DSP Implementation of an Adaptive Control Method for Rejecting Repeatable Runout in Hard Disk Drives

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Abstract

Identification [1,16] and rejection of deterministic and stochastic disturbances are of fundamental importance in positioning of the read/write head in hard disk drives. Many problems – such as attenuation of repeatable and non repeatable [4] runout disturbances, vibration rejection in track following [19,15,13,23], enhancing transient performance in track seeking [20,21], self–tunning controllers for suppressing time–varying disturbances [14], state estimation and control for servos with non–uniform sampling of position error signal [2,9,7,5,8,3], disturbance observers [22] – fall into this category. Although many conventional problems have been relatively well solved, new and emerging challenges continuously occur. For instance, to meet the ever–increasing demand of storage volume in the era of big data, the disk drive industry is moving toward the new bit–patterned media (BPM) recording. Each bit on BPM is stored in a fundamentally different principle,to reach a 20–30 times reduction in the unit storage size [11]. In the new architecture, vibration–related issues have become more important than ever before, with various new challenges such as significant increase of harmonics and much wider span of disturbance frequencies [10]. A novel indirect adaptive control method for the rejection of summation of sinusoidal disturbances has been recently developed in a series of articles by Shahsavari and collaborators [12,6,18,17].

We have deployed the aforementioned adaptive control method to perfectly reject the repeatable runout in BPM recording. Different practical aspects of the algorithms are discussed and methods are suggested for reducing the computational complexity of the algorithms. These algorithms are implemented on a digital signal processor and tested on a 3.5–inch hard disk drive provided by one of our industry partners. The results reported in this paper illustrate the effectiveness of the proposed adaptive control algorithm in almost completely rejecting the repeatable runout.

[1] The author was a visiting scholar in *CML-servo* lab under supervision of Prof. Roberto Horowitz (2014–2016).

1 Introduction

In the past two decades, control methodologies for rejection of periodic and multiple sinusoidal disturbances or tracking this type of trajectories have attracted many researchers and been widely used in industry. A literature review on these methods is briefly discussed in the introduction part.

See more in the full text.

2 Problem Statement

The adaptive controller proposed in this work aims to be implemented in a *plug–in* fashion, meaning that it is used to augment an existing robustly stable closed loop system in order to reject periodic disturbances (track periodic trajectories) that are not well rejected (tracked) by the existing controller.

See more in the full text.

3 Adaptive Control Synthesis

3.1 Parameter Adaptation Algorithm

An adaptive algorithm is reviewed in this section that accomplish the estimation of the closed loop system and noise dynamics in conjunction with the control synthesis.

See more in the full text.

4 Direct Adaptive Control for Repeatable Runout Following in HDD

In this section we evaluate the effectiveness of the adaptive control algorithm in following repeatable runout in a hard disk drive.

See more in the full text.

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5 Computer Simulation Results

6 Experimental Results

6.1 Time–Invariant System Dynamics and Disturbance Profile

The direct adaptive control algorithm is implemented on a Digital Signal Processor. In this section we report the results for the case that the system dynamics and disturbance are time–invariant. That is, the HDD dynamics and RRO profile do not change because we only track–follow on head 0 and track 3000 of the disk. The next section studies to the cases that the head and track changes cause abrupt variations in the closed loop dynamics and disturbance profile.

See more in the full text.

6.2 Time–Varying System Dynamics and Abrupt Changes in Disturbance Profile

In this subsection we study the behavior of the proposed control algorithm in situations that the system dynamics or the disturbance profile changes. These cases are emerged by changing the head that is used for servoing.

See more in the full text.

6.3 Tracking Repeatable Runout of a BPMR HDD

BPMR technology is still in research stage and BPMR HDDs have not been mass–produced yet. However, our industry partners that are pioneers in developing this technology were able to provide us with the noise characteristics of prototype BPMR hard disk drives. It is expected that the hardware of conventional and BPMR HDDs only differ in the media. This implies that using the noise models of a BPMR HDD with the plant dynamics of a conventional HDD can potentially mimic a BPMR HDD characteristics. We extracted the RRO profile at different tracks from the dataset provided by our industry partners. This profile was then artificially added to the PES measurements of the 3.5" HDD in our experimental setup.

See more in the full text.

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