New Optical Disc Technologies for Blu-ray Discs

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Introduction

Mitsubishi Electric has developed a system that automatically optimizes the write strategy for optical discs in order to shorten the development period of Blu-ray Disc (BD) recorders and to ensure stable performance. We have also developed tools for verifying logical specifications, which verifies the disc logical information recorded by a BD recorder or created by a BD content authoring system.

1. Technology for Automatic Optimization of Optical Disc Write Strategy

1.1 Write strategy for optical discs

A BD recorder performs laser light modulation, which is called the write strategy, thereby precisely creating recording marks according to the recording data length, in order to correctly record data on a BD disc. The write strategy involves disc-specific optimal adjustments for optical discs. A typical optical disc recorder pre-stores many types of optimal write strategies in its memory for use when recording. Since the optimal write strategy differs depending on the optical specifications of the optical pick-up and the discs, optimal write strategies for all discs must be prepared when the optical pick-up is modified due to a change in model of the optical disc recorder.

Figure 1 illustrates a write strategy for BDs. The BD uses recording data with 2T to 9T (where T indicates the channel clock period), and creates marks according to each recording data, which requires the laser emitting pattern to be controlled for the multi-pulse type.

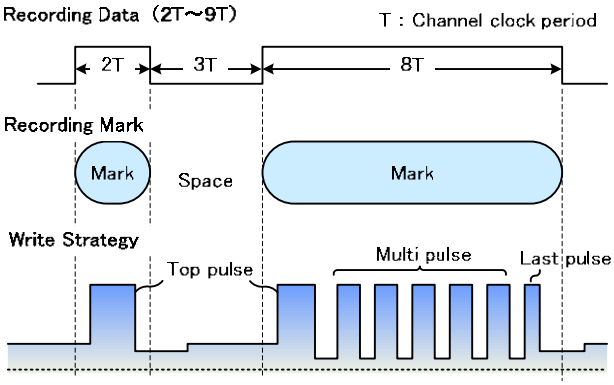

Fig. 1 Write strategy for BD

1.2 System for automatic optimization of write strategy

We have developed a system that automatically optimizes the write strategy, which depends on the characteristics of an optical disc, using a DVD recorder. Figure 2 is a block diagram of the system. The write strategy is optimized by analyzing the playback signals obtained by test recording with a DVD recorder using a digital oscilloscope and computer, and by repeating the closed loops in which the correction amount in the write strategy is fed back to the DVD recorder. The optimization for analyzing playback signals and adjusting the write strategy amount was efficiently achieved by the operators' optimization skills and expertise.

Specifically, the optimization process starts with the step in which the initial write strategy is set in a DVD recorder, and then 8/16-modulated random data are recorded on a DVD disc. Next, the recorded data is played back, and the playback signals after equalization (EQ) that are output from the DVD recorder are stored in a digital oscilloscope. After this process, the playback waveform data after A/D conversion are stored in a computer. The playback waveform data are processed at the playback signal analysis and write strategy calculation blocks. The playback signal analysis block extracts jitter and several waveform parameters from stored playback waveform data; then, based on these parameters, the write strategy calculation block determines the next write strategy setup values. These

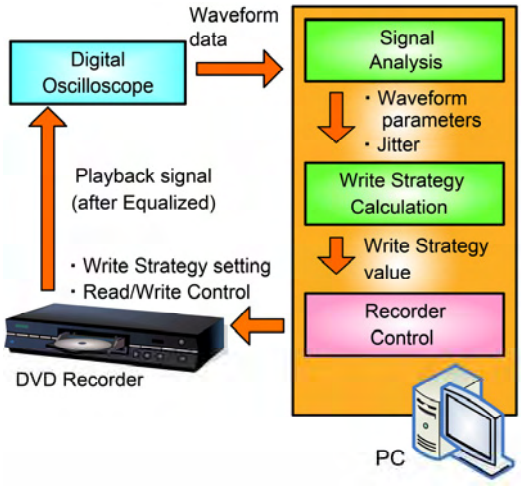

Fig. 2 Block diagram of automatic write strategy optimization system

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processes are repeated until the jitter and waveform parameters satisfy the target values, and finally the optimal write strategy is determined.

Figure 3 shows the processes in the playback signal analysis and write strategy calculation blocks. The playback signal analysis block calculates the signal widths (mark and space widths) based on the slice level from the playback signal data. For mark and space widths, average values are calculated from each recording data length. The peak level corresponding to the recording data with 3T is extracted from the playback signal. The write strategy calculation block selects the parameters of the write strategy required for correction based on the waveform parameters obtained at the playback signal analysis block, and calculates the corrected values. When the jitter and waveform parameters satisfy the target values, the automatic optimization system outputs the optimal write strategy.

1.3 Evaluation of characteristics

In order to examine the performance of the newly developed automatic write strategy optimization system, the jitter performance and optimization time were evaluated using 16 types of commercially available DVD-R discs produced by different manufacturers. Figure 4 shows the jitter performance obtained by the automatic optimization system. As this figure indicates, all discs showed acceptable jitter values, which were lower than the target value of 8%. Figure 5 illustrates playback signals before and after the optimization: (a) shows the playback signal when recording is made using the initial write strategy; (b) shows the playback signal recorded using the optimized write strategy. Lack of sharpness is shown in (a), which indicates the variation at the portions where waveforms are overlapped. Such variation is caused by the influences of inter-symbol interference and waveform distortion because the write strategy is not optimized. On the other hand, in (b), the variation is remarkably eliminated at the portions where waveforms are overlapped. The time required to automatically optimize the write strategy in this system is shown in Fig. 6. As can be seen, the optimization takes from 45 seconds to 2 minutes, 30 seconds. In addition, an automatic write strategy optimization system for BDs is developed by replacing the recorder block of the system with an evaluation equipment that can perform recording on and playback of BD recorders to customize the optimal algorithms for BD's.

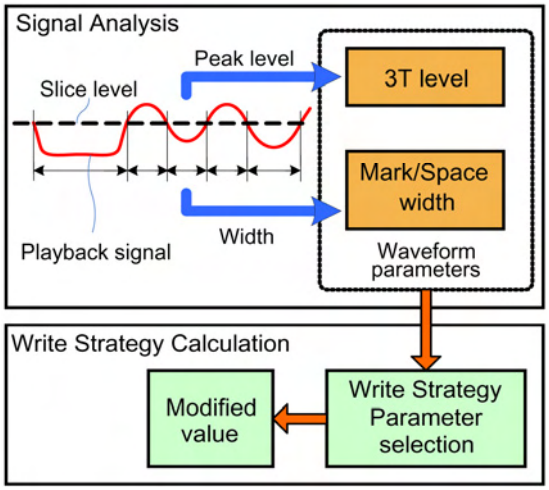


Fig. 3 Signal analysis and write strategy calculation

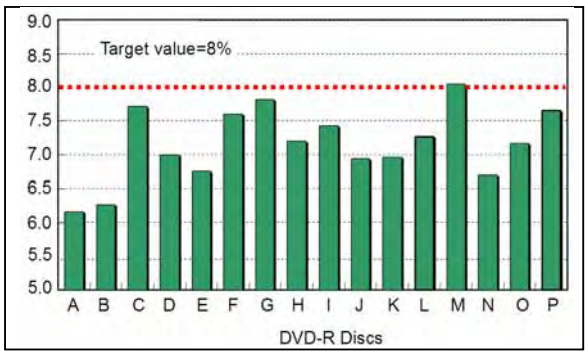


Fig. 4 Jitter value with optimized write strategy

2. Structure of BD Specifications and Formal Verification Tools

2.1 BD specifications

Figure 7 shows the structure of BD specifications. The specifications are classified into three layers. The specifications for the physical layer consist of specifications for rewritable discs, recordable discs, and read-only discs. These three specifications define the type of optical disc and the characteristics of its re-

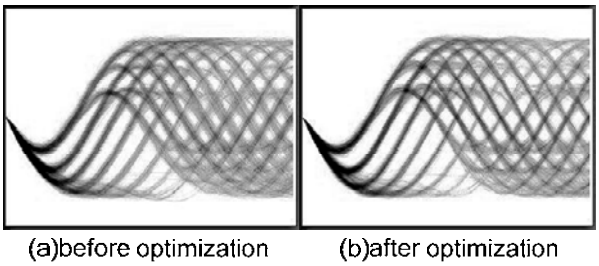


Fig. 5 Playback signal of before and after optimization write strategy

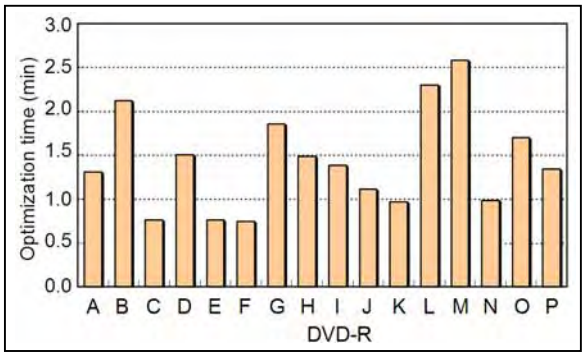


Fig. 6 Time for write strategy optimization

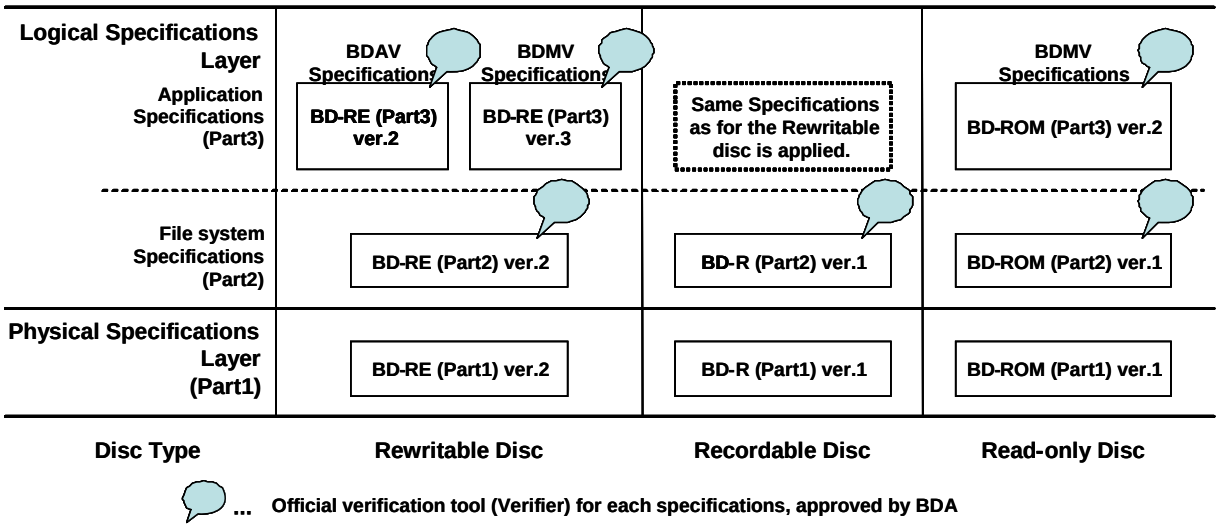


Fig. 7 BD specifications and formal verification tools

cording and playback signals. To maintain and improve the recording signal quality of optical discs, which are interchangeable media, the disc characteristics must conform to those of the recorder. To ensure compatibility between various types of commercially available discs and recorders, it is necessary to secure the quality levels between them. The specifications licenser, BDA, dictates verification tests to the manufacturers to assure compatibility, and only those products that pass the test are certified as BD products. This verification test includes two kinds of tests. One is a confirmation of the signal quality of a disc when it is recorded by a reference recording device; the other is a confirmation of the recording signal quality of a recorder when it records data on a test disc having the qualified characteristics.

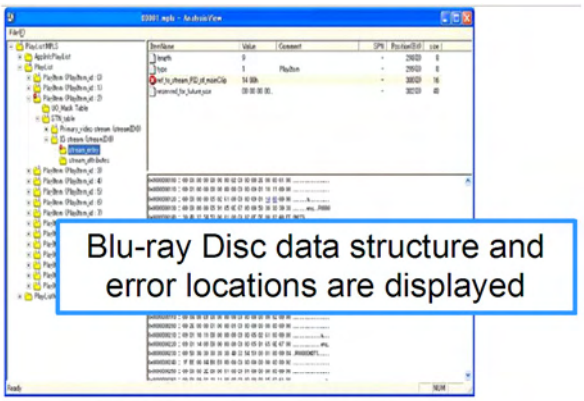
The file system and application layers are collectively referred to as logical layers, which define the alignment and meaning of all data on the optical disc, which include video content to be recorded as digital data files or file management data for them. For the recorder that records video content, the digital video data format recorded on a disc must conform to the logical specifications. In the verification test, test data is recorded on a disc and the disc is analyzed with the formal verification tool, called a verifier, to check whether the data format and alignment satisfy all definitions and conditions in the specifications. There are three specifications for the file system layer, corresponding to each physical specification. The application layer also has three specifications: the Blu-ray Disc Audio/Visual specifications (BDAV) for broadcast program recording, the Blu-ray Disc Movie specifications (BDMV) for movie content, which realizes various video presentations, and the specifications for using the BDMV specifications for personal recording. Verifiers were prepared for each specification.

Compatibility of BD discs recorded by one BD recorder among the other BD recorders or players is assured by confirming that all products satisfy conditions of the specifications in the formal verification test.

2.2 Formal verification tool

Figure 8 shows the configuration of the BDAV specifications verifier used for the recorder verification test, as an example of the formal verification tool. Digitized video data are classified into the stream data group that represents video and audio for a certain period of time, and the control database group that manages and controls the stream data including the connecting relations and replay conditions of each stream data. Each of them is recorded on the disc as a separate file. The specifications define the detailed format of these data, and thus, the recorder shall create data files so that all conditions are satisfied upon recording on a disc.

The verifier, which is a software program that runs on a personal computer, reads recorded data on a disc through a BD drive installed in the personal computer to conduct a test. The verifier is used to inspect whether or not the contents of each file above defined in the specifications conform to the specifications and to precisely inspect whether or not the contents in the management database are consistent with the contents of the stream data groups and their allocation on the disc. If nonconformance to the specifications or inconsistency among data is found, information about the conformance error to the specifications is reported.



Example of analysis result

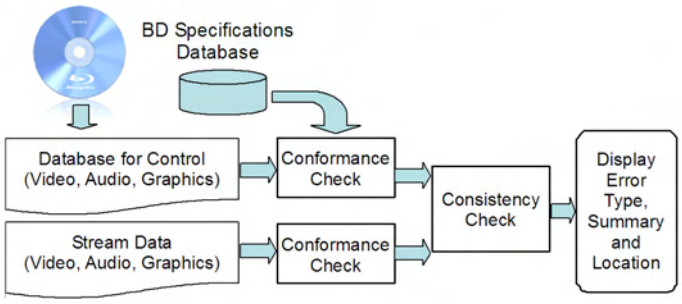


Fig. 8 Functions and features of verifier

The BDAV specifications employ both Moving Picture Experts Group (MPEG)-2 and MPEG-4 Advanced Video Coding (AVC) High Profile. The verifier supports these video compression technologies. The stream data are analyzed in a unit of Group of Pictures (GOP), and conformance to the relevant parameter of the video compression technology standard, which are referred to in the BD specifications, is also inspected. The developed verifier reduces the verification test time by using multi-thread processing for verification operations, and features viewer functions that interactively display management database syntaxes and stream data structures. These features make it easier to detect recorder design failures.

3. Conclusion

We have developed a system that automatically optimizes the write strategy for recorders and drives. We have also developed formal tools for verifying logical specifications for the verification test that checks whether BD products conform to the BD specifications, which are used by BD testing centers.