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Repetitive control mechanism of disturbance cancellation using a hybrid regression and genetic algorithm

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ABSTRACT

The application of a repetitive control mechanism for use in a mechanical control system has been a topic of investigation. The fundamental purpose of repetitive control is to eliminate disturbances in a mechanical control system. This paper presents two different repetitive control laws using individual types of basis function feedback and their combinations. These laws adjust the command given to a feedback control system to eliminate tracking errors, generally resulting from periodic disturbance. Periodic errors can be reduced through linear basis functions using regression and a genetic algorithm. The results illustrate that repetitive control is most effective method for eliminating disturbances. When the data are stabilized, the tracking error of the obtained convergence value, 10^{-14}, is the optimal solution, verifying that the proposed regression and genetic algorithm can satisfactorily reduce periodic errors.

1. Introduction

A feedback control system often results in errors under the effects of perturbations. Many academic scholars have hoped to find a method for eliminating the influence of such output perturbations [25,9,26].

[16] used the direct synthesis method in the nonperiodic disturbance rejection controller. [18] presented and compared four different algorithms used for the cancellation of periodic disturbance. For each method, the theoretical advantages and disadvantages, as well as the computational complexity, execution time, and method of implementation are discussed. In practice, a PID controller or other method is often used to eliminate tracking errors, but these methods have certain defects, that often reduce their accuracy [8]. The most frequently used solutions to this problem are repetitive control and learning control. [31] stated that a feedback-based approach known as repetitive control (RC) is well-suited to track periodic reference trajectories and/or to reject periodic disturbances.

The concept of repetitive control was originally proposed by Inouse for SISO plant in continuous-time for tracking a periodic reference signal with a known period [15]. [33] presents a partial-period adaptive repetitive control method for a class of periodically time-varying nonlinear systems. [20] presented a hybrid proportional derivative/repetitive control for active vibration control of smart piezoelectric structures. [21] extended repetitive control methods to manage the multiple-period disturbances and resonant excitation. [37] proposed a repetitive control method to suppress the periodic disturbances by reducing the harmonic currents. [28] developed a new control topology based on the simultaneous

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implementation of repetitive and resonant controllers to be applied to uninterruptible power supplies. [38] maintained a uniform contact force under repetitive learning (RL) control. [27,32] used iterative learning and repetitive controllers of systems to active noise control.

This study refers to [19] is mainly used to improve the 4 GeV continuous electron beam accelerator running over a 5-mile path, at the Thomas Jefferson National Accelerator Facility. There is only one disturbance frequency, a sine wave at 2 Hz with amplitude of 45. For the original signal, a wavelet analysis is used to decompose and reconstruct the output y; in addition a periodic function is used as a basis function to eliminate periodic interference. The repetitive control law is then used to cancel tracking errors of the feedback controllers during periodic commands. This paper uses two repetitive control laws, regression and a genetic algorithm, for canceling tracking errors, and an inter-comparison, to find a method minimizing their influence.

2. The matched basis function system model

The fundamental purpose of repetitive control is to determine a time function, put into the feedback control system to eliminate periodic interference or periodic tracking errors.

[23,24,36] have performed experiments applying the chosen basis functions individually to the existing feedback control system. In these experiments we wait until steady state response is reached, record the periodic output, and the result is the set of matching output basis functions. When there is a periodic disturbance present, we must conduct two experiments with different amplitudes multiplying the input basis function, and then take the differences of inputs and the differences of outputs, in order to eliminate the effect of the disturbance in defining the output basis functions. In addition, [17] have used basis functions in repetitive control. Consequently, a faster convergence of the controlled error to zero was achieved than those previously ones obtained.

3. The basis function and the system model

3.1. Linear basis function models

The periodic error can be reduced by linear basis functions. Generally:

$$y(X,W)=\sum_{j=0}^{M-1}\omega_j\varnothing_j(X)=W^T\varnothing(X) \tag{1}$$

$\varnothing_j(X)$ are known as basis function. Typically, $\varnothing_0(X)=1$, so that ω_0 acts as a bias.

3.2. Choices for components on basis functions

[12,22 and 2]: there are various ways to recursively determine some estimate of the components on the output basis functions every time step, $\alpha(i)$. In this study, we utilize the regression and genetic algorithm, and the $\alpha(i)$ can be represented as:

$$\alpha(i)=\alpha(i-1)+y_i[y(i)-T_y(i)\alpha(i-1)] \tag{2}$$

Where y_i can be determined a prior, and is not a function of data. The $T_y(i)$ is determined from T_y whose columns contain one period of the periodic basis functions.

3.3. Linear repetitive control laws in terms of components on matched basis functions

The fundamental purpose of repetitive control is to determine a time function. [35]: define T_u as a matrix of n rows, each column representing one period of the corresponding chosen discrete-time basis function. The T_y is the corresponding matrix of output basis functions, giving the output that would be obtained if there were no periodic disturbance. Define column matrices α and βas column matrices of the coefficients of the output and the input basis functions, respectively. If the input is the linear combination defined by $\underline{u}=T_u\beta$, then the steady state response is $\underline{y}=T_y\delta=T_y\beta$. This makes the steady state system response model in basis function space into an identity matrix J:

$$\delta=J\beta \tag{3}$$

A general linear repetitive control law for real time implementation [35]

$$\beta(i+1)=\beta(i)+\Gamma(\delta^*-\alpha(i)) \tag{4}$$

where Γ is a square matrix of learning gains, $\alpha(i)$ is the column vector of current estimates of the output components on the output basis functions, and δ^* is the desired trajectory written in terms of components on the output basis functions, which can be written in terms of the p time step history of one period of the desired trajectory: y^*, according to $\delta^*=T_y^+y^*$, where T_y^+ is the Moore-Penrose pseudoinverse.