Chapter 10
Summary, Future Work, and Conclusion

This final chapter gives brief summaries of each single chapter of this monograph, presents ideas for future work, and finally draws conclusions of this work.

10.1 Summary

Literature Survey and Motivation

Besides on-line and off-line path planning and trajectory generation methods, Chap.2 surveys the fields of robot motion control and hybrid switched-system control. Additionally, force/torque control and visual servo control concepts are discussed as the most common kinds of sensor-guided robot motion control. This survey concludes with the motivation for this work:

“The majority of the surveyed concepts for off-line and also on-line motion generation produce a motion along a specified path. But, is this a good approach? — For purely position/pose and/or trajectory-following controlled motions: Sure and without restriction of any kind! But: When we execute sensor-guided motions, for example, by force/torque or by visual servo control, we do not have a predefined path anyway, because the robot motion directly depends on the sensor signal. We have to dismiss the path during sensor-based motion control! As soon as we embed sensor-guided or sensor-guarded motions, there is no predefined path anymore. In particular, we have to say good-bye to trajectory planning and reference trajectories along previously specified paths. There is no path that can be exactly followed, because everything may depend on sensors whose signals cannot be foreseen.”

Introduction of Different Types of OTG Algorithms

Nine different types of OTG algorithms, Types I–IX, have been introduced in Chap.3 All types generate kinetically time-optimal and time-synchronized

trajectories for mechanical systems with one or more DOFs. Depending on the type, the input and output values of the algorithms are specified. We distinguish between types of on-line trajectory generation algorithms that feature acceleration limitation, jerk limitation, or the limitation of the derivative of jerk. Furthermore, different target motion state parameters can be specified depending on the algorithm type. The simplest cases only allow the specification of a target pose/position, and for more complex types, target velocity vectors, target acceleration vectors, and/or target jerk vectors may be specified. The highest type that has been realized by the author is the Type IV OTG algorithm: This algorithm generates jerk-limited trajectories and allows the specification of a target velocity vector.

On-Line Trajectory Generation for One-DOF Systems

The algorithm for multi-DOF systems consists of three steps, and a part of the first step can also be applied to systems with one single DOF. In a one-DOF system, the algorithm time-optimally transfers the system from an arbitrary initial state of motion to a specified target state of motion. After a general description of the concept, the concrete solution for the Type IV OTG algorithm is presented in detail. The basic idea is that a finite number of motion profiles exists, of which one profile leads to the time-optimal solution. This profile can be selected by a decision tree, and, subsequently, a corresponding system of equations can be set up and solved. The solution contains all required trajectory parameters, such that the output values, that is, the state of motion for the current control cycle, can be calculated. During the solution of these equations, numerical problems appear, such that a procedure that uses a combination of the Anderson-Björck-King method and the simple bisection method was developed. This procedure ensures the robustness of the algorithm, and deterministic solutions for arbitrary input values can be calculated.

On-Line Trajectory Generation for Systems with Multiple DOFs

The key part of this work is an algorithm for the on-line generation of trajectories for robotic systems with multiple DOFs. This algorithm consists of three steps:

1. Calculation of the minimum synchronization time.
2. Synchronization of all DOFs to the synchronization time of Step 1 and calculation of all trajectory parameters.
3. Calculation of all output values for the current control cycle based on the attained parameters of Step 2.

The proposed algorithm for one-DOF systems is used to calculate the minimum possible execution times for all DOFs. The minimum synchronization