3D Visualization of Aurora Considering the Physical Characteristics

Akira Takeuchi*, Hiromitsu Fujii*, Atsushi Yamashita*, Masayuki Tanaka†,
Ryuho Kataoka‡, Yoshizumi Miyoshi§, Masatoshi Okutomi†, Hajime Asama*
The University of Tokyo*, Tokyo Institute of Technology†, National Institute of Polar Research‡, Nagoya University§

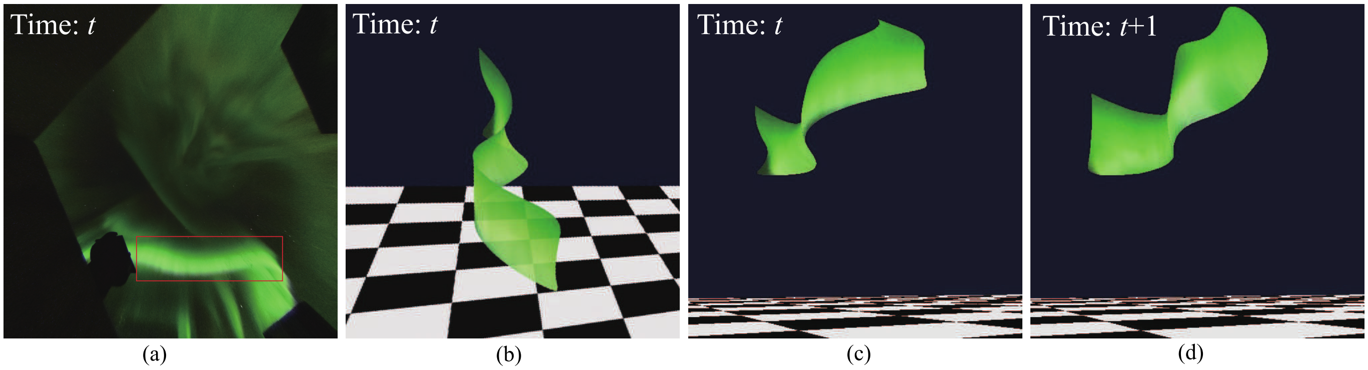

Figure 1: *Input image and 3D visualization results of the aurora. (a): Input image at time t and the region of the aurora which flows into the atmosphere along the direction of geomagnetic line (inside the red rectangle). (b), (c): The shape of the aurora at time t seen from (b) above and (c) bottom. (d): The shape of the aurora at time t+1 seen from bottom.*

Abstract

In this paper, we proposed a novel method to measure and visualize 3D shape of aurora accurately. The proposed method considers not only information of aurora images taken by stereo camera system but also constraints based on the mechanism and physical knowledge of aurora generation. The corresponding points between a pair of stereo images were detected for measurement by triangulation. At the corresponding point detection, detection accuracy was improved drastically by using the information of geomagnetism and altitude of aurora's lower end. Then the shape was visualized by fitting NURBS surface to the detected corresponding point. Figure 1 shows the visualization result. Applying this method, the 3D shape of aurora which didn't contradict the physical knowledge could be visualized.

Keywords: 3D measurement, corresponding point, aurora

Concepts: •**Computing methodologies** → **Reconstruction;** •**General and reference** → *Measurement;*

1 Introduction

Three-dimensional measurement and visualization of the aurora is significant because analyzing its shape and altitude accurately leads to explication of the mystery of the aurora which is not yet elucidated. For a sustainable measurement, our research group set two fish-eye cameras in Alaska, U.S.A, and reconstructed the aurora's shape from a pair of stereo images by image processing [Fujii *et al.* 2014] [Takeuchi *et al.* 2015]. However, the result of the method using only image information for the reconstruction is not necessarily correct physically because it is difficult to get enough information from the translucent aurora's images in which most parts are with low contrast and without texture. In this paper, we propose a novel method to reconstruct the aurora's shape from the images accurately by considering the physical knowledge of the aurora in addition to image information.

*e-mail:{takeuchi,fujii,yamashita,asama}@robot.t.u-tokyo.ac.jp

SA '16 Posters, December 05-08, 2016, Macao
ISBN: 978-1-4503-4540-8/16/12
DOI: http://dx.doi.org/10.1145/3005274.3005285

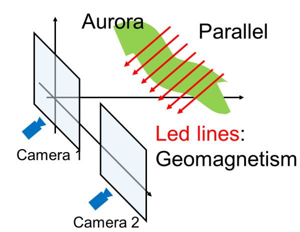

Figure 2: *Aurora along geomagnetism*

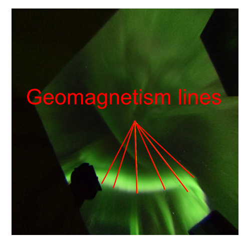

Figure 3: *Drawn geomagnetism line on image*

2 Approach

Aurora shapes are measured and visualized by triangulation. Two fish-eye cameras were installed at the distance of 8.1 km in Alaska to get the aurora's images. For triangulation, the corresponding points from the aurora region on a pair of the images are detected. When the corresponding points are detected, the constraints based on physical knowledge of the aurora are used to improve the accuracy of detection. The constraints are the information of geomagnetism and altitude of aurora's lower end.

2.1 Detection of corresponding points by using geomagnetism

It is known that aurora shape like a curtain depends on the direction and degree of the leaning of the geomagnetism. As Figure 2 shows,

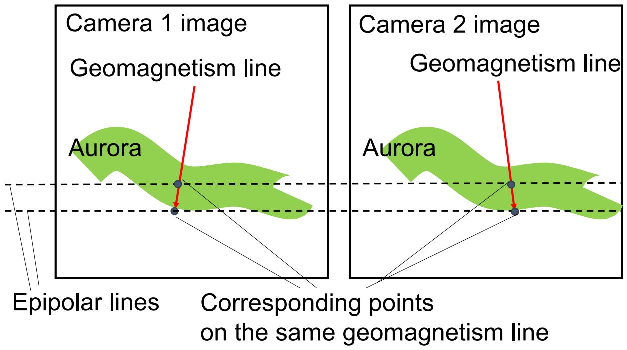

Figure 4: *Corresponding points detection by using geomagnetism line and epipolar line*

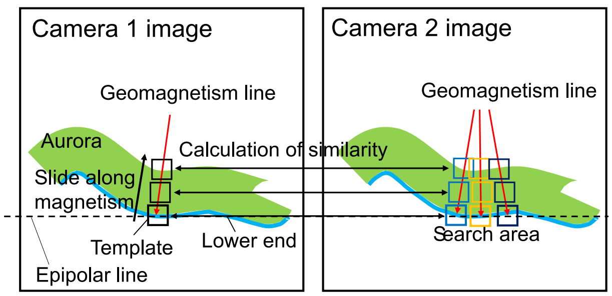

Figure 5: *The same geomagnetism line detection*

aurora generates along geomagnetism. Therefore in this method, first, the geomagnetism information is calculated by referring to GPS information (latitude and longitude of camera's setting point) and the physical geomagnetism model (international geomagnetic reference field model [Thébault *et al.* 2015]), and then the geomagnetism lines can be drawn in the aurora's images as Figure 3 shows. Second, the same geomagnetism line between a pair of images is detected because the corresponding points should be on the same geomagnetism line. As Figure 4 shows, corresponding points should be intersection points with same geomagnetism line and epipolar lines, and the principle can be satisfied by the geometrical constraint of the stereo and the mechanism of aurora generation. Thus identifying the same geomagnetism line between stereo images leads to detecting the corresponding points.

2.2 Identification of the same geomagnetism line between stereo images

The detection of the corresponding geomagnetism lines is performed by evaluating the similarity of the texture around the line. Figure 5 shows the proposed technique which detects the same geomagnetism line. The similarity of the texture is calculated by using block matching. However, the textures around the corresponding lines are in a relation of the projective transformation each other due to the disparity. Thus the transformation of the texture around the line is corrected before the similarity evaluation.

Template is extracted from aurora's lower end of camera 1 image, and areas on epipolar line of camera 2 image are extracted as evaluation area. As the lower end of the aurora is known to exist around an altitude of about 100 km, the evaluation area is extracted from the limited area of the camera 2 image by considering altitude of aurora's lower end. Template and evaluation area are slid along the geomagnetism line, and the similarities are calculated one by one. The pair of the lines of which the similarity sum is maximum should be corresponding line. By this method, the same geomagnetism lines are corresponded, and then the corresponding points on aurora's image are detected densely.

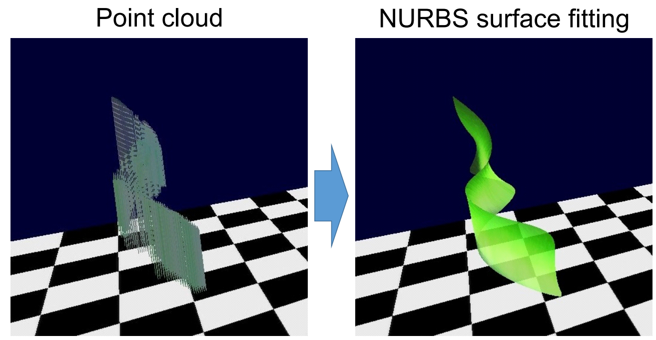

Figure 6: *Visualization of measured aurora's 3D shape*

2.3 Visualization

Finally, the 3D shape of the aurora is visualized by using the detected corresponding points. The 3D coordinates of all corresponding points are calculated by triangulation. Then all points are put on three-dimensional space, and NURBS surface is fitted to the point cloud. Color of surface refers to the color of the corresponding area in the image. The result of visualization is shown in Figure 6.

3 Result

Visualization results are shown in Figure 1. Figure 1-(a) shows the input aurora's image at time t and the aurora region. The visualized results at time t are shown in Figure 1-(b) and Figure 1-(c) from above and bottom respectively. The visualized result at time t+1 is shown in Figure 1-(d). From the results, it is confirmed that the reconstructed shape is like a curtain and moves smoothly with time progress.

4 Conclusion and Future Work

In this paper, a methodology for accurate 3D measurement and visualization of aurora which considers the physics was proposed. By using this method, the 3D shape of aurora reflecting its physical characteristics were visualized. To measure the shape of aurora more accurately, using the information of change of the color depending on the aurora's altitude is considered in future work.

References

FUJII, H., KUBO, T., YAMASHITA, A., TAKEUCHI, A., TANAKA, M., KATAOKA, R., MIYOSHI, Y., OKUTOMI, M., AND ASAMA, H. 2014. Aurora 3D-Measurement and Visualization Using Fish-Eye Stereo Camera. In *Proceedings of ACM SIGGRAPH Asia 2014 Posters*, Article No.24

TAKEUCHI, A., FUJII, H., YAMASHITA, A., TANAKA, M., KATAOKA, R., MIYOSHI, Y., OKUTOMI, M., AND ASAMA, H. 2015. 3D Visualization of Aurora from Optional Viewpoint at Optional Time. In *Proceedings of ACM SIGGRAPH Asia 2015 Posters*, Article No.9.

THÉBAULT, E. *et al.* 2015. International Geomagnetic Reference Field: the 12th generation. In *Earth, Planets and Space 2015*, 67:79.