<table>
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<th><strong>Title</strong></th>
<th>Kempe mechanism in spherical space</th>
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Background

More than a century ago, Kempe (1878) listed movable conditions for Kempe linkage (Fig.1).

Kempe linkage consists of two planar four-bar linkages pivoted together (shown in yellow color).

Such combinations are called double-loop planar linkages (shown in blue and red respectively), whose internal degree of freedom (DOF) is one.

Spherical Mechanism

- Spherical 4R linkage (Fig.2)
  - Six spherical 4R linkages for expected design

In Fig.1, these joints create spherical 4R linkages:
  - Four red joints
  - Four blue joints
  - Two adjacent yellow joints and one red, one blue

- Spherical triangle (Fig.3)
  - 8 pieces of spherical triangles

Spherical triangles with certain angles (60, 75, 80) can’t move freely, Mobility Condition is to be used to find the expected kempe linkage in spherical surface using mathematical method.

Mobility Condition

A rotation matrix rotates the coordinates of a point \( P \) in system \( X_1O_1Y_1 \) to its coordinates in system \( XOY \).

The mobility condition is that the product of the rotation matrices equals the unit matrix, i.e.

\[
R_{X_1} R_{Z_2} R_{X_3} R_{Z_2} R_{X_2} R_{Z_1} = I
\]

From one frame to the next, there are two sub-steps of rotation involved (Fig. 6 on the right)