Trajectory Control

Time-Optimal and Vibration-Reducing Trajectory Planning and Control for Flatbed Printers

Graduate

Simon Wiesinger

Introduction: The company swissQprint develops and produces high-tech large format flatbed UV inkjet printers, with the Kudu model being its current high-end flagship (figure 1). The mechanical and mechatronic design of these printers must fulfill high requirements in terms of precision and speed to achieve excellent print quality. During the printing process the printer carriage moves in straight paths transversely across the printing area (y-direction) and reverses direction at its edge combined with a movement of the printer beam (x-direction). The overall objective of swissQprint is to optimize the turning movement in terms of time and smoothness. Therefore, the goal of this thesis was to develop and implement time-optimal and vibration-reducing trajectory planning and control for the Kudu printer.

Approach: The project consisted of two steps: first, implementing a dynamical model of the printer system and its control system, and second developing and implementing a new trajectory planer. Approximated bode plots based on frequency response measurements were employed to establish a model of the printer in SIMULINK. The approximations had to balance the need to sufficiently resolve the occurring (anti-)resonance frequencies and the problem of over fitting to measurement noise. The required information to model the control system was extracted from the printer's motion control software. The feedback controller consists of a cascading control with filtered signals and velocity feed-forward control. The model was initially tested with acceleration and jerk limited point-to-point trajectories and proved to be fully functioning, yet with potential for improvements. Without changing the overall structure of the motion control, new filter and controller concepts were developed and implemented. The filter strategy was adapted according to information gained from measurements and input from swissQprint. The parameters of the controllers were tuned, optimizing the magnitude and phase margin of the velocity and position open loops of the model. Subsequently, a concept for a new trajectory planer was developed. From several examined approaches, the method of using polynomials of higher order with support points was chosen. It combines the advantages of producing continuous trajectories with relatively simple calculations that can include arbitrary bounds and boundary values of the trajectories. The new trajectory planer was developed using MATLAB and later implemented in the swissQprint codebase using C++. The code consists of two optimization loops, one optimizing time, the other minimizing the y-distance of the movement (figure 2).

Conclusion: The new filter and controller concepts reduced the position and velocity errors of the initial test-trajectories in the modeled system by up to 92.8%. They could be a stepping stone for swissQprint to adopt some of the changes to their system. The successfully implemented trajectory planer was evaluated on all 33 test cases provided by swissQprint and produced the expected and required results. The calculated trajectories are continuous and within all given bounds (e.g. in figure 3). A Fourier analysis of the jerk trajectories showed a significant reduction of frequency actuation, proving the importance of using continuous trajectories. An evaluation of these new trajectories on the SIMULINK-model showed that they reduce the errors of the velocity and position even further.

Figure 1: The flatbed printer Kudu, developed and produced by swissQprint
swissQprint

Figure 2: Structure of the trajectory planer with two optimization loops, one for time and one for y-distance
Own presentment

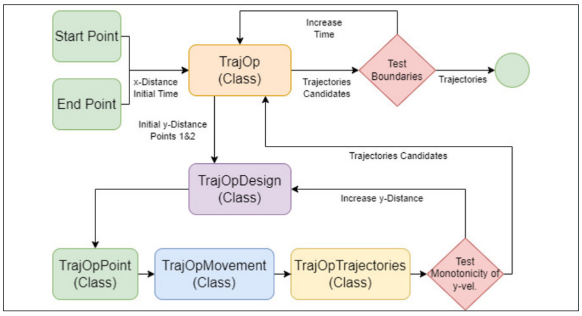
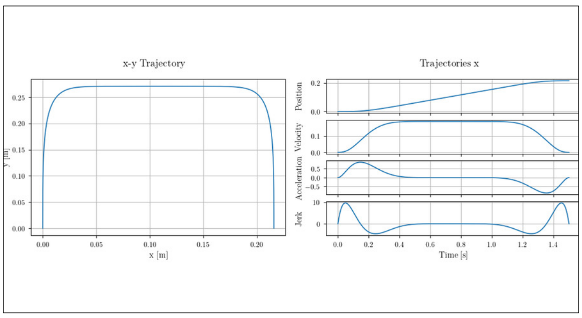


Figure 3: x-y-position-trajectory of a turning movement calculated with the new trajectory planer and its x-trajectories
Own presentment



Advisor
Prof. Dr. Wolfgang Wiedemair

Co-Examiner
Prof. Dr. Rainer Pickhardt

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Mechanical Engineering, Mechatronics & Automation

Project Partner
swissQprint AG, Kriessern, St. Gallen