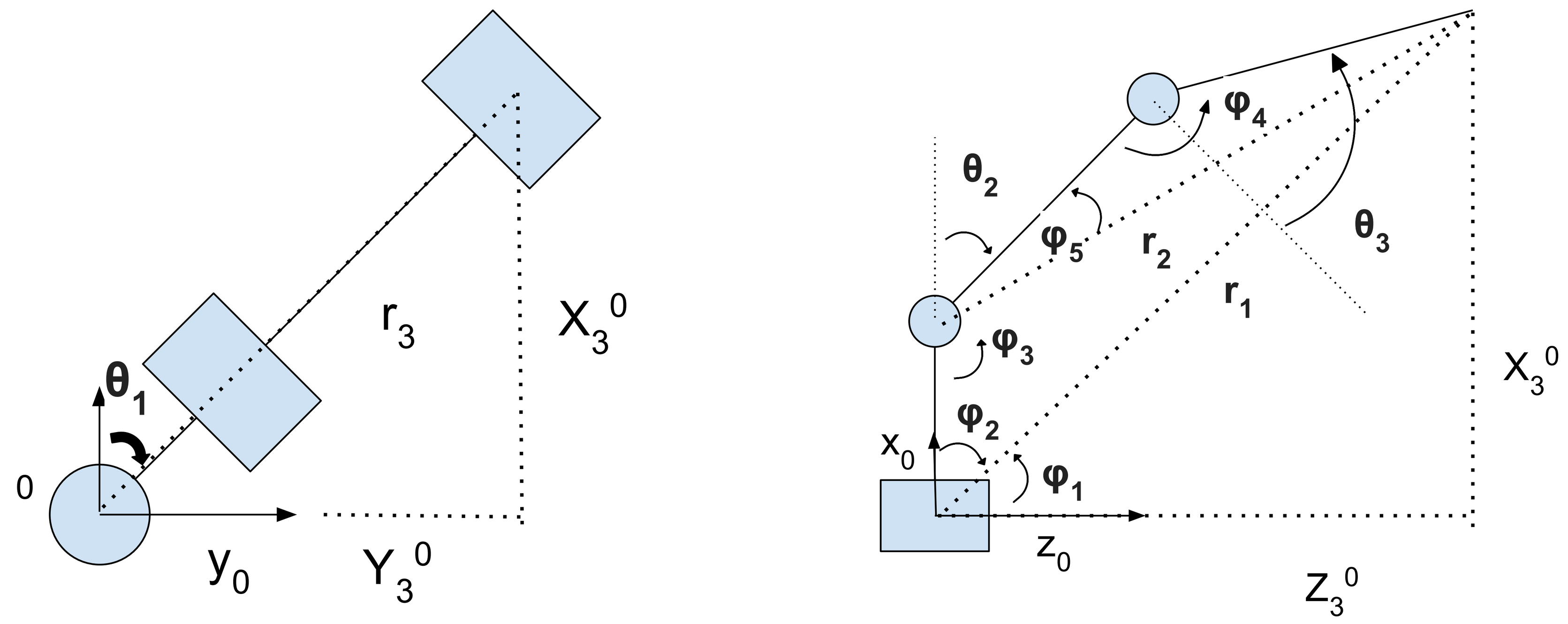
Design Criteria



The manipulator will be mounted on a UAV with a 1 kg payload. With this weight restriction in mind the manipulator is made with carbon fiber, aluminum and laser cut acrylic.

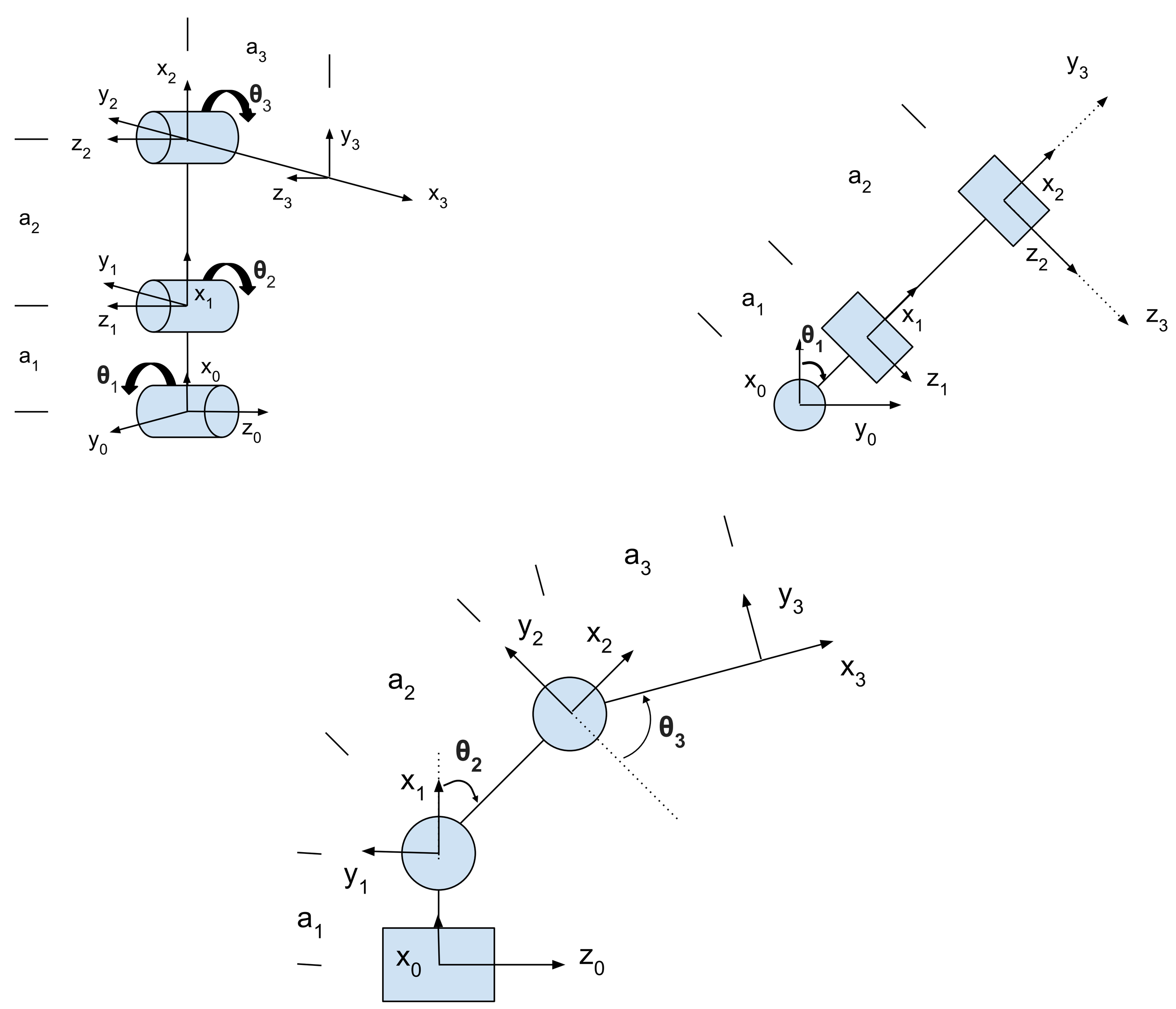
The end effector is outfitted with a passive two DoF, allowing it to flush to surfaces without using redundant actuators.

Inverse Kinematics



The joint angles θi can be found using the desired final [X Y Z] position for the end effector. This is achieved through a combination of trigonometry and algebra based on the figures.

Denavit Hartenberg Model



The Denavit Hartenberg model is used to derive the Homogeneous transformation matrices between each joint, which in turn can be used to find the transformation between the base frame [x_0 y_0 z_0] and the end effector frame [x_3 y_3 z_3].

The relationship between the base and the end effector dictates how each joint must move to achieve a desired end effector position.

Physical Model

Denavit Hartenberg Parameters

Link #	a_i	α_i	θ_i	d_i
1	a_1	$\pi/2$	θ_1	0
2	a_2	0	θ_2	0
3	a_3	0	θ_3	0

Homogeneous Transformation

$$A_i = \begin{bmatrix} \cos(\theta_i) & -\sin(\theta_i)\cos(\alpha_i) & \sin(\theta_i)\sin(\alpha_i) & a_i\cos(\theta_i) \\ \sin(\theta_i) & \cos(\theta_i)\cos(\alpha_i) & -\cos(\theta_i)\sin(\alpha_i) & a_i\sin(\theta_i) \\ 0 & \sin(\alpha_i) & \cos(\alpha_i) & d_i \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

As a test, arbitrary end effector positions were plugged into the system of inverse kinematical equations, and the resulting θ values were in turn plugged into the homogeneous transformation. The system successfully returned the original end effector positions in the form of displacement vectors.

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