The Enhancement of Solar Distillation using Image Processing and Neural Network Sun Tracking System

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Abstract**—**Jordan is one of the water scarce countries in the Arab region and is strategically depend on ground water in additional to the rain water dams. The main aim of this research is to utilize the new control algorithm and the developed computer capabilities in field of sun tracking in order to improve the efficiency of tracking. The new tracking method installed on new innovative approach of water distillation taking advantage of high possible concentration of parabolic trough collector to reach a new level of daily harvest per square meter. The present research utilizes the techniques of image processing to catch the core of the sun as the target, also used artificial intelligence techniques to predict the sun position in abnormal conditions of cloudy, dusty, rainy…etc. The results of tracking using image processing found to be accurate and reliable according to the self monitoring of the focus point validated by the solar radiation results. Neural Network results are very close to the actual data. Water distillation yield shows high percentage output of distillate of about 65%.

Keywords**—** Image processing, Matlab, Solar Distillation, Sun tracker.

I. INTRODUCTION

IN the last decades, many researchers have studied Sun tracking systems for wide range of applications to improve the efficiency of solar systems by adding the tracking equipment to these systems. A comparison study is made in Jordan based on fuzzy decision founds that solar distillation utilizing solar energy was most preferable, then came electricity production, solar water pumping and space heating and ventilation, respectively [1]. Tracking mechanism must be reliable and able to follow the Sun with a certain degree of accuracy, return the collector to its original position at the end of the day or during the night, and also track during periods of cloud cover. Fixed collectors producing heat or electricity throughout the year are usually installed and tilted at an angle equal to the latitude of the installation site facing directly to the Sun. In this case, the energy collected by the solar collector during both winter and summer is less due to Sun's changing altitude. The use of a tracking mechanism increases the amount of solar energy received by the solar collectors resulting to a higher output power. Commercially, one-axis and two-axis tracking mechanisms are available. Usually, the single-axis tracker follows the Sun's East–West movement, while the two-axis tracker follows also the Sun's changing altitude angle.

Early researches by Neville [2] and Hession et al [3] discussed the sun tracking mathematically and the multi usage of sun tracker coupled with collectors. Many researchers devoted their study to use sun tracking systems as improvement factor yields increase in power. Roth et al [4] designed and built an electromechanical system to follow the position of the sun based on four –quadrant photo detector sensor forming closed loop servo systems. Abdallah [5] study different types of trackers to investigate the effect in the voltage-current characteristics in the output power of PV panels, four types of trackers (two axes, east–west, vertical and north–south) gains increase in the output power by (43.87%, 37.53%, 34.43% and 15.69%) respectively.

Also, Abdallah and Nijmeh [6] designed two axes sun tracker based on open loop controller to investigate experimentally the effect of using sun tracking system; the result was a 41.43% increase in the collected power as compared with fixed surface collector with tilt angle 32°. The new algorithms in Artificial Intelligence (AI) i.e. fuzzy and neuro-fuzzy also used in solar energy environment. Alata et al [1] demonstrates the design and simulation of controller using first order sygeno fuzzy inference system, with full simulation in MATLAB – virtual reality toolbox. Al-Mohamed [7] achieved 20% increase in the output power of PV panel due to the use of automatic closed loop sun tracker using photo resistance as sensors, the controller was PLC with computerized monitoring capabilities through Recommended Standard 232 (RS232).

Another study by Bakos [8] based on design and construction of a sun tracking system for parabolic trough, the study aims to investigate the continuous operation of two axis tacking effect in the collected power, and the result showed that sun tracking increased the output by 46.46% using closed loop system. Abu-khader et al [9] investigated experimentally the effect of using multi-axis sun tracking on Flat Photovoltaic System (FPVS) to evaluate it is performance under Jordan climate, the tracker based on time varying system – open loop system – on other words it doesn't use sensors, their result

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showed that an overall increase of about 30-45% in the output power was achieved.

Lakeou et al [10] designed low cost 0.9 kW photovoltaic system with solar tracking system interfaced with 1 kW wind turbine. The control circuit made of low cost logic circuit to track the maximum sun radiation, but it is not easily adjustable for different climates.

Abdallah and Badran [11] deployed sun tracking system for enhancing solar still productivity, the computerized tracker is an open loop controller based on time as the main variable to control the orientation of solar still, and they found a noticeable increase in the productivity of around 22% with an increase in the overall efficiency of 2%.

Tomson [12] tested the high latitude angle – i.e. 60º- in the North European regions with low solar radiation levels, with comparison of continuous tracking and discrete two-positional tracker, the result shows the effect of using discrete systems in energy saving with increase in seasonal energy by 10-20%.

Rubio et al [13] presented a control application that able to track the sun with high accuracy without the necessity of precise procedure or recalibration, the tracker is hybrid system with combination of open loop and dynamic closed loop, taking energy saving factors in considerations.

In astronomical studies researchers depend on the accurate evaluation of the sun angels. Grena [14] proposed a new algorithm for accurate sun angles determination, his result indicates high precision tolerance around 0.0027 º over the period (2003-2023).

Ming and Frank [15] applied image segmentation to detect sun flare properties and use it in sun tracking purposes, center of flare and boundaries and filtering are some of feature analyzed by image segmentation.

II. IMAGE PROCESSING

Recently, robotic vision systems boosted to decide the new rules of science and development, one of the most annoying problem faced the robotics systems was the accuracy of sensing tools due to the continuous trying to emulate the human being sense. Robot vision capability and ability to recognize this vision over analysis, as it subtract the useful data, is one of the advanced sensing capabilities trying to add. In order to make a machine see, Image Processing Techniques (IPT) has been found and developed [16].

Once the IPT started as robotics application, it has been developed and reformed to be suitable for multi industrial applications, in this study the use of IPT as a sun tracking is designed and implemented for sun tracking.

The main attraction to use the IPT in sun tracking controller is to be in touch with the sun image which guide to track the sun accurately. Currently sun tracking systems used traditional sensors like opt-coupler or photo sensor, it can't grantee that the sensor reading is correct or the orientation of the motor directed toward the sun accurately, where IPT controller - vision system- can detect the position of the sun in accurate manner using x-axis and accurate y-distance, due to ability of extracting the sun position as an distinct object. Another feature is ability to check the deduced information by comparing it with snapped image.

Ming and Frank [15] used Image Processing Techniques (IPT) as tracking system by detecting sun flare and trace it. However, the tracking algorithm built in this study is considered to be advanced. Actually few researchers used IPT in sun tracking. Mobasser et al [17] used the IPT to take pictures only to be the input for fuzzy logic controller to enhance sun sensors.

While our technique doesn't depends on the mathematical calculation or angles prediction, also it is independent of the environmental conditions (i.e. rain, snow, summer, winter …etc). Furthermore, it evaluates the sun position continuously without any preprogramming or preoperational procedures or calibration. Because it uses Image Processing Techniques (IPT) and Artificial Neural Network (ANN) for sun angle detection. The present tracking system used the time in abnormal conditions when sun image is not clear, also it uses the current state of the sun to predict the future position.

III. EXPERIMENTAL SETUP

The system designed according to the block diagram illustrated in fig 1, two cameras installed in the system to maintain the parallel and straight of focus line reduce the tolerance and to expand the visual area, see fig 2.

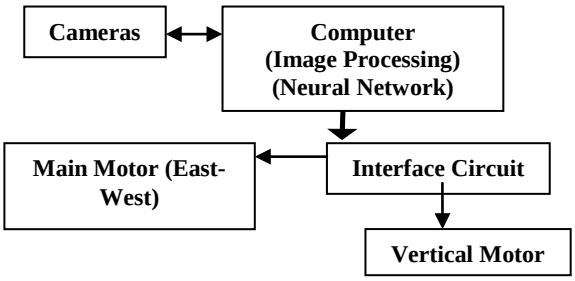


Fig. 1 Experimental setup block diagram

Fig. 2 Experimental Setup

IV. PREDICTION OF THE SUN POSITION

Area and centroid of the sun image are the two main important properties that determined the sun position. Area used to eliminate the object with small sizes by comparing it with reference value, where centroid used to direct the parabolic collector toward the sun. Circular shape is further

more filtering to ensure the right orientation. In some situation, where the sun engaged with white clouds, it appears as irregular shape huge enough to cover the entire image. Compute the centroide in this case is wrong due to the asymmetry in the sun shape. Circular algorithm target is simply tried to answer the question, what is the object circulation percentage? If the answer is 100% it means the object is a complete circle, where it is not applicable to get answer like this, but the correct or accepted answers range between [75%-99%].

If the program failed in the two classifications to distinguish the sun from other noises, it switches the decision to the neural network model. On the other hand, the program success in track the sun with percent of 99% during testing, the remaining 1% the decision switched to the neural network model.

A sample of image processing program and output is carried out and recorded, see Figs 3 to 15. This sample is real time sample of the images taken from two cameras on Tuesday 24/6/2008 at 10:02 AM. Images are both clear, and to test the performance of filters a manual noises are added with different shape and sizes.

Images snap shot

Camera 1 *Camera 2*

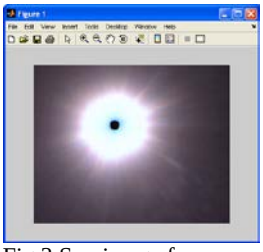


Fig 3 Sun image from camera 1.

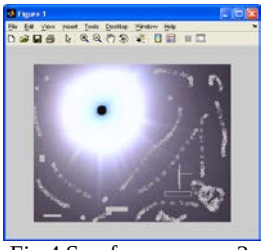


Fig 4 Sun from camera 2, adding some manual noise

Convert Images to Binary photo

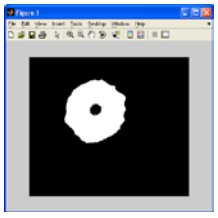


Fig 5 Binary image of camera 1.

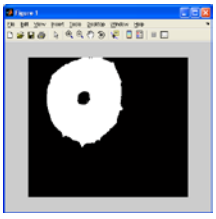


Fig 6 Binary image of camera 2.

Image filtering and enhancing

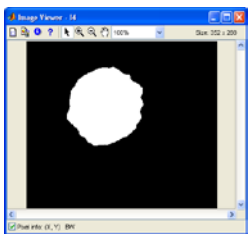


Fig 7 Filtered image of camera 1.

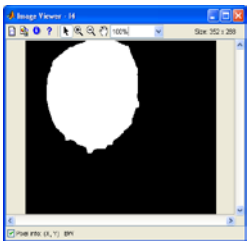


Fig 8 Filtered image of camera 2.

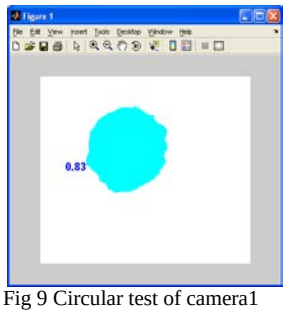


Fig 9 Circular test of camera1

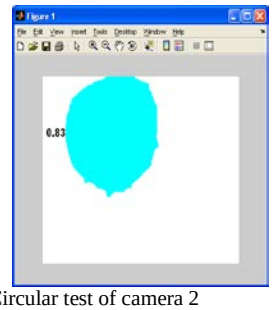
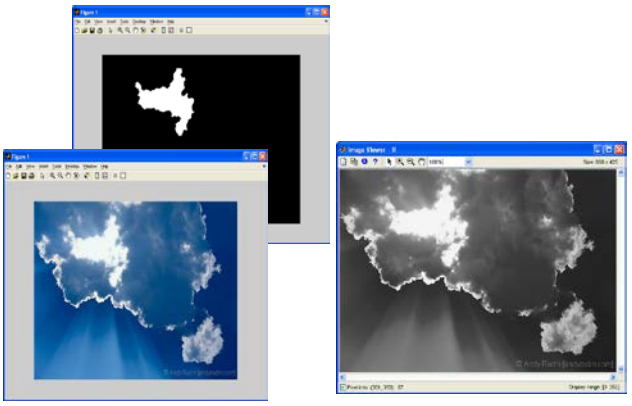


Fig 10 Circular test of camera 2

Fig 11 Cloudy sky

Fig 12 Gray scale image



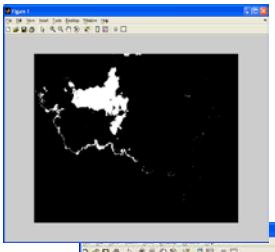


Fig 13 Binary image

Fig 14 Filtered image

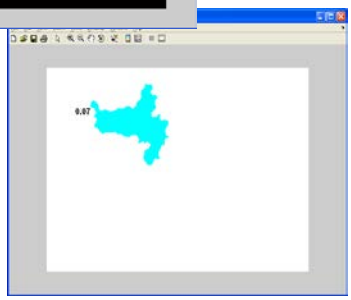


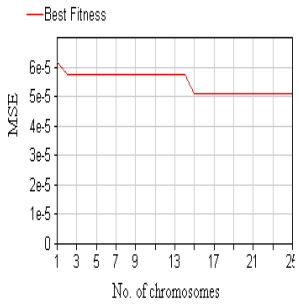
Fig 15 Circular test result

Fig 15 shows that the image fail in the roundness test and the percentage of the circulation is 0.07, the controller decision will be based on neural network.

V. Artificial Neural Network (ANN)

The model of ANN was built based on network genetic optimization through which the continuous update of number of hidden layers and number of PEs in each layer are available to reach the optimum solution and optimum design. The desired level of errors are reached after 25 chromosomes with

mean square error (MSE) about (0.00005), Fig 16 shows the training results with epochs number of (5000).



(A) (B)

Fig 16. Training output (A) Input Vs Desired Plot (B) Best fitness per generation

Many researchers have discussed the two-axis tracking for many solar systems. They have assumed some factors to enhance the operation and increase the yields. Fig 17 illustrates the results of five different models used tracking system, Parabolic distiller is the subject of this study which used image processing coupled with artificial neural network to track the sun continuously. Abdallah and Nejmih [6] have used open loop techniques to track the sun using PLC program, and Rubio et al [13] used hybrid tracking system that consists of a combination of open loop tracking strategies based on solar movement models and closed loop strategies using a dynamic feedback controller. While Bakos [8] model used sensors to direct the reflector toward the sun, also he has used the parabolic collectors as the main surface.

Normalized value of solar radiation has been used for easy comparisons with other workers, as shown in Fig 17. The normalization followed the following procedures:

*Normalized value = relative value /Base Value
Base Value = 1010 : Bakos maximum solar intensity level

VI. Conclusion

The designed tracking system depended on Image Processing Techniques (IPT) and ANN (Artificial Neural Network) concepts to predict the sun position and it is considered as a new innovative algorithm. The image processing techniques depended on camera detection technique which found to be powerful and reliable. While the neural network is able to predict the sun position in any vague (abnormal) conditions. Neural network model is found to be reliable according to the obtained low learning errors. The tracking system has been verified through the collections of accurate solar intensity, and distillation output compared with other researchers in the field.. Through the comparisons with other researchers, it is found that the present study resulted in higher yield and higher solar concentration on the distiller surface.

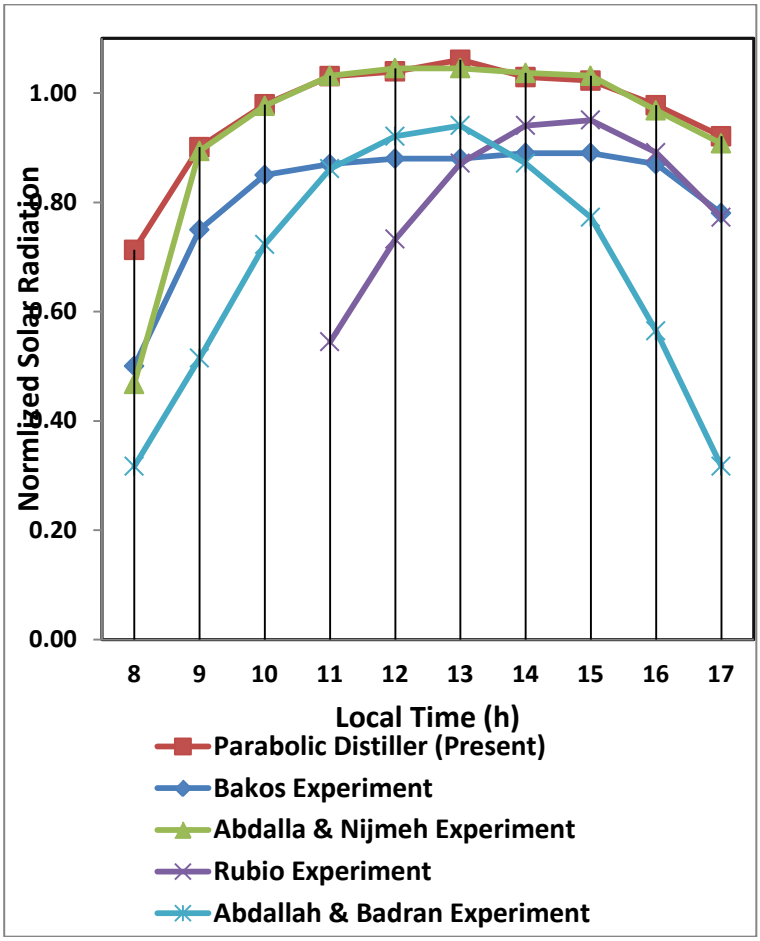


Fig 17. The results of different models of tracking system

The Image Processing and Neural Network methods enhanced the efficiency of solar distiller through utilizing more solar radiation for heating purposes. The system showed its reliability of sun detection and solar angles positioning. Also it has takled the deficiencies due any dusty and cloudy weather.

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