Solar World Congress 2025

NOVEL HELIOSTAT SHAPE CHARACTERIZATION METHODOLOGY USING A TERRESTIAL LASER SCANNER

Summary

Currently, the most used technique for mirror facet characterization in concentrated solar power technologies is deflectometry. Although, it needs to be performed during night-time and the target size in which the fringed pattern is exposed might be considerable. Due to these limitations, new facet characterization techniques need to be developed. Terrestrial laser scanning using a LiDAR scanner was developed and tested in this work. The possibility of acquiring 3D point clouds containing millions of data points regarding the heliostat facet allows to have a flexible and fast technique for shape assessment. Results were compared with previous deflectometry performed at the same heliostats, showing a relative error on the focal length up to 5%. Additionally, the root mean square error of the corresponding slope error matrices was calculated, with values between ranging between 1.03 and 1.79 mrads.

Keywords: CSP, Heliostat Characterization, Slope Error, Lidar

1. Introduction

Enhancement of concentrated solar thermal (CST) technology performance requires the consideration of not only the solar resource, but also other aspects, such as the quality of heliostat facets. The optical performance of CST plants depends, among other factors, on the optical quality of each individual concentrator, which is determined by their optical error. The latter is of key importance, since high optical errors can lead to suboptimal flux distribution changes on the receiver, while also increasing the spillage. The optical error englobes the convolution of specularity, slope and canting errors, although only the slope error will be addressed in this work. The latter characterizes the deviations of the concentrator curvature with respect to its ideal shape. A novel heliostat facet characterization methodology is presented here using a 3D terrestrial laser scanner (TLS). This methodology was developed and tested in a real solar field.

2. Methodology

Field measurements were conducted at Very-High Concentration Solar Tower (VHCST) facility at IMDEA Energy. Madrid (Spain) [1], where multiple scans were performed, see Fig. 1.

Fig. 1: a) IMDEA's solar field in operation; and b) Terrestrial laser scanner from FARO.

It is noticed that, the heliostats need at least a minimum soiling level for this technique to work. This method was preliminary tested in [2] showing promising results. After the scans were performed, the following pre-processing of the data was employed: the heliostat is identified and the background removed, see Fig. 2.

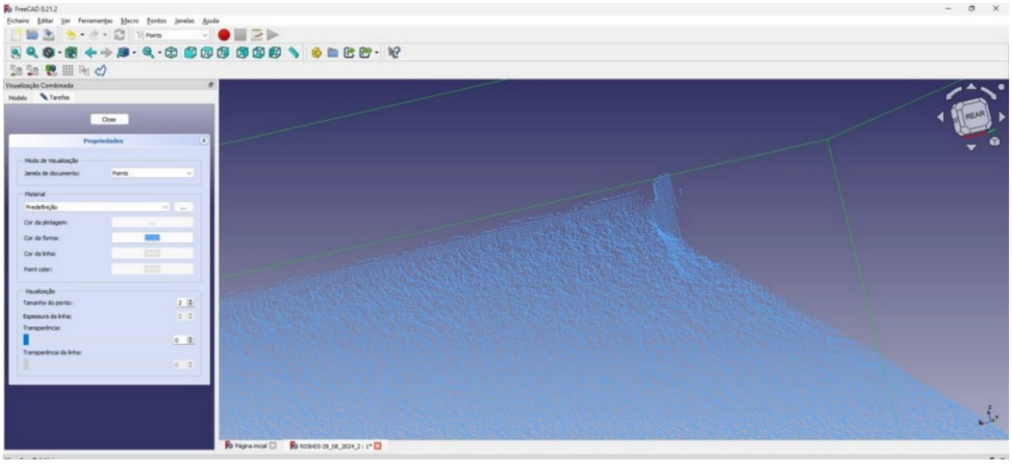

Fig. 2: Heliostat point cloud in which the metallic corners need to be removed as part of the pre-processing stage.

Then, the focal length, f, is calculated by fitting the point cloud with the noise removed to a sphere as follows in eq. 1:

$$f = \frac{\sqrt{(x-x_c)^2+(y-y_c)^2+(z-z_c)^2}}{2}, \qquad \text{(eq. 1)}$$

where x_c, y_c and z_c correspond to the sphere center coordinates. For mirror shape assessment, the generated point cloud was used to create meshes for actual mirror shapes. To calculate the slope error, aligning the scanned meshes with the ideal ones is required. The latter were obtained by designing two perfect spherical shells of 20 and 30 m of focal length (part of a 40 and 60 m of radius spheres). Afterwards, the optical axes of both are calculated. The corresponding rotation and translation are applied, so that the scanned facet's optical axis corresponds to the same of the perfect shape. To calculate the slope error matrices, the normal of each mesh element of the scanned shape was compared to the ideal one. This match was achieved by pairing the elements with the shortest Euclidian distance between their centers, as shown in Fig. 3.

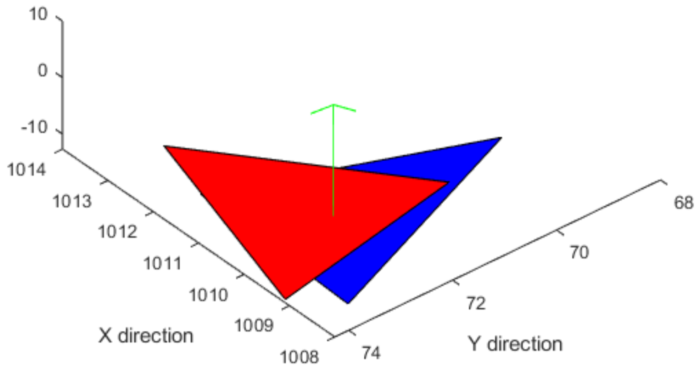

Fig. 3: One to one comparison of homologous triangle mesh elements from both TLS post-processed data and ideal shape.

3. Results and Discussion

Results regarding the focal length are shown in Tab. 1 for four heliostats, H05-05, H05-06, H06-06 and H06-07. The first two digits refer to the row where the heliostat is and the last two digits to the number of the heliostat within that row counting from the east. It is observed that the modulus of the relative error is always below 5%, which are very promising results. Regarding shape assessment, the post-processing englobes fitting the point cloud to a surface by a b-spline interpolation, already smoothing the original data that tends to be noisy. Then, the surface is meshed to have around 474 000 elements, matching the deflectometry resolution.

Tab. 1: Focal length of several heliostats obtained by deflectometry and TLS. The relative error considering deflectometry as the reference is also shown.

Heliostat ID.	Deflectometry (m)	TLS (m)	|Relative Error| (%)
H05-05	22.32	21.37	4.3
H05-06	22.02	21.01	4.6
H06-05	22.65	21.55	0.5
H06-06	21.46	20.69	3.6

Observe Fig. 4 in which it is included the slope error obtained with both deflectometry, TLS for the H05-06 and the ray tracing performed for a specific day (21 June 2024 at 14:00h).

Deflectometry **TLS**

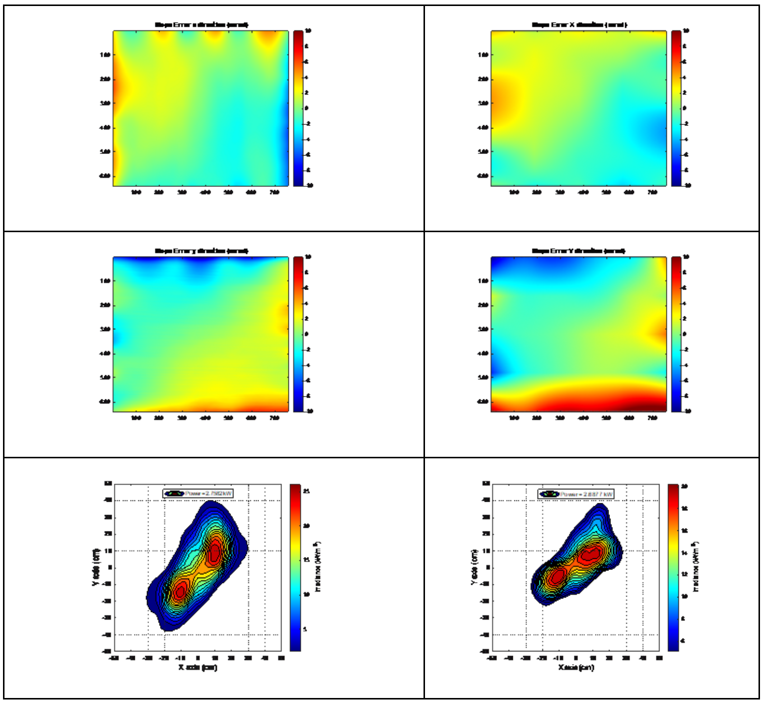

Fig. 4: One to one comparison of homologous triangle mesh elements from both TLS post-processed data and ideal.

The root mean square error between each set of matrices was: $RMSE_x = 1.03, RMSE_y = 1.79$. This shows how this method can be used for a reasonable shape assessment. It is remarked that enhancements can be done, since, for instance, the laser scanner can be performed with a higher resolution and closer to the desired heliostat to be scanned, resulting lower scan error.

4. Acknowledgements

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5. References

[1] M. Romero, J. González-Aguilar, and S. Luque, “Ultra-modular 500 m^2 heliostat field for high flux/high temperature solar-driven processes,” *AIP Conf. Proc.*, vol. 1850, no. June, 2017, doi: 10.1063/1.4984387.

[2] M. Ferreres Eceiza, M. Bitterling, T. Schmidt, W. Baltus, A. Perez, E. Guillot, and G. Bern, “Terrestrial Laser Scanning for Heliostat Surface Shape Determination and Canting Errors Correction,” *SolarPACES Conf. Proc.*, vol. 2, pp. 1–9, 2024, doi: 10.52825/solarpaces.v2i.950.