# Novel Approach for a Piezo Motor Control Loop

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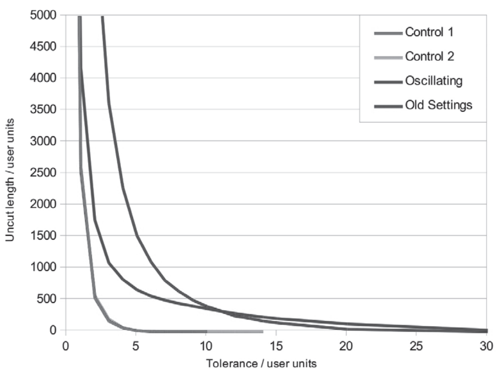
A device of the industry partner of this project uses piezo motors to actuate optical elements guiding laser beams used for imaging and machining applications. The current state of the art requires tedious manual tuning of the controllers of these motors to reach satisfactory performance. The goal of this master thesis was to develop a toolkit to assess the performance of different mechanical and electronic setups and controller settings. 

## Introduction

A device of the industry partner of this project uses ultrasonic, piezo linear motors to actuate optical elements guiding laser beams used for imaging and machining applications. For precise actuation, PID controllers with extended, piezo-specific functions are used.
The optics must be precisely actuated at high velocities with good repeatability in order to achieve a clean dissection of the tissue. The current state of the art requires tedious manual tuning of the controllers to reach satisfactory performance.
The goal of this master thesis was to develop a toolkit to assess the performance of different mechanical and electronic setups and controller settings. The toolkit could then be used to automate the tuning process or to evaluate novel approaches to control the piezo motors.

## Materials and Methods

The test setup used for most experiments consists of the main controller board as used in the device and the optomechanics including the piezo motors. The electronics controlling the device include an ETX form factor computer-on-module and multi-axis motion controller cards.
The test setup was connected to a dSPACE MicroAutoBox II system. A model was then developed in Matlab/Simulink and run on the MicroAutoBox II to monitor in real time the position and controller output of the piezo-actuated axes.




**Prediction model result of several test runs, depending on allowed tolerance.**

A test method to evaluate system performance was developed based on circular motion patterns. To evaluate the trace files obtained in the test, a performance prediction model was developed. This model calculates an estimated precision value based on the trace files. The model focuses on the repeatability of the motion, as this is the key problem for the actual usage of the device.
The device's software running on the ETX computer-on-module was extended with the functionality required to autonomously perform motion test runs, using pre-programmed trajectories and controller settings. This allowed for automated data collection.
To test the developed prediction model, two series of experiments were conducted which allowed to tune the model parameters by comparing model prediction to actual outcome.

## Results

Most elements of the envisaged toolkit were realized. Testing of alternative control approaches or adding an appropriate optimizer algorithm to automatically tune the existing controller is now feasible. However, the performance prediction model still has its limitations, see our discussion below.

## Discussion

Due to the complexity of piezo linear motor control, as well as the lack of literature on control of the exact type of piezo motor used in the device, efforts to evaluate novel control approaches had to be deferred in favor of research on the methods and models needed for evaluation.
The performance prediction model is promising, but still not fully satisfactory because it cannot correctly handle certain motion patterns. The current model can tolerate lateral path deviations below a threshold, but is unable to tolerate them if they occur only over a short distance (see Figure).
Further refinement of the model is required, as are experiments to validate the model.

## Acknowledgements

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