Modeling of a Motorized Gimbal System

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Abstract

By utilizing system identification methods, non-linear models are fitted to a 3-axis gimbal system. The produced models captures the dynamics to a degree were pole placement can be used to reliably tune the system's PID-controllers. However, the models lack an explanation of the internal cables' influence on the dynamics, which is needed for improved accuracy.

Introduction

This project is a continuation of a former project and is part of an ongoing collaboration between Newton Nordic and LINK-SIC. The aim of the project is to model and improve the control of the company's main product, a motorized camera stabilizing system, NEWTON.

The system consists of three axes; *pan*, *roll* and *tilt* corresponding to rotation in the Z-, X- and Y-axis respectively. To control the camera's orientation the system is equipped with PID controlled motors to stabilize the camera's movements.

The NEWTON system.

Results

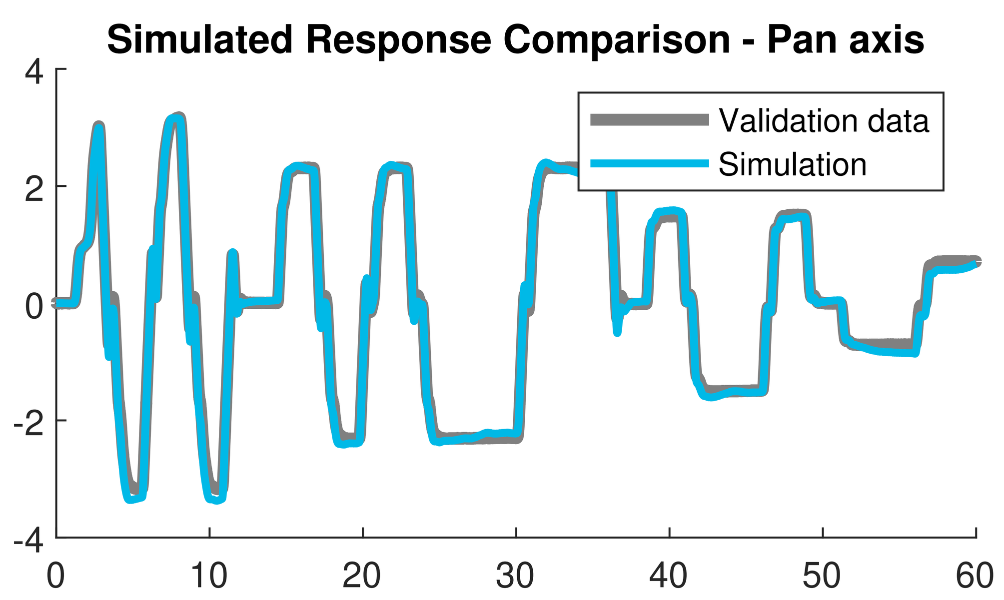
By modeling each axis independently, all three axes can by satisfactory or sufficiently modeled by an inertia, frictional torque and a gravitational torque caused by the misalignment of the rotational axis and the system's center of mass.

$$J\dot{\omega}(t) = u(t) - T_{fric}(\omega(t)) - T_{mc}(\theta(t)) \qquad (1)$$

In the *pan* axis gravitational misalignment is eliminated by the horizontal operation. Two parameters for friction and one parameter for inertia results in a model that successfully captures the main dynamics.

$$T_{fric}(\omega(t)) = T_{coul} \cdot \tanh\left(\frac{\omega(t)}{0.01}\right) + c_{fric} \cdot \omega(t) \quad (2)$$

The model's parameters are optimized to replicate an independent signal and then validated using a separate and more advanced signal. The *pan* model can predict the output with up-to 90% accuracy given the torque input. With noise accounting for some loss of information this is considered a satisfactory result.

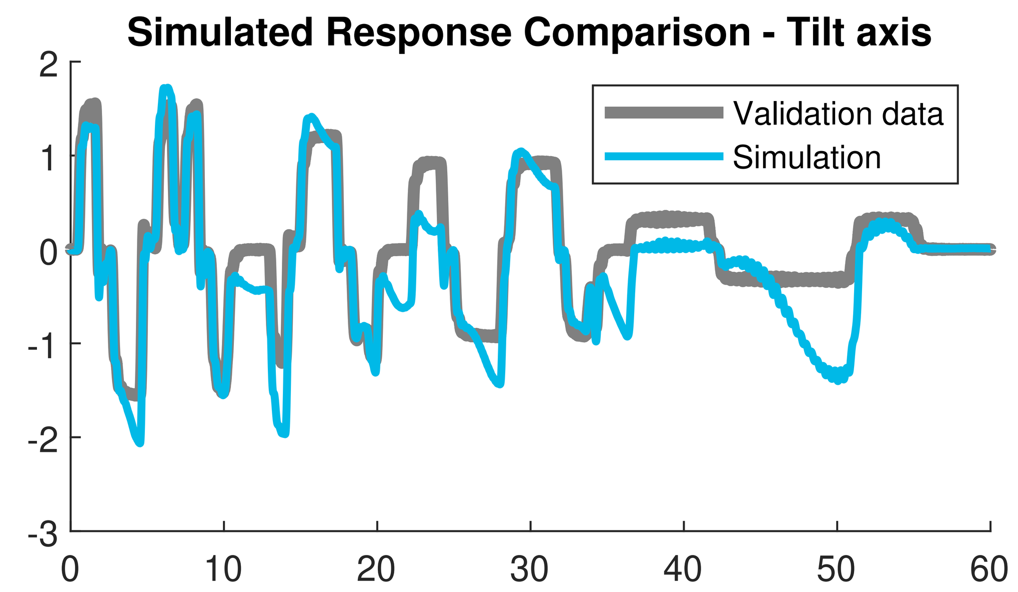


Pan model simulated on validation data.

For the *tilt* axis, the complete model (1) is used with friction according to (2) and gravitational torque modeled by

$$T_{mc}(\theta(t)) = c_{cos} \cdot \cos(\theta(t) + \alpha) \qquad (3)$$

yielding a five-parameter model which can sufficiently capture the main dynamics of the axes, in the best cases reaching about 60% accuracy for validation data. The *roll* axis is modeled in the same way and achieves a similar performance but with a lower accuracy.

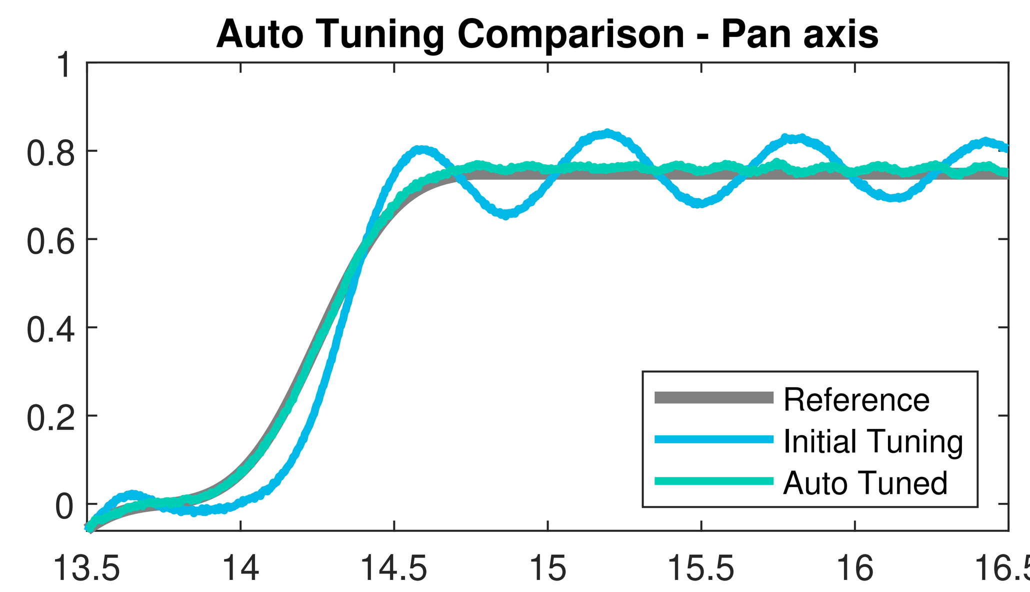


Tilt model simulated on validation data.

The cause of the lower accuracy are the cables running through the joints of the *roll*- and *tilt* axes. With these removed, similar results as for the *pan* axis can be achieved.

To control the system a simple linearization is performed, followed by a pole placement approach. This simple method can be used to successfully tune the system to a stable and non-oscillatory behavior, for all the axes and with several set-ups tested as validation.

An example of the auto tuning performance is shown in the following figure, where the oscillations of the system are clearly reduced.



Performance of the proposed auto tuning.

Conclusions

- To increase performance in *roll* and *tilt* a model capturing the dynamics of the cables is required, however, the current models are sufficient for rudimentary control purposes, such as the PID tuning.
- Implementing the current algorithms is impossible due to their complexity and NEWTON's limited computational capacity. To counter this a more efficient method and/or approximations needs to be developed.
- To improve the control a more advanced method capable of compensating the non-linear effects should be implemented.

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