Harmonization Algorithm to generate Stereoscopic VR Image

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요 약

In this letter, we propose a novel approach for stitching stereoscopic panoramas. When stitching stereoscopic panoramas, the amount of depth retrieved is the most important factor to pay attention for. Also, it is very crucial to deliver the two left and right panoramas with the right depth information to deliver good 3D perception. However, when stitching the two panoramas independently using the state-of-the-art algorithms and methods, we do still have some inconsistencies with the disparity map retrieved from the panoramas. To overcome this problem, we propose a method that modifies the latest conventional algorithm by making the two panoramas dependent of one another. This brings two panoramas with a much more consistent disparity map that lets users fully immerse into a comfortable stereoscopic vision.

1. Introduction[1]

It has been a long time that image stitching has been a widely discussed and developed research area in computer vision. In 2007, when the advanced in-depth 360 image stitching was introduced [1], [2], the major problems such as misalignments were fixed. Also, it performed as a base for many other improvements in this field. Today, there are many the state-of-the-art tools that can handle many problems such as parallax/ghosting while generating 360 panoramas. Although all these tools are good when stitching monocular 360 panoramas, they all fail to produce 360 stereoscopic panoramas. Even though they provide two good quality panoramas, left and right sides, they fail to make them harmonized so reducing the convenience of experiencing stereoscopic vision. To produce stereoscopic panoramas, the conventional methods simply rely on making the two: left and right panoramas separately. It makes them independent and thus not harmonized. When the two side panoramas are stitched independently, it makes them prone to have inconsistencies such as vertical or horizontal disparities. To maintain good stereoscopy, the vertical disparity should be equal to 0 whereas the horizontal disparity must not overlay some threshold [3]. The main reason why conventional algorithms cause inconsistencies in stereoscopy is because the process is performed separately for each for left and right sides. Therefore, not considering the important relationship between the two panoramas. The more recent methods mainly concentrate on improving depth between the two panoramas by stitching the depth map separately like the panoramas [4], or they develop more adaptive warping methods [5], [6] so that the resultant panorama is visualized with fewer errors. Nonetheless, the proposed method tackles this challenge by improving the relationship matrices between the two panoramas to ensure the same disparity for better depth perception.

2. 360 Panorama Stitching

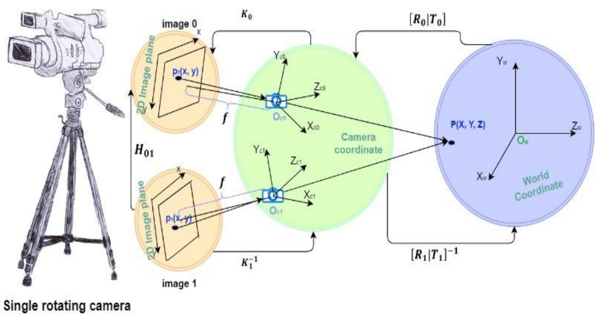

Fig. 1. Geometry of Image Stitching (based on single rotating camera)

The Geometry of Image stitching is comprised of four coordinate systems [7]: World coordinate system, Image coordinate system, Pixel coordinate system, Camera coordinate system. World coordinate system (X_w, Y_w, Z_w) describes the

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position of the camera and calibrates the location of feature points. Image coordinate system is the surface coordinate of the charge-coupled device sensor (camera's sensor). The pixel coordinate system holds u and v axis where u axis is parallel to x axis, while v axis is parallel to y axis. In other words, the pixel coordinate system is the image coordinate system in the computer. The last coordinate system, camera coordinate system is the origin of the camera's location and is regarded as (X_c, Y_c, Z_c) where Z_c axis is the optical axis of the camera and X_c and Y_c are parallel to the image plane. The connection of all these coordinate systems is done through converting each of them step by step.

3. Proposed Method

The proposed method recomputes the projection matrix,

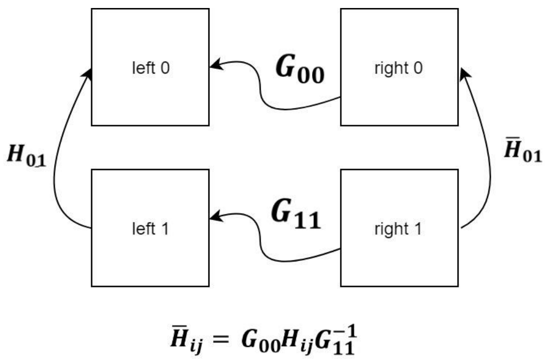

Fig. 2. The Calculation of Relationship Matrices between the first input images of left and right sides.

"Homography" matrix for the right-side panorama only using the first two input images from the left and right.

$$\bar{H}_{ij} = G_{00}H_{ij}G_{11}^{-1} \quad (1)$$

Where $\bar{H}_{ij}$ is the proposed right-side Homography matrix and H_{ij} is the conventional left-side Homography matrix. G_{00} and G_{11} are the relationship matrices obtained from the first two input images of both sides. And their equations are:

$$G_{00} = \bar{K}_0\bar{R}_0^{-1}R_0K_0^{-1} \quad (2)$$

$$G_{11} = \bar{K}_1\bar{R}_1^{-1}R_1K_1^{-1} \quad (3)$$

Where $\bar{K}$ and $\bar{R}$ are the intrinsic and extrinsic matrices of the first right-side input images whereas K and R are for the left-side input images. Overall, the application of (1) guarantees that proposed panorama will identical vertical and horizontal disparity relative to the left side panorama. Therefore, it ensures convenient depth perception.

4. Experiments and Results

Table 1. MSE Results

Image Sets		Right	Right(Proposed)
Set 1	MSE	3.09209	3.00735
Set 2	MSE	1.71658	1.71556
Set 3	MSE	2.41302	2.35376
Set 4	MSE	1.43036	1.40899
Set 5	MSE	2.21404	2.12338
Set 6	MSE	1.1379	1.1208

Table 1 shows the Mean Square Error (MSE) values for 6 different proposed panoramas against the original one Each panoramas used from 50 to 100 input images with a resolution of 4032x3024 pixels. As can be seen the proposed method provides much smaller errors.

Table 2. Number of Matches

Image Sets		Right	Right(Proposed)
Set 1	Matches	3,861	3,691
Set 2	Matches	7,444	7,518
Set 3	Matches	3,199	3,235
Set 4	Matches	1,300	1,283
Set 5	Matches	3,691	3,772
Set 6	Matches	5,609	5,783

Table 2 shows the number of matches for each sets, in which it can be noticed that generally the proposed method was capable of retaining more number of matches in the most cases.

5. Conclusion

This paper proposes a method that addresses two major problems, minimizing errors in image stitching and retrieving better and reliable depth for comfortable stereoscopic effects. It solves the problems by making new formula that calculates the right side Homography matrix using the already existing information gained from left side and the relations between the two panoramas. The experiments and results shows that it outperforms many conventional algorithms with indoors dataset and outperforms most of them with outdoors datasets. It yields that this algorithm is capable of producing good quality stereoscopic panoramas in both indoors and outdoors scenarios.

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