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Research article

Modeling the stochastic mechanism of sensor using a hybrid method based on seasonal autoregressive integrated moving average time series and generalized estimating equations

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ABSTRACT

Sensor, which is one of the main components of control system, plays its vital role in measuring state and output system variables and highlights the importance of having desired statistical information about sensor output signals because it can be monitored, stored, or used as the primary input signal in other devices. However, these signals display noises (i.e. system noise and measurement noise) and even if the effects of system noises are faded away or removed from measured data, there is still some stochastic noise remained in the measurements. Even though SARIMA has been effective in modeling the stochastic noise in the sensor, the present study has found out the necessity of designing a novel approach including a combination of seasonal autoregressive integrated moving average (SARIMA) and polynomial generalized estimating equations (PGEE), to evaluate the stochastic behavior of sensors. Finally, the study tried to employ the proposed approach in real load-cell sensor data to examine its effectiveness.

1. Introduction

A sensor, one of the main elements of control system, measures a physical variable and transmit its sensing data to another device or system to be analyzed, stored, or used. In practice, most sensor output signals in some devices such as thermocouples, load cell sensors, or pressure sensors have low voltage levels and are mainly affected by noises, so they cannot easily be monitored, transmitted, or used for other objectives. In other words, they might not have a suitable level or bandwidth or might have some extra and irrelevant noisy data. Thus, it is essential to obtain valid information from noisy sensor output signals so that one can efficiently measure and transform these analog output signals to digital ones and optimize them for digital devices. However, these signals display noises (i.e. system noise and measurement noise) and even if the effects of system noises are faded away or removed from measured data, there is still some stochastic noise remained in the measurements which can affect the measured data and consequently negatively affect its computational accuracy of whole system performance during the operation. Thus, it is required to lower measurement and system noises to analyze the system better [1–3].

On the other hand, it is worth mentioning that both noise and signal increase when they pass through an amplifier. The noise signal in the system can have some influence on the computational accuracy of the modern instrumentation systems which are not reduced by Analog-to-digital converter (ADC) performance metrics.

When the amplitude of the main data is lower than that of the noise, one can only separate the main data from noise if enough information of the general signal and noise is identified. Nowadays, even though sensor computational capabilities, especially in smart sensors, have increasingly improved, the computational rates have negatively decreased. This issue motivated the researchers to focus more on sensors with lower performance and more advanced computational techniques to better analyze sensors' output information [2,3]. However, they found out that the unwanted data cannot completely be removed from the measured sensor output but the accuracy of measured output data of sensors can be improved through some classical computational methods and digital filtering techniques [2–4].

There are several techniques available to model, estimate, and predict stochastic noise which can be divided into two main categories of model-based estimation methods, namely regression models [5–16] or time series analysis [17–23], and data-based estimation methods, namely Kalman filtering and Wiener process [24–26]. Regression analysis contains simple linear and

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