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Trajectory Control for High-DoF Manipulators

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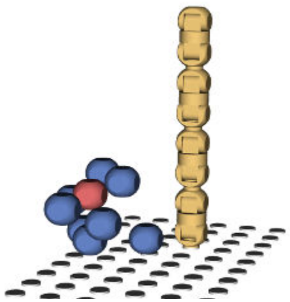
Motivation

Robotic arms, more commonly referred to as manipulators, are one of the most researched areas in robotics. They consist of multiple bodies, connected by mobile joints, and are equipped with tools depending on their purpose. They are useful in automation, as assistants, or even as building blocks for larger robots.

In order for robotic manipulators to be universally useful, we require an algorithm that lets the manipulator reach a certain position. Tasks like grabbing an object and moving it to a new location are essential, and can be computationally expensive when considering considering a high number of joints and obstacles that need to be avoided.

Industrial manipulator with 6 joints and a gripper for grasping objects


Problem: given a manipulator with a high number of joints (yellow), reach the target while avoiding nearby obstacles

State of the art

Standard solutions consist of systematically searching through possible joint rotations and finding a path from the inital position to the target; while avoiding collisions with the surrounding environment. The most popular methods are guided graph search (A*), and sampling based approaches (RRT). Although these methods work reliably enough for manipulators up to 6 joints, the number of possible positions for the manipulator grows exponentially with each additional joint - making it impossible to scale existing approaches to more complex manipulators.

Number of joints	Possible states
4	1049760000
5	188956800000
6	$3{,}4012224 \times 10^{13}$
...	...
10	$3{,}570467227 \times 10^{22}$

Given standard joints with 1° precision and 180˚ range, searching through all possible states quickly becomes impossible, even with heuristics.

Contribution

This thesis introduces a novel method for controlling robotic manipulators that consist of many small modules, and have a high number of joints as a result. The key idea is that instead of searching through the n-dimensional space of possible joint positions, we only search through the 3-dimensional space of possible positions for the end of the manipulator. Upon finding a suitable path for the end of the arm, we use a modern inverse kinematics algorithm to find the corresponding joint positions along this path.

Outline of the work

The first part consists of preliminary knowledge, introducing possible readers outside of the specific field into the problematic and establishing terminology. Then, standard methods and state of the art are introduced, describing the limitations of each approach.The core of the thesis is the design of the new algorithm. By extending existing algorithms, bringing in new ideas, and combining them into this novel method, superior performance is achieved. The final algorithm is evaluated in simulation, and tested in a diverse set of possible environments.

Achieved results

The computation is fast, the performed movement looks natural, and scales very well with respect to a growing number of joints and obstacles. With this algorithm, we can compute on-the-fly movement of robotic arms with more joints than ever before. The achieved results can move the field of robotics as well as computer animation forward, and allow completely new robot designs that can assist us in everyday life.

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