DEVELOPMENT OF AN ALL-SKY CAMERA FOR SHORT-TERM FORECASTING OF PHOTOVOLTAIC GENERATION

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1) INTRODUCTION

In photovoltaic solar generation, the intensity of solar radiation directly influences the power generated. The radiation is strongly affected by the presence of clouds, which modify it quickly and intermittently. In order to take control and management decisions for a photovoltaic installation, it would be desirable to have the ability of predicting the generation drop events (Righini and Aristegui, 2016). Among the different types of forecast available, the forecast using all-sky cameras is the only one capable of predicting the evolution of clouds based on local observation of the sky, allowing the events of the next few minutes to be anticipated (Kazantzidis et al, 2017). In this article we show the development of an all-sky camera prototype which covered both the design of the hardware and the procedure necessary to forecast the evolution of cloud cover, as well as its representation in software.

2) PROTOTYPE

The prototype was built using the Raspberry Pi platform (Gay, 2014). It has a fisheye camera, light sensor, display, real time clock, among other accessories. Figure 1.left shows the block diagram of the developed prototype. The operational advantage of using a Raspberry Pi is that it has a specific port which links the camera to the graphics processing unit (GPU), making capture operations very efficient. In addition, due to its high performance, it is capable of running an operating system, so applications can be developed at a high level, allowing more flexibility from the software point of view.

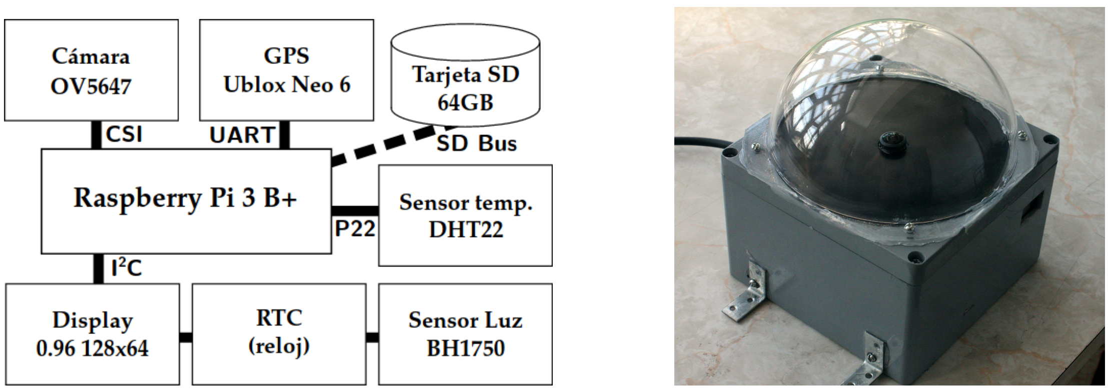

Figure 1: Prototype. Left: Block diagram, right: Cabinet.

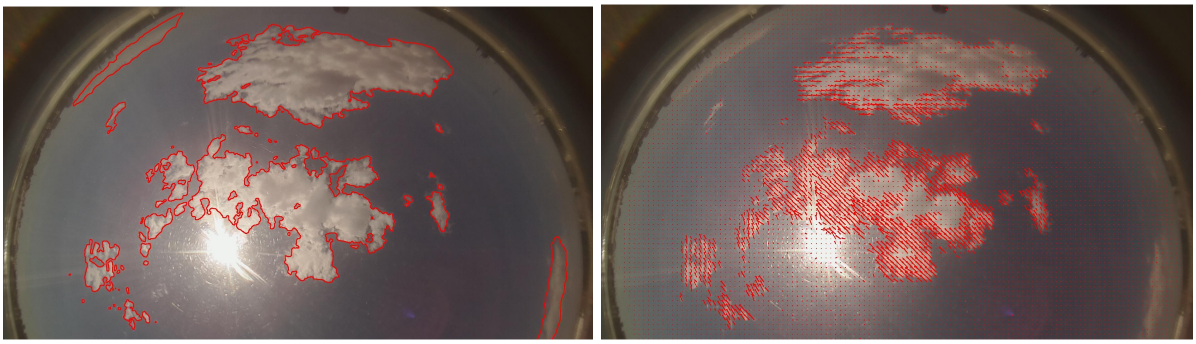

Figure 2: Initial detection. Left: cloud contour, right: Movement field.

The acquisition hardware is encapsulated in an IP65 insulated aluminum cabinet and the camera is housed under a very low distortion acrylic dome (Figure 1.right). This module is capable of acquiring images unattended, storing them locally and remotely, running the forecast algorithms and serving the results through a web interface.

Since 2019, three different prototypes have been installed in different locations near Buenos Aires, all of them have been operational for more than 1 year, proving to be robust and stable. They were mounted outdoors supporting sun, rain and high temperatures. Good thermal behavior was verified and the climate did not alter the operation of the device.

3) PROCESSING

The process that is carried out to forecast radiation can be separated into several stages:

Acquisition: During the acquisition stage, an image of the sky is generated using a high dynamic range (HDR) composition. To produce a forecast it is necessary to obtain two of these images with a time interval between them in order to detect the movement of the clouds.

Cloud detection: Based on the acquired images, processing is carried out to determine the position of the clouds and simplify their contours in order to transform them into polygons that could be manipulated later.

Motion detection: Taking the two acquired images, they are compared to generate a vector field in each pixel that reflects the movement of the clouds between those instants. Motion computation is done using the Gunnar-Farnebäck's dense optical flow detection algorithm (Farnebäck, 2013).

Cloud evolution: Taking the polygon that defines the cloud at the initial instant and the computed velocity field, a projection is made of how the edge of each cloud will evolve as a function of time.

Forecast generation: Knowing how the evolution of the clouds will be in the sky, and being able to compute the solar position, a forecast is produced which attempts to predict whether or not the clouds will cover the sun at each of the future moments in which the cloud evolution was computed.

Figure 2 shows an initial image for the detection of the cloud edges and the estimation of the motion vector field at a given instant. Figure 3 shows a detail of the forecasted cloud edge evolution 1 and 2 minutes later superimposed on the actual images acquired at those times.

The software that implements these stages runs independently for the acquisition, processing and interpretation of the forecast. Some of the software was developed in Python while the rest was in C++. The OpenCV library was used for image management and the pvlib-python library for computations related to the instantaneous solar position and radiation parameters. The software design was developed in a distributed way, being each stage independent of the others, and allowing the parallel execution of different tasks.

The result of the processing is served in a web application that shows the raw data acquired and the forecast. This service runs embedded in the camera and also allows access to the archive of acquired images.

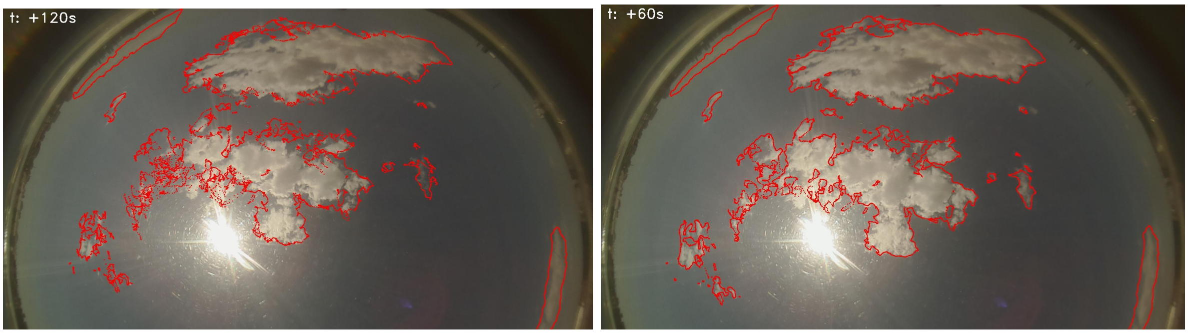

Figure 3: Forecast (red line) compared to actual evolution. Left: +60 s, right: +120 s.

4) CONCLUSIONS

In this work, both the hardware and the complete procedure to carry out the forecast were presented. These prototypes worked as a proof of concept and on that basis it must be redesigned and improved.

The intention is that the final product could quantify the expected solar radiation, perform automatic analyzes on cloud cover and cloud type and, mainly, implement protocols to couple this information to control systems or implement those controls in the device.

The work carried out to date is sufficient to guarantee the feasibility of making a forecast with this technology and with these processing stages. From now on, it must be adjusted and improved in order to take full advantage of the designed platform.

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