On the use of artificial neural networks for automatic heliostat aiming*

J.A. Carballo[1] [0000−0003−0529−5672], N.C. Cruz[2] [0000−0002−5839−9451], J. Bonilla[1] [0000−0002−2322−2867], J.D. Álvarez[3] [0000−0003−2791−8105], and M. Berenguel[3] [0000−0002−3349−7506]

[1] CIEMAT - Plataforma Solar de Almería (PSA). Ctra. de Senés km 4.5, E-04200 Tabernas, Almería, Spain
{joseantonio.carballo,javier.bonilla}@psa.es

[2] Dept. of Computer Architecture and Technology, University of Granada, Periodista Daniel Saucedo Street, 18071, Granada, Spain
ncalvocruz@ugr.es

[3] Dept. of Informatics, University of Almeria, ceiA3 Excellence Agri-food Campus, 04120, Almería, Spain
{jhervas,beren}@ual.es

Abstract. Solar power tower plants are one of the most promising facilities among concentrated solar power systems due to their conversion efficiency and energy storage capabilities. They mainly consist of multiple sun-tracking mirrors (heliostats) that reflect sunlight onto a radiation receiver. The aim is to heat a working fluid to produce electricity using a power cycle. One of the aspects to manage when operating this kind of facility is the aiming of heliostats. Although the naive approach might be to aim all of them at the center of their receiver, it is inappropriate. Receivers have specific operation conditions, and radiation peaks can reduce their working life. Different strategies deal with this control problem, yet the most established methods still rely on fixed patterns, alarms, and human supervision. Nevertheless, an active research line seeks new control solutions using advanced methods, such as meta-heuristic optimizers and field models. This work tries to develop an advanced automatic control system for heliostat fields. It is based on an artificial neural network trained with an accurate model of the field to keep uniform flux distributions while maximizing the absorbed power. Preliminary results in a model of the Solar Platform of Almería are promising.

Keywords: Solar power tower · Artificial neural network · Automatic aiming.

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1 Project statement

Most countries aim to replace fossil-based energy sources with renewable ones to minimize pollution and reduce external dependencies [4]. Among the alternatives, solar energy is the most abundant resource, and concentrated solar technologies stand out from exploitation methods [2]. Solar power plants (SPT) belong to concentrated solar technologies and offer remarkable conversion efficiency and dispatchability due to the high temperatures reached and energy storage [2].

An SPT deploys mirrors called heliostats that track the sun and concentrate radiation onto a receiver generally placed on top of a tower [2]. A working fluid flows inside the receiver, and once it is hot enough, this fluid serves as the input of a power cycle, e.g., to produce steam and move a turbine. In this context, aiming the set of heliostats is a non-trivial task in which radiation peaks and temperature gradients can end the working life of receivers prematurely [2, 3].

As concisely reviewed in [3], multiple solutions have been designed. The simplest ones rely on plain temperature sensors and a reduced set of possible aiming points, including de-focusing or standby ones (as it is common to oversize the field for low-radiation situations). This kind of strategy is complemented by anomaly detection and human supervision. However, there are more advanced approaches that pay attention to optimizing flux distributions, e.g., by minimizing spillage. For this purpose, meta-heuristic algorithms, such as TABU search, ant colony optimization, and genetic algorithms, are powerful tools [2]. As this kind of method relies on system models, simulating the receiver and its field is also of great importance. For example, the work in [2] culminates the authors' research by combining i) a field-tailored model built through machine learning and accurate ray-tracing with ii) a general-purpose offline aiming tool based on a genetic algorithm, and iii) a closed-loop control logic. Unfortunately, it is necessary to combine multiple complex stages, and there is still room for improvement.

Artificial neural networks can be valuable for automatic heliostat aiming due to their ability to learn patterns implicitly [1]. This work will study the design of a deep neural network to be trained with accurate field-specific models to control a whole heliostat field autonomously. Preliminary results in a model of the Solar Platform of Almería, Spain, are promising.

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