Mini Review
Volume 11:12, 2022

Journal of Applied & Computational Mathematics

ISSN: 2168-9679

Open Access

Combining Theoretical Imaging and Computer Vision Canting Heliostats

Nick Cercone*

Department of Computer Science and Engineering, York University, Canada

Abstract

Solar Power Tower technology requires accurate techniques to ensure the optical performance of the heliostats both in commissioning and operation phases. This paper presents a technique based on target reflection to detect and correct canting errors in heliostat facets. A camera mounted on the back of a target heliostat sees an object heliostat and the target facets in reflection. The pixels difference between detected and theoretical borders determines the canting errors. Experiments in a lab scale testbed show that canting errors can be corrected up to an average value of around as low as 0.15 mrad. Experiments were also performed on a real heliostat at Plataforma Solar de Almería. As a result, canting errors (up to 5 mrad) have been reduced below 0.75 mrad. Mirror slope errors, which can be noticeable in large facets, becomes the largest source of inaccuracy in the presented method.

Keywords: Tower for solar power • Model of pinhole camera • Point of equilibrium

Introduction

Thousands of heliostats concentrate direct solar radiation onto a receiver in solar power tower plants (SPTP). Heliostats consist of an array of mirrors, called facets, slightly curved – focused – which must be appropriately oriented to concentrate sunlight in a receiver. The process of tilting each facet to aim at a single point is known as canting. Proper heliostat canting maximizes the annual power intercepted by the receiver. Off-axis canting at specific time instants seems to outperform on-axis canting (facets' normal vectors intersect at the target when sun, target and heliostat center are aligned). Uncanted heliostats result into distorted flux distributions with larger spot sizes, leading to increased spillage losses. According to Landman and Gauché, misaligned facets also increase astigmatic aberrations, which take place under defocus and high incidence angles.

The canting process must be performed both on heliostat field commissioning and throughout its lifetime to ensure an optimized operation of SPTP. In a recent report, issues related with the heliostat optical quality has been identified as one with the largest number of occurrences. Several methods for heliostat facet canting have been developed, which are classified into three groups on-sun, mechanical, and optical. In on-sun alignment, the sun-reflected beam shape on the target is utilized to adjust the misaligned facets while the heliostat is in track. This qualitative process is time-consuming and inaccurate. Mechanical canting methods use gauge blocks or inclinometers while the heliostat is in horizontal position. In these methods, commonly utilized in SPTP, the facets are manually adjusted to the pre-calculated angles in both axes, reaching canting errors below 1.5 mrad with careful measurements. However, these processes are labor intensive, tedious and imprecise because of gravity sag and local slope errors. In the optical category, seven methods can be identified: laser-based, backward gazing, flux map fitting, photogrammetry, deflectometry, camera look-back, and target reflection. In laser-based techniques, the heliostat facets reflect a collimated laser beam into the target. These techniques are very accurate but complex, they also require expensive equipment and are time-consuming [1].

***Address for Correspondence:** Nick Cercone, Department of Computer Science and Engineering, York University, Canada, E-mail: ncercone1@yorku.ca*

Received: 02 December 2022, Manuscript No. jacm-23-88355; **Editor assigned:** 05 December 2022, PreQC No. P-88355; **Reviewed:** 17 December 2022, QC No. Q-88355; **Revised:** 22 December 2022, Manuscript No. R-88355; **Published:** 29 December 2022, DOI: 10.37421/2168-9679.2022.11.508

Discussion

The sun's image is seen through the heliostat's reflection when using backward gazing. The local slope and canting errors are deduced using a mathematical method. A series of spot images of the target are compared to computer-generated distributions in the flux map fitting method. By comparing the simulated and real distributions, canting deviations can be measured. A series of images of the heliostat are used to infer the facets' shape, size, and orientation using photogrammetry techniques. Photogrammetry finds facets that are not aligned with the edges. The uncertainty revealed by the experiments is not sufficient to guarantee the optical quality of the heliostats. Accuracy can be improved with more cameras and target marks, but this comes at the expense of complexity. A camera is used in deflectometry to observe a fringe pattern that is reflected by the facets. After that, the surface normal at each point in the mirror is calculated, making this method applicable to both the characterization of canting and slope. The AIMFAST implementation reached precision below 0.25 mrad. This method is currently reliable in laboratory (or production line) environments rather than in situ due to the complex experimental setup [2].

To find canting errors, camera look-back methods use the camera's own reflection on the facets. The precision of the heliostat encoders is essential for this time-consuming method. The reflection of a known target on the heliostat facets is viewed using target reflection techniques. The difference in pixels between actual and theoretical images is used to calculate the specific canting errors. Sandia National Laboratories proposed two implementations based on the camera's position: The camera is mounted on a drone in UFACET, whereas it is mounted on the tower in HFACET. A nearby heliostat serves as the target in both cases. The SPTP tower, on the other hand, has recently been suggested as the target. In target reflection techniques, confidence in the camera's position is a crucial factor, according to a preliminary study. The target-reflected image shifts noticeably when there is a camera position uncertainty of 10 cm or more, making it difficult to compare actual and theoretical images. Uncertainty regarding a system's position may be a problem for unmanned aerial vehicles. On the other hand, in order to maintain a high image resolution, very large zoom lenses are required when the camera is positioned far from the object heliostat, such as atop the receiver tower [3-5].

Conclusion

The shortcomings listed above are addressed by the new implementation that is proposed in this work, which is based on the target reflection method. A neighbouring heliostat serves as the camera's target. The heliostat itself can be used as a reference to accurately measure the camera position in this manner. In addition, neither a lot of resources nor expensive equipment are required for the proposed method. The procedure can be completed by a single person and takes less time because camera attachment and computation are quick. The proposed method for detecting canting errors in heliostat facets is detailed in this paper. The method and its steps are explained in detail in Section 2. The manuscript contains extensive lab-scale and real-world heliostat experiments to evaluate the method's efficacy. The laboratory-scale testbed and accuracy results are presented in Section 3. Section 4 details the real-world SPTP's experimental campaign, Plataforma Solar de Almera. The challenges and conclusions are discussed in Section 5 of the manuscript

Acknowledgement

None.

Conflict of Interest

None.

References

1. Åkesson, Susanne, Jens Morin, Rachel Muheim, and Ulf Ottosson. "Dramatic orientation shift of white-crowned sparrows displaced across longitudes in the high arctic." *Current Biology* 15 (2005): 1591-1597.

2. Fleissner, Gerta, Elke Holtkamp-Rötzler, Marianne Hanzlik and Michael Winklhofer et al. "Ultrastructural analysis of a putative magnetoreceptor in the beak of homing pigeons." *J Compar Neurol* 458 (2003): 350-360.

3. Biskup, T., Schleicher, E., Okafuji, A., and Link, G., Hitomi et al (2009). Direct observation of a photoinduced radical pair in a cryptochrome blue-light photoreceptor. *Angew Chem Int Ed* 48, 404– 407.

4. Bonadonna, F., C. Bajzak, S. Benhamou, K. Igloi, P. Jouventin, H. P. Lipp, and G. Dell'Omo. "Orientation in the wandering albatross: Interfering with magnetic perception does not affect orientation performance." *Proc Royal Soc B: Biological Sciences* 272 (2005): 489-495.

5. Alerstam, Thomas. "Conflicting evidence about long-distance animal navigation." *Science* 313 (2006): 791-794.

How to cite this article: Cercone, Nick. “Combining Theoretical Imaging and Computer Vision Canting Heliostats.” J Appl Computat Math 11 (2022): 508