Objective: This work generates a new approach to reformulate and solve approximate motion synthesis problems

Introduction

• Approximate motion synthesis generates a mechanism that can move near a given set of task positions.
• Previous methods that address approximate synthesis problems involve an optimization that uses multiple measures within the objective.
• This project proposes a technique based solely on the locations of displacement poles, resulting in a bi-invariant metric.
• The focus is on planar four-bar mechanisms due to their ability to provide efficient solutions to manufacturing or assembly problems
• The motion can then be refined with the addition of cascading mechanisms to create a new class of low DOF machines known as metamachines.

Metamachines

This research assists the design of 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.

Poles:

Any displacement of a rigid body from position \( i \) to \( j \) can be accomplished by pure rotation about the displacement pole.

\[
\begin{align*}
\bar{P}_{ij} &= A_i (A_i - A_j)^{-1} (\bar{d}_j - \bar{d}_i) + \bar{d}_i \\
\bar{Q}_{ij} &= B_i (B_i - B_j)^{-1} (\bar{e}_j - \bar{e}_i) + \bar{e}_i
\end{align*}
\]

Objective function ...

\[
\text{Min } J = \sum (\bar{P}_{ij} - \bar{Q}_{ij})^T (\bar{P}_{ij} - \bar{Q}_{ij})
\]

Subject to the Crank Constraint

\[
\begin{align*}
|\bar{Z}_i - \bar{G}| &= |\bar{Z}_1 - \bar{G}| \\
|\bar{Y}_i - \bar{G}| &= |\bar{Y}_1 - \bar{G}|
\end{align*}
\]

Pole Triangle

"The Pole Triangle Principle" is an important theory that helps reduce the number of position poles needed in optimization synthesis.

<table>
<thead>
<tr>
<th>Number of positions</th>
<th>Number of poles</th>
<th>Minimum poles needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>15</td>
<td>9</td>
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<tr>
<td>7</td>
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<td>11</td>
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<tr>
<td>8</td>
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<td>9</td>
<td>36</td>
<td>15</td>
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<tr>
<td>10</td>
<td>45</td>
<td>17</td>
</tr>
</tbody>
</table>

The poles generated by corresponding positions and the minimum poles for optimization

12 positions of an exact solution

Different solutions for 7 positions

Different solutions for 10 positions

Optimized solution using fewer poles