# Path planning optimization of six-degree-of-freedom robotic manipulators using evolutionary algorithms

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Source: Path planning optimization of six-degree-of-freedom robotic manipulators using evolutionary algorithms (sagepub.com)

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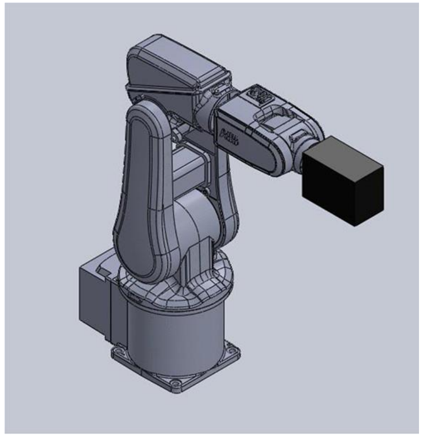
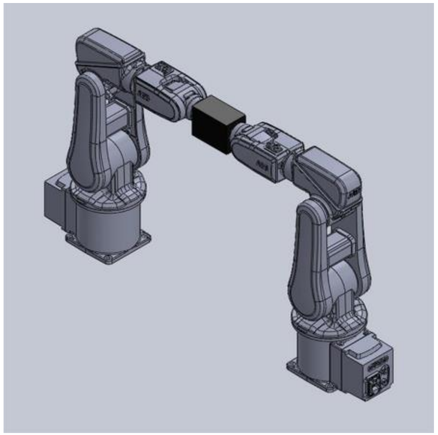
# Introduction

- Minimizing the actuator torque, which dependnds on the joint trajectory
- Less energy required
- Extending overall lifetime of manipulator

# Definition of the problem

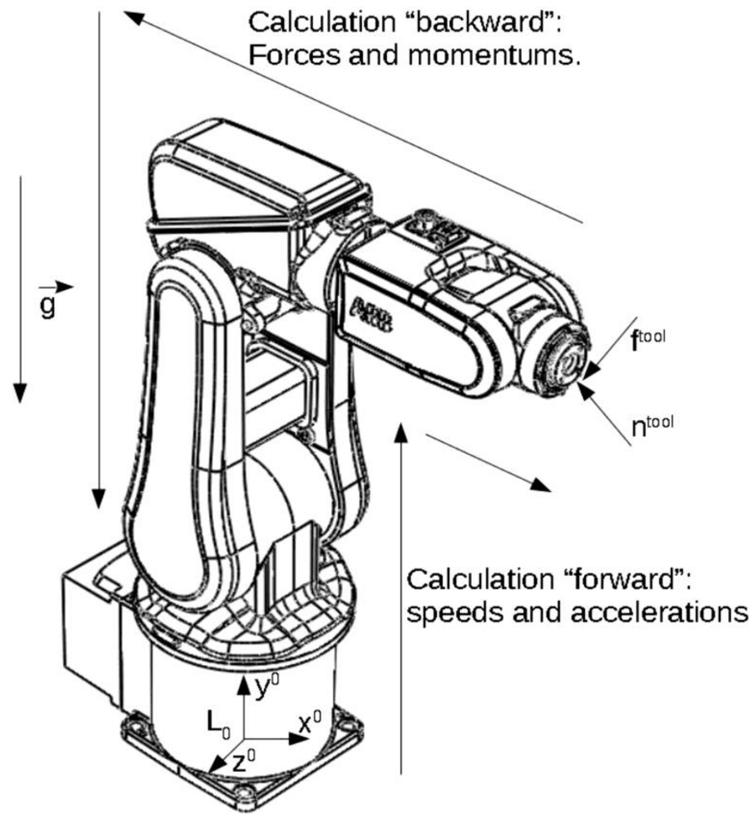
- 2 cases:
- One robot manipulator with six DOFs and two such manipulators working together by following the same path
- ABB IRB 120 was used for testing
- Robotic manipulators are transporting object with mass of 2kg along calculated path
- For path planning all joints start in position of 0 radians and finish in 1 radian
- Manipulators are stationary at the beginning and at the end of movement





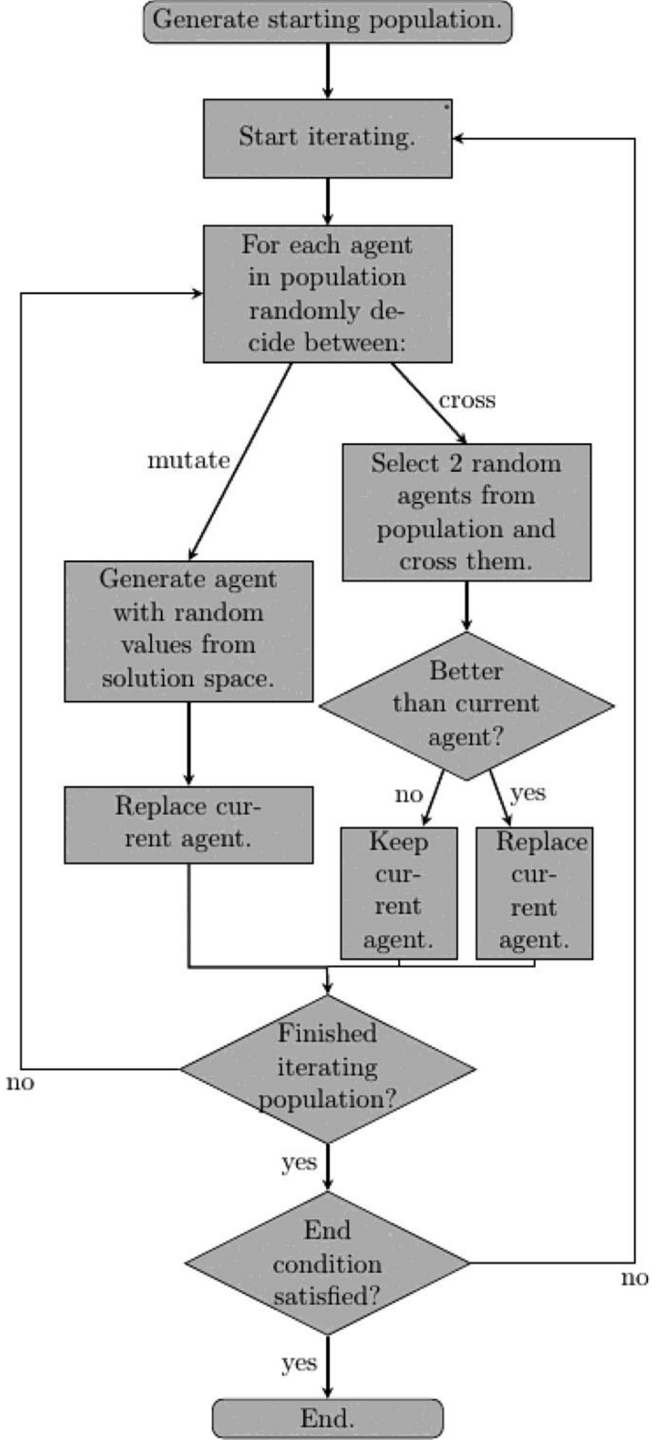
# Robot manipulator dynamics

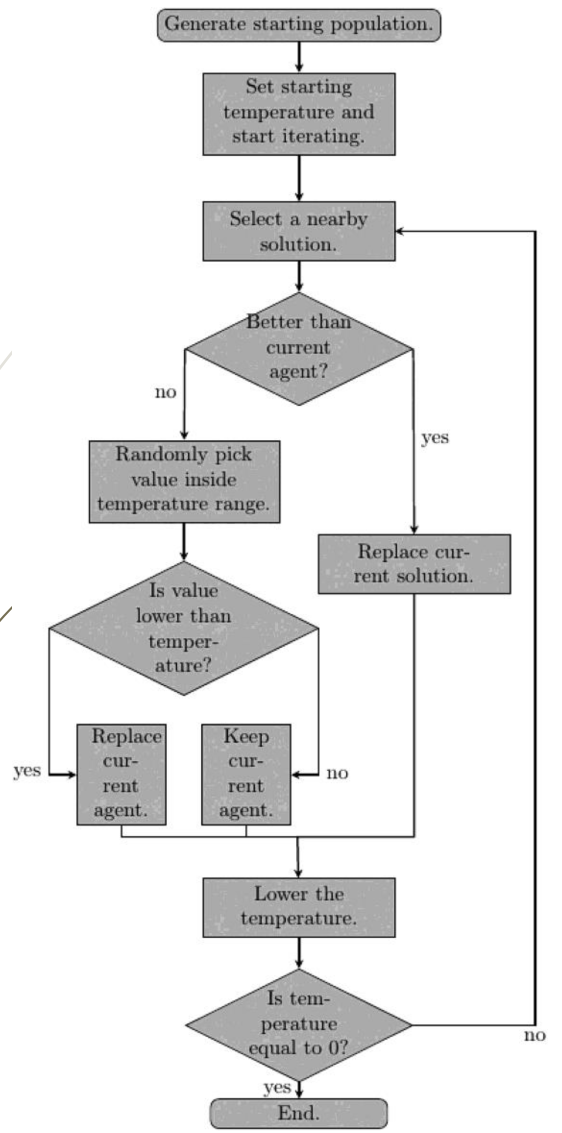
- Two algorithms are used to determine dynamic equations
- Lagrange-Euler and Newton-Euler
- Getting kinematic matrix is crucial step for obtaining kinematic dynamics of the manipulator
- Kinematic matrix is also needed for calculating inverse kinematic equations used in the second case
- Kinematic matricies are obtained using Denavit-Hartenberg method



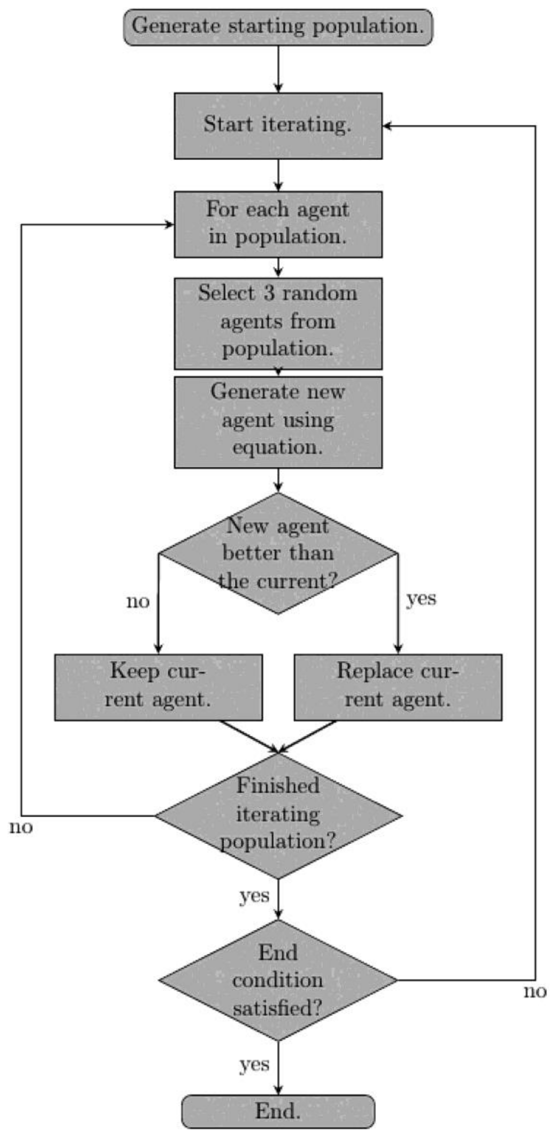
# Used algorithms

- Genetic algorithm with average recombination
- Genetic algorithm with random recombination
- Simulated annealing with linear cooling strategy
- Simulated annealing with geometric cooling strategy
- Differential Evolution






Simulated annealing

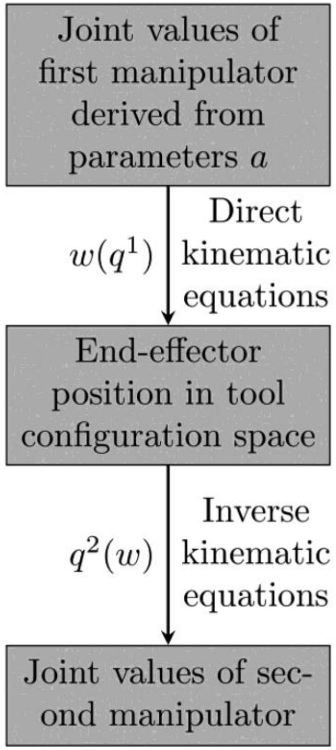



Diff evolution

# Agent construction

Phenotype of the robotic manipulator movement is represented with a parameter of the equation

$$\theta(q) = at^4 + bt^3 + ct^2 + dt + e$$



# Fitness function

- Sum of the total torsion on each point of the trajectory, where total joint torque is defined as the sum of joint torques on each joint of the robotic manipulator(s)

$$f(g) = \sum_{m=1}^{M} \sqrt{\sum_{i=1}^{n} \tau_i^2},$$

- Observed cases have 20 points in trajectory and *n* is either 6 or 12, the fitness function for each of the two cases can be defined for the case with the single robotic manipulator as

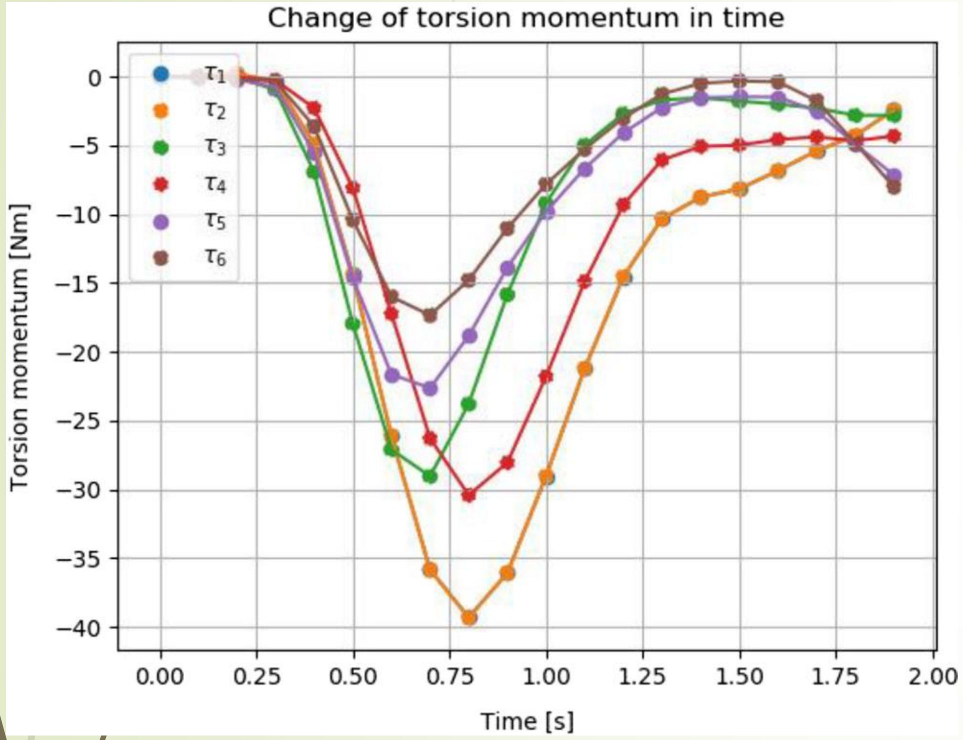
$$f(g) = \sum_{m=1}^{20} \sqrt{\tau_1^2 + \tau_2^2 + \tau_3^2 + \tau_4^2 + \tau_5^2 + \tau_6^2},$$

# Results

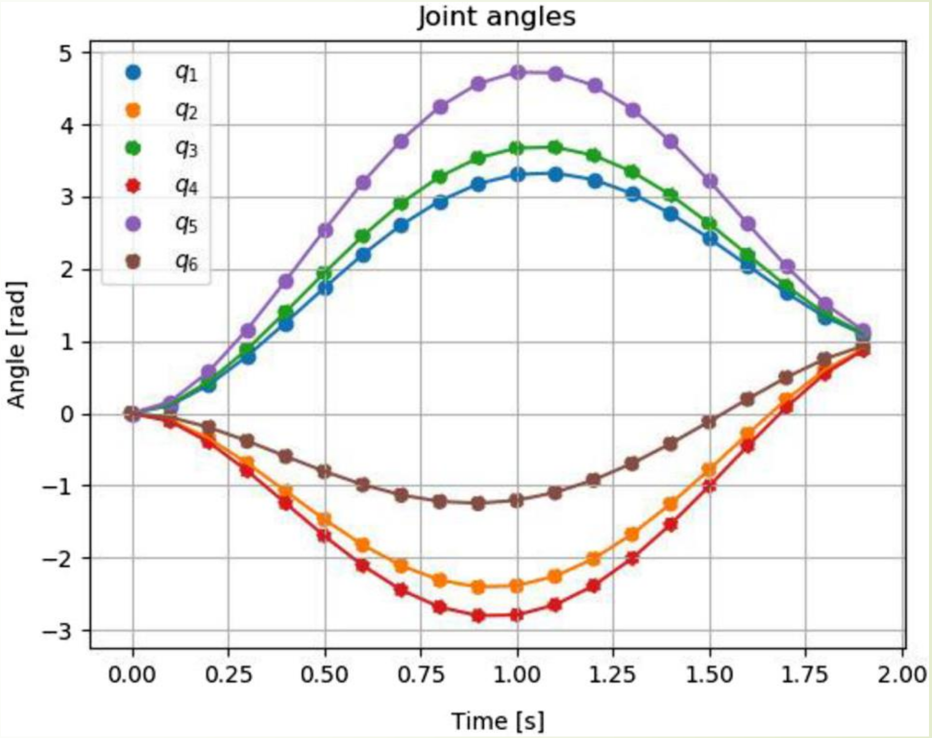
| | Single manipulator | | Dual manipulators | |
|---|---|---|---|---|
| | $\overline{\Delta}$ **Nm** | $\bar{t}$ **m:s** | $\overline{\Delta}$ **Nm** | $\bar{t}$ **h:m:s** |
| GA-A | 104.78 | 02:28 | **86.09** | **05:55:43** |
| GA-R | **177.96** | **02:17** | 54.84 | 06:50:38 |
| SA-L | 70.25 | 20.16 | 36.79 | 10:56:49 |
| SA-G | 100.82 | 08:20 | 14.94 | 17:03:10 |
| DE | 165.49 | 02:18 | 63.44 | 05:58:40 |

GA-A: genetic algorithm with average recombination; GA-R: genetic algorithm with random recombination; SA-L: simulated annealing with linear cooling strategy; SA-G: simulated annealing with geometric cooling strategy; DE: differential evolution.

# Results for single manipulator

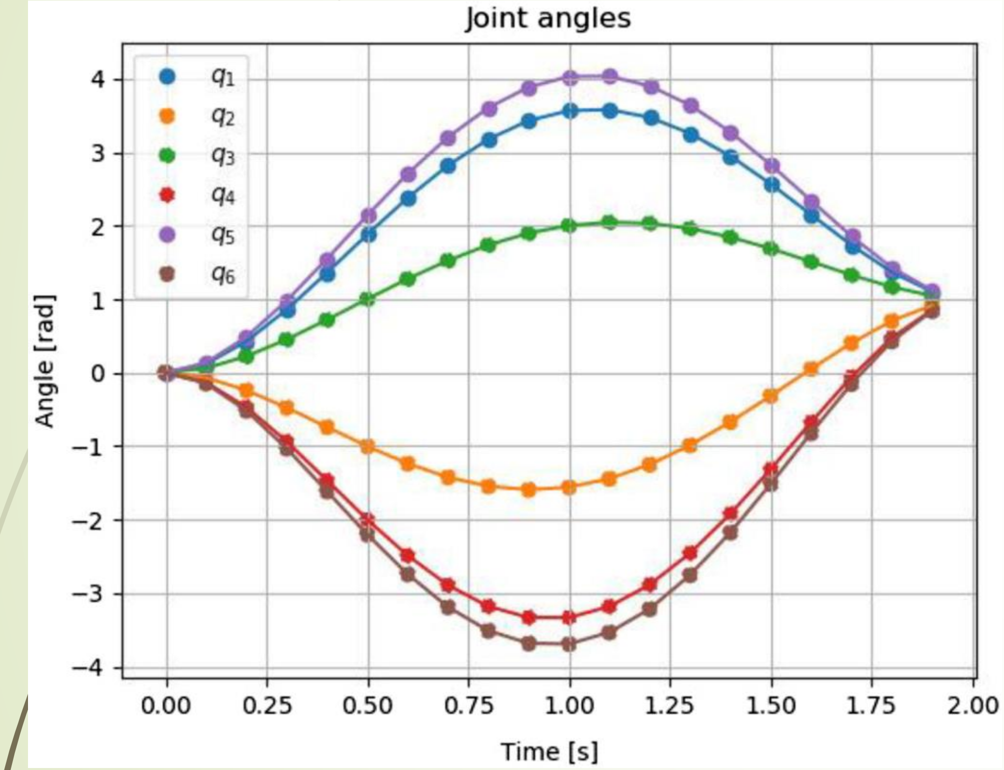



Change of torsion momentum in time

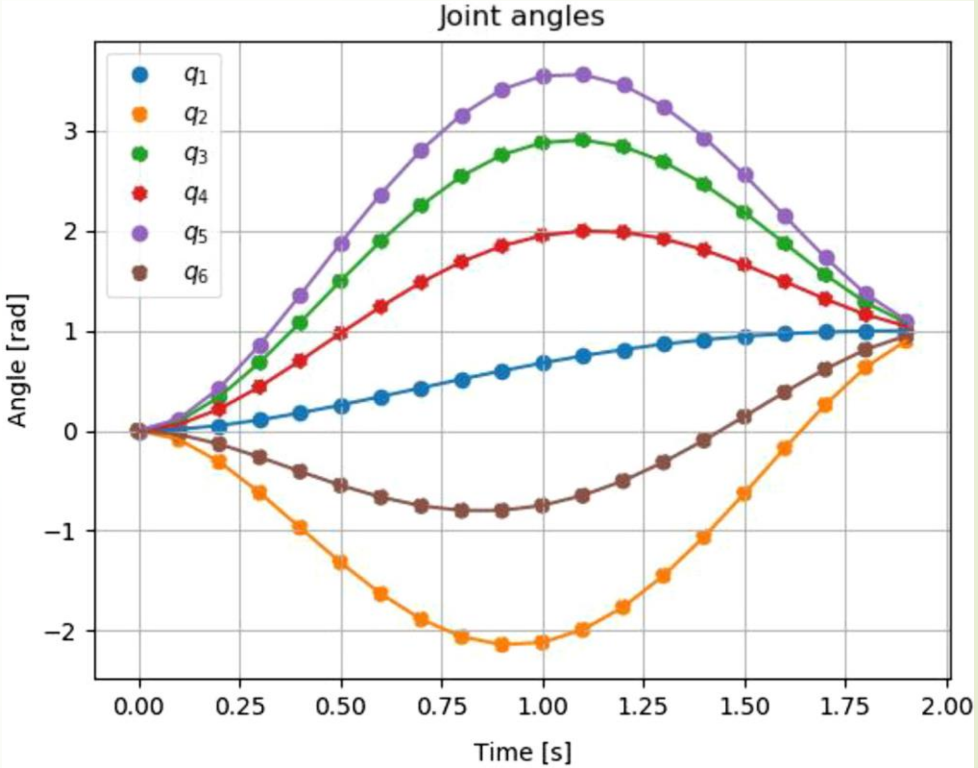



Joint trajectory for single manipulator

# Results for two manipulators

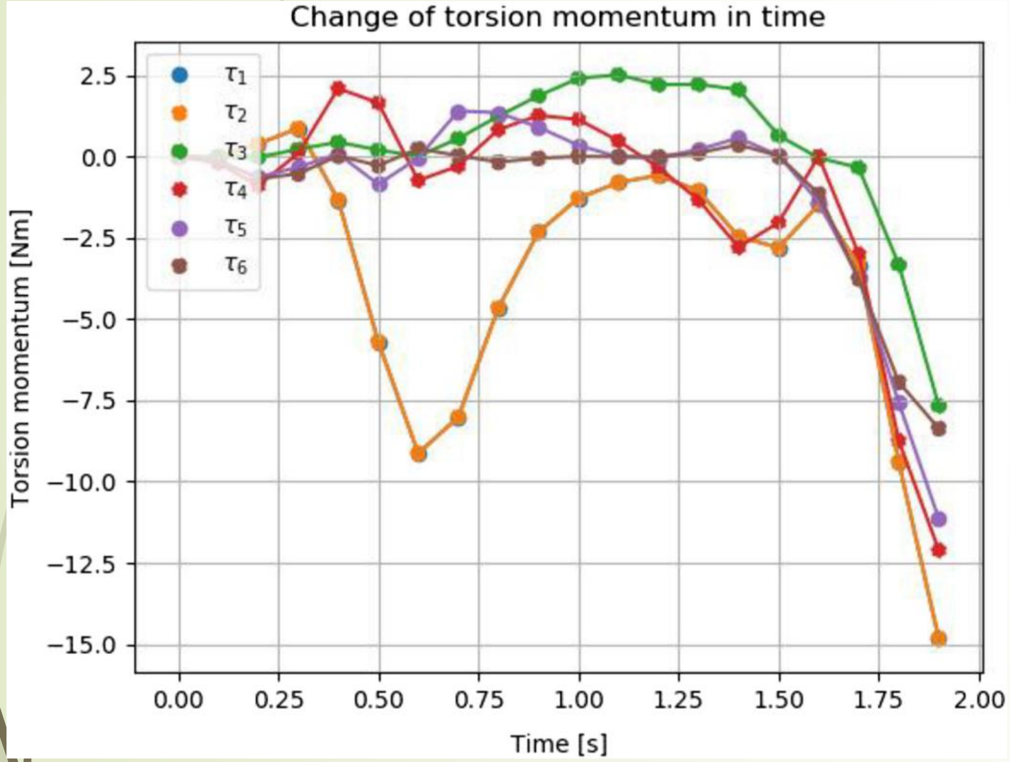



Joint trajectory for first manipulator

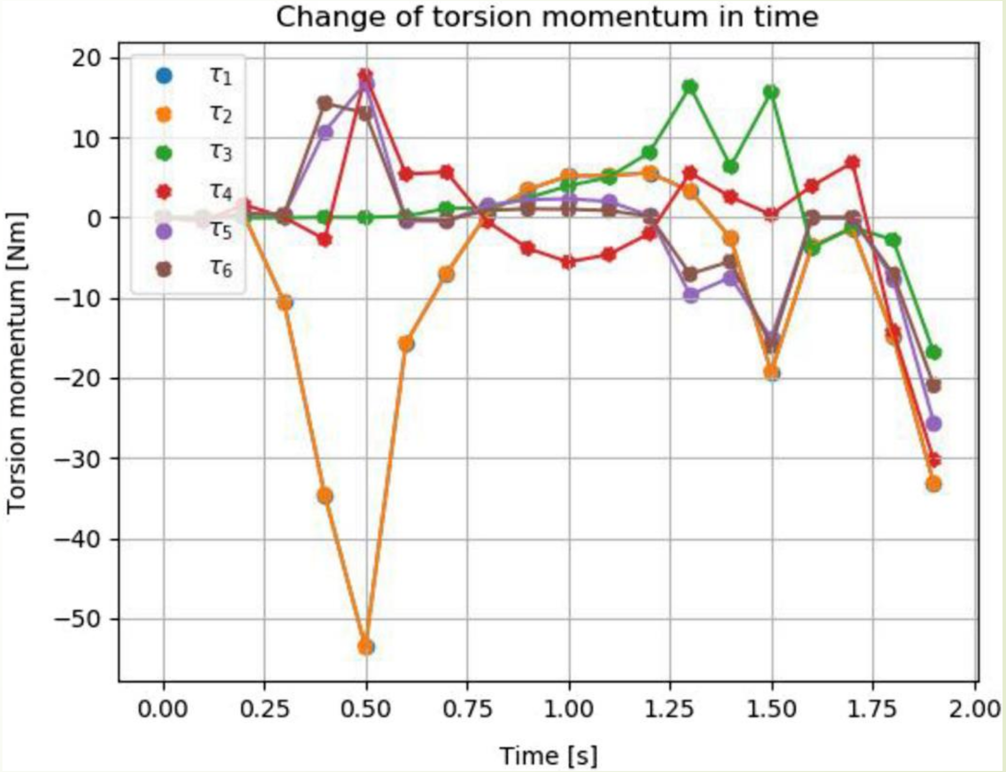



Joint trajectory for second manipulator

# Results for two manipulators




First manipulator




Second manipulator

# Conclusion

- Successful optimization in both observed cases using evolutionary algorithms
- Genetic algorithm with random recombination for single robotic manipulator and with average recombination for dual cooperating manipulators are providing best results
- In practice the amount of energy used for the robotic manipulators to perform work could be lowered along with the longevity increase
- Optimization results are high quality for the used robotic manipulator
- Only used on the point-to-point path planning
- Future work could concentrate on multi-objective optimization that would attempt to lower the joint torques as one objective, and provide a smooth curve as the other and more equal joint torque distribution along with adding continuous path planning