1. Title of the Invention:

Disk Device and Data Reassignment Method

2. Detailed Description of the Invention:

[0001]

[Field of the invention]

The present invention relates to the field of error processing in a disk device. More specifically, the invention relates to a disk device and method which execute transfer of data when an error occurs, that is, data reassignment.

[0002]

[Background art]

A disk device is one which records data on tracks formed on a disk and also regenerates the recorded data from the disk tracks. The data recording and regeneration is performed by a head with a signal converter. When recording or regenerating data, the head is positioned by an actuator over a desired track on a disk where data has been recorded or will be recorded. By rotation of the disk, the head is gotten to a desired sector where data has been recorded or will be recorded and then performs data recording or regeneration.

[0003]

If the size of data is large and exceeds the capacity of a single sector when the data is recorded, the following data will usually be recorded on sectors which are continuous in the circumferential direction of the disk. In the case where the sectors on the same track have all been used, a head is moved to an adjacent track and data recording is continued. It is known to those having skill in this field that by

arranging data in this way, the recording and regeneration of continuous data can be performed at high speed.

[0004]

However, if data recording or regeneration is not performed accurately for defects such as defects in disks, errors will occur. For the errors, there are recoverable soft errors and unrecoverable hard errors by rereading, etc. In the case where a hard error occurred in a certain sector, there has hitherto been performed data reassignment which records the data of that sector on the alternative sector called a spare sector.

[0005]

On the other hand, to meet the low-cost and large-capacity requirements of disk devices in recent years, various techniques to enhance recording density have been developed. One of them is a technique called zone bit recording (ZBR). In the ZBR method, the surface of a disk is segmented into a plurality of concentric and circular areas called zones, and each zone has a plurality of tracks. The clock frequencies for recording and regeneration are equal for the same zone, but between zones the clock frequency for recording and regeneration becomes higher as the zone gets nearer to the outer circumference of the disk. In this way, the number of recordable bits per inch (BPI) is averaged over a area from the inner circumference of the disk to the outer circumference, and the recording capacity of the entire disk can be increased.

[0006]

In Figure 1 there is shown the disposition of a spare sector on a disk which adopts the ZBR technique. The data area on which data is stored is divided from zone 0 which is the outermost circumferential zone up to zone N which is the innermost circumferential zone. A area for data reassignment is provided inside the zone N, and the spare sector is disposed in this area. A track for data reassignment is called a spare track, which comprises one or a plurality of tracks. When data reassignment is performed for each zone, the spare sector is disposed not in the zones but in the spare track.

[0007]

In Figure 2 there is shown the read operation of a head in the case where in the conventional example of Figure 1 defective sector D exists in the zone 0 and where the data on the sector D is reassigned to spare sector S on the spare track.

(1) The head attempts to read out data from the defective sector D but knows that the data on the sector D has been reassigned to the spare sector S.

(2) The head seeks a spare track on which the spare sector S is present. During this operation, the head is substantially in a full-track seek state.

(3) The head follows the spare track, on which the spare sector S is present, to read out the data on the spare sector S.

(4) The head seeks a track on which a sector next to the defective sector D is present. During this operation, the head is substantially in a full-track seek state.

(5) The head follows the track, on which the sector next to the defective sector D is present, to read out the data on the sector next to the defective sector D.

[0008]

In the aforementioned example, a full-track seek operation is performed twice and a track follow operation is performed twice. Therefore, the total time of the time required for two full-track operations and the time required for two track follow operations is required until the data on the sector next to the sector D has been read out after the attempt to read out the data on the sector D. For example, when the full-track seek time is 10 ms and the rotational speed of the disk is 5400 rpm (about 11 ms per revolution), the track follow time is between 0 and 11 ms. Therefore, 42 ms, that is, the time required for the disk to make four revolutions, is required at the maximum, and 20 ms, that is, the time required for the disk to make two revolutions, is required at the minimum. This becomes the cause of a temporary reduction in the data transfer rate.

[0009]

[Problems to be solved by the invention]

With an increase in the number of multimedia applications and an enlargement in the capacity of disk devices, the chance to regenerate multimedia applications with disk devices is increasing in recent years. If the aforementioned reduction in the data transfer rate arises in the application for performing image regeneration or voice regeneration at real time, among others, a phenomenon where images or voices stop for a moment will take place, so a solution has been demanded.

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[0010]

An objective of the present invention is to provide a disk device and a data reassignment method which minimize a reduction in the data transfer rate.

[0011]

Another objective of the present invention is to provide a disk device and a data reassignment method which are suitable for regeneration of multimedia applications.

[0012]

[Summary of the invention]

According to a preferred form of the present invention, a spare sector is disposed:

(a) in a spare area within a data zone of each zone to which data in which a hard error occurred belongs; and also

(b) at a position spaced more than a predetermined angle relative to the center of a disk from a position of the data in which the error occurred.

[0013]

According to another preferred form of the present invention, a spare sector is disposed:

(a) in a spare area within a data zone of each zone to which data in which a hard error occurred belongs; and also

(b) at a position spaced more than a predetermined angle relative to the center of a disk from a position of the data in which the error occurred; and furthermore

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(c) so that the time required for a head to get from an arbitrary radial direction on a data area to the spare area is within a predetermined time.

[0014]

[Preferred embodiment]

Figure 3 shows an example of a disk device to which the present invention is applied. As shown in Figure 3, the disk device 310 is constituted by a disk enclosure 320 and a hard-disk controller (HDC) 340. The disk enclosure 320 is equipped with a motor 324 which is used to spin a spindle 322. Disks 326A and 326B are mounted on the spindle 322 so that they rotate integrally with the spindle 322. In the example of Fig 3, there are provided two disks, but one disk or three or more disks may be provided.

[0015]

Heads 328A, 328B, 328C, and 328D are supported and disposed by actuator arms 330A, 330B, 330C, and 330D so that each head is opposed to the corresponding disk surface. The actuator arms 330A through 330D are attached to a voice coil motor (VCM) 334 through a pivot shaft 332. If the pivot shaft 332 is rotated, each of the heads 328A through 328D is positioned at a desired radial position on the disk. The motor 324 and the VCM 334 are connected to the HDC 340 so that the number of rotations or rotational speed can be controlled. The HDC 330 is connectable to a host computer.

[0016]

Data tracks are concentrically formed on a magnetic disk such as a magnetic hard disk. The reading or writing of

information with respect to a magnetic disk is performed after a seek operation where the magnetic disk is rotated and where also the head is moved along the radius direction of the magnetic disk so that it is positioned over a specific data track. The operation of positioning the head over a specific data track is performed by reading out the head position identification information prerecorded on the magnetic disk by the head.

[0017]

After the positioning of the head over the desired track, data reading or writing is performed. At this time, there are some cases where reading or writing failure of accurate data, that is, errors occur. Most causes of the errors which occur on disks is data loss. There are many cases where this data loss is caused by damages such as scratches on disks which occurred with the passage of time and a specular change in magnetic material. The reading of data from disks is usually executed under standard reading condition set between a disk, a head, and a HDC.

[0018]

According to these predetermined standard condition, data reading is performed. When errors occur, data reading is again executed to recover errors by intentionally reducing a follow-up speed or maintaining the amplification factor of automatic gain control (AGC) for signal amplification constant. The error recovery based on these changes in the reading condition is performed by starting an error recovery procedure (ERP) which executes a plurality of error recovery steps in sequence.

[0019]

If an error is not recovered even by the aforementioned ERP, the error will be recognized as a hard error and there will be performed a data reassignment operation of recording the data of the sector on an alternative sector called a spare sector.

[0020]

In Figure 4 there is shown the location of the spare sectors on a disk according to the present invention. In the figure, zone 0 includes one spare track or two or more spare tracks predisposed in the approximately central portion of the zone 0. That is, the data area of the zone 0 is segmented into data area 1 and data area 2 by the spare track of the zone 0. The spare track includes a plurality of spare sectors. Also, the spare track is disposed so that the time required for the head to get from an arbitrary radius position on the data area to the spare track, often called the seek time, is within a predetermined time, for example, the time required for the disk to rotate in a 180-degree arc. It is preferable that the zone 0 be disposed in the radial central portion of the zone 0. For zone 1, a spare track is likewise disposed. Also, in Figure 4, only two zones, the zones 0 and 1, are shown, but the same may be said of the case of three or more zones.

[0021]

In Figure 5 there is shown the read operation of the head in the case where in Figure 4 defective sector D exists in the zone 0 and where the data on the sector D is reassigned to spare sector S on the spare track at a position (spaced about 180 degrees in the rotational direction) on approximately the opposite side with respect to the center of the disk.

(1) The head attempts to read out data from the defective sector D but knows that the data on the sector D has been reassigned to the spare sector S.

(2) The head seeks a spare track on which the spare sector S is present. During this operation, the head seeks approximately the half width of the zone 0.

(3) The head follows the spare track, on which the spare sector S is present, to read out the data on the spare sector S.

(4) The head seeks a track on which a sector next to the defective sector D is present. During this operation, the head seeks approximately the half width of the zone 0.

(5) The head follows the track, on which the sector next to the defective sector D is present, to read out the data on the sector next to the defective sector D.

[0022]

In the aforementioned example, a seek operation for about half of the width of approximately the zone 0 is performed twice and a track follow operation is performed twice. Therefore, the total time of the time required for two seek operations for about half of the width of approximately the zone 0 and the time required for two track follow operations is required until the data on the sector next to the sector D has been read out after the attempt to read out the data on the sector D. For example, when the seek time for about half of the width of approximately the zone 0 is 5 ms and the rotational speed of the disk is 5400 rpm (about 11 ms per revolution), the track seek operation (the aforementioned operations (1) and (2)) is completed during the time the disk rotates in a 180-degree arc (about 5.5 ms). Therefore, as soon as the disk rotates in a 180-degree arc, the disk can read out the spare sector S. That is, in this case the track follow time will be about 0.5 ms. In the case (the operation (3)) where the track

on which the sector next to the defective sector D is present is sought after the spare sector has been read out, it likewise takes 5 ms. Also, it takes 0.5 ms for the disk to follow the track to read out the data on the sector next to the defective sector D (the operation (4)). Thus, the time the operations (1) through (4) take will be about 11 ms and equivalent to the time it takes for the disk to make one revolution. In this embodiment, the spare sector S has been disposed at the position where the disk rotated through 180 degrees. However, as can be understood from the aforementioned description, the spare sector S may be disposed so that it will be spaced an angle (more than 180 degrees × 5/5.5 for this case) more than the angle through which the disk rotates for the track seek time.

[0023]

In Figure 6 there is shown the locus on the disk of the operation of the head in Figure 5. In the figure the zone 0 is depicted in exaggeration so that the locus can be easily viewed. Also, reference numbers (1) through (4) correspond to the operations (1) through (4) in Figure 5, respectively.

[0024]

In Figure 7 there is shown a method of disposing a spare sector. In step 700, when an error occurs in data as the data is read from or written to a desired sector, it is not recovered even by the ERP, and needs to be reassigned, the steps thereafter are executed by the HDC 340. In step 702 the physical position (address) of the aforementioned defective sector is taken to be sector A. In step 704 the optimum physical position of a spare sector is calculated and this is taken to be sector B. The value of B is calculated as follows:

(1) Let X = A + (number of sectors per track)/2.

(2) When X ≥ (number of sectors per track), let B = X - (number of sectors per track).

(3) When X < (number of sectors per track), let B = X.

[0025]

In step 706 it is checked whether the sector B on the spare track has already been used or not and it is judged whether the sector B is usable or not. If the sector B is usable, in step 708 it will be registered as a spare sector. If the sector B is unusable, step 706 will advance to step 710. In step 710 it is judged whether the sector B on the spare track of another head (disk surface) is usable or not. If the sector B is usable, in step 708 it will be registered as a spare sector A. If the sector B is unusable, step 710 will advance to step 712. In step 712 the physical position of the following sector is calculated and this is taken to be sector B. The value of B' is calculated as follows:

(1) When B = (number of sectors per track) - 1, let B = 0.

(2) When B ≠ (number of sectors per track) - 1, let B = B + 1.

[0026]

After calculation of the value of B, step 712 returns to step 706.

[0027]

These steps are stored on memory such as a ROM in the HDC. Also, all or some of these steps may be stored on a disk. In that case, data is read out from the disk when the hard-disk

device is started, and the data is stored on a memory, such as a RAM, for execution.

[0028]

[Advantages of the invention]

As has been described above, when conventional data reassignment is performed, the time required for two rotations of a disk at least and the time required for four rotations of a disk at most are required until the data on the sector next to a defective sector is read out after an attempt to read out the data on the defective sector. On the other hand, in the present invention, only the time required for one rotation of a disk is required, so a reduction in the data transfer rate can be minimized.

3. Brief Description of the Drawings:

Figure 1 is a diagram showing the disposition of a spare area in background art;

Figure 2 is a diagram showing how a head in Figure 1 is operated;

Figure 3 is a schematic diagram showing a disk device according to an embodiment of the present invention;

Figure 4 is a diagram showing the disposition of a spare area in the present invention;

Figure 5 is a diagram showing how the head in Figure 4 is operated;

Figure 6 is a diagram showing the locus on the disk of the operation of the head in Figure 5; and

Figure 7 is a flowchart showing a method of reassigning a spare sector.

[Description of symbols]

310 ... Disk device
320 ... Disk enclosure
340 ... Hard-disk controller (HDC)
322 ... Spindle
324 ... Motor
326A, 326B ... Disk
328A, 328B, 328C, 328D ... Head
330A, 330B, 330C, 330D ... Actuator arm
322 ... Pivot shaft
334 ... Voice coil motor (VCM)

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4. Claims:

(1) A disk device comprising:

a recording disk with a plurality of data zones each having a spare area;

a head for recording or reproducing data to or from said recording disk;

an actuator for moving said head over a predetermined radius position on said recording disk;

a motor for rotating said recording disk; and

data reassigning means for reassigning data, in which an error occurred when writing the data to one of said plurality of data zones, so that the data is recorded on said spare area; and

wherein said data reassigning means reassigns the data in which said error occurred:
(a) in a spare area within a data zone to which the data in which said error occurred belongs; and also
(b) at a position within said spare area spaced more than a predetermined angle relative to a center of the disk from a position of the data in which said error occurred.

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(2) The disk device as set forth in Claim 1, wherein said error is a hard error.

(3) The disk device as set forth in Claim 1, wherein said predetermined angle is an angle through which said disk rotates for the maximum time required for said head to get from an arbitrary radial direction of said data zone to an arbitrary radial position of said spare area.

(4) The disk device as set forth in Claim 1, wherein said predetermined angle is substantially 180 degrees.

(5) The disk device as set forth in Claim 1, wherein, when a position on said spare area spaced more than said predetermined angle has been used, the data in which said error occurred is sequentially reassigned to the following position of that position.

(6) The disk device as set forth in Claim 5, wherein said following position is a sector with the same physical sector on another disk surface.

(7) The disk device as set forth in Claim 5, wherein said following position is a physical sector adjacent to a position on the used spare area.

(8) The disk device as set forth in Claim 1, wherein said spare area is disposed so that the time required for said head to get from an arbitrary radial position on said data area to said spare area is within said predetermined time.

(9) The disk device as set forth in Claim 8, wherein said predetermined time is the time required for said disk to rotate through 180 degrees.

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(10) The disk device as set forth in Claim 1, wherein said spare area is located substantially in a central portion of each zone relative to a radius direction of the disk.

(11) In a disk device comprising a recording disk with a plurality of data zones each having a spare area, a method of reassigning data, in which an error occurred when writing the data to one of said plurality data zones, so that the data is recorded on said spare area, the method comprising the steps of:

specifying a position at which said error occurred; and

reassigning a corresponding spare track; and

wherein said step of reassigning a corresponding spare track reassigns the data, in which said error occurred, in a spare area within a data zone to which the data in which said error occurred belongs and also at a position within said spare area spaced more than a predetermined angle relative to a center of the disk from a position of the data in which said error occurred.

(12) The method as set forth in Claim 11, wherein said error is a hard error.

(13) The method as set forth in Claim 11, wherein said predetermined angle is an angle through which said disk rotates for the time required for said head to get from an arbitrary radial direction of said data zone to an arbitrary radial position of said spare area.

(14) The method as set forth in Claim 11, wherein said predetermined angle is substantially 180 degrees.

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(15) The method as set forth in Claim 11, further comprising a step which, when a position on said spare area spaced more than said predetermined angle has been used, subsequently reassigns the data, in which said error occurred, to the following position of said position.

(16) The method as set forth in Claim 15, wherein said following position is a sector with the same physical position on another disk surface.

(17) The method as set forth in Claim 15, wherein said following position is a physical sector adjacent to a position on the used spare area.

(18) The method as set forth in Claim 11, wherein said spare area is disposed so that the time required for said head to get from an arbitrary radial position on said data area to said spare area is within said predetermined time.

(19) The method as set forth in Claim 18, wherein said predetermined time is the time required for said disk to rotate through 180 degrees.

(20) The method as set forth in Claim 11, wherein said spare area is located substantially in a central portion of each zone.

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