RESEARCH ARTICLE | MARCH 22 2024

Soft computing based solar follower using Raspberry pi 4B

Kanhaiya Kumar ✉; Lokesh Varshney; A. Ambikapathy; Raunak Singh; Yasharth Rai; Sarthak Sikriwal; Rajkishor Prajapati

AIP Conf. Proc. 2816, 090004 (2024)
https://doi.org/10.1063/5.0177498

Soft Computing Based Solar Follower Using Raspberry Pi 4B

Kanhaiya Kumar[1, a)], Lokesh Varshney[1, b)], A. Ambikapathy[2, c)], Raunak Singh[2, d)], Yasharth Rai[2, e)], Sarthak Sikriwal[2, f)] and Rajkishor Prajapati[2, g)]

[1]*DEECE, Galgotias University, Greater Noida, U.P, India*
[2]*EEE Department, GCET, Greater Noida, U.P, India*

Corresponding author:[a)]kkanhaiyakumar@gmail.com
[b)]lokesh.varshney@gmail.com
[c)]ami_ty21@yahoo.com
[d)]raunaksingh332@gmail.com
[e)]yashanita21@gmail.com
[f)]Sarthaksingh5710@gmail.com
[g)]rajkishorprajapati4550@gmail.com

Abstract. The proposed work deals with image based solar tracker utilizing raspberry pi 4B. The system works fine with a webcam supporting the digital image processing within the raspberry pi model 4B board which manages to arrest the Sun's Image during hazy days due to clouds. India is the country that acquires Sunlight all-round the year. Sunlight can be utilized as substitute energy to fossil fuels or hydroelectricity for the generation of electricity. There are numerous methods which are available to expand the harvesting of solar energy but few are expensive and others can't provide accurate position of the Sun during hazy Sunlight. Raspberry Pi is the foremost board which is used to replace the CPU (central processing unit) to develop and process the Sun image. The two servo motors consisting of tilt \& pan are helping to position the web camera to track the position of the Sun. The system provides easy execution of Sun followers with the ability to find the centroid of the Sun on sky pictures. The Raspberry board then sends the instruction to the driver and it rotates in line with the trajectory of the Sun. The result states that tracking error reduced to 0.040 on haze or cloudy days with the use of raspberry pi model 4B.

Key words. *Solar follower, Solar power, Digital image processing, Azimuth angle, Raspberry Pi 4 B.*

INTRODUCTION

Sun energy is an easily available renewable energy and it can be harnessed persistently and steadily, generally in the nations where the Sunlight is available all through the year. There are various types of solar harvesting systems currently used [1]. It is anticipated that the worldwide energy accumulation by PV will reach nearly 4670 GWp [3] and installed capacity (4.67 TWp) by 2050, because of that price of power could be minimized in the Sun-belt nations. In order to produce Sun energy coherently, Sun trackers can be utilized to assure the concentrated gathering of solar energy by tracking the location of the Sun. The IRNEA [4] 2020 report on Solar energy generated electricity of world and India is shown continuously given in Figure 1.

Advance Computing and Ingenious Technology in Engineering Science
AIP Conf. Proc. 2816, 090004-1–090004-9; https://doi.org/10.1063/5.0177498
Published by AIP Publishing. 978-0-7354-4789-9/$30.00

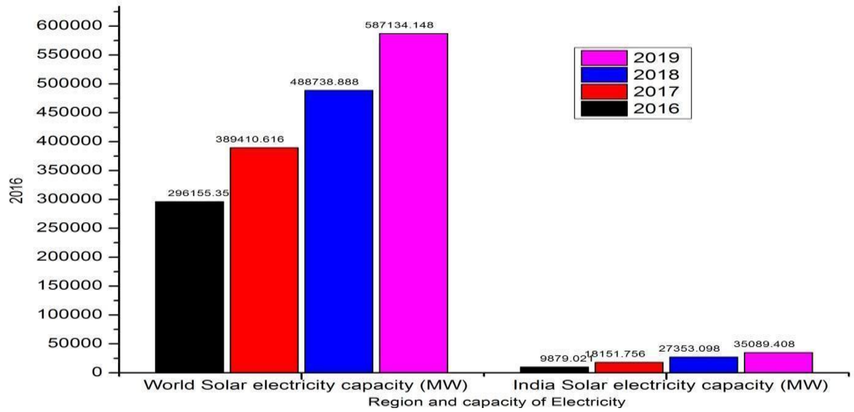

FIGURE 1. World and India electricity generation by solar energy. (created by the author)

Sun follower in the recent study & research utilize transducer like photodiodes and photo-transistors [5]. These sensors track down the position of the Sun based on the Sunlight intensity. The drawbacks of these types of trackers are that they are highly responsiveness to climate change like humidity, heat and worst weather situation [6]. Many other solar tracker use an intricate control systems and complex circuitry [7] which replace the problem of high sensitivity & reduce demanding price.

In order to remove the hitches referred above, a DIP based Sun follower has been made in modern era. Exceedingly accurate Sun following system using budget web camera was designed, which used to trace the Sun trajectory and deduce its location with tracing precision of 0.1° without getting effected by weather conditions. Also, an image-based Sun tracking sensor and tracing controller consisting of image processing algorithm [8 - 11] initiated solar image tracing model. This system is able to deal the issue of unstable tracing when the weather is cloudy and accomplish tracing precision of 0.04°. It proves the possibility of tracking the Sun with the use of image processing techniques which motivates the analysis shown in the work [12].

The proposed work introduces a Sun tracing system with the use of DIP algorithms as the main components and the price can be minimized with the help of a web camera as a substitute of a costly camera. The DIP processing is done within Raspberry Pi (RP) board. The RP was designed in the United Kingdom by Raspberry Pi foundation. It is an integrated board computer whose leading objective was to upgrade the education of fundamentals of computers in educational institutions. It consists of two main models and both of them are alike excluding the model B, it contains an Ethernet, 2 USB (Universal Serial Bus) ports and 1 GB synchronous DRAM can work on a Linux operating system. In this project we have used RP Model 4B.

METHODOLOGY

Design & Operation of hardware

The solar tracker system diagram shown in Figure 2 and hardware layout consists of a RP board, servo motors and finally a web camera shown in Figure 3. The Raspberry Pi (RP) is the primary board that operates the images and controls the servo motor. The web camera catches the pictures from the sky and sends it to the RP board through the camera port. The sky image is processed to find out Sun picture and their centroid co-ordinate. The servo motors are attached to RP board through General Purpose Input/output port. After tracing down the exact solar position, Raspberry Pi rotates the servo motors, either pan or tilts or both if necessary. Sometimes both tilt & pan are necessary to adjust so that the Sun will be placed exactly at the centroid of the sky image.

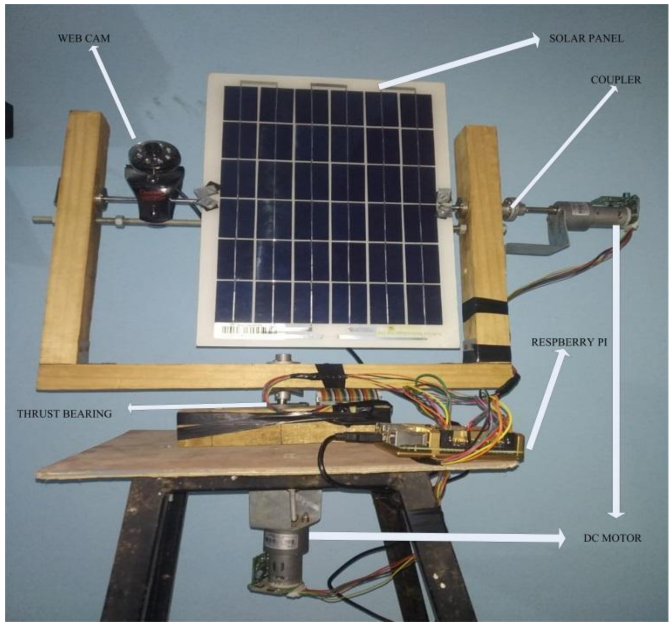

FIGURE 2. Solar tracker system diagram. (created by the author)

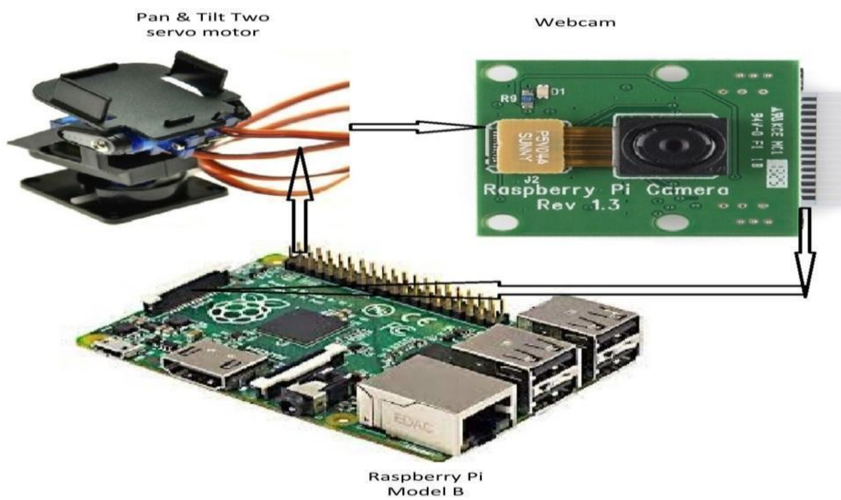

FIGURE 3. Design of DIP Solar trackers. (created by the author)

If the Sun is not recognized in pictures, RP board will continue to rotate the servo motors till the Sun discover. If the Sun is positioned at the centroid of the picture, the RP board sends the message to driver motor to remain at their current position for next ten minutes.

Processing of Image

As image is captured from webcam, it's a 24- bits coloured image and later converted into an 8-bits gray-scale image to permit the efficient processing of the sky image. The processing of image [13] uses OpenCV module. The OpenCV coding, converts twenty –four bits coloured image into eight bits coloured image. Than eight bit coloured image is converted to gray image by OpenCV code then finally gray-scale picture is converted into binary picture [14] which is threshold to recognize the circle or curved shape of the Sun as shown in Figure 4.

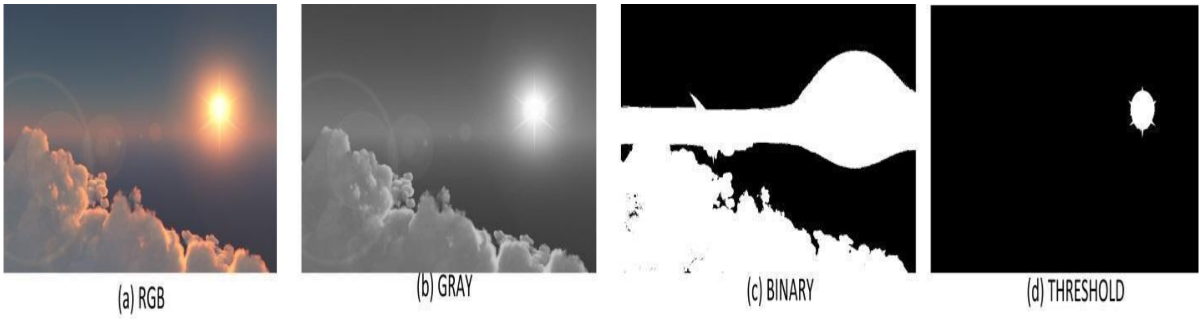

FIGURE 4. Processed Images. (created by the author)

Adaptive Thresholding is an excellent method for transforming the gray image to binary image and in addition to this, the thresholding provides an easy and convenient way to separate background pixels (usually set to black) from those corresponding to the target objects (usually set to white). The source image is the first parameter in adaptive thresholding. The maximum nonzero value allotted to pixel for which the situation is fulfilled. In adaptive method the adaptive Gaussian thresholding [15, 16] algorithm were used. There are two types of adaptive methods-

Adaptive mean thresholding: The threshold value is the mean of the neighbourhood area minus the constant C. Adaptive Gaussian thresholding: The threshold value is a Gaussian-weighted sum of the neighbourhood values minus the constant C. By using thresholding we separate Sun from image taken by web cam as shown in Figure 5.

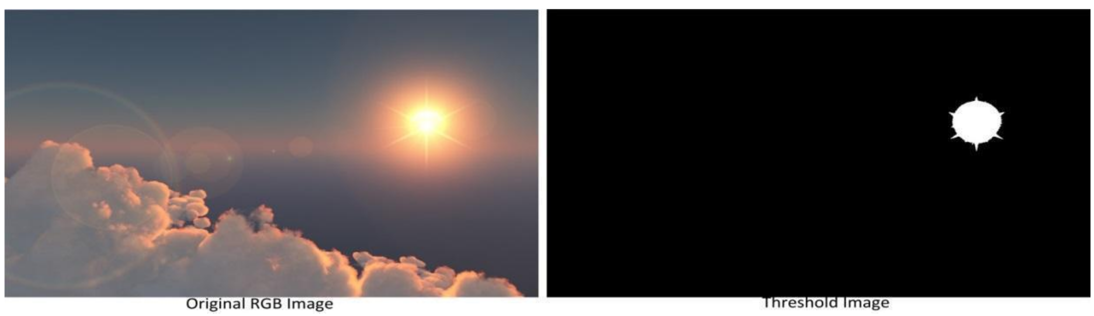

FIGURE 5. Adaptive Gaussian Thresholding (created by the author).

Hough transformation is used to recognize the shape of the Sun where the circle figure is shorted because of Sun circular shape from the source image; it can be 8-bits image in binary format. The work deal HOUGH-GRADIEN method where

$$dp = \left(\frac{Accumulator\ resolution}{Image\ resolution}\right)^{-1}$$

Assume that *dp =1*, then

$$Accumulator\ resolution \ = \ Source\ image\ resolution$$

Assume that *dp =2*, then

$$\text{Accumulator resolution} = \frac{1}{2}(source\ image)$$

Criterion 1 along with Criterion 2, the first along with the second, the particular method is to set up. The lowest level radius called the minimum radius of the circle, which is used for purposes of the identification. The maximum radius of the circle also used for purposes of identification.

Motor control

Servomotors control depends on pulse width modulation signal via RP board. Pulse width modulation indicators can be managed using Sun's placement in the photograph. Figure 6 show the flow chart which represent technique to recognizing the coordinates of Sun by identifying the Shape of the Sun.

FIGURE 6. Flow chart of motor driver movement. (created by the author)

When the Sun is not identified in the picture, since the webcam's face away from the Sun, the Raspberry Pi arbitrarily deliver pulse width modulation signal to the servo driver. The process will go till the Sun is recognized in the images. When the Sun is recognized, the RP board will have to analyse its orientation and proceed further to control pan as well as tilt of driver. When the Sun is in the right / left side of the pan tilt control, the RP board sends a command to the pan-tilt control in order to set the location of the Sun at the centre of Image. Figure 7 represent the pan and tilt of the Sun in the image. In given figure 7(a) is a real RGB image and rest 7(b), 7(c) and 7(d) represent the right traced, left traced and centre traced threshold scanned image respectively. If the traced tilt and pan is not at centroid than Raspberry board will generate the pulse width signal to change the pan-motor towards the pan line to come near the Sun centroid. The similar action occurs for tilt motor. When Sun comes exact at the centre of the picture shown in Figure 7(d), RP board will send the same pulse width modulation signal continued for ten minutes.

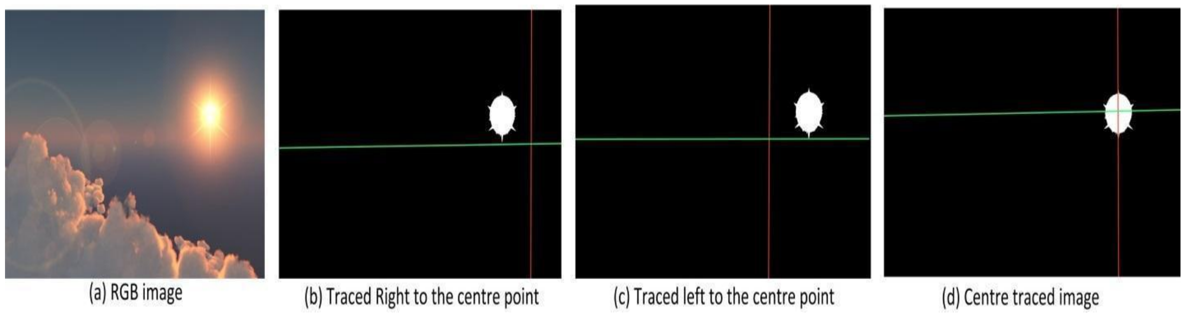

FIGURE 7. Control of tilt & pan.(created by the author)

Control of PWM

GPIO control and PWM library are the two methods to control PWM in servo motor. The sleep time is controlled in order to transfer PWM signal to driver. Sleep time is a delay time which is regularly sends to driver shown in Figure 8. The time ‘a’ lie within 1ms to 2ms (millisecond) depends on the orientation require to face web camera towards the Sun. The co-relation of time ‘a’ \& ‘b’ stated as b = (-a) + 20ms, where ‘b’ is in ms.

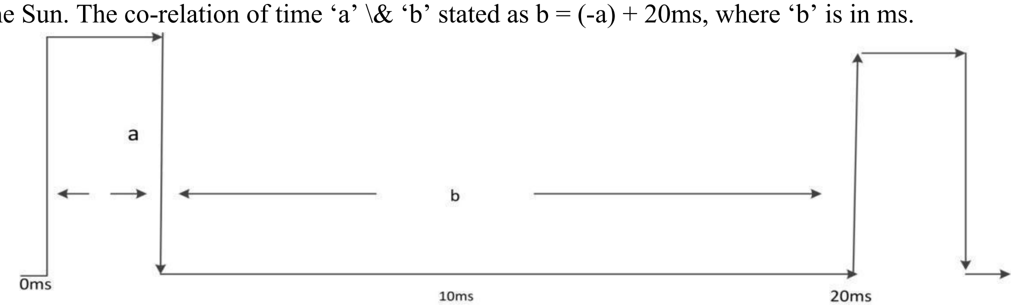

FIGURE 8. Time ‘a’ & ‘b’ relation in millisecond. (created by the author)

RESULTS AND PERFORMANCE

Hardware

GPIO Port 22 \& 23 is connected to pan signal of PWM and servo motor \& these servo motor powered by Pi board itself shown in Figure 9. Raspberry Pi camera is directly connected to the camera port in Raspberry Pi board. It can be transmit to personal computer through USB.

FIGURE 9. Raspberry Pi B4 board. (created by the author)

Processing of Image

The pixel range of web camera is 2048 × 1536 and it has 3.15 mega pixel images. It also has dual light emitting diode (LED) flash and auto focus.

The given Figure 10 is taken by web camera at noon and one hour after the rain and their Gray and binary conversion shown. We can clearly observe that Sun is not clearly visible because of clouds. We put this image under image processing and it can be seen in Figure 11 that the Sun's circumference or boundary and centre is being detected.

FIGURE 10. Image processing. (created by the author)

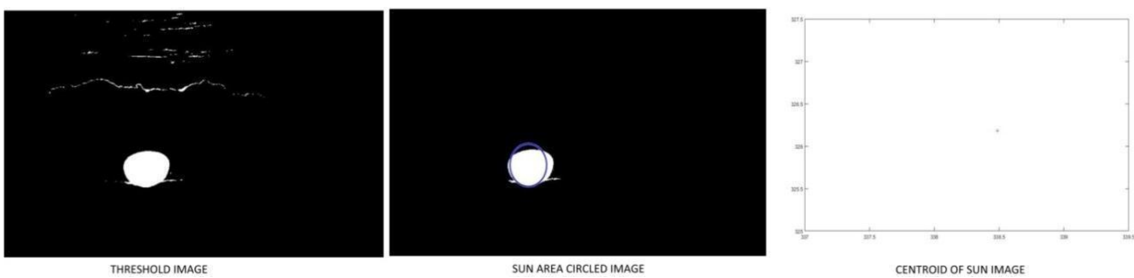

FIGURE 11. Sun boundary and centre detection. (created by the author)

The red and green lines show pan and tilt servo motor respectively assuming both are perpendicular to each other. The servo motor moves the webcam towards the centre of Sun with the help of Image centre shown in Figure 12.

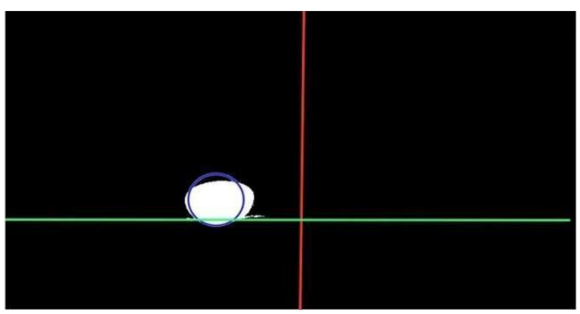

FIGURE 12. Traced Image.(created by the author)

The degree of rotation is requiring reducing so the pan servo motor lines cross the centre, than the Sun is located. At 90 degrees, the Raspberry Pi send PWM signal of 1.49 ms, as shown in Table 1. According to this, when the pulse width signal directed to the driver is lower, which is 1.28 ms, the orientation will be equal to 70 degrees. The same is repeated with tilt of servo motor.

Line of tilt should pass the blue circle which is present slightly left to the circle hence rotation degree of the servos should be reduced. The tilt lines are at degree 90 so now lines are hence decreased to 750 and the signal has taken 1.32ms. Various images data were given in Table 1. The observed results represented in Figure 13 where Image and Sun centre coincide and pan \& tilt line cross each other at image centre.

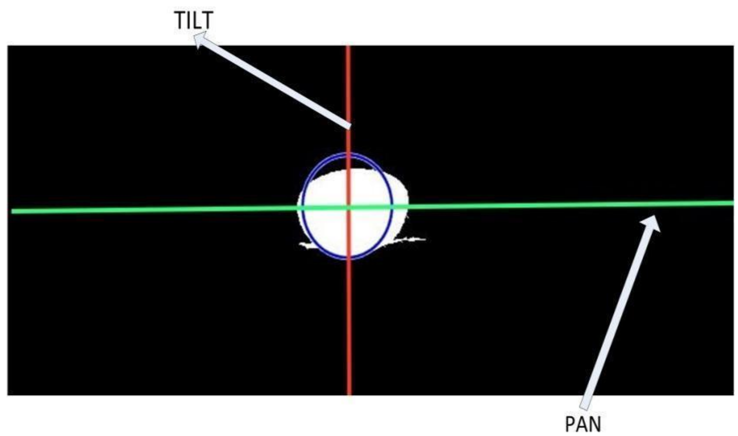

FIGURE 13. Centroid of Sun located (created by the author).

TABLE I TIME L AND K RELATION WITH THE RATE OF ROTATION OF THE MOTOR.

Picture	L (ms)	K (ms)	Rotation(Degree)
1	0.56	19.48	0
2	1.03	19.01	40
3	1.49	18.55	80
4	1.96	18.08	120
5	2.42	17.62	160
6	3.78	16.26	180

In given Table 1 high signal of the PWM which given to drivers to calculate the rotation degree of motor shown in Figure 14.

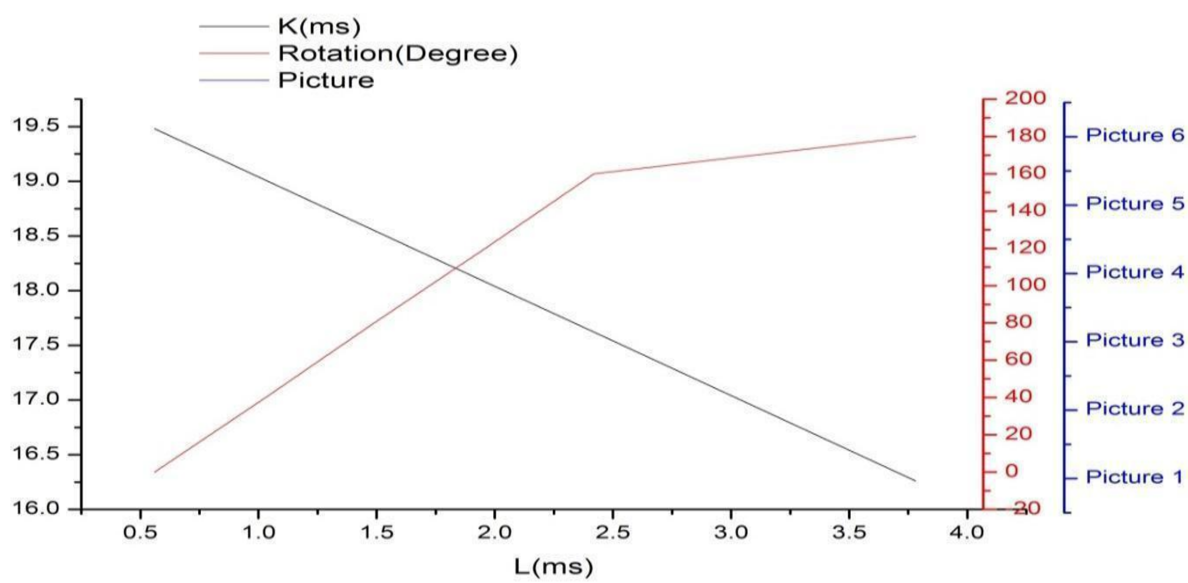

FIGURE 14. Result analysis.(created by the author)

CONCLUSION

The proposed work based on solar tracking by the raspberry pi 4 B board systems. The system consist of webcam with image processing by raspberry pie board which is effective and works very well in tracking the Suns position during the cloudy days. This has effectively increased the efficiency of the solar power output. The system has the capability to track and to find the centroid of the Sun by the Sun's picture which initiates the motors to rotate according to the position of the Sun. The Sun following system using photo-diode or photo-transistors presents drawbacks due to changing weather and environment effect. To upgrade this work in future the system needs an optimistic approach by doing proper adjustment and a more efficient algorithm to cope up with the real time operation on ground level.

REFERENCES

1. K. Kumar, L. Varshney, A. Ambikapathy, R.K. Saket, and S. Mekhilef, Int. Trans. Electr. Energy Syst. 31, (2021).
2. R. Alur, C. Belta, F. Ivančić, V. Kumar, M. Mintz, G.J. Pappas, H. Rubin, and J. Schug, Lect. Notes Comput. Sci. (Including Subser. Lect. Notes Artif. Intell. Lect. Notes Bioinformatics) 2034, 19 (2001).
3. C.-P. TAN and Y.-W. TONG, Sustain. Matters 301 (2017).
4. G.J.G.J. Prinsloo and R.T.R.T. Dobson, 1 (2016).
5. G. Prinsloo and R. Dobson, Sun Tracking and Solar Renewable Energy Harvesting: Solar Energy Harvesting, Trough, Pinpointing and Heliostat Solar Collecting Systems (2015).
6. S.A.M. Said, G. Hassan, H.M. Walwil, and N. Al-Aqeeli, Renew. Sustain. Energy Rev. 82, 743 (2018).
7. M. Abdollahpour, M.R. Golzarian, A. Rohani, and H. Abootorabi Zarchi, Sol. Energy 169, 136 (2018).
8. K. Kumar, L. Varshney, A. Ambikapathy, V. Mittal, S. Prakash, P. Chandra, and N. Khan, Int. J. Power Electron. Drive Syst. 12, 1880 (2021).
9. C.D. Lee, H.C. Huang, and H.Y. Yeh, Sensors 13, 5448 (2013).
10. C.C. Wei, Y.C. Song, C.C. Chang, and C.B. Lin, Sensors 16, 1995 (2016).
11. K. Kumar, L. Varshney, A. Ambikapathy, I. Ali, A. Rajput, A. Bhatnagar, and S. Omar, Int. J. Power Electron. Drive Syst. 12, 1431 (2021).
12. J.A. Carballo, J. Bonilla, M. Berenguel, J. Fernández-Reche, and G. García, Renew. Energy 133, 1158 (2019).
13. Kumar K, Saurabh, Devendra, Nisha Gaur. A Review on Image Processing. National Conference on Emerging Trends in Electrical, Instrumentation & Communication Engineering. pp. 47-55, Vol.4, No.7, 2013.
14. K. Kumar and A.A. Khan, in Green Technol. Smart Effic. Manag. (2012).
15. D. Cho, T.D. Bui, and G. Chen, Int. J. Wavelets, Multiresolution Inf. Process. 7, 299 (2009).