Depth Generation using Structured Depth Templates

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Keywords: Depth Map, Stereoscopic, Structured Depth Template.

Abstract: We propose a new stereoscopic image / video conversion algorithm by using a two-directional structured depth model matching method. This work is aimed at providing an effect depth map to a 2D scene. By analyzing structure features of the inputting image frame, a kind of depth model called structured depth model is estimated to be as an initial depth map. Then the final depth map can be obtained by a depth post processing. Subjective evaluation is performed by comparing original depth maps generated manually and generated from the proposed method.

1 INTRODUCTION

Since 3D stereoscopic images provide higher realistic viewing experience than conventional monoscopic images, 3D stereoscopic technology and display system (i.e. 3D-TV) are nowadays often seen as the next major milestone in the ultimate visual experience of media (Harman, 2000). An important part in any 3D system is the 3D content generation. However, the traditional capture techniques with a single camera leads that the tremendous amount of current and past media data is in 2D format but in lack of 3D video content. To evade this situation, 2D to 3D conversion technology is used to convert a monoscopic image or video movie to a stereoscopic image or video movie.

A necessary step of 2D to 3D conversion processing is depth map generation, which recovers the depth information by analyzing and processing the 2D image. Some of conversion methods are using image classification (Battiato et al., 2004), vanishing line (Cheng et al., 2009), motion estimation (Moustakas, 2005; Kim et al., 2007). In one side, these methods are difficult to be processed in real time because of higher complexity and more memory needs. In another hand, some of them are just suited to special scenes, like object motion scenes or outside scene with vanishing line. So these methods have some limitations to general applications, like 3D home TV or broadcasting with various scenes.

In view of the foregoing, the intent of this paper is to impart a new depth map generation algorithm by using a two-directional structured depth template matching approach (SDTM). In the proposed method, a kind of initial component, named structured depth template (SDT), is defined. Two SDTs for horizontal and vertical directions are estimated respectively by analyzing structure features of the inputting scene. Then the final accurate depth map can be obtained by a depth post processing. The SDTM method may be applied in a real-time software or hardware system because of the lower complexity and higher performance.

2 DEPTH MAP GENERATION BY SDTM

2.1 Main Architecture

The main architecture operates on an embodiment described below with reference to figure 1. The whole processing consists of several constitutive modules

At image preprocessing stage, the noise reduction, gray conversion and resolution reduction processing will be done, which can enhance accuracy of depth estimation and also reduce the computational complexity.

From template change detection to depth map post processing stages, a depth map matching the inputting scene will be estimated and generated. The details of these stages will be described later.

Finally, the stereoscopic image pairs are generated by using computed depth map and the original video (Kim et al., 2007).

Zhang, L.
Depth Generation using Structured Depth Templates.
DOI: 10.5220/0007916903260330
In *Proceedings of the 16th International Joint Conference on e-Business and Telecommunications (ICETE 2019) - Volume 1: DCNET, ICE-B, OPTICS, SIGMAP and WINSYS*, pages 326-330
ISBN: 978-989-758-378-0

2.2 SDT Designation

Before describing details, a plurality of depth structures called SDT are designed, which can describe characteristics of a 2D scene in 2 dimensions as shown in figure 2. There includes V0-V4 for vertical direction and H0-H4 for horizontal direction. The darker color denotes smaller depth, and the brighter color denotes bigger depth. According to the characteristics of structure, each independent SDT or combination of several SDT can describe any scene.

To any SDT, depth value SDT(x,y) of position (x,y) is a mapping of position p(x,y), direction and type, which can be describes as follows.

$$SDT(x,y) = F(p(x,y), direction, type) \quad (1)$$

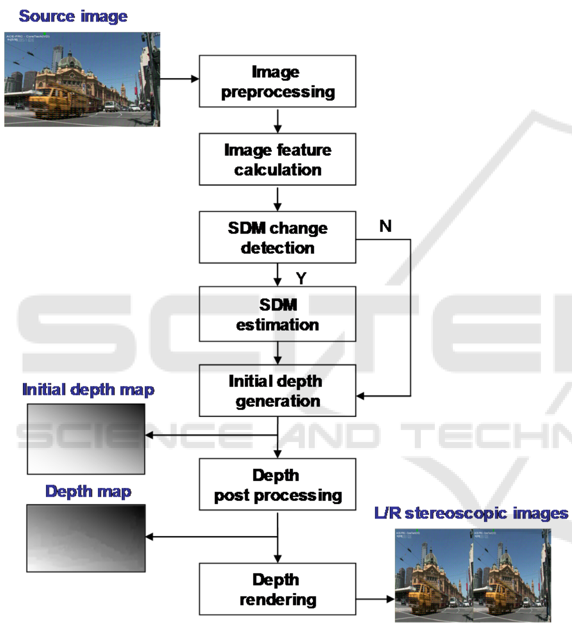


Figure 1: SDTM's architecture.

where direction means one of two directions, including horizontal, vertical directions. Type means one of 5 SDTs as shown in figure 2. The definition domain of the mapping function F(p(x,y), direction, type) is from MinDepth to MaxDepth, where MinDepth and MaxDepth are the minimum and maximum values of the expectable depth. In general, they are 0 and 255.

The equation 2 describes an example of the mathematic relationship for V2.

$$V2: \begin{cases} SDT_V(x,y) = \dfrac{2*y}{M}, top-half \\ SDT_V(x,y) = \dfrac{2*(M-y-1)}{M}, bottom-half \end{cases} \quad (2)$$

where M is height of the image. The structure of V2 is shown in figure 3. Based on the same way, each SDT can be easily calculated when it is required. They don't need to be stored in memory.

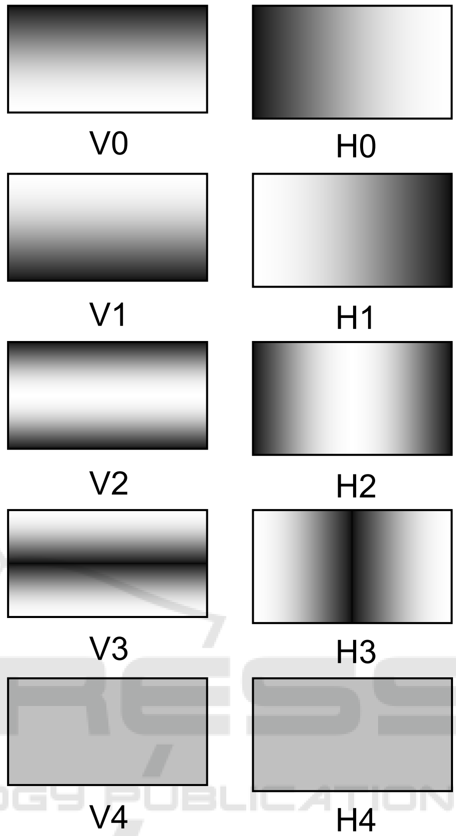


Figure 2: Structured depth models for horizontal and vertical directions.

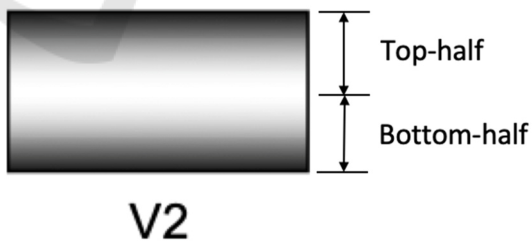


Figure 3: Structure of V2 template.

2.3 Image Feature Calculation

Figure 4 shows a block diagram for describing image feature calculation. It comprises a frame blocking processing which selects 6 blocks regions from the inputting image. The size of L (left), C (center) and R (right) blocks in horizontal direction is W_B*H and the size of T (top), C (center) and B (bottom) blocks in vertical direction is W*H_B

$$W_B = a * W$$
$$H_B = b * H \quad (3)$$

where W and H mean width and height of the target image H.

Then for each block, three feature parameters will be calculated, which include high frequency component (HF), mean value (MV) and histogram vales (HV). HF is the sum of edge pixels' values, which can be obtained from edge detection. MV is the average value of all pixels inside of a block. HV is a matrix of histogram values from 0 to 255, which describes distribution of pixel values of a block.

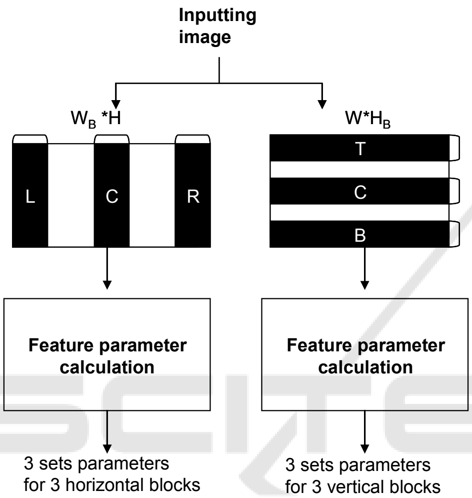


Figure 4: Image feature calculation.

2.4 SDT Estimation

Firstly, the feature value need to calculated, which is the weighted average of HF and MV by a following equation

$$FV_j = k \cdot HF_j + (1-k) \cdot MV_j \quad (4)$$

where j is one of the three block. FV is corresponding feature value. And k is weight, which can be set adaptively according to different frames.

Secondly, the feature value should be regularized through comparing three FVs. We use two symbols "0" and "1" to indicate minimum and maximum value respectively.

Thirdly a SDT could be decided. Figure 5 shows an example of vertical SDT decision based on the values of 3 parts. The horizontal SDT decision is same to this.

Based on the method mentioned above, the SDT can be estimated for each received frame independently. However, to an video sequence, SDT estimation is sensitive to camera parameters change or environment noise. The similar scenes of successive frames maybe have different SDT. As result, the flicker will be shown which makes users uncomfortable. In order to avoid this problem, a SDT changing detection is used. This is a kind of local scene change detection, which is not only to enhance the stability but also to keep the flexibility.

To each block, HF, MV and HV in current frame and previous frame are compared to decide whether the scene inside this block is changed or not, i.e. a new object appearing or the old objects disappearing. If the scenes in several blocks are changed, SDT should be estimated for current frame. Otherwise, the SDTs of current frame are same to them of previous frame.

The initial depth map is generated by composing 2 SDTs estimated. The equation is as follows

$$z(x,y) = w \cdot SDT_H(x,y) + (1-w) \cdot SDT_V(x,y) \quad (5)$$

where z(x,y) is initial depth value of (x,y) point. w is weight for SDT of horizontal direction.

The initial depth map is just showing basic depth structure that is not enough to describe the image accurately. So a depth post processing will be used.

As we know, generally if the neighborhood pixels have similar color or luminance, they belong to a same object area. So we should set same depth value to them. Based on this theory, a local bilateral filtering is presented.

Separating the inputting image and corresponding initial depth map into several sub-blocks. The size of each is m*n.

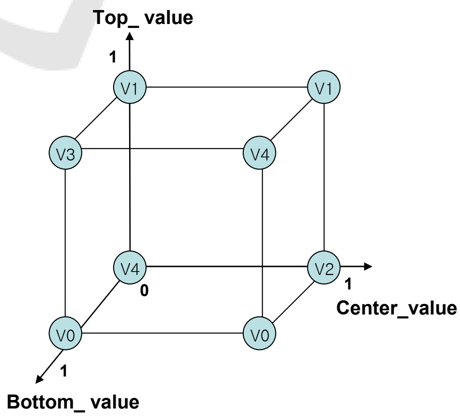


Figure 5: SDT decision rules.

In each sub-block, the bilateral filtering (Tomasi et al., 1998) is used. The depth values in the initial depth map will be reset based on the similarity of pixel values (color or luminance) in the source image. Figure 6 shows a diagram;

Using median filtering to process the whole depth map.

By those steps mentioned above, the final depth amp can be obtained. Comparing to the initial depth map, the final depth map matches objects accurately, which can enhance the 3D feeling

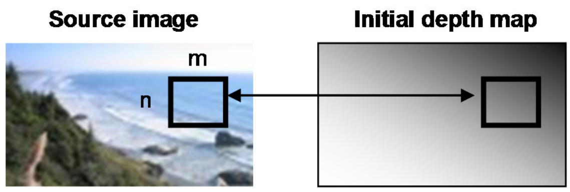
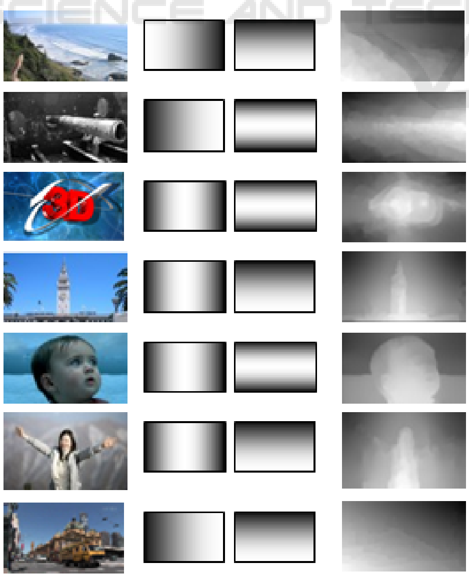


Figure 6: Depth map post processing by local bilateral filtering.

3 EXPERIMENT RESULTS

We used a PC with a 40-inch stereoscopic display device. In order to evaluate the proposed algorithm, various images and video sequences with 1280x720 and 1920x1080 resolution were used, including natural scenes, computer graph scenes, animation scenes and so on. The weight k for FV calculation is set to 0.9. The weight w for two SDTs composition is set to 0.5.



(1) (2) (3)

Figure 7: Simulation results. (1)~(3) shows inputting image, two-directional SDTs and final depth map respectively.

Figure 7 shows results of depth maps for 7 test images. In this figure, the first column shows original 2D images. The central two columns show corresponding SDTs of two directions. And the last column shows the final depth maps after depth post processing.

The simulation results indicate the proposed method has good performance. It describes the structure information of each 2D image fully and correctly. So it makes the final depth map reasonable to the real scene.

Finally, through comparing ground-true depth maps and the estimated depth maps generated by two-directional SDTM, subjective evaluation can be done. As shown in figure8, the depth ordering and structures in the estimated depth maps are similar to them in the original depth maps, which indicate validity of two-directional SDTM.

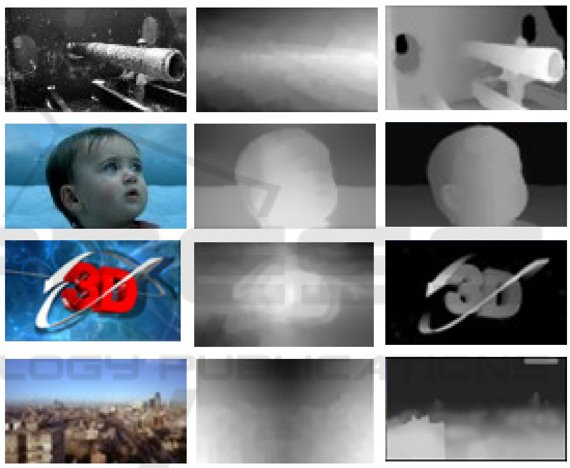


Figure 8: Subjective evaluation by comparing original depth maps genrated manully and generated from two-directional SDTM.

4 CONCLUSION

In this paper, we developed a new scheme to automatically achieve 2D to 3D converting. The proposed method describes the structure feature of the inputting 2D image by estimating SDTs in two directions. Then based on SDTs, it achieves reasonable depth maps which can be verified by the experimental results. Future works should focus on improving the performance of the method, such as adding SDTs in diagonally direction. At the same time, the proposed method should be combined with the other depth cues in order to determining the depth map for more complicated scenes.

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