A Model based Predictive Control Strategy using LED Communication Channel in Networked Control Systems

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네트워크 제어 시스템에서 LED 통신 채널을 이용한 모델 기반 예측 제어 전략

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Abstract

Networked Control Systems (NCS) through wireless channels are becoming more frequent in industry, because, thanks to these communication networks, the control can be conducted in a cost-effective way. However, using these wireless networks in communication increases the possibility of data loss, which can be harmful for the stability of the plant connected to the NCS. On that condition, the controller might work inappropriately and probably drive the overall system to an unstable condition. In this paper we present a simulation of a predictive control strategy in networked control system that can lead with possible data loss, while using an optical LED communication channel.

Ⅰ. Introduction

An NCS is a set of systems, sensors, actuators that are interconnected through a local network or Internet. The theory of networked control studies the ownership of control systems where the communication between sensors, actuators and controllers is not always perfect. This occurs due to the presence of a shared means of communication, possible delays in communication or the desertion of packages, among others.

The basic capabilities of any NCS are the acquisition of information (sensors/users), command (controllers/users), communication, network, and control (actuators). The controller node will receive the measurements from the sensor node through a wireless communication network.

Experiments using NCS suggest that there might be periods of time when the destabilization of NCS occurs because of time delays. Some authors have different proposals to reduce the effect of this phenomenon in the control of a given process [1]

Model Predictive Control (MPC) is an algorithm that enables to control a process using the minimum cost. [2] Using a model described by a discrete-time transfer function, the plant response is given by:

$$y(k+i|k) = \frac{B(z-1)}{A(z-1)}u(k+ik) \quad (1)$$

The general expression for the objective function is:

$$J = \sum_{i=N_1}^{N_2} Q(i)[\hat{y}(k+i|k) - w(k+i)]^2 + \sum_{j=1}^{N_u} R(j)[\Delta u(k+j-1)]^2 \quad (2)$$

where

$$\hat{y}(t+j|t) = \sum_{j=1}^{m} a_j \hat{y}(k+i-j|k) + \sum_{j=0}^{n} b\hat{y}(k+i-(j+1)|k) \quad (3)$$

$Q(i) \in R$ and $R(j) \in R$ are values that penalizes the plant process and the controller. w(t+ j) is the trajectory function. N_u is the control horizon, defined as $N_2 - N_1 = N_u$.

In order to minimize this function, some constraints are needed and we calculate the vector control.

$$u(k+i|k) = u(k|k) + \Delta u(k+i|k) \quad (4)$$

The use of the MPC in an NCS seeks to maximize the profit, while making higher economic efficiency on industrial process. Some authors have proposed strategies to improve the performance of the NCS using MPC and the prediction capability of the MPC algorithms to tackle with variant time delays and packet dropout [3] [4] [5] [6].

LED communication, also known as mobile device light communications, is a technique that repurposes mobile computer displays and other light-emitting diodes (LEDs) for communication purposes. It uses high-brightness, fast-switching LEDs to transmit information in the visible light spectrum for short range wireless communication. They offer potential benefits like conserving the radio spectrum and making it difficult for eavesdroppers to intercept communication signals. LED communication offers several benefits, such as energy efficiency, low cost, and reduced radio spectrum interference, making it a promising alternative for short-range communication applications [7] [8] [9].

Ⅱ. Control Strategy

In this paper we consider an NCS composed of five nodes as follows: a sensor node, a controller node, an actuator node, a communication wireless network and a model of the plant. Before the controller node, a register was installed in order to save all the data from the sensor node in case of data loss in the communication channel between the sensor and the controller.

In a similar case, a buffer was installed before the actuator where the control vector is stored. The possibility of data loss occurs when the sensor node sends the measurements output trough the wireless network communication during the main control cycle. The sensor node measures the output of the process at instant t and sends the measurements to the controller node through the communication network.

The controller receives the data sent by the sensor node and computes a control signal vector **u(k)** for each response of the plant, using a predictive control algorithm.

The controller node, the sensor node and the actuator node are time-based, and they are running at the same sampling period. A data package from the sensor node is considered lost if it is received by the controller node after a certain time out of the sample interval.

The controller node waits for the signal from the sensor node. The probability of data loss is given by a stochastic process and will be defined only two successes: packet dropout occurs or not. This variable will have the following values:

$$\theta_{k+1} = \begin{cases} 1, & packet\ loss\ occurred \\ 0, & packet\ loss\ not\ occurred \end{cases} \quad (5)$$

and

$$u(k+1) = u(k) + \sum_{i=0}^{r} (1 - \theta_{k+1}) \Delta u(k+i+1) \quad (6)$$

where **r≤m−1** indicates the number of consecutive data loss, and m is the number of elements in the vector **u(k)**. The strategy consists of using the next elements of the vector u(k) to control the plant.

As a communication channel the LED wireless communication was used because of the benefits that offer. The strategy is depicted in Fig. 1.

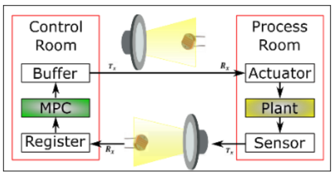

Fig 1. MPC Strategy in NCS

The controlled plant has the following transfer function:

$$G(s) = \frac{1.17647}{0.30748\, s+1} e^{-0.2851\, s} \quad (7)$$

As a sampling time T = 0.092666(s) is chosen.

III. Results

In Fig 2 the response of the plant with a 40% of data loss in the wireless channel is shown, it can be noticed that the system can go out of stability or reach an unwanted state. Using our predictive control strategy, the controller can lead with packet loss and bring the system to the desired state we show in Fig 3.

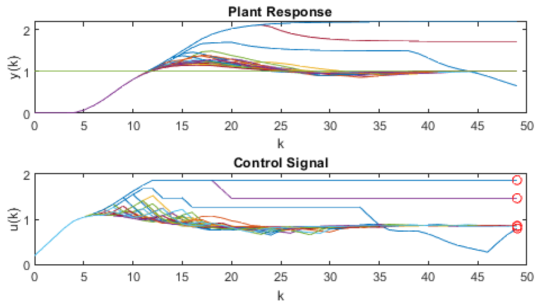

Fig 2. Response of the plant with a 40% of packet loss.

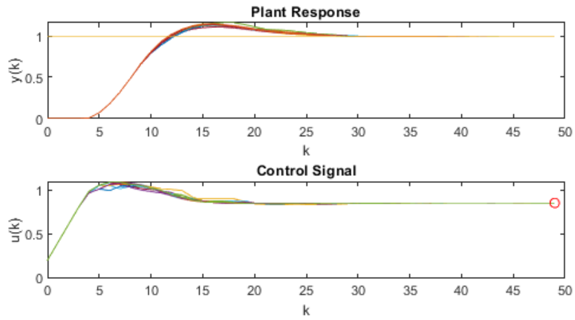

Fig 3. Response of the plant with a 40% of packet loss using the proposed control strategy.

IV. Conclusions

In this paper, the capabilities of a MPC control algorithms have been considered when data losses occur in NCS LED communication on the sensor side. The simulation has showed that our proposed method works, maintaining the plant under control despite the possible data loss. It is important to note that this simulation did not consider the disturbances of the system, which will be left as future work.

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