Overview

Gantry crane is one type of crane, which is widely used in manufacturing factories for objects lifting and displacement. In this project, network control system is constructed with trajectory and anti-swing controllers, imperfect network, and Extend Kalman filter as the estimator. Besides, we test the control performance in ideal network, packet-dropping network, and packet-delay network, and the relationship between the maximum swing angle and network properties is analyzed.

Methodology

State space modeling

\[
\dot{x} = f(x,u) + w
\]

PID controller

The controller, consisting trajectory control and anti-swing control, receive the state data from the sensors or from estimators, calculate the expected performance of actuators according to PID algorithms, and send the output to the actuators. The state model is:

\[
\begin{cases}
\dot{x}_1 = x_2 \\
\dot{x}_2 = x_3 \\
\dot{x}_3 = x_4 \\
\end{cases}
\]

Extended Kalman filter

Since the highly nonlinear property of the state-space model, we give up the linearization and implement extend Kalman filter as the estimator. The state-space model is:

\[
\begin{cases}
\dot{x}_1 = x_2 \\
\dot{x}_2 = x_3 \\
\dot{x}_3 = x_4 \\
\end{cases}
\]

Results

We conducted the experiments, in which network control system with packet-dropping property and only sensors’ data passing through the network is built and network . In same drop rate, the experiment is repeated 30 times to derive the distribution of the maximum angle.

The result turns out that the maximum angle has the mean almost independent from the dropping rate and the variance increases as dropping rate increases.

Estimation in packet-dropping network

In packet-dropping network, at time \( k \), \( y_k \) is a flag indicating whether the packet transmitting is dropped. The EKF needs to be modified as:

\[
\begin{align*}
\hat{y}_k &= y_k \\
\hat{y}_{k+1} &= \hat{y}_k + \hat{y}_k
\end{align*}
\]

Estimation in packet-delay network

In packet-delay network, the delay time of the network at time \( k \) is represented as \( d_k \). Assuming the maximum length of the buffer in estimator D, the maximum delay time that can be recovered by the estimator is D-1. For any \( d_k \geq D \), the corresponding packet is considered as dropped. \( y' \) is the indicator, representing whether \( y \) arrives at time \( k \).

\[
\begin{align*}
\hat{y}_k &= y_k - y_k \\
\hat{y}_{k+1} &= \hat{y}_k + \hat{y}_k
\end{align*}
\]