A Magnetized Grain Modeling Method Based on the Image of Real Magnetic Grains for Two-Dimensional Magnetic Recording

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Abstract

In two-dimensional magnetic recording (TDMR), the readback signal is obtained by convolving the read head sensitivity function with a magnetized medium. Thus, a good model for generating the grain structure of the medium together with a method to magnetize the data bits onto such a medium are becoming increasingly important. Therefore, we propose a magnetized grain modeling method for TDMR, where the image of real magnetic grains is used to construct the magnetized medium. It will be shown that the proposed magnetized medium is more closely related to the actual one, which contains more realistic grains with non-magnetic grain boundaries, than the existing grain modeling methods.

Keywords: Grain structure, image processing, magnetic medium, two-dimensional magnetic recording (TDMR)

1. Introduction

TDMR is a promising technology for future hard disk drives (HDDs) because it can achieve an areal density up to 10 Tb/in^2 by storing one data bit per few magnetic grains [1]. The performance degradation of TDMR systems depends not only on the severity of two-dimensional (2D) interferences but also on the grain size effect in a magnetic medium. Then, having an accurate model to generate a realistic magnetized medium is of great importance, because the TDMR readback signal is obtained by convolving the read head sensitivity function with the magnetized medium.

Several methods to generate the magnetic medium used for TDMR have recently been proposed [2, 3], which are based on a continuous/discrete Voronoi model and a discrete grain model. In addition, an accurate medium modeling method for a discretized granular medium with non-magnetic grain boundaries was presented in [4]. Nonetheless, all of them rely on many mathematical techniques to construct the medium (such as a Voronoi based modeling), which are complicated and yield unrealistic grains for the medium.

Therefore, we propose a magnetized grain modeling method based on the image of real magnetic grains by using some image processing techniques. Specifically, the proposed method can generate a more realistic magnetized medium with non-magnetic grain boundaries by applying the blob feature extraction technique [5] to demarcate the grains. In addition, our method is relatively easy to implement in terms of signal processing development.

2. Proposed Method

The magnetized grain modeling method based on the image of real magnetic grains is shown in Fig. 1, which consists of four steps, i.e., 1) preprocessing the image to enhance its quality; 2) generating a random binary data sequence; 3) assigning the binary data bits onto the image; and 4) applying a blob feature extraction algorithm to map the data bits onto the medium.

Basically, to make the medium modeling process more reliable and similar to the characteristics of the actual medium used in HDDs, we utilize the digital image taken from a real magnetic medium (see Fig. 2) as the input for our proposed method. In general, the image taken from an actual medium is in color. Thus, the first step is to convert this color image to a grayscale image, and then change it to a binary image by using a thresholding method according to

$$f(x, y) = \begin{cases} 1, & \text{if } g(x, y) \geq m \\ 0, & \text{if } g(x, y) < m \end{cases}, \tag{1}$$

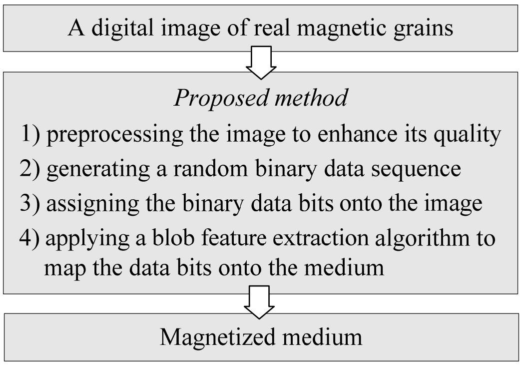

Fig. 1 A block diagram of the proposed method.

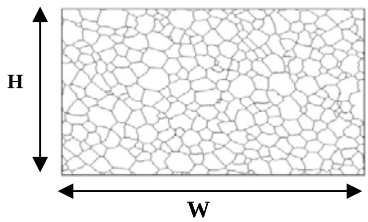

Fig. 2 The image of an actual medium with W×H pixels.

where $f(x, y)$ and $g(x, y)$ are the 2D function of the digital image at the x-th row and y-th column pixel, respectively, and m is a threshold value.

Next, we generate a random binary data sequence and specify the number of tracks N_T and the number of bits per track ($N_{B/T}$) that will be used on a given medium image in Fig. 2. For example, Fig. 3 shows an example of assigning the data bits onto the image of W×H pixels, when Fig. 3 (a) for one track (with 10 bits), and Fig. 3 (b) for two tracks (each with 8 bits). Note that one data bit covers a group of grains. Therefore, an XOR operation is employed to magnetize the data bits in Fig. 3 onto the medium image as demonstrated in Fig. 4.

The mapping in Fig. 4 is still not good because the grains at the boundary of bit ‘0’ and ‘1’ are not fully magnetized. To make it more accurate, we propose to use the blob feature extraction algorithm to refine the magnetized grains so as to obtain the magnetized medium depicted in Fig. 5. It is apparent that all grains at the boundary of bit ‘0’ and ‘1’ are fully magnetized according to the recorded data bits. Consequently, our proposed method can generate the magnetized medium, which closely resembles the actual magnetized medium found in HDDs

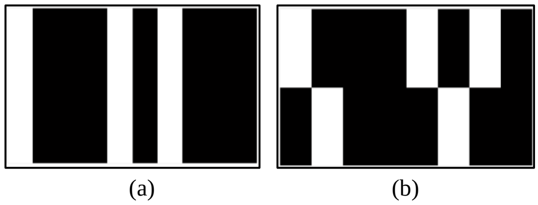

Fig. 3 An example of assigning data on the image when (a) $N_T = 1$ and $N_{B/T} = 10$, and (b) $N_T = 2$ and $N_{B/T} = 8$.

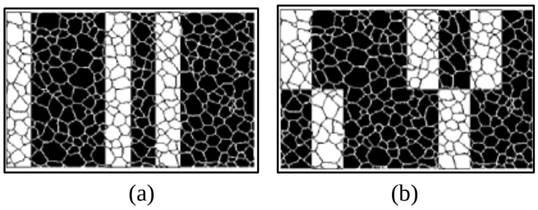

Fig. 4 A magnetized medium after using XOR operation when (a) $N_T = 1$ and $N_{B/T} = 10$, and (b) $N_T = 2$ and $N_{B/T} = 8$.

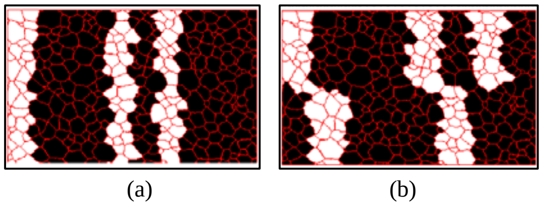

Fig. 5 The magnetized medium after the blob feature extraction algorithm when (a) $N_T = 1$ and $N_{B/T} = 10$, and (b) $N_T = 2$ and $N_{B/T} = 8$.

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