Mechanical Systems and Signal Processing 115 (2019) 434–449

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

journal homepage: www.elsevier.com/locate/ymssp

Compensation and identification for external disturbances in head positioning systems of hard disk drives based on a data-based design method

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ARTICLE INFO

Article history:
Received 14 May 2017
Received in revised form 1 October 2017
Accepted 1 June 2018

Keywords:
Hard disk drives
Positioning control
Data-based controller design
Disturbance compensation
Support vector machine

ABSTRACT

This paper introduces a compensation and identification method for external disturbances in head positioning systems of hard disk drives (HDDs). For increasing a data capacity of HDDs, head positioning control system must compensate for any disturbance which worsen positioning accuracy. However, the traditional model-based controller design method mayn't design a controller for the disturbances compensation. Because, it is difficult to create a mathematical model of the external disturbances. The proposed method can design the controllers without the mathematical model. Moreover, it can identify the characteristics of external disturbances simultaneously. It's effectiveness has been verified by experiments in the head positioning control.

1. Introduction

Rapid growth in demand for a larger data capacity requires to increase areal density of hard disk drives (HDDs). Increasing the data capacity requires improving head positioning accuracy [1]. To realize the high data capacity, a head positioning control system of an HDD must compensate for any disturbances since they worsen the head positioning accuracy [2–8]. Especially, it is important to compensate for external disturbances in the head positioning system of 2.5type HDDs [9,10]. 2.5type HDDs are mainly implemented to mobile devices, that is, the head positioning systems are susceptible to the external disturbances. For example, the external disturbances are caused by build-in speakers, which is one of the major disturbance sources in notebook PC for 2.5inch HDDs [11–13]. In general, a mathematical model of the disturbances is difficult to create precisely because a signaling pathway is very complex dependent on each device. The traditional model-based controller design method can't design an ideal controller in such as cases.

Some control methods are proposed to compensate for such as the disturbances. Disturbance observer is one of representative methods and its effectiveness has been verified in previous studies [14,15]. On the other hand, an adaptive feed-forward control has been proposed to compensate for such as the external disturbances [16–22]. The control method doesn't need the mathematical model in the disturbance compensation, controller parameters are updating automatically based on the adaptive algorithm in real-time. Although the control method is effectiveness for the disturbance compensation, there are two concerns with respect to convergence property of the adaptive algorithm [23,24]. The adaptive feed-forward control doesn't work well until adaptive parameters reaching convergence values and the performance can be varying in each experiment. The previous study has proposed to solve the concerns by setting adequate initial parameters.

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https://doi.org/10.1016/j.ymssp.2018.06.001
0888-3270/

This paper proposes a compensation and identification method of the external disturbances based on a data-based design method. By using the experimental data directly, the proposed method can design the controllers without the mathematical model of external disturbances. Moreover, it can identify the characteristics of external vibrations in frequency domain. To deal with the experimental data directly, the proposed method employs support vector machine (SVM). SVM is well-known as one of powerful tools for classification, and recent studies employ SVM in control engineering [25–29]. In this study, SVM is applied to determine boundaries the characteristics of the controller according to performance in frequency domain. As a result, the proposed method can derive adequate frequency responses of the controller. In addition, the characteristics of external disturbances can be identified based on the classification results.

To verify the effectiveness, the designed controller has been implemented to the head positioning control systems of HDDs. The experimental results indicated that the designed controller can compensate for the external disturbances and it can identify the disturbances characteristics.

2. Head positioning systems of HDD

2.1. Block diagram of head positioning systems

Fig. 1 illustrates the head positioning control system in HDDs. The position error signal represents the displacement of the magnetic head from the desired location to read and write the data on the desired track. Purpose of the head positioning control is to maintain the position error signal at zero. The head positioning control system must compensate for any disturbances since the position error signal can be increased by the disturbances. Especially, it is important to compensate for the external disturbances. To compensate for the external disturbances, the adaptive feed-forward control has been proposed in the previous studies [16–22].

Fig. 2 shows a block diagram of the head positioning control system with the adaptive feed-forward control, where P is a plant, C_{FB} is a feedback controller and C_{FF} is an adaptive feed-forward controller. t is time, k is sample number, $r(k)$ is reference signal and $e(k)$ is position error signal. The external disturbances are denoted as $d_0(t), d_0(t)$ is considered as input to the system as a change in the reference after going through the transfer function M. M is a transfer function from $d_0(t)$ to $e(k)$. K is an acceleration sensors to measure $d_0(t)$ as the sensor output $u(k)$ [30]. C_{FF} generates a command to cancel $e(k)$ caused by $d_0(t)$.

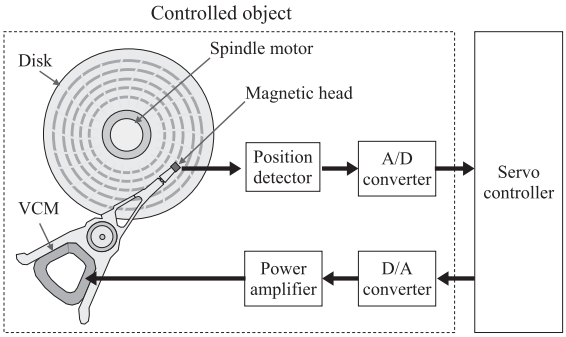

Fig. 1. Schematic of an HDD head positioning control system.

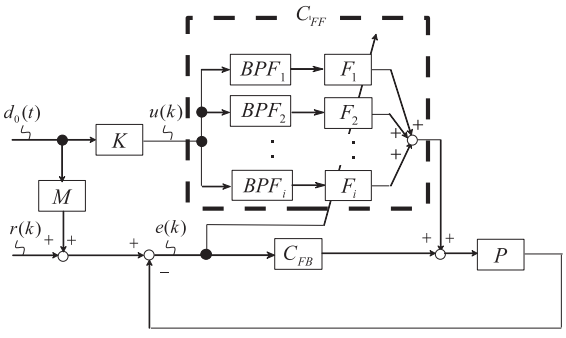

Fig. 2. Block diagram of positioning control systems with an external disturbances.