A Fast Algorithm for Solving the Kinematics of Hyper Redundant Robots

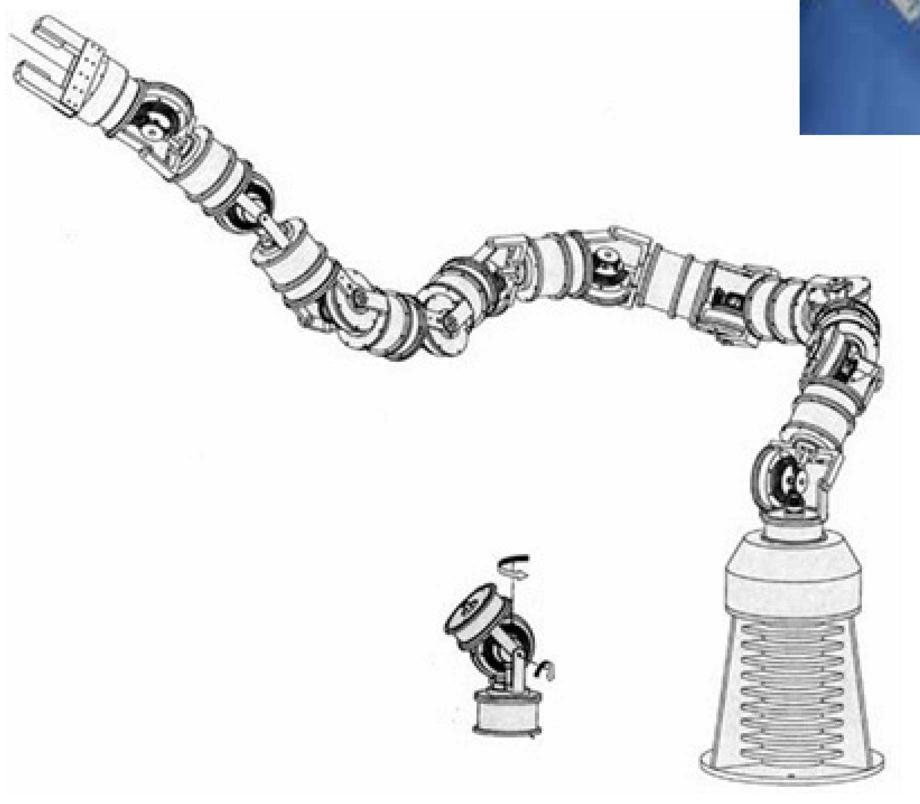
Tiangang Chen
Advisors: Dr. Andrew Murray & Dr. David Myszka
Department of Mechanical & Aerospace Engineering

Research objectives: To approximate a desired curve that specifies the configuration or shape of the robot and to accurately position the tool at the end of the robot.

Introduction

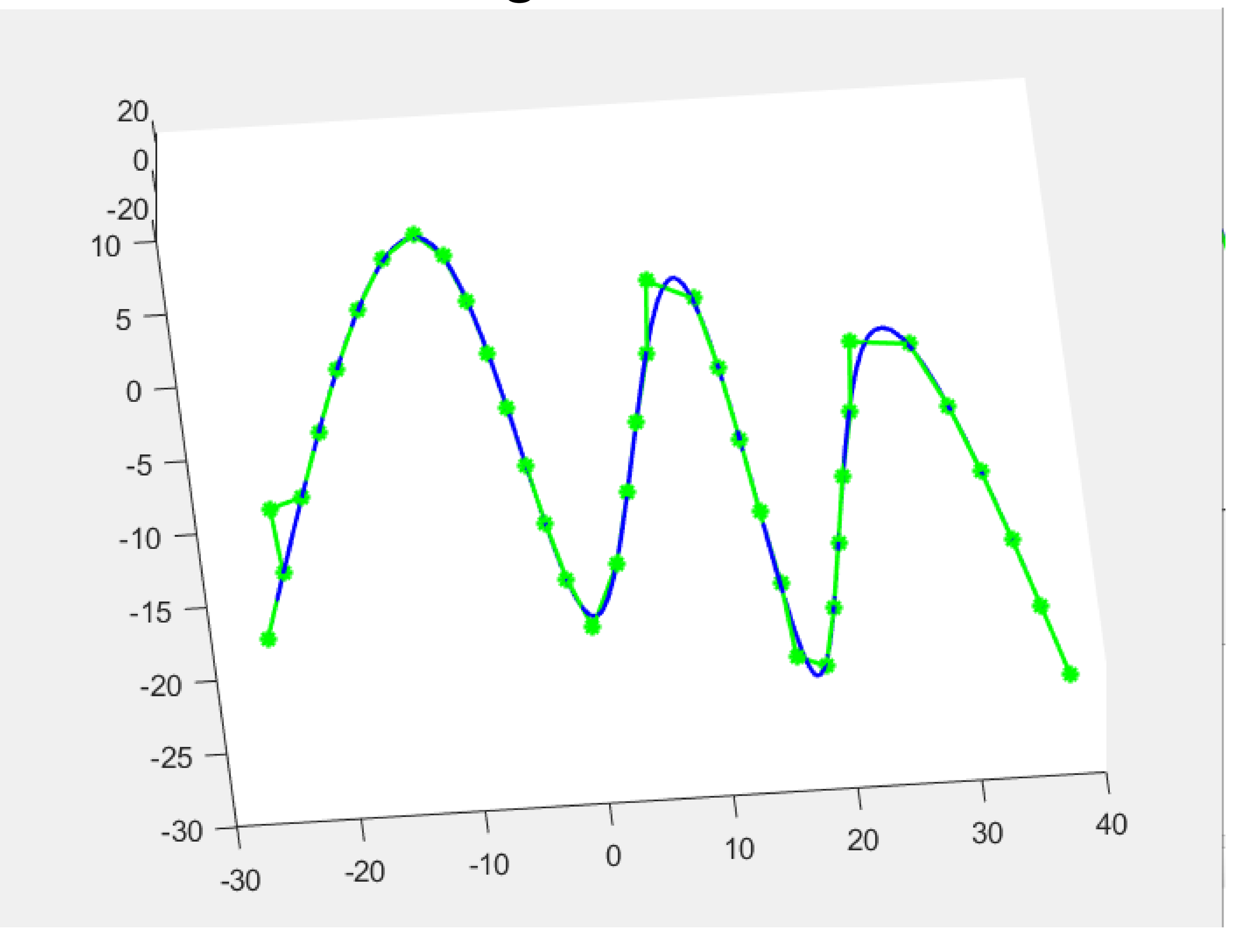
Hyper redundant robots consist of many equal length rigid links connected by a large number of universal joints. This significant number of joints gives the robot many degrees of freedom enabling it to function in highly constrained environments. This work introduces a methodology to solve the kinematics of a hyper redundant robot. Addressing the kinematics includes two issues. The first issue is to approximate a desired curve that specifies the configuration or shape of the robot. The second issue is to accurately position the tool at the end of the robot. These two issues are addressed by analyzing the desired curve describing the hyper redundant robot as piecewise linear similar to the analysis for generating target profiles in shape-changing mechanism theory. There are two advantages to this approach. First, the error will be small. Second, the speed of the calculation is fast.

Hyper Redundant Robots

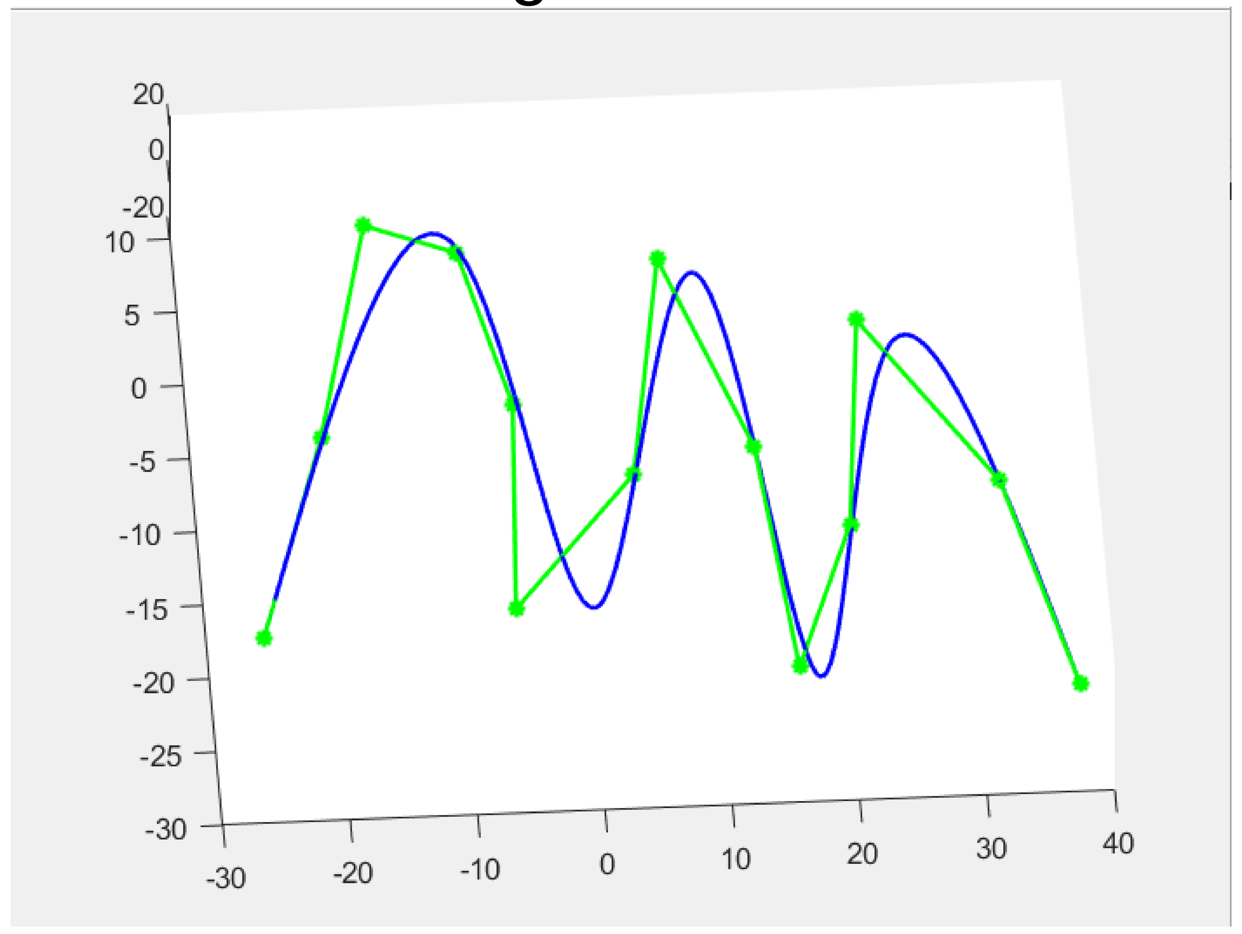


Example

39 Segment Robot

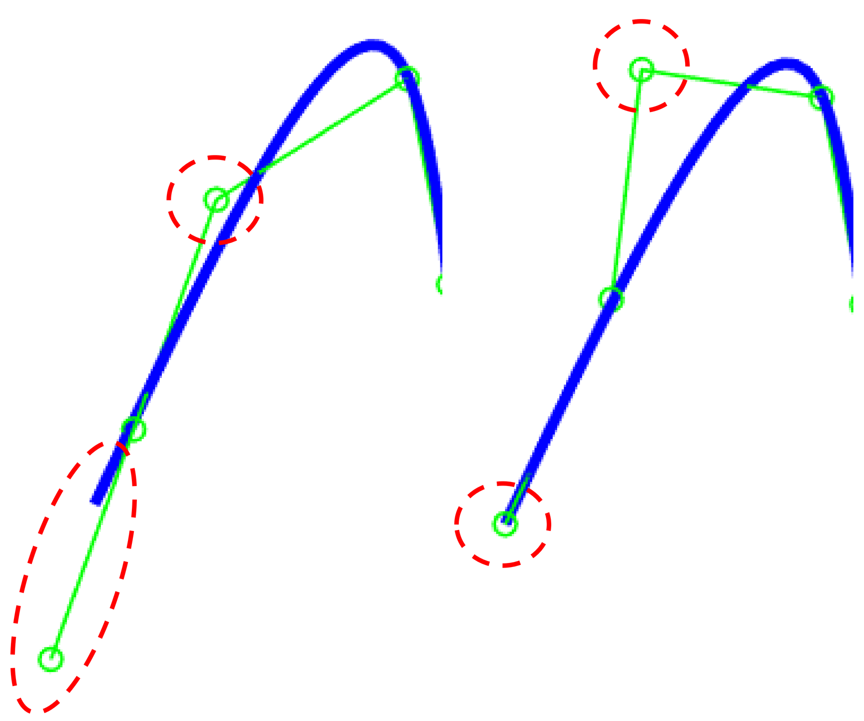


13 Segment Robot



Modify the end

Modify the last three points to make the position and the orientation of the last segment the same as the original curve.



Tracking the Shape

Calculate the position of every joint to match the robot to the target curve

$$U_{1(1)} = U_{0(1)}$$

$$\vec{n} = \frac{U_{0(1+ni-n)} - U_{1(i-1)}}{\left\| U_{0(1+ni-n)} - U_{1(i-1)} \right\|}$$

$$U_{1(i)} = U_{1(i-1)} + l\vec{n}$$

Position the Tool

Change the last joint location to match end position and direction of target curve

$$U_{1(end)} = U_{0(end)}$$

$$\vec{v} = \frac{U_{0(end-1)} - U_{0(end)}}{\left\| U_{0(end-1)} - U_{0(end)} \right\|}$$

$$U_{1(end-1)} = U_{1(end)} + l\vec{v}$$

Connection Point

Where is the third joint from the end?

$$M = \frac{U_{1(end-1)} + U_{1(end-3)}}{2}$$

$$\vec{s} = U_{1(end-1)} - M$$

$$r = \sqrt{l^2 - t^2}$$

$$\begin{cases} S_x(A_x - M_x) + S_y(A_y - M_y) + S_z(A_z - M_z) = 0 \\ A_y = \dfrac{S_y}{S_x}(A_x - P_x) + P_y \\ A_z = \dfrac{S_z}{S_x}(A_x - P_x) + P_z \end{cases}$$

$$\vec{w} = \frac{A - M}{\|A - M\|}$$

$$U_{1(end-2)} = M + r\vec{w}$$