RDO-based joint bit allocation for MPEG G-PCC

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Abstract

In this paper, a rate-distortion optimization (RDO) model is proposed to find the joint bit allocation of geometry data and color data based on geometry-based point cloud compression (G-PCC) of Moving Picture Experts Group (MPEG). The mechanism of the method is to construct the RD models for geometry and color data through the training process. Afterward, two rate-distortion (RD) models are integrated as well as the decision of the parameter λ to obtain the final RDO model. The experimental results show that the proposed method can decrease 20% of the geometry Bjøntegaard delta bit rate and increase 37% of the color Bjøntegaard delta bit rate compared to the MPEG G-PCC TMC13v12.0 software.

1. Introduction

With the development of 3D acquisition technology, point cloud as an important type of 3D data description is widely used in many fields such as 3D modeling, virtual reality, augmented reality, and artificial intelligence. However, a 3D object represented by a 3D point cloud usually contains more than millions of points such as the point cloud dataset with more than 3 billion points used in researching deep learning algorithms [1]. Therefore, effectively compressing the enormous amount of point cloud data for storage, transmitting and processing has become a focus of point cloud research.

In point cloud compression (PCC) research, Moving Picture Experts Group (MPEG) has made significant progress on PCC standardization. The experts in MEPG developed two coding solutions for compressing different types of point cloud data. One is video-based point cloud compression (V-PCC) for solving dynamic point cloud compression. The other is geometry-based point cloud compression (G-PCC), which is mainly applied to compress the static or dynamic point cloud data. Thus far, standardization activities of MPEG PCC have been focused primarily on improving compression efficiency based on V-PCC and G-PCC. The reserach on the joint bit allocation of geometry bits size and color bits size needs to be studied to consolidate the compression efficiency.

Rate distortion optimization (RDO) is widely used to find the best compromise between quality and encoded bit sizes for reconstructing an image/video. However, the existing coding scheme of the RDO method cannot be used directly in MPEG PCC due to the unknown relationship between geometry and color coding. The encoded sizes of geometry and color bits in G-PCC are controlled by their quantization parameters (QP) respectively. And the reconstructed quality of point clouds depends on the compressed bit allocation of encoded geometry and color data, while the encoded size of target bits is predefined. One solution to obtain the best combination of the QP values for geometry and color data is to encode point clouds based on all QP combinations then compare the results, while it consumes too much time. Therefore, it is necessary to find an efficient solution for G-PCC such as rate-distortion optimization (RDO) method to obtain the joint bit allocation of geometry bits and color bits.

There are some contributions related to RDO of MPEG PCC so far. Liu et al. [2] put forward to tackle the joint bit allocation problem of geometry and color based on the rate and distortion models for V-PCC. Hur et al. [3] proposed a method to select the best predictor to optimize attribute coding through the rate-distortion optimization proceeding. A rate-distortion optimization of the quantization encoding method has been developed to quantize the values of the RAHT transformed coefficients to improve the compression efficiency of G-PCC [4]. There is no research on the joint bit allocation between geometry and color based on RDO for G-PCC so far.

This paper proposes an RDO model to achieve the best tradeoff between the reconstructed quality and the size of encoded bits for G-PCC based on the predefined total bits. We encode the training datasets based on most of the combinations of the QP values. By observing the training results, we find that the QP values and the bits of per point have a linear relationship for geometry and color data. Then, the rate distortion (RD) models are constructed for geometry and color data respectively. Furthermore, the proposed RDO model is obtained by integrating two RD models and defining a parameter λ to control the distribution of geometry and color bits in the total bits.

The remainder of this paper is organized as follows. Section 2 describes the proposed RDO-based joint bit allocation method. The experimental results are presented and discussed in Section 3, and the paper is concluded in Section 4.

2. Proposal

A RDO model for G-PCC is proposed to achieve the best tradeoff between the reconstructed quality and the size of encoded bits. And the overall proposed method is shown in Figure 1[5].

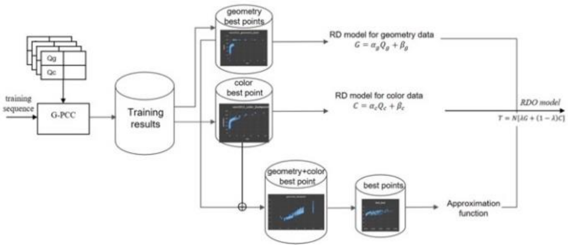


Figure 1. Proposed method

Since the size of geometry and color bits are determined by their parameters, we encode the training datasets by adjusting the geometry quantization parameter (Q_g) and color quantization parameter (Q_c) with an octree-prelift configuration and obtain the training results. We find a linear relationship between the bits per point and geometry/color quantization parameter by observing the training results, as shown in Fig. 2 and Fig. 3. Therefore, the RD models for geometry and color data are constructed respectively, which are defined as Eq. (1) and Eq. (2).

$$T/N = G = \alpha_g Q_g + \beta_g \quad (1)$$

$$T/N = C = \alpha_c Q_c + \beta_c \quad (2)$$

where T is the total number of bits and N is the total number of points in the original point cloud. α_g is the coefficient of Q_g, and β_g is the constant of Q_g. And the α_c is the coefficient of Q_c, and β_c is the constant of Q_c.

After that, some training results are selected based on the reconstruction quality to define a similarity function to determine the value of λ. Moreover, the RDO model is obtained by integrating the geometry RD model (Eq.1) and the color RD model (Eq.2) as defined as Eq. (3)[5][6].

$$T = N[\lambda(\alpha_g Q_g + \beta_g) + (1-\lambda)(\alpha_c Q_c + \beta_c)] \quad (3)$$

And λ is a weight factor, which can adjust the allocation of the geometry and color bits from the total bits according to T.

3. Experimental Result

The efficiency of the proposed RDO model is evaluated in this Section. As shown in Table 1, the point cloud data used in MPEG PCC are selected as our training datasets and test datasets [7]. And the MPEG G-PCC codec (version 12.0) [8] is used to investigate the performance of the proposed method.

Table 1. Training datasets and test datasets

	Type	Test material dataset filename	Input points	Geometry Precision
Training data	vox10/11	redandblack_vox10_1550	757,691	10bit
		basketball_player_vox11_00000200	2,925,514	11bit
		dancer_vox11_00000001	2,592,758	11bit
		head_00039_vox12	13,903,516	12bit

	vox12	soldier_viewdep_vox12	4,001,754	12bit
		loot_viewdep_vox12	3,017,285	12bit
	vox13/14	ulb_unicorn_vox13	1,995,189	13bit
		facade_00015_vox14	8,907,880	14bit
		landscape_00014_vox14	71,948,094	14bit
Test data	vox10/11	loot_vox10_1200	805,285	10bit
		facade_00064_vox11	4,061,755	11bit
	vox12	frog_00067_vox12	3,614,251	12bit
	vox13/14	facade_00064_vox14	19,702,134	14bit
		palazzo_carignano_dense_vox14	4,187,594	14bit

To verify the performance of the proposed RDO model, we estimate Q_g and Q_c by using the proposed RDO model and decide the parameter of λ according to the sizes of compressed bits obtained from the G-PCC codec under the common test conditions (CTC) as shown in Table 2. Different 3D point cloud data can have different geometry precision, as shown in Table 1. Fig. 2 shows the relationship between Q_g and T/N for different geometry precision. The larger geometry precision, the faster the value of T/N when the value of Q_g increased. Meanwhile, it can be obviously identified that Q_c is also changed based on Eq. 3. Therefore, three different types (vox10/11, vox12, vox13/14) are defined to obtain Q_g and Q_c according to the geometry precision of the 3D point cloud data.

Table 2. Estimated results

Type	Estimated Function	λ
vox10/11	T/N=λ(1.041*Qg-0.1273)+(1-λ) (-0.0226*Qc+1.065)	0.68
vox12	T/N =λ(4.434*Qg-0.1187)+(1-λ) (-0.05482*Qc+2.583)	0.69
vox13/14	T/N =λ(10.26*Qg-0.2332)+(1-λ) (-0.2423*Qc+11.13)	0.39

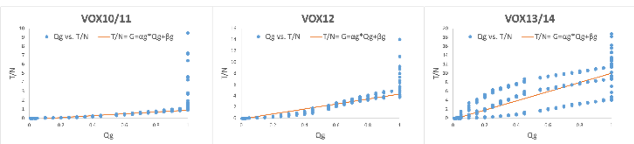
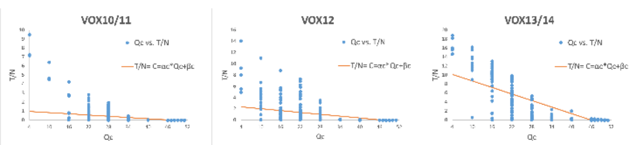


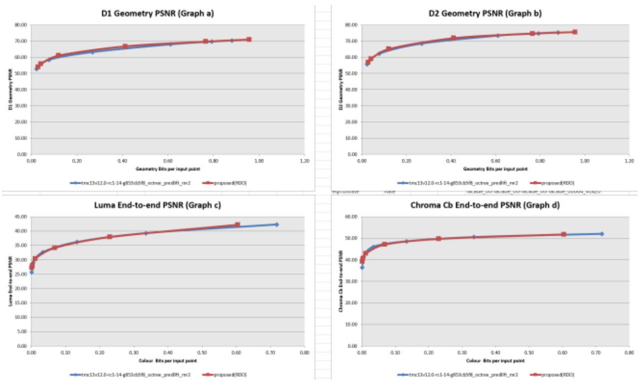
Figure 2. Illustration of the relationship between $\boldsymbol{Q_g}$ and $\boldsymbol{G}$



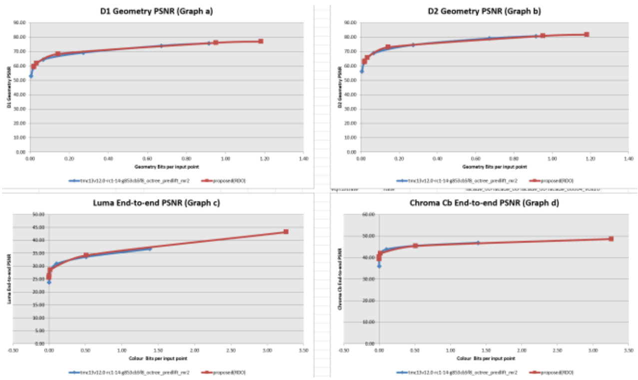
(a) training data with 12 geometry precision

Figure 3. Illustration of the relationship between $\boldsymbol{Q_c}$ and $\boldsymbol{C}$

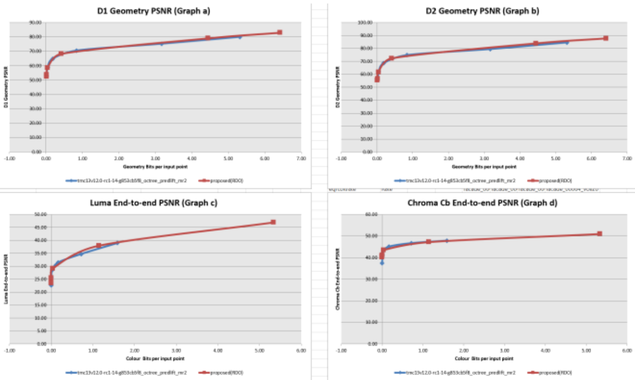
Fig. 4 shows the RD curves with p2pointRSNR (D1) and p2planePSNR (D2) geometry performances and lumaPSNR and ChromaCbPSNR color performances of the proposed method compared with G-PCC under lossy geometry and lossy attributes (C2) of CTC. The results show the RD performance of the proposed method is close to that of G-PCC on CTC. As shown in Fig. 4(a)-4(c) and Fig. 4(e), the RD performance obtained by using the proposed RDO model is higher than that of using the CTC test condition. Nevertheless, in Fig. 4(d), a significant difference has been observed from the facade_00064_vox14 results. The reason is that many input points in the test data shown in Table 1 result in small changes of the RD curve for each point. The proposed RDO model is very efficient in finding geometry and color joint bit allocation while maintaining the RD performance according to the above analysis.



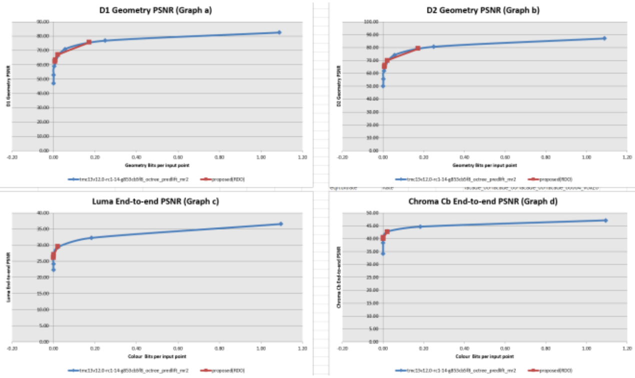
(a) loot_vox10_1200



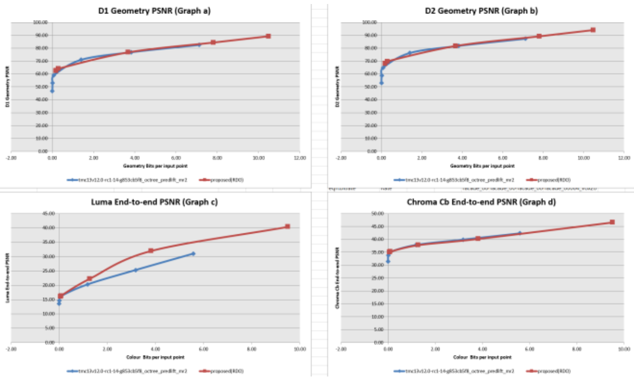
(b) facade_00064_vox11



(c) frog_00067_vox12



(d) facade_00064_vox14



(e) palazzo_carignano_dense_vox14

Figure 4. RD performance comparison

4. Conclusion

In this paper, we proposed a joint bit allocation method for MPEG G-PCC based on rate-distortion optimization. The proposed RDO model combining geometry and color RD models, and the value of λ is obtained for determining the proportional distribution of geometry bits size and colors bit size. The experimental results show that the proposed RDO model has close performance compared with the anchor results given in CTC. In addition, we will continue to investigate the RDO model to achieve the value of λ more efficiently.

Acknowledgment

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