Control of a Gantry Crane

Project Code: SL1-12

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Project Overview

Introduction

We design and analyze control algorithms for a gantry crane in an ideal setting, where sensor-estimator communication is perfect, and in a networked setting, where such communication is lossy, typical in wireless sensor networks.

Aims and objectives

- **Aims**
  - Implement a control algorithm that can suppress the swing angles of the gantry crane in the ideal setting.
  - Analyze the degradation of this algorithm in the networked setting as well as seek ways to cope with lossy communication.
- **Objectives**
  - Improve the performance of a real sized gantry crane eventually in the field based on our study
  - Understand the system behavior in a networked setting and eventually make it feasible to use wireless sensors on gantry cranes.

Methodology

Block diagram

- High level view of the gantry crane control system

\[ \begin{align*}
  & \text{Reference} \rightarrow \text{Controller} \rightarrow \text{Sensors} \\
  & \downarrow \text{Disturbances} \\
  & \text{Communication link} \\
  & \downarrow \\
  & \text{State estimator} \\
  & \rightarrow \text{State} \\
  & x_k, y_k, u_k, e_k, x'_k
\end{align*} \]

Reference: the desired state input by user
Controller: consists of a PID controller and an input shaper
State estimator: implemented with a modified Kalman filter
Communication link: unreliable channel with packet-drops
\( e_k \): difference between reference and estimated state at time \( k \)
\( u_k \): control signal computed by the controller based on \( e_k \)
\( x_k \): state of the gantry crane system
\( y_k \): sensor measurement of the system state
\( f(y_k) \): sensor data after passing through communication link
\( x'_k \): estimated system state based on received sensor data

Results

Control in an ideal setting

In the experiment, the gantry crane trolley was programmed to move back and forth in a designated path. The figure shows that the control algorithm is capable of keeping the swing angles within five degrees under perfect communication.

Control in a networked setting

The plots here show angle change over time in these two settings.

- Maximum and average swing angles increase with larger sensor data loss probability.
- Though sensor packets are lost randomly, we can show that the crane trolley still approach the destination, given that process noise is small.
- In the presence of sensor transmission energy budget, we can schedule timing of transmissions to optimize state estimation performance.

The plots here show angle distributions in these two settings.