Approximate Motion Synthesis by Using the Poles of Planar Displacements

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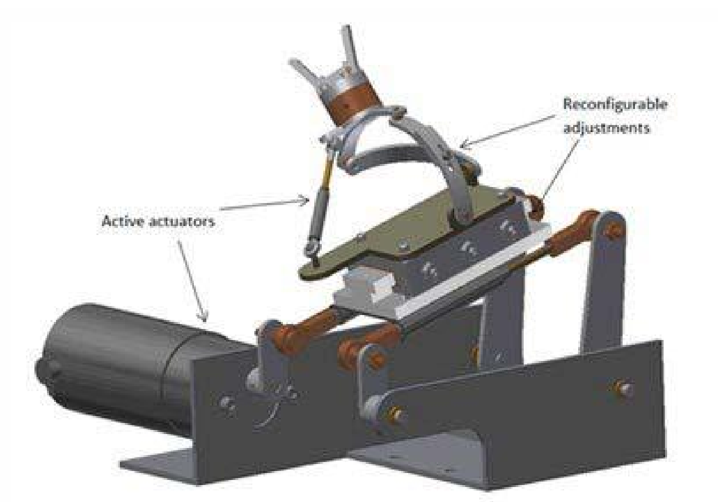
Objective: This work is to reformulate and solve a basic machine design problem called approximate motion synthesis

Introduction

The need for this reformulation is that prior techniques rely on numerical methods and the need for significant user input. The pole method being proposed herein is a more straightforward approach that is simpler to implement and requires fewer inputs to find a solution. Our research focuses on approximate motion synthesis for the simplest of linkages, a planar four-bar. The reason for this is that a four-bar can produce an approximate solution to a manufacturing or assembly problem, and then modest variation in its components can be added to create an exact solution to the problem. The variation in its components is essentially the mingling of the four-bar with robotic components, which generates a new class of low DOF machines called metamachines. Hence, the four-bar is the approximate solution, and the metamachine is the mixture of the four-bar with the robotic components having the capacity to produce an exact solution.

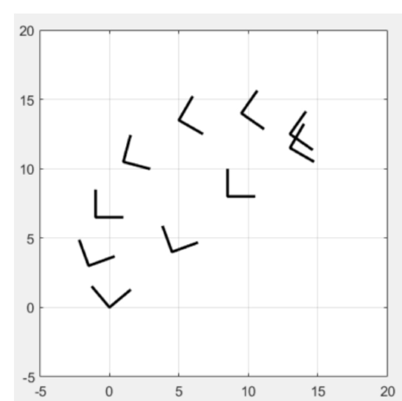
Metamachines



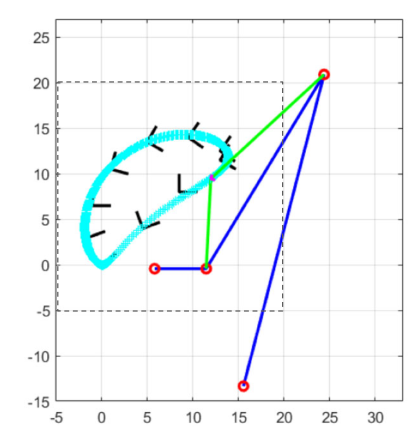
This research is on a new class of low degree of freedom machines called metamachines:

- Significant impact on automated manufacturing by providing the spatial pick & place motions required to perform spatial assembly tasks.
- Energy efficient when compared to traditional industrial robots.
- Reconfigurable to accommodate a variety of subassemblies or part families.

Using Poles to Build a Mechanism



(a) Expect moving reference



(b) The mechanism result base on (a)

Pole Location:

$$\vec{P}_{ij} = A_i(A_i - A_j)^{-1}\left(\vec{d}_j - \vec{d}_i\right) + \vec{d}_i$$

$$\vec{Q}_{ij} = B_i(B_i - B_j)^{-1}(\vec{e}_j - \vec{e}_i) + \vec{e}_i$$

Minimize …

$$\text{Min } J = \Sigma\left(\vec{P}_{ij} - \vec{Q}_{ij}\right)^{\top}\left(\vec{P}_{ij} - \vec{Q}_{ij}\right)$$

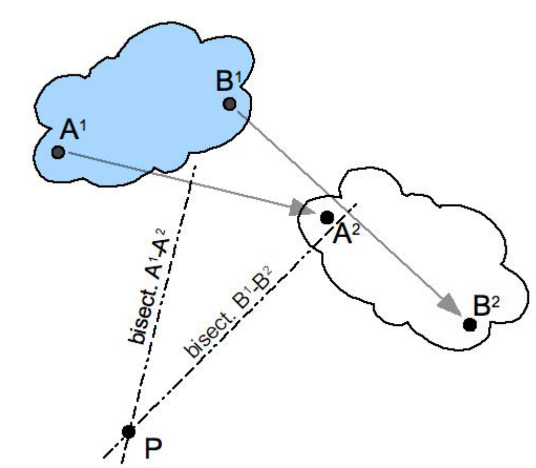
… subject to the Crank Constraint

$$\left|\vec{Z}_i - \vec{G}\right| = \left|\vec{Z}_1 - \vec{G}\right|$$

$$\left|\vec{Y}_i - \vec{G}\right| = \left|\vec{Y}_1 - \vec{G}\right|$$

What is a Pole?

A planar displacement has a unique pole. The displacement can be viewed as a rotation around this pole.



Wikipedia, "Instant center of rotation", https://en.wikipedia.org/wiki/Instant_centre_of_rotation

Finding a pole graphically:

- Select two points A and B on the body.
- Locate the corresponding points on the second location of the body.
- Find line segments A1A2 and B1B2.
- Construct their perpendicular bisectors.
- The intersection point of the two bisectors is the pole of the planar displacement.