MSc Thesis at Dept. Automatic Control, LTH

Popular Science Summary

Accuracy Improvement in Torque-Based Robot Arms Relieving Joint Stiction With Dithering

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Robot arm joints are driven by motors. Gearboxes are often used to communicate the rotation of the motor shaft to the robot joints. These might suffer from static friction (stiction) when moving at low angular speeds, reducing the motion accuracy. To relieve its impact, dithering signals can be integrated into the robot controller. This Master's Thesis investigates how this can be done and presents results from experiments.

The experiments were done with two robot arms with 7 joints that are designed to interact with people, also known as collaborative robot arms. One of the main problems with inaccuracies in the robot's motion is because of friction, which is complex to model and sometimes not included in the robot control algorithms. Static friction, shortened as stiction, is a component of friction that generally appears at low speeds. To relieve the negative effects caused by stiction, dithering signals can be integrated into the robot controller. A dithering signal is a periodic wave, in this case sinusoidal, that induces small vibrations in the robot that help to reduce stiction. To find the optimal dithering signals, the stiction was characterized first. Since the robot arm joints have different dynamical characteristics, it was necessary to study them individually and to create a specific signal for each of them.

Two approaches were considered to characterize the stiction. First, a more theoretical method that involved dynamics identification and relied on moving the robot around in its workspace to find its dynamic model. Dynamics refers to the study of the relationship between the motion of a robot and the forces and torques acting on it. Second, an empirical procedure named Single Joint Experiment (SJE) which targets each joint individually, moving only one joint at a time. The stiction modeling results from the latter proved superior and were thus selected for further investigation.

Following the characterization of stiction, custom dithering signals were generated for each joint and integrated into the robot controller. To see the impact of dithering on the accuracy, the Generated Trajectory Experiment (GTE) was conducted. This experiment involved creating trajectories in the shapes of a triangle and a pentagon, with and without the custom dithering signals being applied. Figures 1 and 2 showcases how the dithering cases (green) follow the ideal or reference trajectory (yellow) better than the non-dithering ones (red) for both shapes, which means that dithering reduces the path deviations. While Figure 1 plots the robot's paths in the XY-plane, Figure 2 shows the error comparisons of these paths in the Z coordinate.

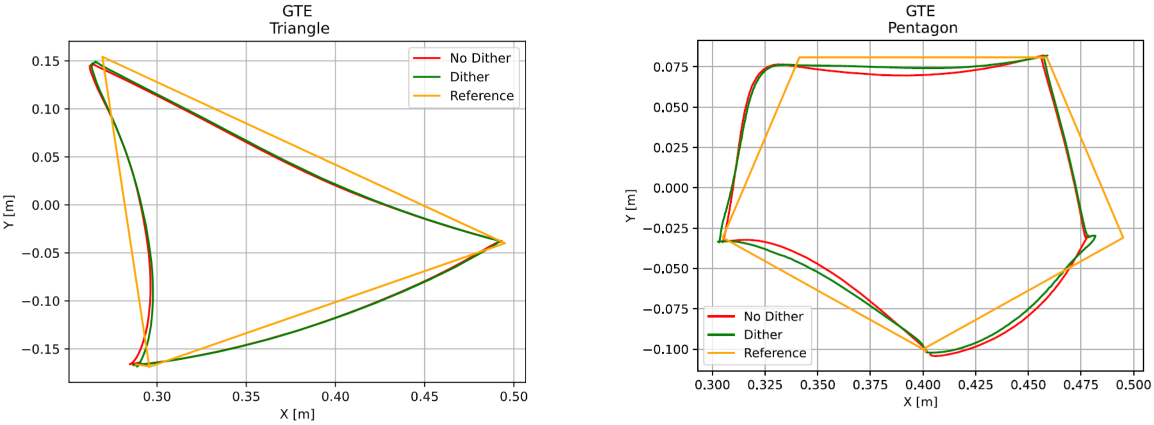

Figure 1: Triangle (left) and pentagon (right) paths conducted by the robot manipulator, with and without dithering compared to the reference. Only the X and Y coordinates from the 3D space are represented.

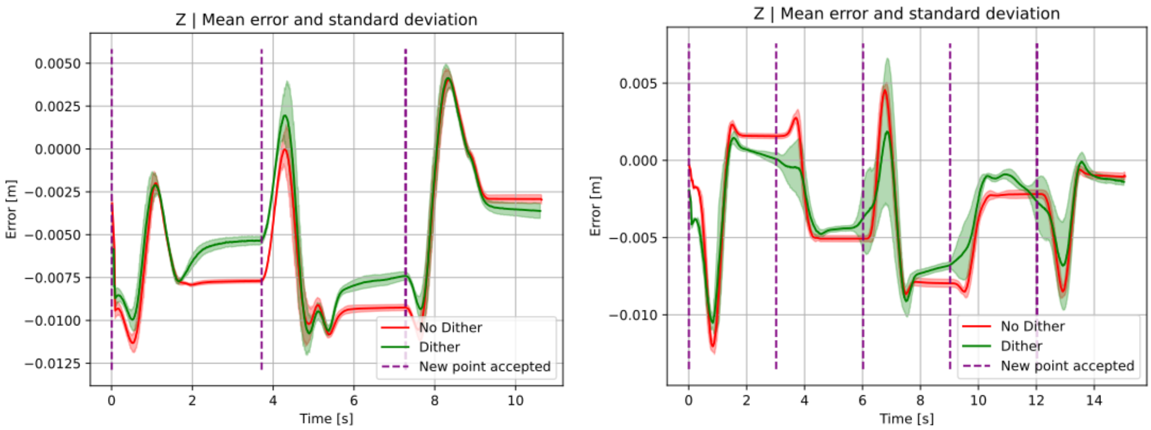

Figure 2: Comparison of errors for the Z coordinate of both the triangle (left) and pentagon (right) paths, with and without dithering. The vertical purple dashed lines represent the vertices of the triangle/pentagon, where the robot reduces its velocity and stiction mainly appears. If the error is closer to 0, the accuracy is improved since the manipulator follows the reference better.

This thesis work developed an empirical procedure (SJE) designed for characterizing stiction in the robot arm joints, which is applicable to any robot arm that admits torque control. At the same time, it shows an application of dithering in the robotics field, specifically related to collaborative robots. In conclusion, this thesis contributes to the improvement of accuracy in the robot arm movements, especially for high-precision tasks where even millimeters matter.

The full thesis can be downloaded from https://lup.lub.lu.se/student-papers/.