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An Interrupted Projection using Seam Carving for 360-degree Images

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Abstract

A projection method is proposed which can create an interrupted 360-degree images. This method is inspired by the Goode homolosine projection. The cutting curves are positioned manually in the Goode homolosine, however for general 360-degree images the cutting curves should be determined adaptively not to cross the important objects.

The positioning method of cutting curves is based on seam carving. We tested on some 360-degree images captured outside by Ricoh THETA S. In the experimental result, the distortion of the important objects was relatively small.

Introduction

Various types of omnidirectional camera systems have been developed recently. Some systems consist of two image sensors and two fish-eye lenses and they are placed in a camera housing. Others consist of more than two (typically six) image sensors and they are placed in a camera rig. In either type of systems, captured plural images are merged into a single 360-degree image. This process is called as stitching. Stitching process creates an image whose shape is a spherical surface.

As the shape of the stitched 360-degree images is not a rectangular but a spherical, such images requires a dedicated viewing software to be displayed. There are two types of 360-degree image viewer. One displays only a part of the 360-degree image. A user can move the field of view or zoom in and out in real time. Head mounted display VR system and 'YouTube' [1] are included in this type. The other displays the overall image at once. The displayed image is created from the spherical surface by projecting. 'Ricoh THETA' [2] viewer is one of the 360-degree viewer that can create the overall image.

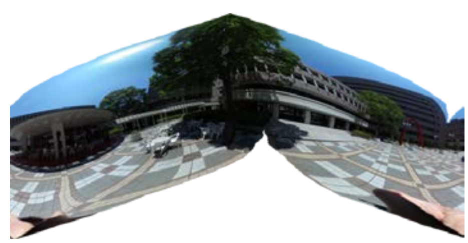
Figure 1 shows the overall images. (a) and (b) are created by Ricoh THETA viewer. Equirectangular projection is used for (a). Subjects in the middle area in a longitudinal direction of (a) is not almost distorted, however subjects in upper and lower ends are strongly enlarged and distorted. The area ratio between the middle and the ends is a lot different from 1. (b) is an example of 'Mirror-ball type'. The image shape is a circle. (c) is created with sinusoidal projection. The area ratio is accurate in any places, however subjects is left and right edges are strongly distorted.

In this paper, we present a new method of creating the overall projected image. The aim is to improve the accuracy of both the area ratio and the subjects' shape. The method is incorporated into world map projection methods especially the structure of Goode Homolosine projection, which makes an interrupted projection map. Cutting lines in Goode Homolosine projection are located in the oceans. In the proposed method, cutting lines are selected in less texture areas using seam carving algorithm. Seam carving is an image retargeting algorithm which can choose areas for elimination automatically [3]. A seam is defined as 8-connected path of pixels on an image from top to bottom. We use the seam as a cutting curve to switch from a projection surface to another.

(a) Equirectangular projection.

(b) Mirror-ball type.

(c) Sinusoidal projection.



(d) Proposed method.

Figure 1. Projected images with various methods.

Map Projection Methods

A world map is a projection of the earth's spherical surface. There are various types of projection [4]. Some methods are described below.

Sinusoidal Projection

Sinusoidal Projection is also known as Sanson–Flamsteed projection. Figure 2 (a) is a diagram of the sinusoidal projection map. 5 parallels and 13 meridians are shown in the map. The lands and oceans are not shown for ease of viewing. Parallels are placed evenly spaced apart. A meridian whose longitude is θ is drawn as a sinusoidal curve (x, y),

$$x = \theta \cos(y). \quad (1)$$

The area ratio between any two areas is accurate. The disadvantage is the fact that the shape in high latitude area is strongly distorted. This projection is very simple, but is not used much because of the distortion.

Mollweide Projection

Figure 2 (b) is a diagram of the Mollweide projection. Parallels are not placed evenly spaced apart. A parallel whose latitude is φ is drawn as a line,

$$y = \sqrt{2} \sin t\ , \quad (2)$$

where t satisfies the following formula.

$$\pi \sin \varphi = 2t + \sin(2t) \quad . \quad (3)$$

A meridian whose longitude is θ is drawn as a ellipse curve (x, y),

$$\frac{\pi^2 x^2}{8\theta^2} + \frac{y^2}{2} = 1\ . \quad (4)$$

The area ratio between any two areas is accurate. The shape in high latitude area is distorted. The distortion is not so strong as in the sinusoidal projection.

Goode Homolosine Projection

Goode homolosine projection map consists of 12 parts as shown in Figure 2 (c). The center vertical line differs for each part. The sinusoidal projection is used in low latitude area, and the Mollweide projection in high latitude area. The cutting lines between adjacent areas are located in the oceans. That reduces the distortion in the land areas. The area ratio between any two areas is accurate.

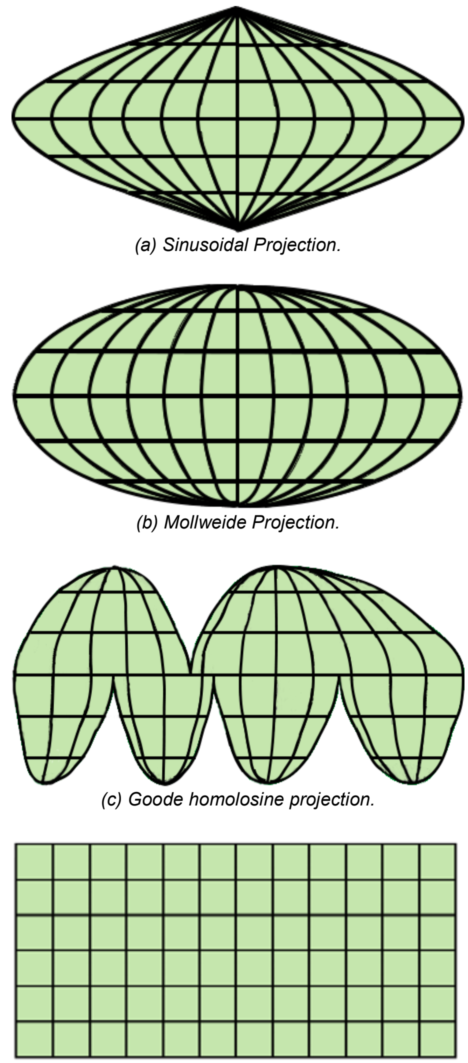
Equirectangular Projection

The map shape is a rectangular whose height is half the length of the width. All parallels and meridians are displayed as straight lines and placed evenly spaced apart, i.e. $x = \theta$, $y = \varphi$ at any point in the map. All points on the map are located at proportionately correct distances from the equatorial line. The disadvantage is the area ratio is not accurate because subjects in high latitude area are enlarged laterally.

Related Works

Visualization method for 360-degree image has been introduced depending on the application. In [5], a system which supports users to locate objects in the surrounding environment. Frontal, top-down, and bird's eye views are utilized in the system depending on the situation. In [6], a head-mount-displays system which can be used to interface for planet type view and feet interaction. The equirectangular, spherical, and stereoscopic projection are displayed for users to obtain a whole view of the environment.

As far as we searched, there has not been any research about the interrupted projection such as Goode homolosine projection method for 360-degree images.



(a) Sinusoidal Projection.

(b) Mollweide Projection.

(c) Goode homolosine projection.

(d) Equirectangular projection.

Figure 2. Schematic view of various world map projection methods. 5 parallels and 13 meridians are shown in the map. The lands and oceans are not shown for ease of viewing.

Proposed Approach

A described above, the shape distortion is small around the center meridian in the sinusoidal and Mollweide methods. Using this property, a method where a 360-degree image is cut in the region where the subjects have less distinct texture is proposed. The center meridian is set in the region where the subjects have distinct texture.

The overall procedure is shown in Figure 3. The input image is an equirectangular image $I(x,y)$, since it can be output by most stitching software. The input image firstly is divided into upper and lower. The subsequent processing is performed for both the upper and lower, independently.

Next, cutting curves are determined by selecting a path of pixels located in the area where texture is not strong. For the upper half image, the path starts from the top of image, and ends at the center

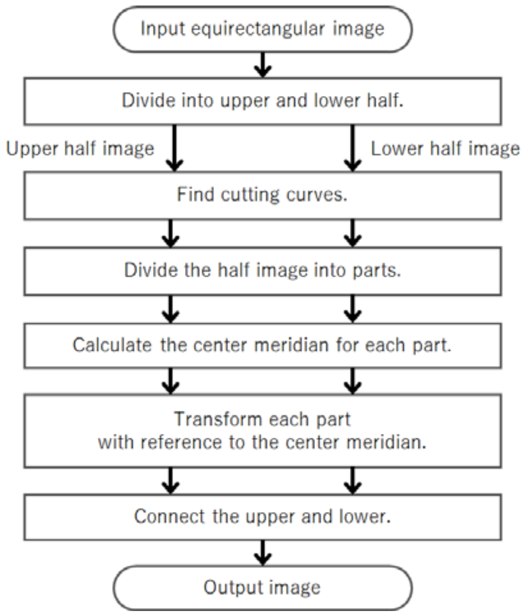


Figure 3. Overall procedure.

in the vertical direction. For the lower half image, the path starts from the bottom of image, and ends at the center in the vertical direction. The path selecting is achieved by seam carving algorithm. The energy function $E(x,y)$ is defined as the absolute sum of a horizontal central difference and a vertical central difference of the each RGB value, such as

$$E(x,y) = \sum_{c=\{R,G,B\}} \left(\left| \frac{\partial}{\partial x} I(x,y;c) \right| + \left| \frac{\partial}{\partial y} I(x,y;c) \right| \right). \qquad (5)$$

The predetermined number of cutting curves are obtained by repeating the seam carving.

Then, each half image is divided into parts bounded by two cutting curves. After that, the center meridian is calculated for each part. The center meridian is defined as a curve which is obtained by connecting the midpoint on each line between the left border and the right border.

In the next step, the image is transformed at each part. The point (x, y) is moved to (x', y) in accordance with the following formula,

$$x' = \begin{cases} x_c + (x - x_c)\cos\theta, & (x \geq x_c) \\ x_c - (x_c - x)\cos\theta, & (x < x_c) \end{cases}, \qquad (6)$$

$$\theta = \frac{\pi}{N}\left| y - \frac{N}{2} \right| , \qquad (7)$$

where x_c is the x coordinate of the center meridian at each line, and N is the image height of the input image. Finally, the transformed upper and lower half images are connected to obtain a whole image.

Experiments

We tested on the proposed method on some 360-degree images taken by Ricoh Theta S. The output images from the camera are equirectangular projected. The equirectangular images are shown in Figure 4 (a). The sinusoidal images by converting from (a) are shown in (b). Figure 4 (c), (d), (e) are made by the proposed method, and is divided into 2, 3, 4 parts, respectively.

The buildings of the left images are bending outside in (a), and bending inside in (b). In the left image of (e), buildings are straight. The cutting curves are mainly positioned in the sky regions without crossing buildings.

Conclusion

We proposed an interrupted projection using seam carving for 360-degree images. It can display a whole 360-degree image keeping real area ratio. By interruption, the distortion is smaller than the sinusoidal projection. The cutting curves are located in the less-texture area to avoid cutting an important object.

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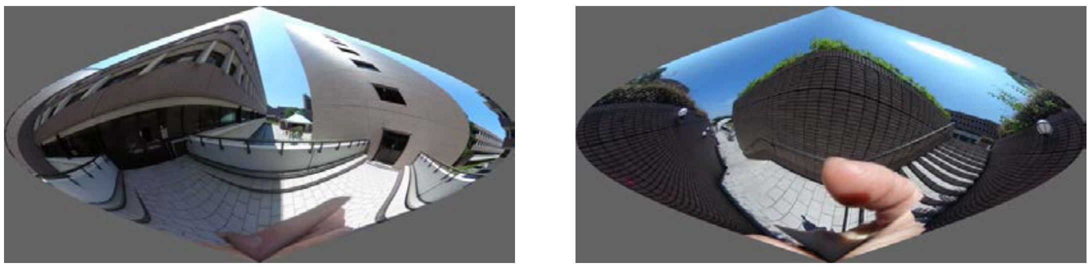
Author Biography

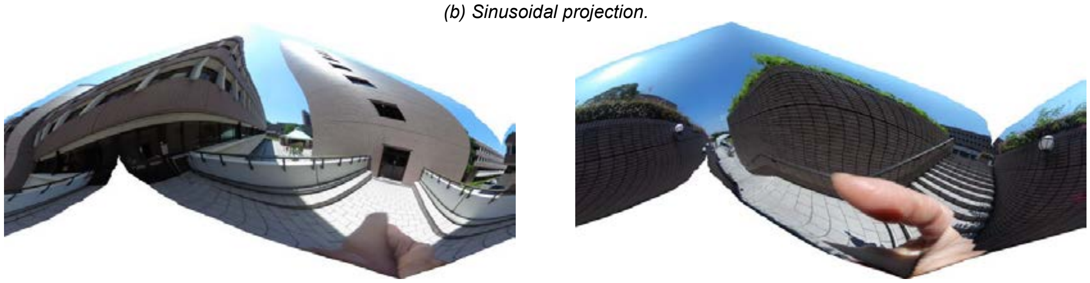
Ikuko Tsubaki received her BS from Tokyo Institute of Technology (1995) and her PhD from the University of Tokyo (2004). She has worked in Tokyo University of Technology since 2016. Her research interest is image processing and computer vision.

Kazuo Sasaki received MA in product design from the Chiba University (1983) Since then he started career in Japan Broadcasting co. as visual designer of TV program. Awarded as Best TV Designer from Japan Television Art Organization, in 1989 and 1998. From 2007, he started research project of Internet Broadcasting in Tokyo University of Technology. His work has focused on Interactive media, from Projection Mapping Contents to Nature Simulation Application on Smartphone.

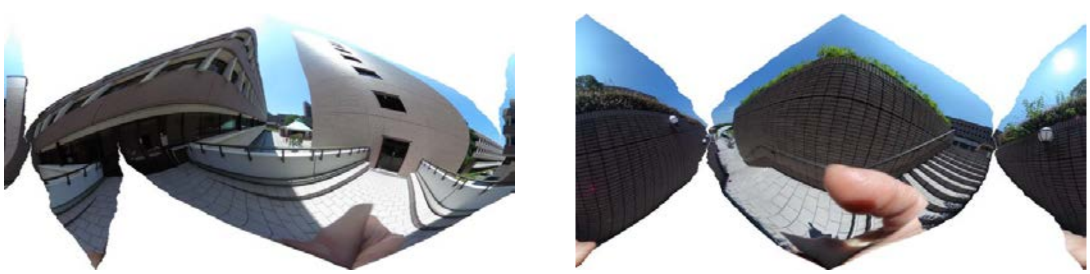
(a) Equirectangular projection.



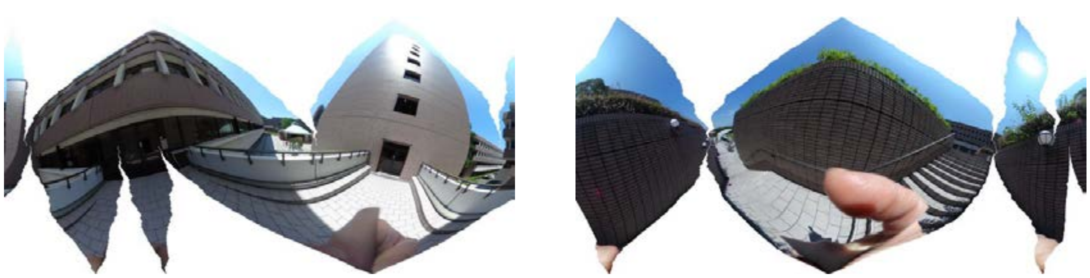
(b) Sinusoidal projection.



(c) Proposed method (dividing into 2 parts).



(d) Proposed method (dividing into 3 parts).



(e) Proposed method (dividing into 4 parts).

Figure 4. Experimental results.