Bachelor thesis

Design of the trajectory generator for the robot manipulator and its experimental verification on the KUKA LWR 4+ robot

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1. Introduction

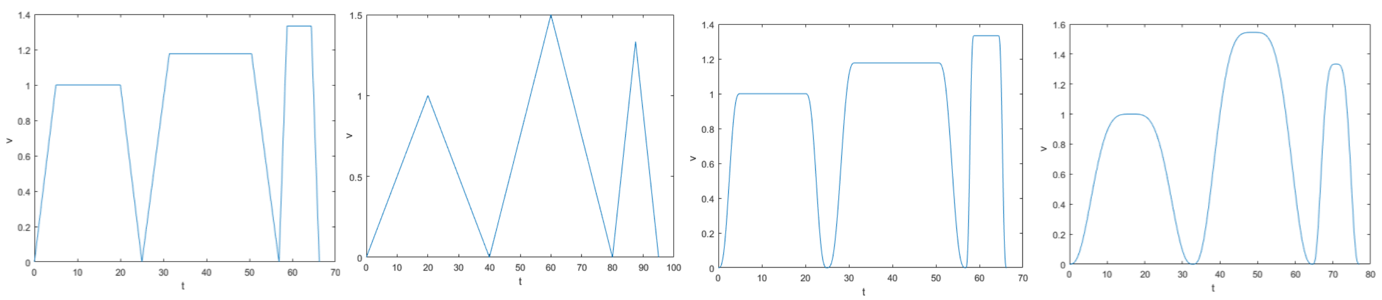
The purpose of the research was to implement the trajectory generator for a manipulator with any kinematic structure. The program was written in Matlab. It allows the user to define the requirements for TCP motion in Cartesian coordinates or displacements in joint space. As a result, it is a universal tool supporting the planning and setting of robot motion.

The work at first focused on familiarization with theoretical issues related to the generation of trajectories, then on the implementation of three basic velocity profiles (trapezoidal, sinusoidal and 7th degree polynomial) and two elementary path types (straight lines and arcs). The work concerned also synchronization of motion in joints, development of TCP orientation changes and method of connecting trajectory segments (to avoid stopping at intermediate points). In the final phase, the possibility of computer simulation of motion was prepared and practical tests were carried out on the KUKA LWR 4+ robot.

Figure: KUKA LWR 4+

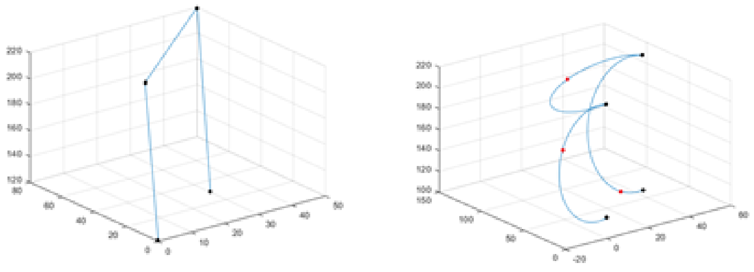
2. Velocity profiles and paths

Trajectory planning task can be divided into two stages. The first consists of planning the path in generalized coordinates - specifying a set of intermediate points (spatially in Cartesian coordinates or in configuration coordinates). The second stage is parameterization of the path in the time domain. It is determined by taking a specific course of changes of coordinate and its derivatives in time, called the velocity profile.



(a) Trapezoidal profile (b) Triangular profile (c) Sinusoidal profile (d) Polynomial profile

Figure: Sample graphs of velocity for different velocity profiles



(a) Linear path (b) Circular path

Figure: Sample motion paths consisting of lines and arcs

3. Simulations and experiments

Experiments planned in Cartesian space

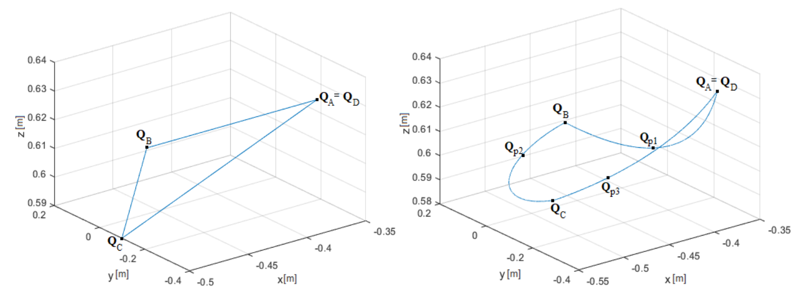


Figure: Planned Cartesian paths

Tests of velocity profiles were carried out on paths defined in Cartesian coordinates, as shown. The generated data cannot be directly transmitted to the robot. First, the inverse kinematics task must be solved to determine the joint coordinates corresponding to the Cartesian position and orientation at any time.

Experiments planned in Joint space

The manipulator motion was examined when joint coordinates generated at the appropriate frequency were sent directly to the robot. An experiment was conducted with lower velocity and acceleration values, later with higher. In both cases all velocity profiles were analyzed.

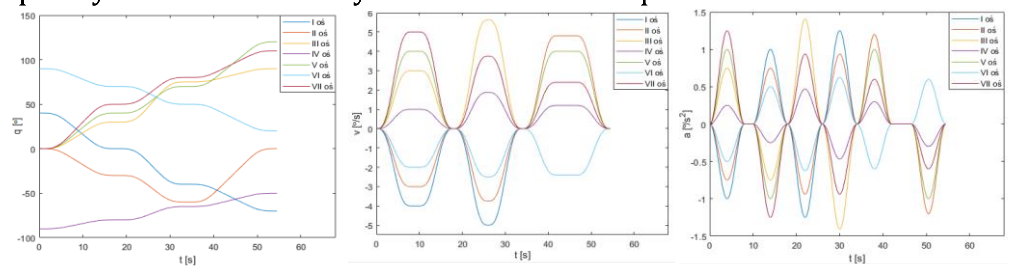


Figure: Positions, velocities and accelerations in axes (sinusoidal profile)

4. Conclusions

The user is allowed to choose between straight lines and circular shapes of paths, opt for velocity profile, impose kinematic restrictions on motion in different axes, synchronize axes motion, round the desired path to a varying degree to avoid stopping at any intermediate point.

- Practical tests confirmed the effectiveness of used solutions.
- Program allows to simulate motion – to display the path in space and kinematic parameter courses in the time domain. This enables effective planning of motion.
- Based on the data from the manipulator sensors, it was found that the set trajectory was reproduced with satisfactory accuracy, while this accuracy decreases with increasing velocity.
- A given path with assumed kinematic limits can be realized the fastest with a trapezoidal velocity profile, and the slowest with a polynomial, which in return ensures the continuity of acceleration function and smoothing kinematic parameters courses.