Cartesian Compliance Parameter Optimisation for Serial Arm Robots

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PROBLEM STATEMENT

Recently, serial arm robots drew the attention of the machining industry due to;

1. ***High dexterity***
2. ***Large workspace***
3. ***Ability to conduct various tasks***
4. ***Reduced capital cost compared to machine tools***

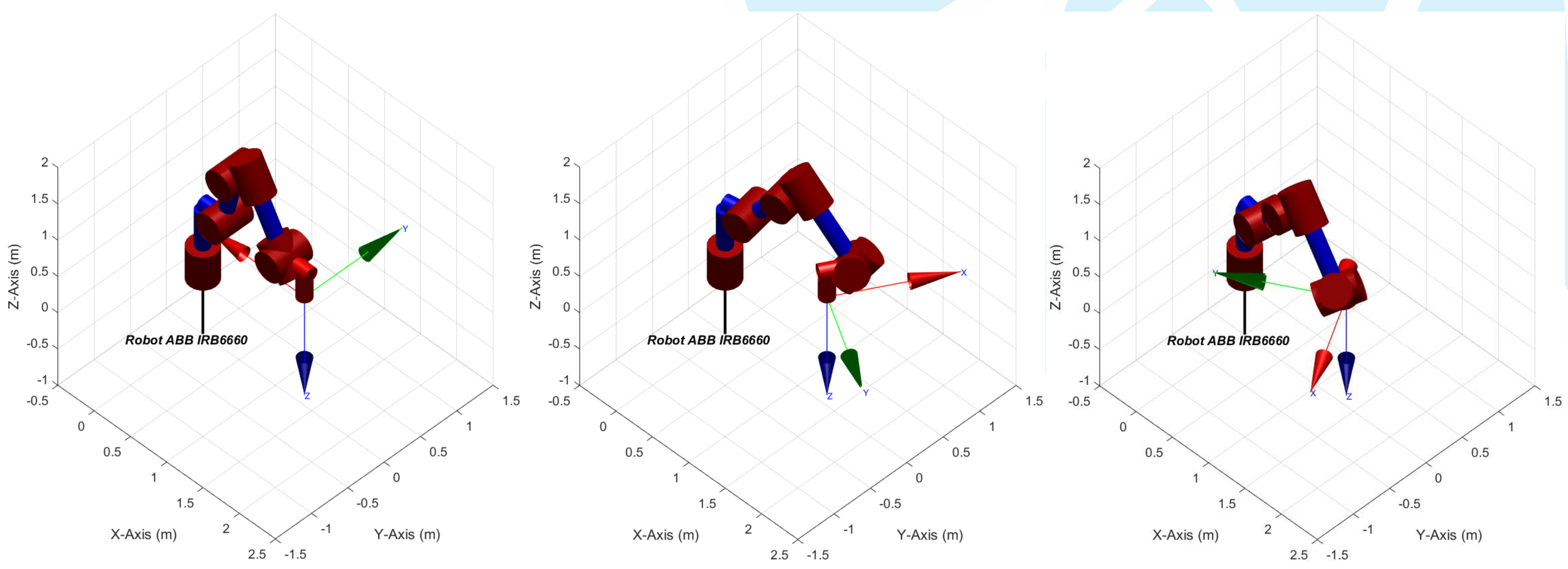
However, serial manipulators tend to have;

1. ***Poor and varying stiffness***
2. ***Low precision***

Which are the main impediments for application of manipulators to machining operations. Therefore, proper development of stiffness and dynamic models is crucial to predict and compensate the tool deflections under cutting forces. However, this is only part of the solution, and there is a need for Cartesian stiffness/compliance enhancement to minimise the static and transient deflections of tool centre point during 5-axis milling operation.

THEORY & METHODOLOGY

Cartesian compliance parameter optimisation is based on utilisation of functional redundancy around the tool axis attained when employing a 6-DoF serial arm robot, ABB IRB6660, for 5-axis machining operation. The machining table surface with a fixed height was divided into a mesh of evenly spaced points with the tool alignment perpendicular to its surface. The functionally redundant degree of freedom was varied sequentially, and robot configurations achieving the desired poses were determined through inverse kinematics for each scenario. An exemplary sequential reconfiguration of the manipulator for a 5-DoF pose can be seen in the figures below;



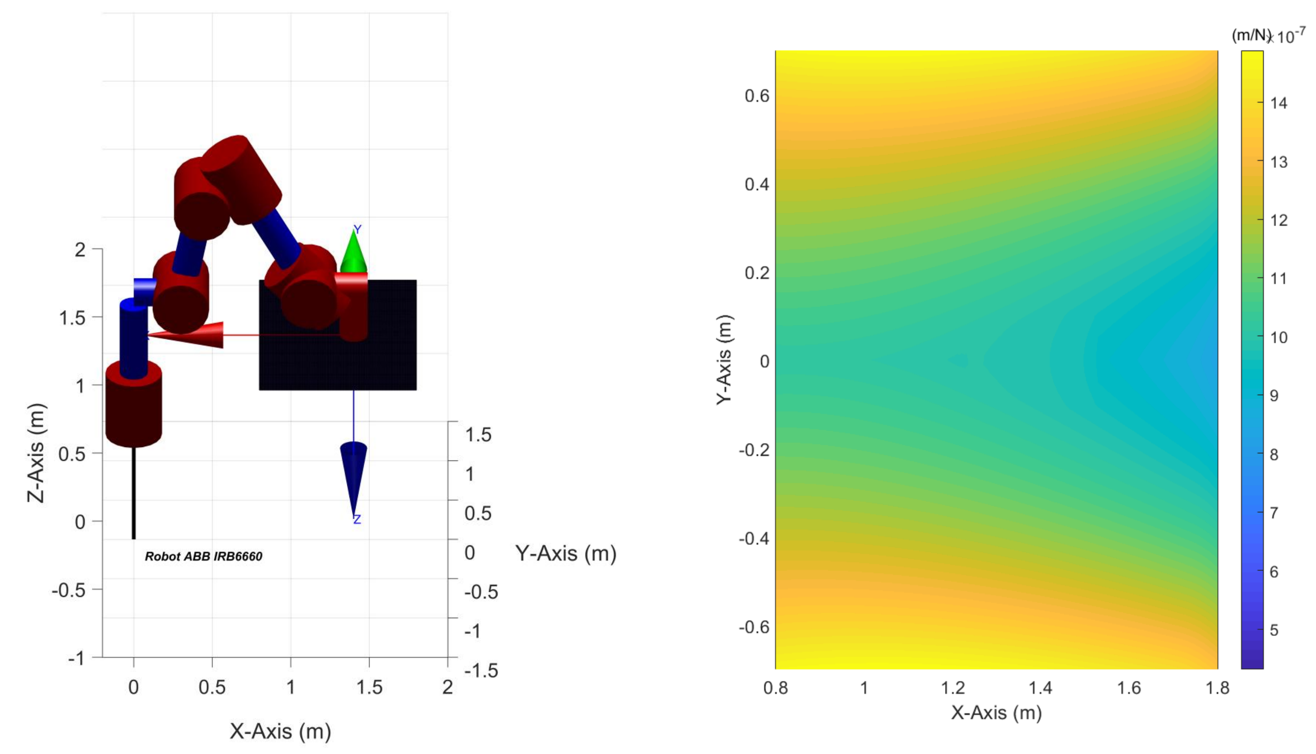
The Cartesian compliance matrix was then computed for every configuration by using the equation below;

$$C_c = J_\theta C_\theta J_\theta^T$$

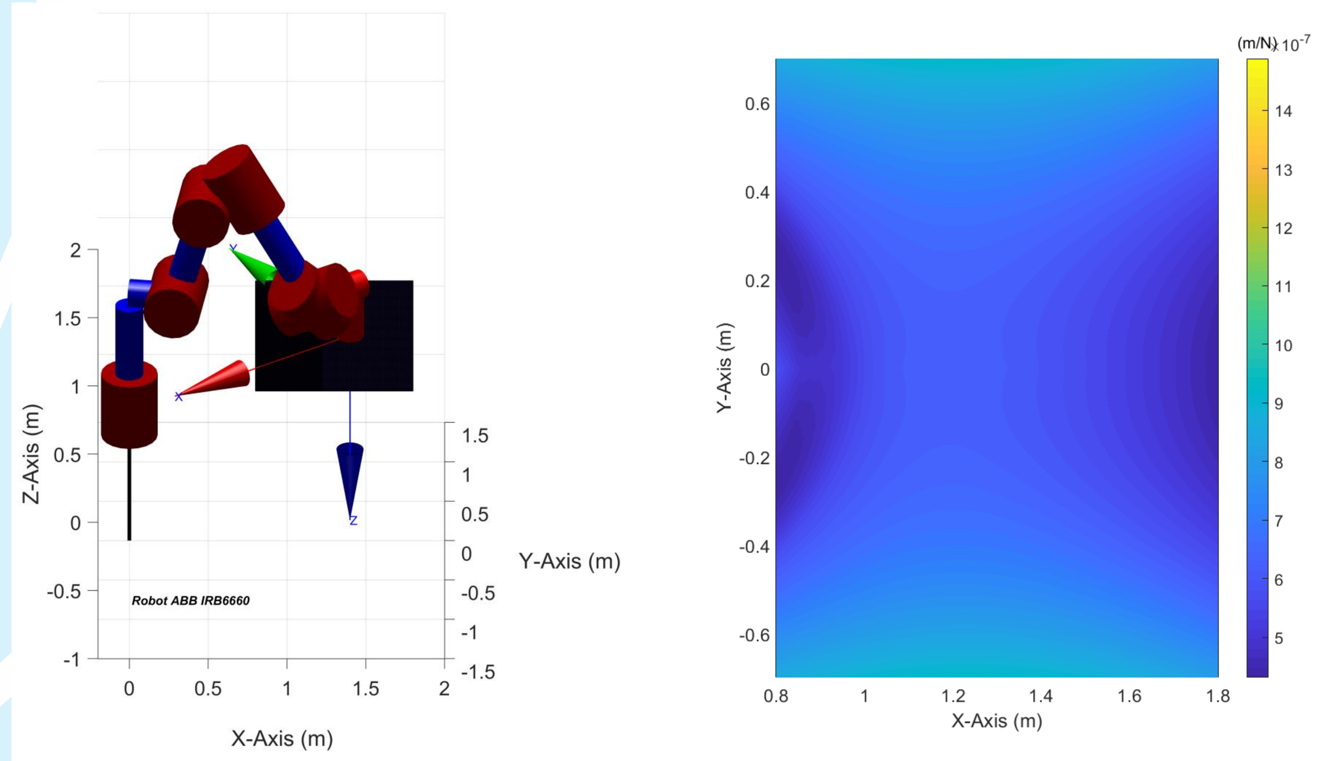
and the one having the optimum Cartesian stiffness parameter in an arbitrary coordinate was selected. Consequently, a map of the optimum Cartesian stiffness parameter over the surface of the machining table was obtained.

RESULTS - Optimisation of c_{xx} Parameter

Maximised c_{xx}

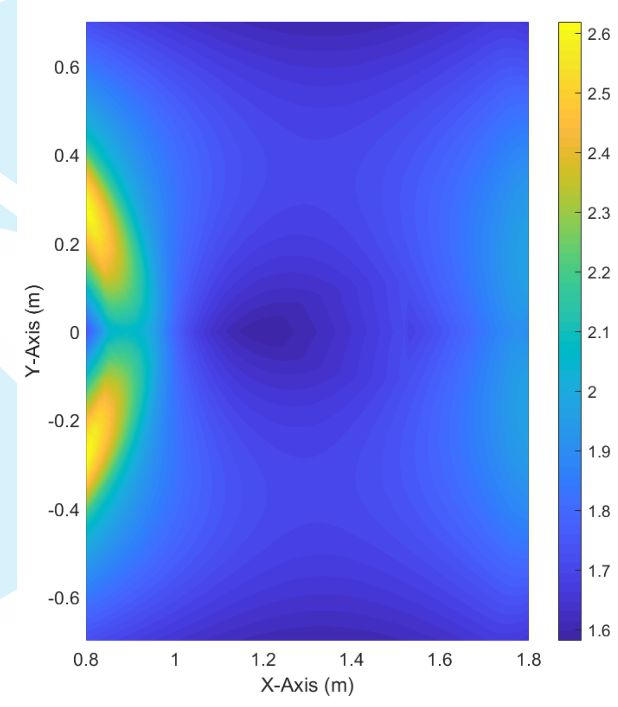


Minimised c_{xx}



Ratio of Minimum to Maximum c_{xx}

The below figure shows the improvability of the stiffness of the manipulator along X-axis to a force applied in the same direction by optimising manipulator configuration.



CONCLUSION & FUTURE WORK

By optimising c_{xx} parameter of the manipulator throughout the machining table surface it is possible to minimise the flexibility of the manipulator by a maximum of 161% closer to the base of the robot at regions with yellow colour and by a minimum of 58% which appears to be along X-axis at (1.21,0,0.5) m.

In latter stages of the project, this work will be used for static deflection compensation and potentially for chatter avoidance in robotic milling operations.

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