ED6002 – Optimization Methods in Engg. Design

Project Presentation

Optimization of link lengths of a 2R palletizing robot manipulator for maximizing force isotropy

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Objectives

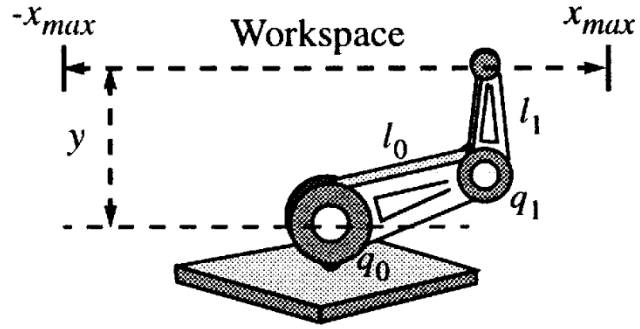
- Given a workspace, find the optimum link lengths for which a 2R palletizing robot shows the best performance, measured in terms of the Global Isotropy Index(GII)
- Implement an exhaustive search & a minimax optimization algorithm to find the optimum link length & compare the results

Introduction

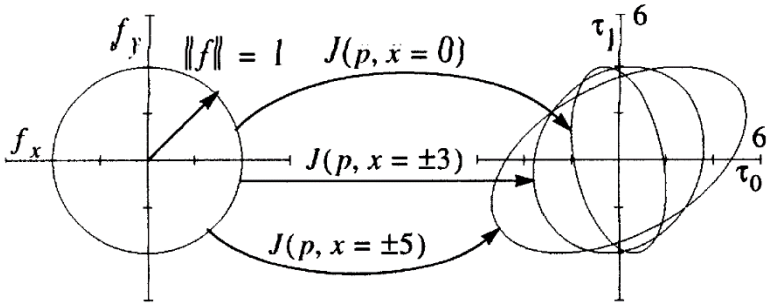
- Designing a robot for modern applications such as haptic interfaces and surgical assistants has led to performance demand increasing far beyond traditional applications
- Relationship b/w torque applied by actuators & force exerted by end effector varies with position & direction

Introduction- Isotropy

- Force exerted by the end effector is related to motor torques by a linear map $\tau = \mathbf{J}^T\mathbf{F}$
- If magnitude of force to be produced is restricted to unity in all directions, the actuator torques produce an ellipse in the torque domain
- For different points in the workspace, the ellipse produced is different

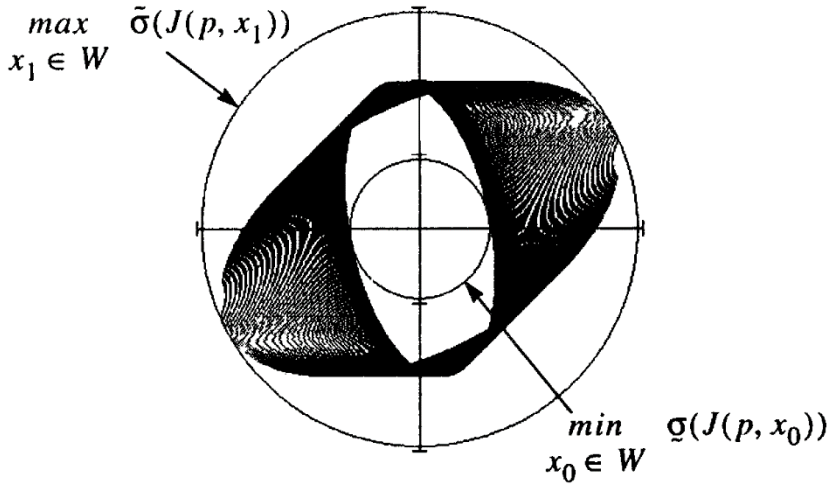


A 2R manipulator with a specified workspace



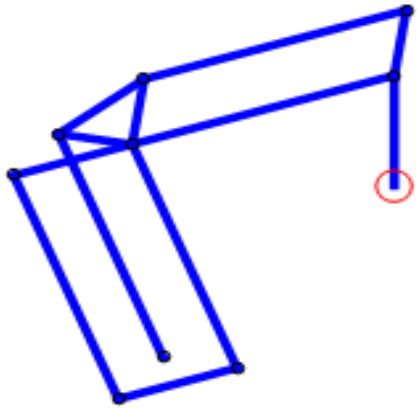
Torque ellipses for various positions in workspace

Introduction- GII



- The global isotropy index(GII) is used as a measure to define the "goodness" of a set of link lengths
- The GII is defined as the ratio of the smallest singular value to the largest singular value in the entire workspace
- A GII value of 1 implies that a mechanism behaves consistently at all points in the workspace

Problem Formulation



- The kinematic diagram of a palletizing robot is shown in the figure
- Parameter space is reduced to a single dimension by setting length of 1st link = 1 unit and varying length of 2nd link
- The workspace is defined to be a square of side 0.5 units located at a suitable distance from the base of the robot
- The limits of the length of 2nd link is set by ensuring that boundaries of usable and reachable workspaces are separated by a minimum safety margin of length K
- Objective: Maximize GII

Exhaustive Search

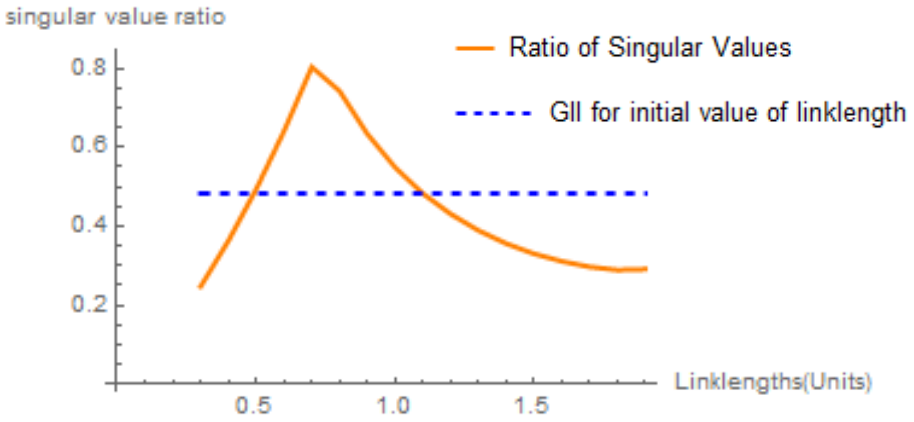
- An optimization algorithm is to be defined which finds the globally optimum parameter from a discretized parameter space within a discretized workspace
- Involves calculating torque ellipses at all points in the usable workspace & then defining the GII
- This needs to be done for all link lengths in the parameter space & then the length which has the maximum GII is chosen for best performance

Minimax Culling Algorithm

- As the objective is to find the best "worst-case" scenario, minimax optimization algorithms are suited for this problem
- The algorithm iteratively culls non-optimal parameters from the parameter space until only the best parameter remains
- Global optimum is guaranteed in this algorithm

Culling Algorithm- Iteration 1

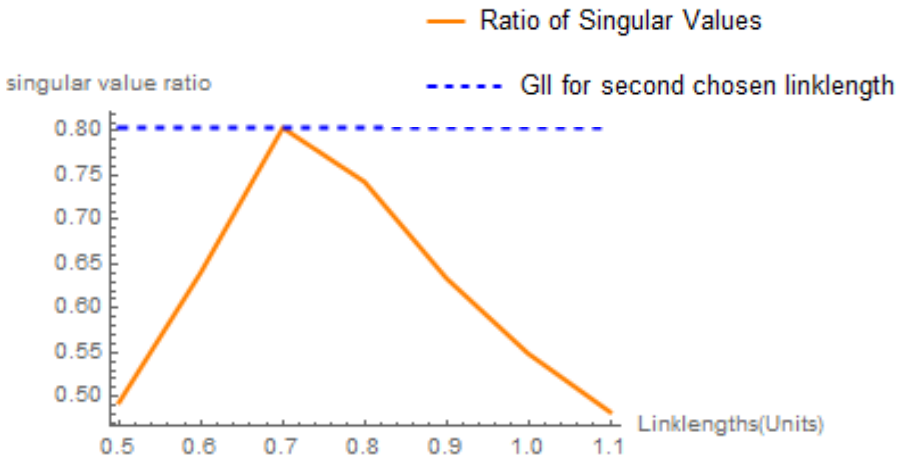
- A link length is chosen from the parameter space & it's GII is computed
- The locations of it's best and worst positions are saved



- Singular values at these positions are computed for all remaining lengths in the parameter space and their ratios are found
- All parameters showing a performance worse than the GII computed for the initial chosen link are removed from the parameter space

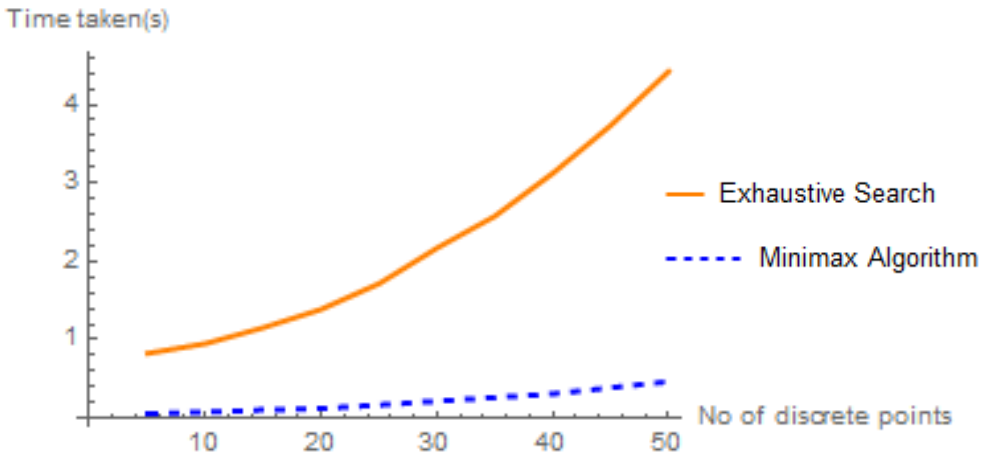
Culling Algorithm- Iteration 2

- A link length is again chosen from the new parameter space & it's GII is computed
- The same process is repeated



- As the ratio of singular values of all other links is less than the GII, the search is terminated & the optimum value of the link length & GII is returned

Results



- The number of points in the workspace versus the time taken for computation is plotted for by an exhaustive search and the minimax algorithm
- The minimax algorithm is found to be orders of magnitude faster
- Efficiency of algorithm is due to parameters close to each other having similar behaviour at similar configurations

References

- Ashitava Ghosal, "Robotics: Fundamental Concepts and Analysis"
- L. Stocco, S.E. Salcudean, F. Sassani, "Fast Constrained Global Minimax Optimization of Robot Parameters", Robotica, Int. J. Info., Edu. & Res. in Robotics & Artificial Intelligence, v. 16, pp. 595-605, 1998

Thank You