

Standard ECMA-420

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Device interface information for high- speed collation using holographic optical correlation

Standard



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Introduction

In recent years the technologies for image sensor, image processing and memory made big progress. As a result, miniaturization and performance up to high definition resolutions evolved not only traditional cameras, but also in smart phones, drive recorders and monitoring cameras.

On the other hand, high speed and high capacity internet technologies are permeated, anyone can upload many photos and moving pictures at any time. As a result, infringing of copyright and leakage of personal information are explosively increasing.

These illegal images or illegal moving pictures are found and requested to delete by using computer system with collation technology day by day. However, the numbers of object pictures are too much and current computer systems cannot handle them in a reasonable time.

Since holographic optical correlation can collate between original image and reference image in parallel operation with light speed, it is expected to become a high-speed retrieval and collation technology for moving images, videos and pictures.

This ECMA Standard specifies the device interface information for high-speed image retrieval and collation using holographic optical correlation.

This Ecma Standard was developed by Technical Committee 31 and was adopted by the General Assembly of December 2021.

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Device interface information for high-speed collation using holographic optical correlation

1 Scope

This Ecma standard specifies the device interface information and requirements for high-speed image retrieval and collation using holographic optical correlation based on shift-multiplex recording of coaxial holography.

This standard specifies:

- operating environments
- holographic optical correlation
- holographic optical correlation system
- recording information for hologram database creation
- readout information for collation
- report information.

This standard is mainly used for professional field such as high-speed illegal movie picture retrieval systems, video and picture hosting web sites, data centres and so on.

2 Conformance

To conform to this standard, device interface information shall meet all applicable “shall” requirement in Clause 7 to Clause 9.

3 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ECMA-377, Information Interchange on Holographic Versatile Disc (HVD) recordable cartridges – Capacity: 200 Gbytes per cartridge, 1st edition (May 2007)

4 Term and definition

For the purposes of this document, the following terms and definitions apply.

4.1

coaxial holography

optical means of making hologram by arranging circular object light on the inside of an objective lens and annular reference light on the outside of circular object light

4.2

collation

method of inspection that the specific image is the same or not the images stored in the database by using optical correlation technology

4.3

finalizing

operation after which no further hologram recording is allowed

[SOURCE: ECMA-377:2007, 4.16]

4.4

fixing

operation for deactivating holographic recording material by use of an illumination

[SOURCE: ECMA-377:2007, 4.17]

4.5

holographic optical correlation

optical means that can perform the parallel correlation operations using hologram technology

4.6

object pattern

two-dimensional pattern which is used as object light for hologram recording

4.7

reference pattern

two-dimensional pattern which is used as reference light for hologram recording

4.8

shift-multiplex recording

multiple recording method while shifting the recording position of the hologram little by little while rotating the disk

4.9

Spatial Light Modulator (SLM)

device used to spatially modulate the intensity of a light beam following a two-dimensional pattern

5 List of acronyms

CNN	Convolutional Neural Network
CW	Continuous Wave
DBS	Dichromic Beam Splitter
HCD	Holographic (Optical) Correlation Device
NA	Numerical Aperture
PBS	Polarizing Beam Splitter

6 Operating environments

6.1 Operating environment for Holographic (Optical) Correlation Device (HCD) writer

The operating environment is the environment where the air immediately surrounding the HCD writer shall have the following properties (see Figure 2 in 8.2).

Temperature	18 °C to 28 °C
-------------	----------------

Relative humidity 20 % to 80 %

Atmospheric pressure 60 kPa to 106 kPa

6.2 Operating environment for read only HCD

The operating environment is the environment where the air immediately surrounding the read only HCD shall have the following properties. (see Figure 4 in 8.3)

Temperature 18 °C to 28 °C

Relative humidity 20 % to 80 %

Atmospheric pressure 60 kPa to 106 kPa

7 Holographic optical correlation

7.1 General

Holographic optical correlation can realize a parallel correlation operation at the light speed only irradiating the object light to the hologram. So, it is possible to achieve the very-high-speed correlation compared to the computer-based correlation operation.

In this document, the coaxial holography method shall be used as a holographic optical correlation method. This method, optical and mechanical system is simple, can record the hologram without stopping the rotation of the disk. As a result, it is possible to record holograms of high linear density by shift-multiplex recording. After hologram recording, high-speed retrieval and collation can be achieved by rotating the disk at high speed.

At the hologram recording process, original image for database shall be transformed to circular image pattern with circular object light pattern (object part) and annular reference light pattern (reference part) and this circular image is recorded as a hologram. While collation image shall be transformed to circular image with object part only and used for readout hologram.

7.2 Basic configuration and operation for holographic optical correlation

Figure 1 shows the recording and readout principle in holographic optical correlation using the coaxial holography. On the process of hologram recording, a high-power short pulse width laser is used, while the holographic disk is being rotated low-speed rotation because to obtain the enough energy for hologram recording. On the process of readout hologram, a low power CW laser is used. A photo detector with spatial filter is used to detect the correlation signal. As use of photopolymer for recording material, green wavelength to violet wavelength laser can be used for hologram recording and reading. For the focusing and tracking control servo system, a red laser is used because of the insensitivity to the hologram material (See Annex A).

A recording laser light reflected by PBS enters to SLM. A hologram-recording pattern projected on the SLM consists of a circular object light pattern (object part) located in the centre area and a reference of annular light pattern (reference part) located on the outer area. These two light patterns reflected by SLM are focused on the material of holographic disk by objective lens, and the hologram is recorded as interference fringing pattern.

After recording of holograms for original image data (hologram database), holograms are read using a circular object light pattern (object part) converted from a collation image. If the collation image corresponds to the images recorded in the image database as hologram, a large correlation signal (annular pattern signal) can be obtained via a photo detector.

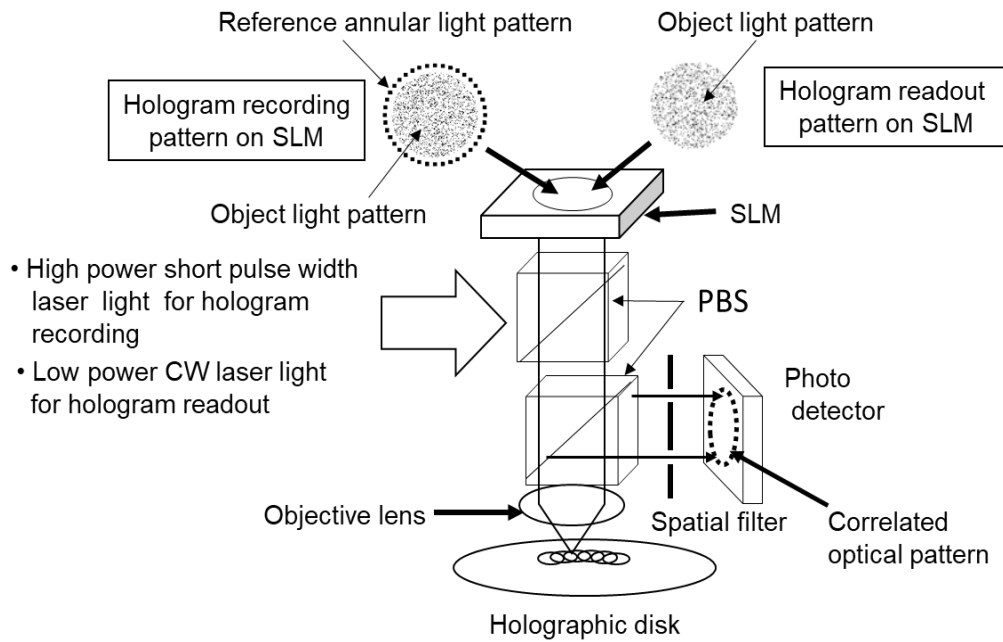


Figure 1 — Recording and readout principle in holographic optical correlation

Readout speed of the holograms is proportional to the hologram pitch and rotational speed. Average holographic optical correlation speed or collation speed can be express as follows.

$$\text{Average correlation speed} = \eta \times N \times 2\pi \times r_{ave} / h_p$$

Where, η : recording efficiency, N : disk rotational speed (rpm), r_{ave} : average radius of recording track (mm), h_p : hologram pitch (μm)

If $\eta = 0.95$, $N = 5,400$ rpm, $r_{ave} = 40$ mm for 120 mm diameter disk and $h_p = 3 \mu\text{m}$, average collation speed will be about 7.19M frames/sec or holograms/sec and average number of holograms per track are over 79,500. In case one image consist of 256×256 pixels, equivalent data transfer rate is expected about 460Gbps. If track pitch is $32 \mu\text{m}$ and recording stroke is 30 mm, then total number of tracks are over 930 and total number of holograms are over 74,000,000 per disk.

On the other hand, recording speed of holograms depends on SLM speed, disk rotational speed, recording peak power and pulse width of the pulse laser. For example, a Q-switch giant pulse laser with short pulse width is used for recording, recording speed is mainly proportional to SLM writing speed. When Ferroelectric Liquid Crystal on Silicon type (FLCOS) SLM is used, hologram recording speed is expected to be over 1 kHz to 2 kHz and total hologram recording time of the disk is 10.8 hours to 21.7 hours considered recording efficiency of 0.95. Upper limit of the disk rotational speed for hologram recording depends on the pulse width of the Q-switch giant pulse laser and recording pitch of holograms.

8 Holographic optical correlation system

8.1 General

The optical correlation system using holograms consists of a system for recording holograms for optical correlation using HCD writer (creation of hologram database) and a system for image retrieval and collation using large numbers of read only HCDs. HCD writer has not only a function of recording of holograms, but also functions of retrieval and collation using recorded holograms.

8.2 Holographic optical correlation system with HCD writer

Figure 2 shows the holographic correlation system configuration for the HCD writer with readout function. System controller PC controls interfaces of original image database and user PC, and device interface for HCD writer. Furthermore, system controller PC manages image processing module and auto-encoder module.

Readout images from the original image database shall be applied the feature extraction in the image-processing module. There are several feature extraction methods such as edge detection methods and CNN methods (see Annex B). These methods are generally used for image recognition and/or collation in the current computer system. Then feature-extracted images shall be converted into a two-dimensional pattern with object part and reference part in the auto-encoder module with re-size of data, white rate control and re-location function (see Annex C) for hologram recording. The two-dimensional pattern (i.e., processed image data for recording (see Annex A)) are sent to the HCD writer via device interface. White rate and data size of the processed image are determined by every HCD unit. In case of edge detection, data size means image data size, but in case of CNN, data size does not mean image data size. When recording holograms continuously, the velocity of the feature extraction in the image-processing module or auto-encoder module cannot keep up with the speed of the HCD writer. In that case, it is necessary to use multiple Image processing modules and auto-encoder modules in parallel operation, or to process and store them in advance. Image processing technology is also used in computer-based image collation system.

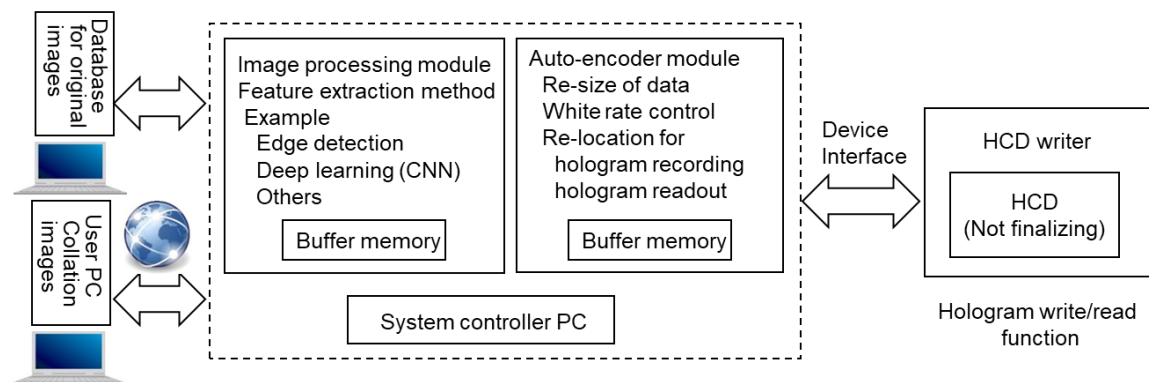


Figure 2 — Holographic correlation system configuration for the HCD writer with readout function

Figure 3 shows the configuration of HCD writer, which consists of the removable HCD, interface controller, write function including writing system and a high-power Q-switch green pulse laser, which is used to obtain enough exposure energy for hologram recording, but size is big, so that this laser cannot include in HCD.

On the hologram recording process, the holographic disk is rotated at low speed because to obtain enough exposure energy and small shift of hologram position. On the holographic correlation process, the holographic disk is rotated several ten times over higher speed than that of hologram recording, because to obtain the high-speed retrieve and collation. Therefore, spindle motor is required stable control and low jitter in the one revolution at low speed for hologram recording, and stable control at higher speed rotation for hologram readout operation.

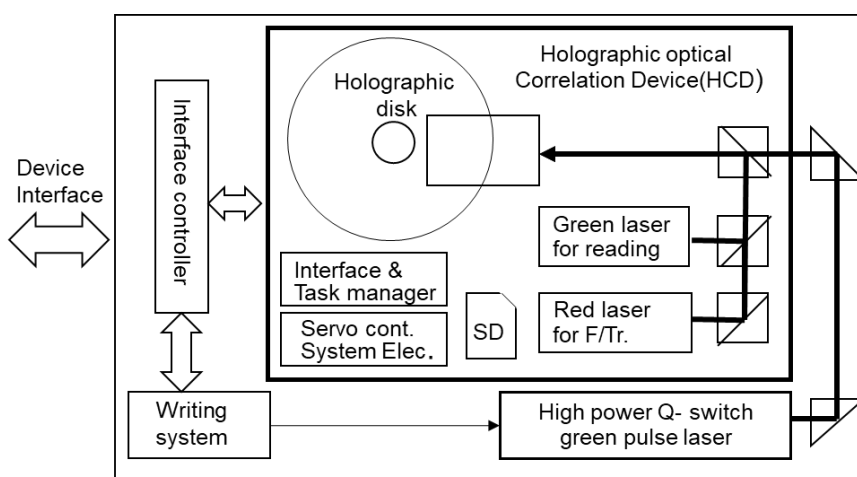


Figure 3 — HCD writer with hologram recording/readout function

The HCD writer has two hologram recording modes. One mode is to record holograms in whole area and another mode is to record partial area of the disk at once. After recording holograms, all area of the holographic disk shall be fixing (see 9.6 in ECMA-377) and finalizing (see 17 in ECMA-377). Then the HCD can be removed from the HCD writer and can be used as the read only HCD in a day.

Another mode is alternately to record holograms and to readout of recorded holograms. In this mode, hologram recorded area should be carried out partially fixing every day. In case all area of the disk was recorded or one month has passed, fixing and finalizing shall be carried out. Then the HCD can be removed from the HCD writer and can be used as the read only HCD.

8.3 Holographic correlation system configuration with many read only HCDs

Figure 4 shows the holographic correlation system configuration for high-speed image retrieval and collation with many read only HCDs. The images for collation from user PC shall be managed using the same image processing method (feature extraction method) and the same auto-encoder process when creating the hologram database of each HCD. High-speed retrieval and collation can be achieved by sending the same processed image data for collation (see Annex A) via device interface, while holographic disk shall be rotated at several tens high speed than that of hologram recording.

The system controller PC can simultaneously access one HCD or multiple HCDs to retrieve and collation via device interface. Access one HCD is when it is known that the picture stream containing the collation image is in the database of specific one HCD. Access multiple HCDs is when the picture stream containing the collation images is somewhere on more than one HCD, or when the retrieve and collation is multitasking.

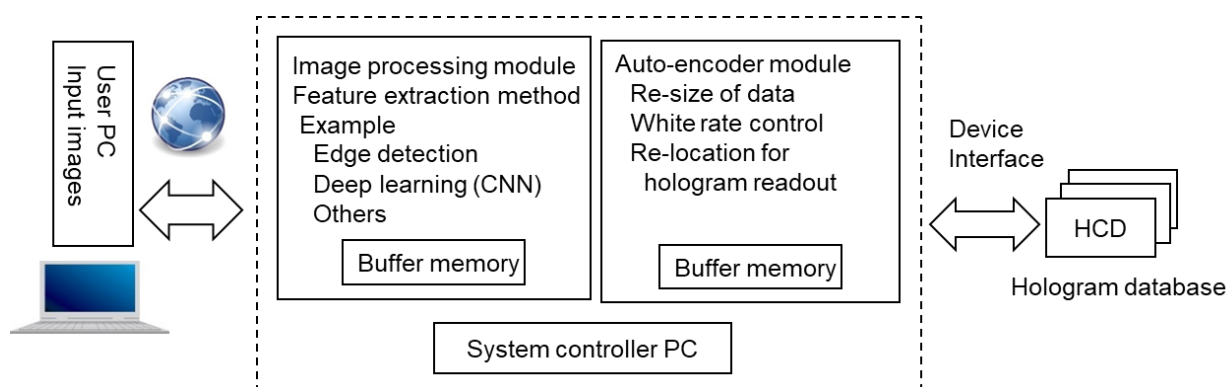


Figure 4 — Holographic correlation system configuration with many read only HCDs

Figure 5 shows read only HCDs as hologram database for high-speed retrieval and collation using holographic optical correlation. The HCD consists of a holographic disk clamped on spindle motor, a green CW laser for readout holograms, a red laser for focusing/tracking, SD card (a removable memory card) for disk information, interface & task manager, servo controller, system electronics including interface. HCD can be realized small size because of no need including big size high power laser for writing.

The read only HCD can be reused as a new unrecorded HCD by replacing the recorded holographic disk and the SD card to the new one. The replaced holographic disk and SD card can be reused again.

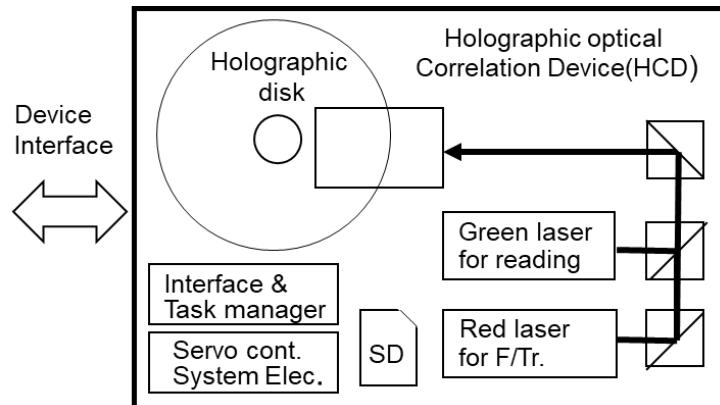


Figure 5 — Readout only HCD for high speed retrieval and collation

9 Device interface information

9.1 General

As explained in Clause 8, two kinds of interface information are required. One is HCD writer interface information, which is for hologram recording operation and for readout operation for collation. There are two kinds of recording operation, the continuous recording operation and alternately repeating partial recording operation. Another is read only HCD interface information, which is readout operation for collation only.

According to Clause 7.2, over 74 million holograms will be recoded on a holographic disk. If the average number of frame sampling rate is 10 frames per second, more than 2,000 one-hour picture (or video) streams can be recorded in one HCD. In case of 3 minutes picture streams, 40,000 picture streams can be recorded in one HCD. To record these many picture streams as holograms, the address information of each stream, image processing method, white rate, the processed image data for hologram recording and local fixing information are required.

9.2 Recording information for HCD writer

9.2.1 General

When an unrecorded HCD is loaded into the writer, the writer shall send information of HCD writer number, HCD number, holographic disk number and possible recording numbers of hologram to the system controller PC. Based on this information, system controller PC shall send the information that need to create the hologram database to the HCD writer in the following procedure (see 9.2.2 and 9.2.3). The address of the picture stream described below is a logical address. As the physical address of hologram is determined by each HCD, it is not handled here. White rate of image data shall be set one value for one HCD, because this value depends on the hologram recording power. Each picture stream data for recording consists of many processed image data for recording, which is a two-dimensional pattern with object part and reference part (see 7.2 and Annex A).

9.2.2 Interface information for continuous recording

Set new HCD or reused HCD with new holographic disk to the HCD writer. The HCD writer shall send status information of HCD writer number (3 bytes), HCD number (4 bytes), holographic disk number (1 byte) and possible recording numbers of hologram (4 bytes) to the system controller PC.

Following number of CR-*n* means *n*th action step of continuous hologram database recording.

Start hologram database recording:

CR-1 System controller PC shall send HCD information:

HCD writer number: 3 bytes
HCD number: 4 bytes
Holographic disk number: 1 byte
Numbers of picture stream title per disk for recording: 3 bytes

CR-2 System controller PC shall send white rate:

White rate (1 byte) shall be set as follows.

00000000: 20 %, default white rate
00000001: 15 %
00000010: 25%
00000011: 30 %
00000100 to 11111111: Reserved

User shall determine one white rate for one HCD.

CR-3 System controller PC shall send the first picture stream information:

Name of the first picture stream title: 64 bytes (2 bytes code: 32 characters)
Total numbers of frame for the first picture stream (i.e. total numbers of hologram): 3 bytes
Write start address of the first picture stream: 4 bytes

CR-4 System controller PC shall send image processing method:

Image processing method (1 byte) shall be set as follows.

00000000: Edge detection method 1,
00000001: Edge detection method 2
00000010 to 00001111: Reserved
00010000: CNN method 1
00100000: CNN method 2

00110000 to 11110000: Reserved

Each image processing method is defined by user.

CR-5 System controller PC shall send the first picture stream information for recording:

First frame processed image data for recording
Second frame processed image data for recording
Continue

Continue
Last frame processed image data for recording

CR-6 System controller PC shall send the second picture stream information:

Repeat CR-3 to CR-5 for second picture stream.

CR-7 System controller PC shall send the third to before the last picture stream information:

Repeat CR-3 to CR-5 for the third to before the last picture stream.

CR-8 System controller PC shall send the last picture stream information:

Repeat CR-3 to CR-5 for last picture stream.

CR-9 End of hologram recording.

CR-10 Fixing and finalizing shall be carried out for the recorded holographic disk.

Holographic disk information such as the HCD number, holographic disk number and all recorded hologram interface information are recorded in the SD card. After this operation, the HCD can be removed from the HCD writer and used as the read-only HCD (see Figure 4).

9.2.3 Interface information for partial recording

Partial recording is used when one disk cannot be recorded continuously, or when recording and reading are carried out alternately.

Set new HCD or reused HCD with new holographic disk to the HCD writer. The HCD writer shall send status information same as continuous recording (see 9.2.2).

Following number of PR-*n* means *n*th action step of partial recording.

Start partial recording:

PR-1 System controller PC shall send HCD information for the partial recording:

HCD writer number: 3 bytes
HCD number: 4 bytes
Holographic disk number: 1 byte

PR-2 System controller PC shall send white rate:

White rate (1 byte) shall be set as follows.

00000000: 20 %, default white rate
00000001: 15 %
00000010: 25%
00000011: 30 %
00000100 to 11111111: Reserved

User shall determine one white rate for one HCD

PR-3 System controller PC shall send numbers of picture stream title per the first partial recording: 3 bytes

PR-4 System controller PC shall send the first picture stream information for the first partial recording:

Name of the first picture stream title: 64 bytes (2bytes code: 32 characters)
Total numbers of frames for the first picture stream (total numbers of hologram): 3 bytes
Write start address of the first picture stream: 4 bytes

PR-5 System controller PC shall send image processing method:

Image processing method (1 byte) shall be set as follows.

00000000: Edge detection method 1,
00000001: Edge detection method 2
00000010 to 00001111: Reserved
00010000: CNN method 1
00100000: CNN method 2
00110000 to 11110000: Reserved

Each image processing method is defined by user.

PR-6 System controller PC shall send the first picture stream information for the first partial recording:

First frame processed image data for recording
Second frame processed image data for recording
Continue

Continue

Last frame processed image data for recording

PR-7 System controller PC shall send the second to the last picture stream information:

Repeat CR-4 to CR-6 for the second to the last picture stream.

PR-8 End of the first partial recording.

PR-9 Waiting for next partial recording and maybe readout of recorded area for collation.

PR-10 Fixing should be carried out the recorded area of the holographic disk if one day passed.

PR-11 System controller PC shall send numbers of picture stream title per the second partial recording: 3 bytes

Repeat PR-4 to PR-10 for second partial recording.

PR-12 System controller PC shall send numbers of picture stream title per the third to last partial recording: 3 bytes

Repeat PR-4 to PR-10 for third to last partial recording.

PR-13 End of partial hologram recording.

PR-14 Fixing and finalizing shall be carried out for the holographic disk.

Holographic disk information such as the HCD number, holographic disk number and all partially recorded hologram interface information shall be recorded in the SD card. After this operation, the HCD can be removed from the HCD writer and used as the read-only HCD (see Figure 4).

9.3 Image retrieval and collation, and report information

9.3.1 General

Image retrieval and collation by using optical correlation is applied to read only HCD. In addition, it is also applied to the areas of HCD that have already been recorded in a mode in which writer alternates recording (partial recording) and readout (see 8.2 and 9.2.2).

To improve the reliability of the collation, plural collation images are used for one picture stream. The reason is to respond to poor quality of the image for collation, crawled image is not appropriate, etc. The numbers of collation image are decided by the system user.

The collation image from user PC shall be applied same as image processing method, white rate and image data transform (except reference part) for each HCD as hologram recording.

The HCD shall check whether there was hit or not for each collation image. If a matched image was found, HCD shall be reported the number of the HCD, the title of the stream, and the address of the hit image.

9.3.2 Image retrieval and collation

First, the system controller PC shall send HCD information, white rate and image processing method to target HCD. Next, the start address and stop address of the picture stream for retrieval and collation shall be sent to target HCD. In case multi picture streams, start address of the first picture stream and stop address of the last picture stream shall be sent to target HCD. The processed image data for collation (see Annex A) shall be sent to HCD, and the retrieval and collation with each collation image shall be carried out. The address indicates a logical address.

Start retrieval and collation:

System controller PC shall send HCD information:

HCD number: 4 bytes
Holographic disk number: 1 byte
Numbers of picture stream titles per disk: 3 bytes

White rate: 1 byte (15 % to 30%).

00000000: 20 %, default white rate
00000001: 15 %
00000010: 25%
00000011: 30 %
00000100 to 11111111: Reserved

System controller PC shall send one image processing method: 1 byte

00000000: Edge detection method 1,
00000001: Edge detection method 2
00000010 to 00001111: Reserved
00010000: CNN method 1
00100000: CNN method 2
00110000 to 11110000: Reserved

System controller PC shall send start address, stop address and processed image data for collation:

Read start address: 4 bytes
Read stop address: 4 bytes
Numbers of collation image: 1 byte
First processed image data for collation
Second processed image data for collation
Continue

Continue
Mth processed image data for collation

HCD shall carry out retrieval and collation:

First collation image
Second collation image
Continue

Continue
Mth collation image

End of retrieval and collation.

9.3.3 Report information

HCD shall report the information of the retrieval and collation result to the system controller PC from the first to the Mth collation image. The address indicates a logical address.

HCD shall send HCD information:

HCD number: 4 bytes
Holographic disk number: 1 byte

HCD shall send collation results:

First collation image, hit or not (1B), hit: 00000001, not hit:00000000
Hit address 1: 4 bytes
Hit address 2: 4 bytes

Hit address J: 4 bytes

J is arbitrary number and larger than 2.

Continue

Kth collation image, hit or not (1 byte), hit: 00000001, not hit:00000000
Hit address 1: 4 bytes
Hit address 2: 4 bytes

Hit address J: 4 bytes

J is arbitrary number and larger than 2.

End of report.

Annex A (informative)

Optical and mechanical configuration for holographic optical correlation

Figure A.1 shows the configuration of recording and reading of optical correlation system using coaxial hologram. In the figure, $\lambda/2$ is a $\lambda/2$ plate, and used to change the polarization direction by 90 degrees. $\lambda/4$ is a $\lambda/4$ plate and used to convert linear polarization to circular polarization, or circular polarization to linear polarization. Further, PBS is a polarizing beam splitter and DBS is a dichroic beam splitter. DBS is used for red laser light and green laser light reflected and /or transmitted with minimum loss. L is a lens, B.E is beam expander and PMT is photo-multiplier tube. The reflected light from the SLM is changed 90 degrees with a mirror attached to the Focus/Tracking actuator and is focused on the reflective surface of the holographic disk with an objective lens.

By using a high-power Q-switch green pulse laser, holograms can be recorded while the holographic disk is rotated at a low speed. A low-power CW green laser is used to readout holograms on the disk. Readout speed is mainly based on the rotational speed of the spindle motor and the response speed of the photodetector such as PMT. Claus 7.2 shows an example of a disk rotation speed of 5,400 rpm, but there is a possibility of further high-speed rotation

The holographic disk has the structure in which photopolymer material is sandwiched between glass 2P substrate and cover glass substrate. On the glass 2P substrate, tracking, address and clock information are formed, and on which formed reflection layer. As used of glass substrates, the surface deflection is smaller than that of a current optical disk using a polycarbonate substrate. On the other hand, the eccentricity is same as that of a current optical disk, it is desirable to adjust the eccentricity.

As red LD light is insensitive to the photopolymer material, red laser can be used to obtain the focus / tracking control signal, the hologram recording timing signal and address information from the holographic disk. In addition, the BCA (Burst Cutting Area) code [2] specified in DVDs can be used to manage the holographic disks.

At the hologram recording, a two-dimensional pattern with object part and reference part (processed image data for recording) shown on the right upper side of the SLM in Figure A.1 is used. The centre-circled pattern is object light pattern and the outer ring-shaped pattern is a reference light pattern, and these two kinds of pattern are displayed on the SLM. The light from the Q switch green pulse laser is incident to the SLM, and the reflected light pass through the objective lens, and focused on the holographic disk. It is called a coaxial hologram because object light and reference light exist simultaneously in one objective lens. The hologram size depends on the aperture of the SLM, length from SLM to the objective lens and its focal length, and generally use the size of 150 μm to 300 μm . This type of hologram is extremely sensitive to hologram position shifting, so that it can be possible high-density hologram recording as described in Clause 7.2.

On the process of collation, the image is applied the image processing method same as hologram recording and converted into a two-dimensional collation pattern (processed image data for collation) as an object light shown on the right under side of the SLM in Figure A.1 and displayed on the SLM. The light from the low power green CW laser is incident to the SLM, and the reflected light pass through the objective lens, and focused on the holographic disk. Holographic optical correlation is carried out only applied the laser light to the hologram, and when the image used for collation is same as the image for hologram recording, the reconstructed light is the ring-shaped reference pattern and centre area involved DC light, the space filter is located front of PMT to remove the unused DC light.

Figure A.2 shows the holographic optical correlated readout signal when No. 200 frame image is used as collation image. Where holograms on the disk are recorded using the 1,000-frames movie stream, which sampling rate is 10 frames/sec, and include No. 200 frame image. The correlate readout signal has a high peak signal at the hologram of No.200 frame. This means easy correlation and collation can be done using holographic optical correlation method. In this way, holographic optical correlation is suitable for fast correlation and fast collation without use of complex computation such as current computer system.

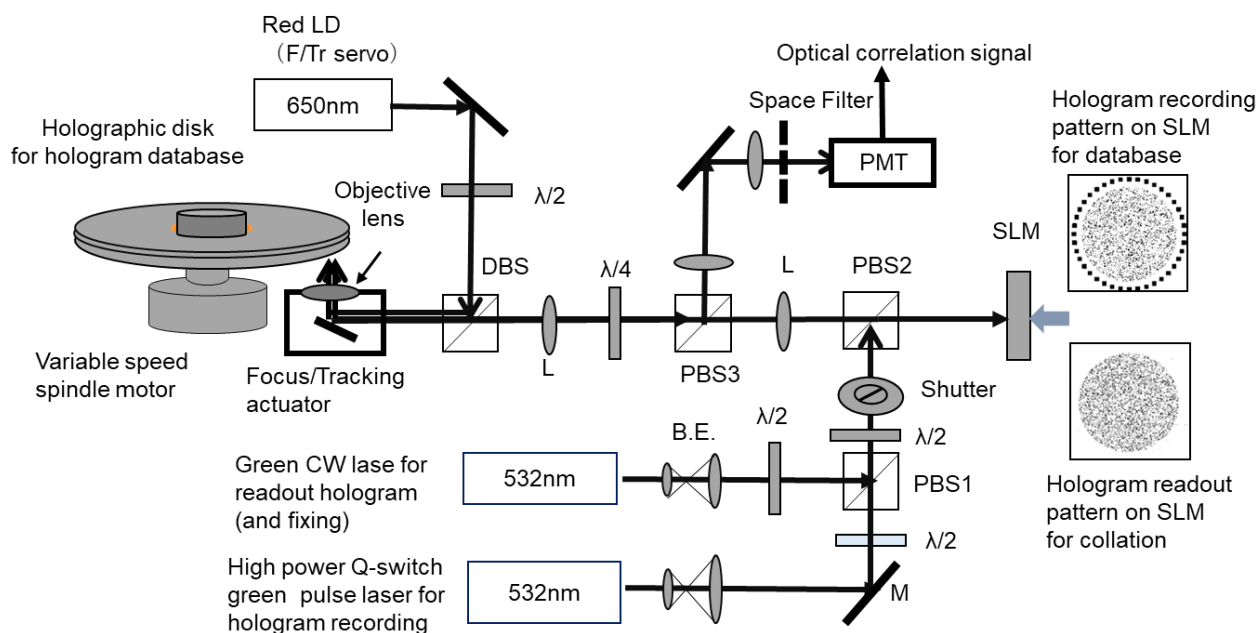


Figure A.1 — Typical optical and mechanical configuration for holographic optical correlation

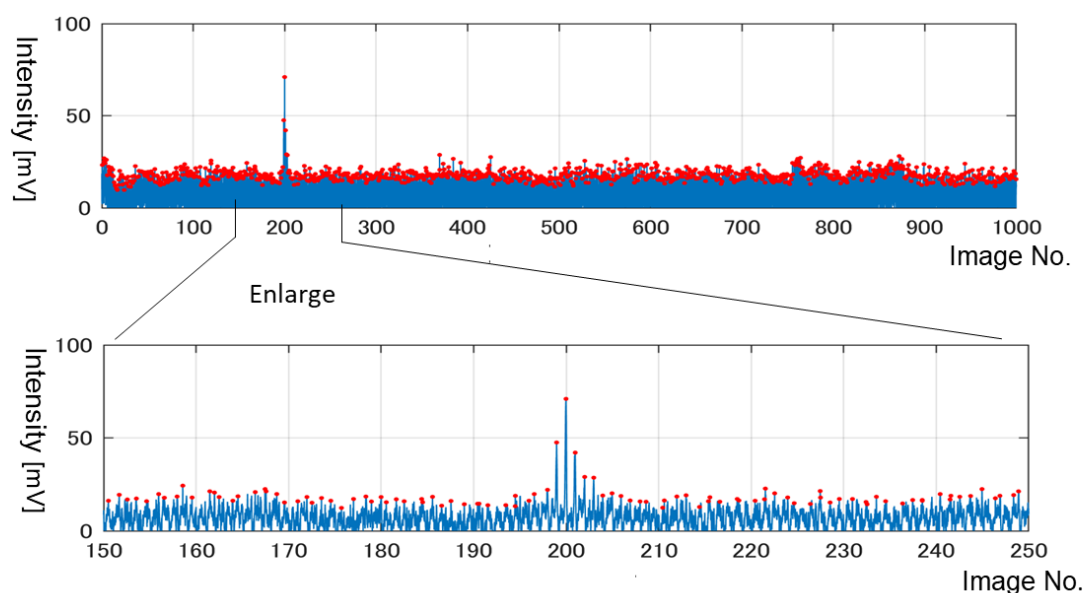


Figure A.2 — Samples of detected optical correlation signal

Annex B **(informative)**

Feature extraction for Image processing

In general, images used in retrieval and collation systems are unified and reduced in different image size (pixel size) to speed up the system and to improve efficiency. This processed image is the normalized image of the image for database creation and collation. As a normalized image, a thumbnail image (96×128 pixels) is often used in a collation system for illegal movies or video on the Internet using a computer from the viewpoint of matching several to dozens of images. On the other hand, the optical correlation does not depend on the number of pixels in the correlation calculation time. For this reason, images with 4 to 8 times more pixels than thumbnail images are used as reference images so that more precise matching can be performed. However, if the number of pixels of the normalized image is increased more than necessary, the time of image processing on the computer will be longer and a large NA objective lens will be required in the optical holographic correlation system.

When collation between images, it is commonly used to extract features from these images and match them using extracted feature information. Features of this image extraction method include an edge detection (extraction) method and a deep learning method using CNN. There are advantages and disadvantages to each, and it can be used according to the application.

Edge detection (extraction) methods are used not only for image matching but also for various image processing fields such as image measurement and image recognition. The principle of edge detection can be achieved by differentiation and binarization regarding two-dimensional images. This method is used by combining several methods depending on the purpose. A typical edge detection method is the canny method.

On the other hand, there are images with flat edges, images with enlarge, scale up or down, rotation and changed positions, or tampered images. For this reason, it may be difficult to match images with conventional edge detection methods. To respond to this, there is a method of image recognition using CNN, which is one of the deep learning methods.

Typical CNN methods include ResNet-50 and AlexNet. Since both methods are for image recognition, the last binding layer is not used, but as a feature extractor of the input image using the 2,048-dimensional feature amount of the previous layer. In addition, since AlexNet has learned more than a million images, it is also possible to use this database for general images. Recently, several methods that have developed these methods have been proposed, but image recognition is the main application.

Annex C (informative)

Data transform for optical correlation

Figure C.1 shows a block diagram for data transform for optical correlation. As described in Annex B, image data for database and image data for collation are resized so that the image size is normalized size, and then the feature extraction of the image is performed. The edge detection (extraction) method and the CNN method which is one of the deep learning are used for this feature extraction method. The choice is determined by the system user according to the application. After this, the feature extracted image is binarized to be assigned white level. The binarized data is converted into the circular pattern with the object light and the reference light in figure C.1 at the case of hologram recording, while at the case of collation, it is converted into the pattern of only the object light indicated lower.

In the optical correlation, as shown in Annex A.1, a two-dimensional pattern for hologram recording is displayed on a SLM, a laser light is irradiated on it, and the reflected light is focused with an objective lens to record hologram. Since the set of white levels of the display pattern becomes laser power (energy) for hologram recording, it is not dependent on the image and is made to be at a constant white level. For this, it is necessary to do a banalization so that the white level becomes the specified value (default:20%) using edge detection and information on images extracted by CNN.

The case of edge detection, which is commonly used, the level of binarization is set at high level and there are few white-level pixels for highlight of the features. On the other hand, in the optical correlation, when the edge detected image is binarized by the white level of 15% to 30% (default: 20%). This value is related to the laser power (energy) during hologram recording and the ratio of object light to reference light.

In the case of collation, a pattern of object light binarized value at the specified white level is arranged in a circular two-dimensional pattern using an object image for collation, and a two-dimensional pattern for collation is created. By sending the information of this two-dimensional pattern to HCD via device interface, it is possible to collate with the hologram database.

On the other hand, in the feature extraction method using CNN, the last binding layer tuned for image recognition is not used, but a 2,048-dimensional feature amount of the previous layer is used as a feature extractor of the input image. Since this feature amount does not correspond to the normalized image size, it is necessary to create a two-dimensional pattern corresponding to hologram recording and collation.

For more information about data transform, see a website of The University of Electro-Communications [6].

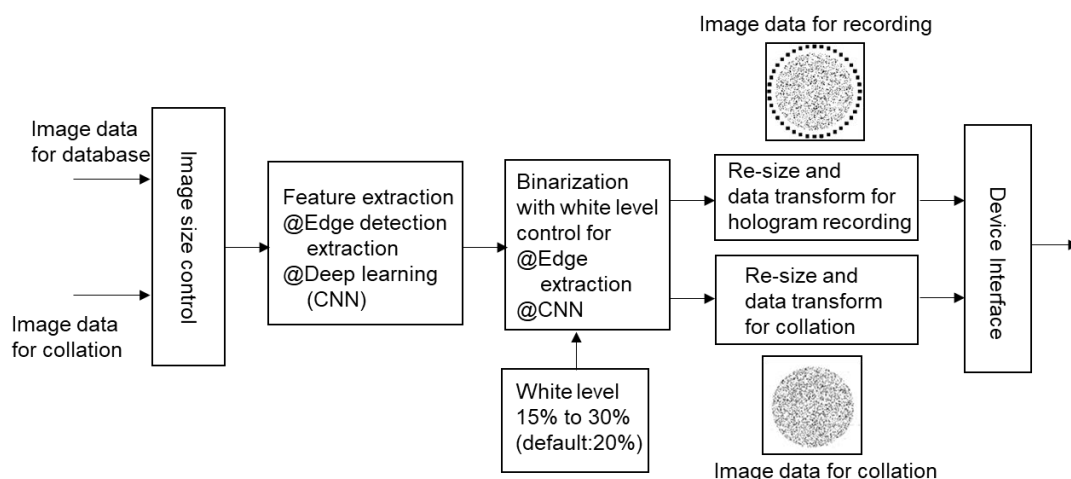


Figure C.1 — Data transform for optical correlation

Annex D

(informative)

Recommended interface hardware information

HCD, like data storage devices such as HDD, can be used plural units for standalone system. On the other hand, for use of sever system may use over several hundred units for image retrieval and collation. Furthermore, transfer rate may require more than 1Gbps. Therefore, as a hardware of the device interface, SAS (SCSI Trade Association, Serial Attached SCSI) and USB (Universal Serial Bus) are desirable.

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