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Trajectory Generation for Path-Accurate Jerk-Limited Sensor-Based Path Corrections of Robot Arms

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***Abstract*— In previous work of the authors, trajectory generation for immediate path-accurate stopping is presented. It turns out that, with some extensions, this method is also applicable to generic trajectory generation, especially for computing a velocity profile for online modifications of the desired path, e.g. due to unexpected sensor data. The method computes a trajectory that satisfies constraints on the velocity, the acceleration, and the jerk, while staying as close as possible to the sensed desired path. A feasible solution is always found, even if exact path accuracy is not reachable. In contrast to time-optimal execution of the desired path, in this presentation the goal is to synchronize with the original robot program. So, e.g. after the execution of a sensed deviation the robot continues the original trajectory, maybe shifted by a sensed offset. The new trajectory is computed by iterative forward scaling and backtracking, where in contrast to other previous work the arc length is interpolated (ALI). In this way the path accuracy is superior to that with direct pose interpolation (DPI), which may feature undesired blending of subsequent path segments. Because of its time-efficiency the algorithm can be applied in each sampling step, e.g. every 4 ms for a standard KUKA robot with RSI interface.**

The poster presentation is based on a previous paper of the authors on trajectory generation [1]. There, programmed robot motion is refined by sensor data, where one challenge is to generate a feasible trajectory. A trajectory is feasible if it satisfies the constraints that are given by the industrial controller. Typically the velocity, the acceleration, and the jerk is constrained. In contrast to other methods the goal is not to reach a target pose in minimum time but to modify the sensed trajectory in such a way that

- it keeps the desired path, i.e. the geometrical shape of the sensed trajectory is preserved,
- after a possible deviation with respect to the original trajectory the latter is reached again, i.e. the original schedule is maintained.

These two conditions are required in order to avoid undesired contact forces and to run in parallel with other robots or devices which share the same workspace.

[1] generates the trajectory by iterative scaling and backtracking, where scaling accounts for non feasible acceleration or jerk and backtracking inhibits overshooting. If path accuracy cannot be maintained due to suddenly sensed significant changes, the acceleration and the jerk are directly scaled (direct scaling DS), resulting at least in a feasible trajectory.

Though [1] usually fulfills the requirements, there are special cases in which the used direct position interpolation (DPI) causes small path inaccuracies. See Fig. 1 for an example. A KUKA KR16 robot is programmed to go down while moving horizontally, each with 0.07 m/s. Then the trajectory is updated by a distance sensor, that stops the descent while continuing the horizontal motion. The resulting path is displayed in Fig. 1. Pure scaling results in overshooting while scaling and backtracking with DPI causes blending of the two path segments.

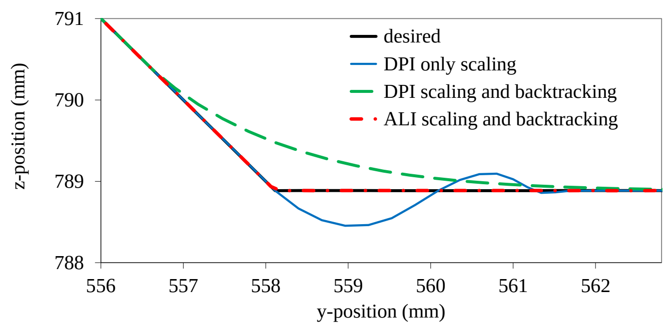

Fig. 1. Sensed and generated trajectories with different methods.

This can be avoided by using arc length interpolation (ALI), which has been introduced in [2] for the dual application of stopping a robot. This method is now generalized to generic trajectory generation. The fundamental ideas have already been submitted to [3], however the latest results are not yet included there.

In contrast to interpolating the axis positions directly, a scalar parameter $s(k)$, the arc length, is interpolated. It represents the time instant of the sensed trajectory which can be executed at time step k. So the computed sampling points of the new trajectory are always on the sensed path.

In the example of Fig. 1 the robot motion is decelerated substantially before the vertex. Then it is accelerated such that the original horizontal motion is reached.

Current and future work concentrate on methods that reach the original trajectory as fast as possible.

References

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[2] F. Lange and M. Suppa. Trajectory generation for immediate path-accurate stopping of industrial robots. In *Proc. 2015 IEEE Int. Conf. on Robotics and Automation (ICRA)*, Seattle, WA, USA, May 2015.

[3] F. Lange and M. Suppa. Path-accurate trajectory generation for an online sensed desired path. *submitted to IEEE Trans. on Robotics*, 2015.

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