

METHOD FOR UPDATING DEFECT INFORMATION IN A HARD DISC DRIVE

This patent application claims priority from U.S. Provisional Application No. 60/133,830 filed May 12, 1999.

5 The present invention relates generally to a hard disc drive. More particularly, the present invention relates to a method for updating defect information in the hard disc drive.

Background of the Invention

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Before a disc drive leaves the factory it is scanned to determine the location of media defects that will give rise to problems in reading back data. Modern disc drives use various method to store information concerning the locations of the defects. One method is to store the information in a defect table
15 that is created during the defect scanning process. The defect table is stored in a reserved area of the drive intended for storage of vendor information and is not generally accessible to the end user.

The defect table allows the firmware to skip over the locations of known defects during a functional mode of the disc drive, thus creating a virtual 'defect
20 free' drive. The defect table is a unique entity that is not transferable from drive to drive, since each and every drive will have vastly different defect information dependent on its media. As such, it is vital to ensure integrity of the defect table throughout the usable life of the disc drive. Loss of this data would render the drive virtually useless as the user would experience data loss, which defeats a
25 fundamental purpose of the disc drive.

Most implementations of a scheme involving defect information ensure that a user will not have access to the drive data if no defect information is retrievable on power up. The drive firmware will usually 'paralyze' the drive in such a situation. To minimize the risk of this occurring most implementations
30 store this information as multiple copies. This is known as redundancy and increases the probability that at least one copy of the defect information is readable.

As noted above, one method of storing defect information is in the form of a defect table. The defect table is also used to store other data such as

defect pending entries relating to transient reading back problems, zone crossing information, reassignment information etc. This may call for changes to the defect table, such as adding or deleting defect pending entries during the useful life of the disc drive. However, whenever an update to the defect table is
5 necessary, there is always a risk of corrupting the defect table. In such a situation, having multiple redundant copies may not help as the possibility of all copies being corrupted is high. Even if backup copies are kept, this may at best allow the disc drive to power up and remain functional, but all information that was updated during run time, such as reassignment etc. would be lost. This will
10 also cause data loss, although on a smaller scale when compared to total loss of defect information.

Summary of the Invention

15 The present invention relates to a method for updating defect information in a hard disc drive which addresses the above-mentioned problem.

Because corruption of defect information during updating is likely to occur in unique electrical situations which are unlikely to be duplicated, it is desirable to employ partial updating of multiple or redundant copies of the
20 defect information. Partial updating may ensure that at least one good or uncorrupted copy of the defect information remains in the event that a problem is encountered and/or the information is corrupted while updating the defect information. Partial updating may also avoid crippling functionality of the disc drive as a result of defect information being unable to be retrieved on power up.
25 For example, assuming that there is a total of (4) four copies of the defect information (ie. 3 redundant copies) three only of the four copies may be updated during any one updating cycle.

The updating may be performed in a sequential or circular manner. A pointer may be employed to track a logical first copy of the defect information to
30 be copied during the next updating cycle. The pointer may be advanced during the updating process to ensure that defect information which was most recently updated is preserved.

According to one aspect of the present invention there is provided a method for updating defect information stored in a hard disc drive with redundant copies of the defect information. The method has a step for updating the defect information such that at least one copy of the defect information is preserved substantially unchanged during any one updating cycle. The at least one copy includes a copy which was updated during an updating cycle immediately preceding the one updating cycle.

Defect information, C_0 , may be stored in the hard disc drive with n redundant copies $C_1, C_2 \dots C_n$ thereof, C_0 being the initial copy. The n redundant copies and the initial, C_0 , of defect information are further marked with a revision count, k , such that each updating cycle would increase the revision count by 1. The revision count, would enable the most recent updated defect information to be determined.

In some embodiments two or more copies of the defect information may be preserved substantially unchanged during any one updating cycle.

In another aspect of the present invention a disc drive having a method for updating defect information such that multiple number of copies of defect information is updated with a means to read back the updated defect information is provided.

In another aspect of the present invention, the method can also be applied for updating real time system data like S.M.A.R.T. (Self Monitoring Analysis and Reporting Technology) data update, etc.

Brief Description of the Drawings

A preferred embodiment of the present invention is described with reference to the accompanying drawings: -

Fig. 1 shows an exploded view of a hard disc drive.

Figs 2 shows four copies of a defect table (copy 0 – copy 3) undergoing four updates (from $2'$ to 2^v) wherein one redundant copy is not updated during each updating cycle.

Fig. 3 shows four copies of a defect table (copy 0 – copy 3) undergoing four updates (from $3'$ to 3^v) wherein two redundant copies are not updated during each updating cycle.

Detailed Description

Figure 1 shows a disc drive in exploded view. Briefly, the disc drive 10 includes a housing base 11 and a top cover 12, which engage a gasket 13 to form a sealed housing that maintains a clean environment therein. A plurality of disks 14 is mounted for rotation on a spindle motor hub 15. A plurality of transducer heads 16 is mounted to an actuator body 17. The actuator body 17 is adapted for pivotal motion under control of a voice coil motor (VCM) including a voice coil 18 and magnets 19 to controllably move a head 16 to a desired track 20 along an arcuate path 21. Signals used to control the VCM and the heads 16 pass via a flex circuit 22 and a connector 23 to and from electronic circuitry on controller board 24. The controller board 24 includes a fibre channel interface 25, a serial port connector 26 and a spindle connector 27.

15 In a disc drive, there are multiple copies of a defect table provided. This helps to keep track of defect information at the time of the manufacture and also subsequent defects or errors that arise in the lifetime of the disc drive. The following detailed description shows how the present invention enable a more efficient manner of keeping track of defect information.

20 Fig. 2 shows four copies of a defect table marked copy 0, copy 1, copy 2, copy 3. Each copy is marked with a revision number (rev 0) to track each update. Rev 0 is the initial revision before additional revision or updating takes place. A first updating cycle in which all copies except copy 0 are updated is shown from 2' to 2" in Fig. 2. The arrow bridging Figs. 2' and 2" points to the copy (copy 0) which was not updated during the current updating cycle. An asterisk indicates the first copy (copy 1) to be updated during the next updating cycle. The arrow and asterisk are advanced sequentially or in a circular manner after each updating cycle to ensure that defect information, which was most recently updated is preserved. From 2" to 2"', a second updating cycle wherein all copies except copy 1 are updated. Because copy 1 was updated in the previous updating cycle (from 2' to 2"), the current updating cycle will preserve a most recently updated copy of the defect table.

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2ⁱⁱⁱ to 2^{iv} shows a third updating cycle wherein all copies of the defect table except copy 2 are updated. Again it will be noted that copy 2 was updated in the previous updating cycle (from 2ⁱⁱ to 2ⁱⁱⁱ).

2^{iv} to 2^v shows a fourth updating cycle wherein all copies of the defect table are updated except copy 3, which was updated in the previous updating cycle (from 2ⁱⁱⁱ to 2^{iv}).

Once an updating cycle is written to the disc there is a chance that it cannot be read back for one or more reasons either due to hardware or software problems. The method of the present invention facilitates retrieval of a most recently updated defect table which was written before corruption took place. Because only information added during the last updating cycle will be lost, loss of information may be minimized. In a read back, where no corruption has occurred, the first copy that is read has its revision count memorized. Each subsequent copy that is read would also have a revision count. If the revision count of a preceding copy is lower than the revision count in the current copy that is read, the current copy would have the most recent updated defect information. For example, from updating cycle 2ⁱ to 2ⁱⁱ, the copy 28ⁱ reads Rev 0 for its revision count, which is memorized. In the next copy read, 29ⁱ, the revision count is Rev 1. Therefore, the most recent updated defect information would be found in 29ⁱ. However, if the revision count of the current copy reads less than that in the immediate preceding copy, then the read back proceeds to the next available copy. Where the revision count of that next available copy is higher than the current copy memorized, that next available copy would have the most recent updated defect information. For example, from 2ⁱⁱ to 2ⁱⁱⁱ, the copy 28ⁱⁱ, having a revision count Rev 2, is first read and memorized. The subsequent copy 29ⁱⁱ is then read. 29ⁱⁱ bears the revision Rev 1, which indicates that it is a copy updated in the previous updating cycle 2ⁱⁱ. The read back proceeds to read copy 30ⁱⁱ. The defect information in 30ⁱⁱ has been updated in the most recent updating cycle 2ⁱⁱⁱ and the revision count reads Rev 2. Therefore if no corruption has taken place, the copy with the most recent updated defect information would be copy 30ⁱⁱ. Where a corruption has occurred in 30ⁱⁱ, this copy 30ⁱⁱ would be considered as bad and the read back would carry on to 31ⁱⁱ. The copy 31ⁱⁱ carries revision count Rev 2. If the defect information in 31ⁱⁱ is not corrupted, this copy would have the most recent updated defect

information. If however, copy 31" is also corrupted, then the only copy to rely on with Rev 2 would be copy 28" which provide the updated defect information in the present updating cycle. If the copy 28" is also corrupted, then copy 29" would provide the most recent updated defect information from the immediate preceding updating cycle in 2". However, this copy would have one update cycle information missing since it was not updated in the updating cycle from 2" to 2"". This illustrated how the revision count is used to determine which copy of defect information would be used when a corruption occurs.

To illustrate this benefit, assume that the current updating cycle from 2^{iv} to 2^v is bad, ie. the updating has been corrupted by an unknown electrical situation which cannot be duplicated. A good copy may nevertheless be obtained in "copy 3/rev 3" which was not updated during the current updating cycle. Because "copy 3/rev 3" was updated during the previous updating cycle (from 2ⁱⁱⁱ to 2^{iv}) only the latest update (revision 4) has been lost but defect information from revisions 0 to 3 have been preserved.

Figs. 3 shows four copies of a defect table undergoing four updates (from 3' to 3^v) wherein two redundant copies are not updated during each cycle. Fig. 3 shows four copies of a defect table marked copy 0, copy 1, copy 2, copy 3. As in Figs. 2 (from 2' to 2^v), each copy is marked with a revision number to track each update. 3' to 3" show a first updating cycle in which copy 0 and copy 3 are not updated whilst copy 1 and copy 2 are updated. 3" to 3^{iv} show a second updating cycle in which copy 0 and copy 1 are not updated whilst copy 2 and copy 3 are updated. 3^{iv} to 3^v show a third updating cycle in which copy 0 and copy 3 are updated whilst copy 1 and copy 2 are not updated and 3^v shows a fourth updating cycle in which copy 0 and copy 1 are updated whilst copy 2 and copy 3 are not updated.

When compared to the method shown in Fig. 2 (the updating cycle from 2' to 2^v), the method shown in Fig. 3 (from 3' to 3^v) provides a different balance of redundancy against risk of writing multiple bad copies. This balance may be adjusted at the factory to improve defect table integrity by shielding against multiple bad writes during a single power up of the disc drive. The balance may be adjusted empirically to achieve a preferred result in a given set of circumstances.

The read back for the embodiment illustrated in Figure 3 is similar to that in Figure 2. The only difference is that in the event of a corruption, two copies defect information from a previous updating would be available instead on one. This further minimizes loss of information.

5 The present invention is also enabled according to a method for updating defect information stored in a hard disc drive 10, with redundant copies of the defect information 28, 29, 30 and 31. The method provides for defect information to be updated such that at least one copy 28' of the defect information is preserved and substantially unchanged from 28 to 28' during any one updating cycle. In particular, the preserved copy 28' contains defect information which was updated in an updating cycle 2' immediately preceding the one updating cycle 2". The defect information, Copy 0, is stored in the hard disc drive with 3 redundant copies Copy 1, Copy 2, and Copy 3, Copy 0 being the initial copy. The 3 redundant copies and the initial, Copy 0, of defect information are further marked with a revision count, Rev 0, Rev 1, Rev 2, etc. such that each updating cycle would increase the revision count by 1. With the revision count, the most recent updated defect information can be determined.

20 The present invention also provides for at least two copies from 32 to 32' and 35 to 35' of the defect information to be preserved and substantially unchanged during any one updating cycle 3' to 3".

According to the present invention a disc drive having a method for updating defect information such that multiple number of copies of defect information is updated with a means to read back the updated defect information.

25 It is to be understood that even though numerous characteristics and advantages of various embodiments of the present invention have been set forth in the foregoing description, together with details of the structure and function of various embodiments of the invention, this disclosure is illustrative only, and changes may be made in detail, especially in matters of structure and arrangement of parts within the principles of the present invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed. For example, the particular elements may vary depending on the particular application for the disc drive while maintaining substantially the same functionality without departing from the scope and spirit

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of the present invention. In addition, although the preferred embodiment described herein is directed to a hard disc drive, particularly in area of defect information updating, it will be appreciated by those skilled in the art that the teachings of the present invention can be applied to other storage systems
5 which incorporate recordable media, without departing from the scope and spirit of the present invention.



CLAIMS

What is claimed is:

1. A method for updating defect information stored in a hard disc drive with
5 redundant copies of the defect information, said method including:
updating the defect information such that at least one copy of the defect
information is preserved substantially unchanged during any one updating
cycle, wherein the at least one copy includes a copy which was updated during
an updating cycle immediately preceding the one updating cycle.
- 10 2. A method according to claim 1 wherein the defect information C_0 is
stored in the hard disc drive with n redundant copies $C_1, C_2 \dots C_n$ thereof, C_0
being the initial copy and n is an integer.
- 15 3. A method according to claim 2 wherein the n redundant copies and the
initial copy C_0 of defect information are marked with a revision count, k , such
that each updating cycle would increase the revision count by 1, $k \in \{0, 1, 2, \dots,$
 $n\}$ and n is an integer.
- 20 4. A method according to claim 3 wherein the revision count, k , provides for
the most recent updated defect information to be determined.
5. A method according to claim 1 wherein at least two copies of the defect
information are preserved substantially unchanged during any one updating
25 cycle.
6. A disc drive having a method for updating defect information wherein the
method provides multiple number of copies of defect information to be updated
and a means to read back the updated defect information.