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Translation and Sorting of Point Cloud Data for H.265/HEVC

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ABSTRACT

Point cloud data include information about accurate surface shape of objects. In the case of colored point cloud data, RGB information at each coordinate point is included in addition to XYZ positional information. Point cloud has been applied to 3D modeling, medical image processing, DEM (Digital Elevation Model), etc. On the other hand, data size of point cloud can be massive depending on the acquisition of coordinate values with wide range and high accuracy. Therefore an efficient compression method is necessary for storing or transmitting the data. In this paper, we propose a point cloud data format translation method for H.265/HEVC (High Efficiency Video Coding) in order to efficiently compress the data. Simulation results show that the combination of the proposed method and H.265/HEVC reduces point cloud data size in about 1/10.

1. INTRODUCTION

Point cloud generally represents surface shapes of various objects as a set of positional data in a three-dimensional coordinate system [1]. It can be acquired by using 3D laser rangefinder or other depth sensors. Because point cloud has a scale same as the real object, it has been applied to 3D modeling, medical image processing, generation of DEM (Digital Elevation Model) in GIS (geographic information system), etc. On the other hand, data size of point cloud can be massive depending on the number of points or accuracy of coordinate values. Therefore, data compression for a point cloud is effective to reduce the data size with holding semantic contents.

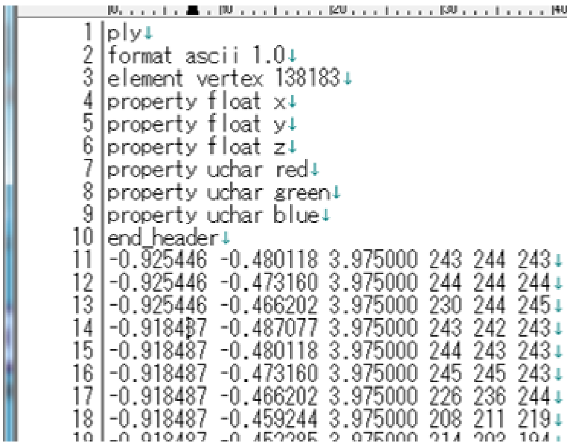
LZSS [2] (Lempel-Ziv-Storer-Szymanski) used for a ZIP format is well known as representative algorithm for lossless data compression. This algorithm is widely used for general data. On the other hand, the point cloud data we target in this study contain color information as well as 3D coordinate. H.265/HEVC [3] is widely known as a method to compress color information of pictures. it is expected to compress effectively color data of point cloud by using H.265/HEVC. In this study, we propose a data translation method that can be compressed both of XYZ positional and RGB color data by using H.265/HEVC.

The rest of this paper is organized as follows. Section 2 explains point cloud data and its formats. An outline of H.265/HEVC is also explained in the section. Section 3 describes the proposed method that translates and sorts the point cloud data to apply it to H.265/HEVC. Section 4 describes the experimental environment and results. Section 5 concludes this paper.

2. RELATED MATTERS

2.1. POINT CLOUD DATA

Because of recent improvements in 3D sensors such as laser rangefinders and depth sensors using infrared ray, accurate digital data for the shape of many physical objects can be acquired. Especially, the advent of KINECT sensor allows us to easily and inexpensively obtain point cloud data. There are many file formats for point cloud data such as OBJ by Wavefront Technologies Inc., STL by 3D Systems Inc., PLY by Stanford University, and LAS for LIDER (light detection and ranging) data. Figure 1 shows an example of PLY file format. In this figure, the contents from line 1to 10 are header information. In each line from line 11 to the end, the first three numbers mean X, Y, and Z positional values, respectively. The next three numbers mean R, G, and B color values. In other words, the point cloud data have not only positional but also color information for each point.



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 1 ply
 2 format ascii 1.0
 3 element vertex 138183
 4 property float x
 5 property float y
 6 property float z
 7 property uchar red
 8 property uchar green
 9 property uchar blue
10 end_header
11 -0.925446 -0.480118 3.975000 243 244 243
12 -0.925446 -0.473160 3.975000 244 244 244
13 -0.925446 -0.466202 3.975000 230 244 245
14 -0.918487 -0.487077 3.975000 243 242 243
15 -0.918487 -0.480118 3.975000 244 243 243
16 -0.918487 -0.473160 3.975000 245 245 243
17 -0.918487 -0.466202 3.975000 226 236 244
18 -0.918487 -0.459244 3.975000 208 211 219
```

Figure 1 Example of PLY file format

2.2. H.265/HEVC

H.265/HEVC is the latest international video compression standard that is standardized jointly by ITU-T (International Telecommunication Union Telecommunication Standardization Sector) and ISO (International Organization for Standardization). It is mainly comprised of intra/inter frame prediction with motion compensation, discrete cosine transform, quantization, and entropy coding. This standard supports YUV color space. According to ITU-R (International Telecommunication Union Radiocommunication Standardization Sector) BT.709[4], YUV color space is derived by

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.2126 & 0.7152 & 0.0722 \\ -0.1146 & -0.3854 & 0.5000 \\ 0.5000 & -0.4542 & -0.0458 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (1)$$

from RGB color space.

3. PROPOSED METHOD

3.1 OUTLINE

A purpose of this study is to convert point cloud data into picture data suitable for H.265/HEVC compression. Point cloud targeted in this study contain 3D XYZ positional and RGB color data. In these data, the RGB are converted into YUV data according to Equation (1) as usual. We name them as "genuine-YUV". On the other hand, the XYZ positional data are first converted to "pseudo-RGB" data which have values of eight-bit-range from 0 to 255. The "pseudo-RGB" data are then converted into "pseudo-YUV" data according to Equation (1). The sets of "pseudo-YUV" and the "genuine-YUV" are then sorted to improve correlation of values of adjacent points. The sorted data are finally arranged as target picture data compressed by using H.265/HEVC. The following paragraphs describe in detail.

3.2 GENERATION OF "PSEUDO-RGB"

The XYZ positional values are converted to "pseudo-RGB" values by using a linear formula. That is, for each coordinate of X, Y, and Z, parameters α and β are first obtained using the following formula:

$$\begin{bmatrix} 0 \\ 255 \end{bmatrix} = \alpha \cdot \begin{bmatrix} p_{min} \\ p_{max} \end{bmatrix} + \beta \qquad (2)$$

where p_{min} and p_{max} are the minimum and maximum values of each coordinate, respectively. Each positional value p is then converted to c using the following formula:

$$c = \alpha \cdot p + \beta \qquad (3)$$

Y	U	V
52	236	118
54	234	118
53	235	117
52	235	118
52	235	118
52	226	133
52	226	133
53	226	133
53	225	132
53	225	132

(a)

Yc	U	V
52	236	118
52	235	118
52	235	118
52	226	133
52	226	133
53	235	117
53	226	133
53	225	132
53	225	132
54	234	118

(b)

Y	U	V
52	226	133
52	226	133
52	235	118
52	235	118
52	236	118
53	225	132
53	225	132
53	226	133
53	235	117
54	234	118

(c)

Y	U	V
52	226	133
52	226	133
52	235	118
52	235	118
52	236	118
53	225	132
53	225	132
53	226	133
53	235	117
54	234	118

(d)

Figure 2 Examples of sorting

where c is a value converted to "pseudo-RGB." The "pseudo-RGB" data are then converted into "pseudo-YUV" data as described in 3.1.

3.3 SORTING SETS OF "PSEUDO-YUV" AND "GENUINE-YUV"

The sets of "pseudo-YUV" and "genuine-YUV" data are sorted to make correlation of values of adjacent points higher. For example, in Figure 2, (a) shows the sets of original "pseudo-YUV." Figure 2(b) shows the sets sorted in ascending order with value Y as a key. The same value may continue such as the parts surrounded with bold-faced squares of Figure 2(b). The parts are then sorted, respectively with value U as a key as shown in Figure 2(c). Figure 2(d) shows the result of sorting with value V similarly.

3.4 GENERATION OF TARGET PICTURE

The sets of "pseudo-YUV" and "genuine-YUV" data after sorting are arranged as two-dimensional picture data. First, values of "pseudo-Y" only are two-dimensionally aligned in order same as a raster scan. Then, values of

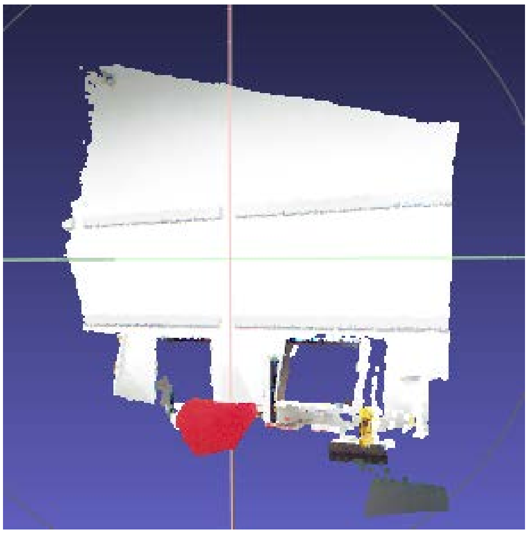

Figure 2 Acquired point cloud

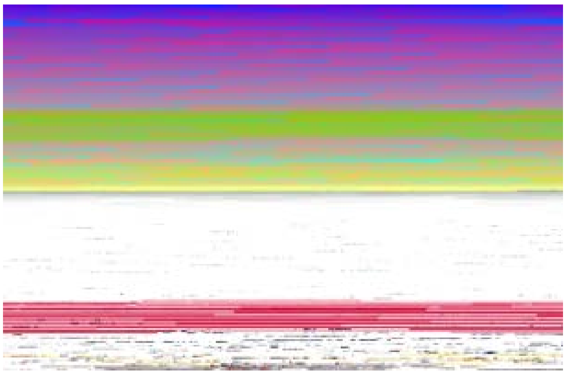

Figure 3 Generated target picture

"pseudo-U" are successively aligned. After that, values of "pseudo-V," "genuine-Y," "-U," and "-V" are similarly aligned in this order.

4. EXPERIMENTS

First, we made point cloud data with PLY format to use for the experiments. The data are acquired by using KINECT and MATLAB. The number of acquired points is 138,183. Each position value of XYZ coordinate is 32 bits float precision, and RGB color is 8 bits integer. The contents shown in Figure 1 are parts of the data. The image of the acquired point cloud is shown in Figure 2.

We converted the XYZ position data to "pseudo-YUV" via "pseudo-RGB," and converted the RGB data to "genuine-YUV." Then we arranged the "genuine-YUV" and "pseudo-YUV" data as two-dimensional

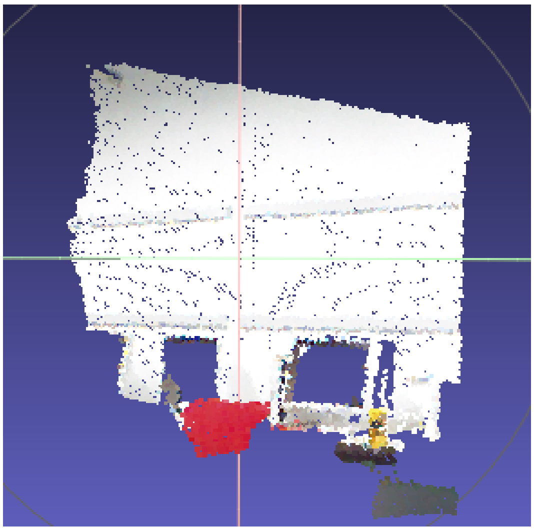

Figure 4 Point cloud after conversion

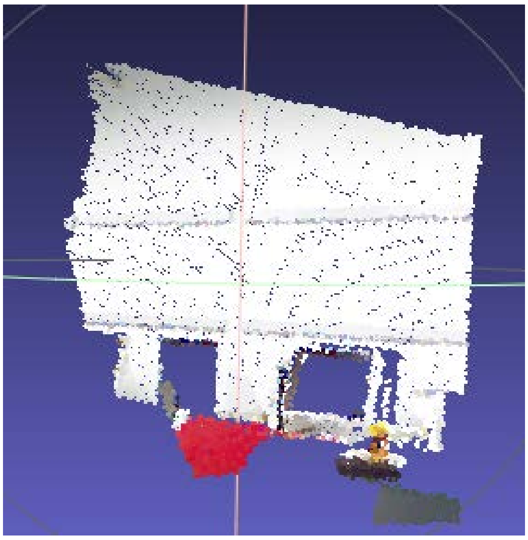

Figure 5 Point cloud after compression

Table 1 PSNR of each coordinate

	X	Y	Z
PSNR	44.89162	42.35487	50.8976

Table 2 Data sizes of original and ompressed images

	Data size (Byte)
Original data	2,072,745
Compressed data	204,509

picture having VGA resolution (640x480 pixels). Figure 3 shows the target picture for compression.

Because the precision of YUV data is 8 bits whereas the precision of XYZ data is 32 bits, a quantization error occurs in the process of the conversion. The point cloud after converting to "pseudo-YUV" and inversely converting to XYZ is shown in Figure 4. This figure indicates that some positions slip off by the quantization error. Table 1 shows PSNRs by the error.

We compressed the target picture consisting of "pseudo-YUV" and "genuine-YUV" data by using HM (HEVC Test Model) [5] which is the formal software encoder of H.265/HEVC. Quantization parameter of it was set to 0. Table 2 shows sizes of the original point cloud data and compressed data. This table indicates that the compression of the picture produced by the proposed translating and sorting method reduces data size in about 1/10. However, more quantization error occurs as shown in Figure 5 which shows the reconstructed point cloud after compression.

4. CONCLUSIONS

In this paper, we proposed a translating and sorting method of point cloud data to compress by using H.265/HEVC. The combination of the proposed method and H.265/HEVC reduces point cloud data size in about 1/10. However, quantization error which occurs in the process of the data translation brings the position gaps of the coordinate points. It would be necessary to study methods to solve the problem.

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