Master's Thesis TFRT-6075, Department of Automatic Control, Lund University, Sweden, Dec 2018 Marcus Peterson

Vibration Reduction of a Gantry Robot using System Identification

Ever since the advent of robots in the mid '50s, there has been a constant drive towards ever faster and more efficient robots, especially in the manufacturing industry. Without a proper method of control the robot can collide with objects in the work-space, or unwanted oscillations may occur. To avoid this a proper control strategy must be developed for each robot. However, not all robots are designed with a mathematical model in mind, but rather built on experience and through the tried-and-true method.

A proper control strategy can help reduce time between cycles of a machine, making it more efficient, as well as reduce the wear and tear that comes from excessive movements.

This thesis aims to identify a suitable linear model of a 2-axis Gantry robot, which could be used to implement a control strategy so as to eliminate vibrations during operation in the robot.

By using a linear model to try to approximate a non-linear process, the thesis aimed to identify parameters in such a way, that the linear model could give similar values to the real-world process and give insight into how the process worked. To try to come as close to reality as possible the friction was also studied. The behaviour of the Gantry robot was modelled as a two-mass system connected by a spring and a dampener.

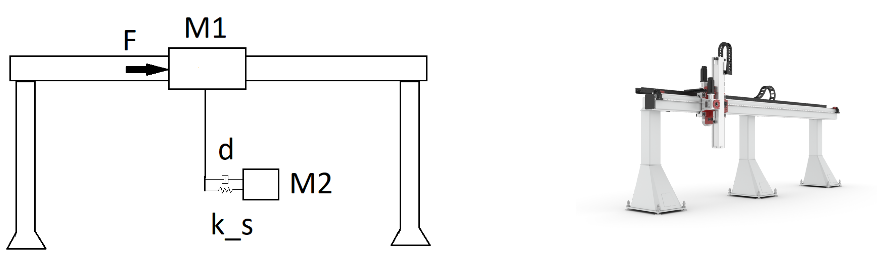

Figure 1: Figures of the model and the real robot system.

The first step to identify the friction in the Gantry robot was to use constant speed tests to see what torque was required at different speeds to combat friction. This was plotted in a curve and fit to the LuGre-model of friction. This was done using Matlab. The next step was to run chirp-signal tests to explore the widest range of frequencies possible, which is limited by the maximum output torque of the motor. The lowest part of the cart system, where undesired oscillations had been noticed on the real robot system, was measured with sub-millimeter accuracy using a laser-based sensor. The sensor collected position measurements, which together with measurements from internal sensors in the cart were put into Matlab. These measurements were used to try to estimate parameters of the model to fit the experimental data. This was done using both Grey-box and Black-box estimations. No complete model of the real robot was reached, but a nonlinear friction model was estimated and the resonant frequency of the system found (around 6Hz).

The same methodology with friction and model estimation was also applied for a second robot setup, but based on acceleration measurements of the robot tool tip instead of the position measurements. In this case we could show that a more complex friction model was required as, for example, stiction changed significantly within the workspace, with depencance of the motor angle of robot base joint.

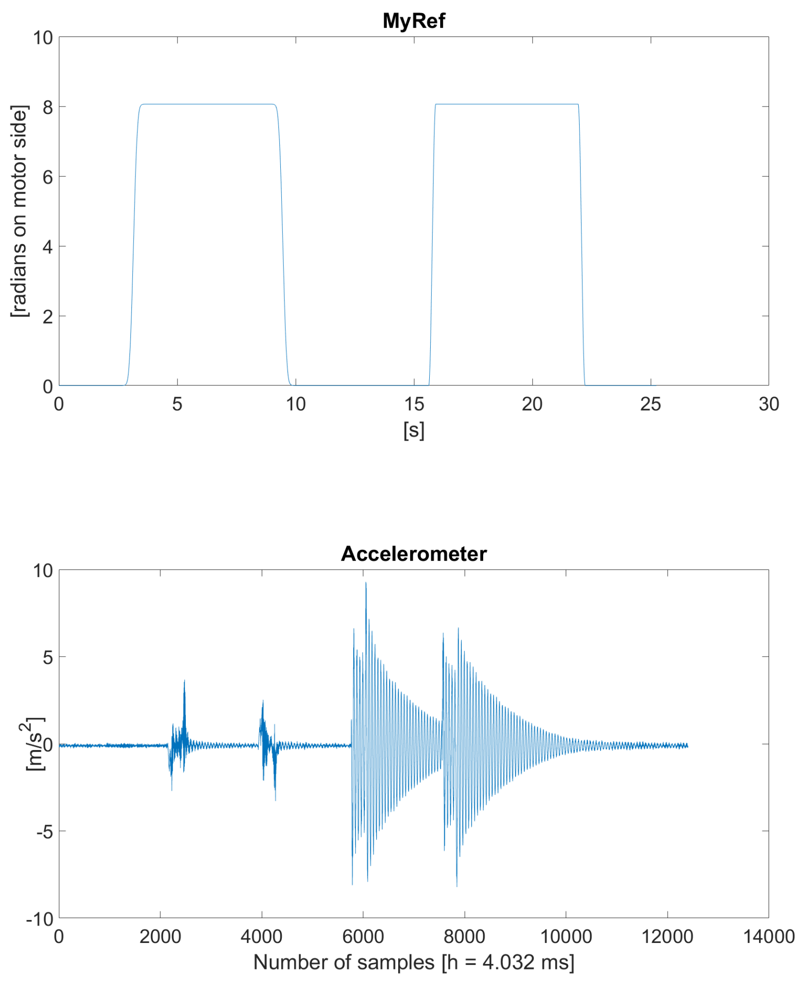

Figure 2: (Upper) Position reference based on a trapetsoidal velocity profile, first notch filtered, then unfiltered. (Lower) Corresponding acceleration measurement at tooltip. Notice the large difference between the responses for the filtered and unfiltered reference, with minimal differences in transition times.

Based on the identified resonance frequency, an experiment with a notch-filtered reference trajectory (reducing the frequency component of the resonant mode) showed significant reductions of vibrations, see Figure 2. The resonant frequency found that a notch filter on the reference signals could be used to eliminate vibrations. This is done to filter out the frequency at which the system becomes resonant. This causes almost no loss in speed of movement.

This is useful for increased efficiency of the system, as well as a reduction in wear and tear. Should some disturbance enter the system from outside, it is important to have a control structure that reduces these. To implement such a structure, knowledge of the model of the system is needed to make it as efficient as possible.

References

[1] M. Peterson, *Vibration Reduction*, Master's Thesis TFRT-6075, Department of Automatic Control, Lund University, Sweden, Dec 2018