High–Precision Solar Tracking System

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***Abstract*—In this work we propose an innovative system for tracking the sun which is based on the use of a commercial web cam as the sensor element. An experimental electro-mechanism was designed and developed to evaluate its accuracy and efficacy in tracking the sun under different weather conditions. The impact on the system performance caused by intermittent cloud cover and temperature changes were also analyzed. The system showed an accuracy of 0.1º and high immunity to temperature variations. It demonstrated to be able to relocate the sun, as well as extrapolate its position when it cannot be observed for a period of time.**

***Index Terms*—Solar tracking system, sun tracker, webcam as a sensor.**

I. Introduction

Solar collector systems require high-precision solar trackers to increase their photovoltaic or thermodynamic efficiency [1]. The trackers currently in use apply discrete elements such as light dependent resistors or photodiodes to establish the approximate position of the sun [2]-[4]. One of the main disadvantages of using this type of sensor is its high sensitivity to weather conditions such as temperature and humidity [5]. To overcome this disadvantage, solar tracking systems which currently present a better performance and accuracy depend on sophisticated control systems [6], [7] and complex electronic circuitry. Moreover, their installation and maintenance costs are usually very high [8]. Very few alternative solutions have been proposed [9]-[11].

The use of low cost webcams as sensing elements in solar tracking systems has not been explored previously. Webcams provide a highly developed technological platform that can be easily adapted to any type of solar tracking mechanism.Worth mentioning that in most of the solar concentrators, computers are frequently used to monitor and registering information regarding the amount of energy obtained, so that in most cases a computer is available and it does not imply any additional inversion [12].

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II. Materials and methods

A commercial plug and play webcam was used (Genius 312S), it offers an image resolution of 640 x 480 pixels. A polarized filter of welding mask was fitted to the webcam to prevent saturation of the charge-coupled device (CCD) when solar radiation is very intense. The filter was also found useful to develop a real time pre-binarization of the image, see Fig.1. This pre-binarization speeds up the process of locating the sun.

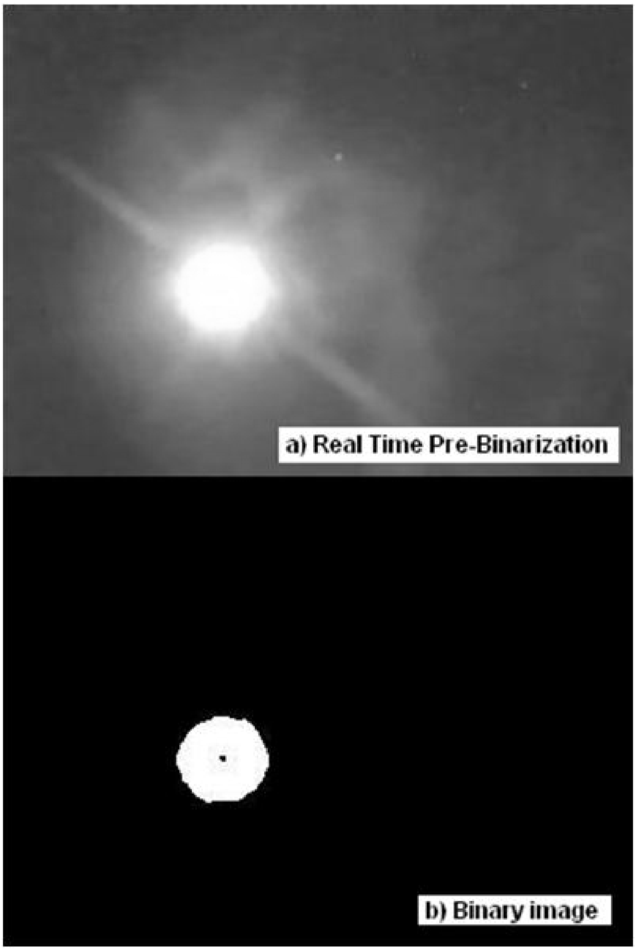

Fig.1. Processing of one frame. a) Result of real time Pre-Binarization. b) Calculus of the coordinates of the centroid.

The webcam was connected to a personal computer through USB port. We used MATLAB to implement a simple image processing algorithm on the incoming frames. Finally, the electronic control signal was output via the printer port of the computer Fig.2.

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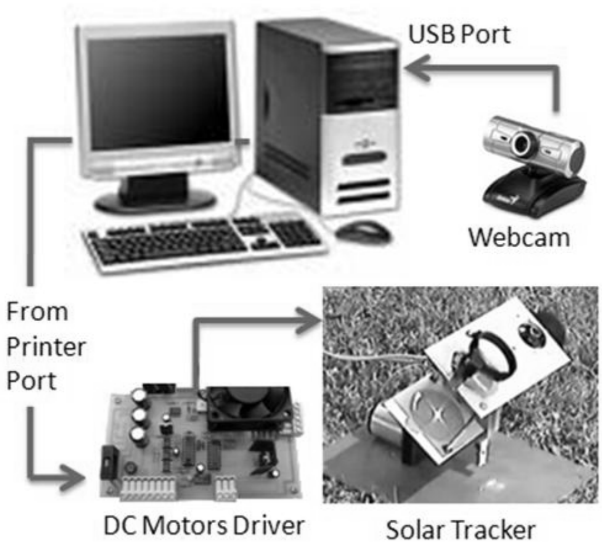

Fig.2. Block diagram of the solar tracker system.

The system calculates the centroid of the sun and its coordinates S(x, y), then they are forced to match with the coordinates of the center of the image C(x, y) or the coordinates defined by the user U(x, y), this is achieved by sending the necessary control commands through the printer port to an electrical motors controller. The control program can be instructed to fix the coordinates of the sun at any position on the screen. When the position of the sun changes and either of the two coordinates varies the system sends a digital signal via the printer port to the motor associated with the respective coordinate. The signal obtained is proportional to the error into the value of the coordinates.

The tracker was implemented on a purpose-built electromechanical system with two degrees of freedom, Fig.3. A direct current motors controller previously designed was used to convert the control commands provided by the computer into electrical pulses for the motors. Pulse-width modulation was used with a frequency of 10 kHz.

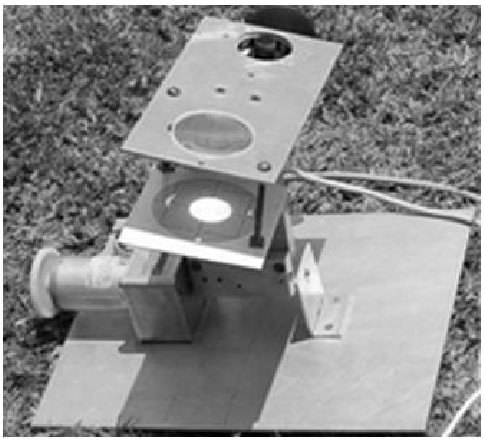

Fig.3. Electromechanical system.

The software developed in MATLAB allows the user to see the image of the sun and to set the coordinates in which the centroid of the sun must be fixed.

The system was oriented in the north-south direction, without attention to exactness. The motors were manually activated from the computer keyboard and the CCD was moved until the image of the sun appeared on the screen. The automatic tracking program starts running. The system was tested working under different weather conditions and also different north-south and east-west orientations were used. To evaluate its accuracy a graduated scale was adapted exactly at the focal length of a concave glass, Fig.4.

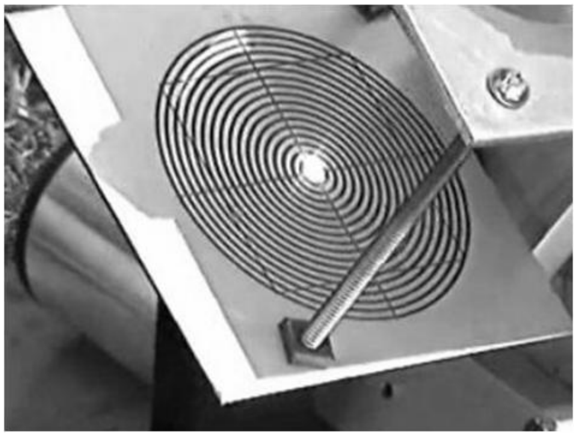

Fig.4. Graduated scale.

III. Results

Once the solar tracking program is running, the image of the sun does not move on the screen, since the control fixes the S(x, y) coordinates. When a passing cloud prevents the sensor from "seeing" the sun, the tracking system holds at the last known position of the sun. When the sun reappears within the CCD limits, the original position of the sun on the screen is automatically re-established by the motors. The movement of the motors is soft enough to avoid affecting the quality of the image of the sun on the screen. If the sun is partially detected by the sensor, the position is located at the centroid of the partial luminous object. The overall accuracy obtained was higher than 0.1º. Weather conditions such as temperature and humidity did not affect the accuracy of the tracker. Tracking results were the same in all north-south and east-west orientations. The computer takes 1/32 seconds to locate the sun. This characteristic allows for data to be collected from other sensors connected to the solar collectors.

IV. Conclusion

The use of a commercial webcam as the sensor element allowed us to avoid most of the common problems usually presented on the solar trackers currently in use. One of them is the high sensitivity of the discrete elements such as photodiodes or phototransistor to weather conditions, particularly to temperature and humidity. Another important aspect to consider is the rapid deterioration that may occur in discrete elements under extreme weather conditions and the cost of the constant maintenance that this implies. Installation procedures of discrete elements are also more complex and critical to achieve the desired level of accuracy. The system that we propose does not present most of these disadvantages.

The electronics needed to activate the motors are simple and the system can be applied to any electromechanical configuration. With minor adjustments it can be used with various types of collectors including flat-plate, compound parabolic, evacuated tube, parabolic trough, Fresnel lens, parabolic dish and heliostat field collectors.

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