1. MOTIVATION
In today’s times, it is essential for the humanoids to match up to the dexterity of the humans. These skills contribute significantly in their capacities for feeling, exploring, learning, planning and subsequently acting. iCub Humanoid, developed at our facility, was designed explicitly to promote research for the same. In this work, we focus on the enhancement of the wrist dexterity.

2. CAD-BASED APPROACH

2.1 2DOF Gimbal Mechanism
Serial mechanism with the desired behaviour. This is our point of reference.

2.2 4-UU Mechanism
4 identical limbs with mirror-symmetric architecture of RRRR chains.

2.3 Spherical Six-Bar Mechanism
Six spherical linkages connected by R joints with a central gimbal.

3. ORIENTATION WORKSPACE ANALYSIS

3.1 Gimbal
Compact Design
Full Pitch-Yaw Decoupling

3.2 4-UU
Regular/Symmetric Workspace
Higher Payload-to-Weight Ratio

3.3 S6B
Simpler Kinematics
Large Range of Motion

4. ISOTROPY ANALYSIS
The mechanism isotropy is defined as follows, where J are the Jacobian matrices computed numerically from the simulation data and ‘n’ is the order of the task space:

\[ \Delta = \frac{M}{\Psi} = \frac{\sqrt{\text{det}(JJ^T)}}{\text{trace}(JJ^T)/n} \]

\[ J = \begin{bmatrix} \frac{\partial \theta_1}{\partial \psi} & \frac{\partial \theta_2}{\partial \psi} & \cdots & \frac{\partial \theta_n}{\partial \psi} \\ \frac{\partial \theta_1}{\partial \phi_1} & \frac{\partial \theta_2}{\partial \phi_1} & \cdots & \frac{\partial \theta_n}{\partial \phi_1} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\partial \theta_1}{\partial \phi_2} & \frac{\partial \theta_2}{\partial \phi_2} & \cdots & \frac{\partial \theta_n}{\partial \phi_2} \end{bmatrix} \]

4.1 ISOTROPY

5. CONCLUSIONS

5.1 a) Warping in the Workspace: Mechanism behaviours are not symmetric, i.e., the plots are not centered with absolute zero. Workspace diverges towards the extremes, as in case of 4-UU.

5.2 b) Yaw-Pitch Coupling: Unlike gimbal, pitch and yaw contours are not straight lines, i.e., the motions are coupled with each other and one input produces both outputs.

5.3 c) Asymmetric Parasitic Roll Motion: Platform posses undesired Roll motion in case of 4-UU, which becomes difficult to be compensated. Central gimbal prevents the same for S6B.

5.4 d) Anisotropy: Mechanisms are not fully isotropic throughout the workspace. S6B best with \( \Delta \geq 0.9 \) for significantly large section of the workspace.

NEW WRIST = ❌ Work in Progress ...