A prototype of solar panel position control system based on image processing

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Abstract. The position of the solar panel towards sunlight is very influential on the electrical energy production. The solar panel orthogonal to the sunlight is the best position to produce electrical energy. The aim of this research is creating a prototype of the solar panel position control system. The expected position of the system is solar panels are always perpendicular to the sun. In this research, we used image processing to control the solar panel position. We used a webcam to capture a shadow image of a 4cm bolt that placed on a flat plane. Then, the image from the shadow is processed to get the angle of the sun. We use trigonometric formulas to convert bolt shadows into angles. After that, the angle used as input for the solar panel drive motor. Thus, the solar panel can be adjusted to follow the angle of the sun. So that the positions are orthogonal to each other. The research finding discovered that the prototype can always follow the direction of incoming sunlight with an accuracy rate towards the center point is 95% for azimuth (X-axis) and 96% for altitude (Y-axis).

1. Introduction
Indonesia, a country where the sun shines all year long, has great potential to use solar energy as renewable energy. Solar energy not only has many advantages, such as fewer and unlimited pollution [1]. But also, solar energy can be used in various things such as in industry and residential [2]. Solar panels are devices used to convert solar energy into electrical energy. One way to optimize the output of solar panels is to position solar panels orthogonal to sunlight. To maintain the position of the solar panel, we need sun tracking.

In previous studies, there were several methods carried out for sun-tracking, namely using the LDR sensor [3], based on date/time [4], a combination of sensors and based on date/time [5]. Two types of sun-tracking that are often used [6]. The first type is single axis [7-8] and the second type is dual-axis [9-10]. The ability of dual-axis to maintain the position of solar panels perpendicular to sunlight results in better efficiency than single axis [11].

In this paper, we present a prototype of a solar panel position control system based on image processing. The type of axis used in this system is dual-axis. The primary purpose of this system is tracking sunlight by processing the shadow image of the rod object (4 cm bolt) into an angle. Then, the angle obtained becomes the input to drive the servo motor. This servo motor drive can move the solar panel along with the acrylic plate where the object is attached. Thus, the position of the solar panel to the sun is always perpendicular.
2. Methods

The solar panel position control system proposed in this study consists of hardware and software. The main function of the software is to process the image of the plate shadow into an angle. The hardware part consisting of plates, cameras, microcontrollers, and servo motors, the function is to take the image of the plate and control the position of the plate. In Figure 1 displayed the overall system block diagram.

![Diagram block of the proposed solar panel position control system.](image1)

2.1. Hardware system design

In the proposed solar panel position control system, a webcam used to capture the shadow image of the object. The object used is a bolt that is 4 cm long and 1 mm in diameter. So that the object's shadow can be captured with the camera, the object is mounted on the center of the acrylic plate that has coated with tracing paper. The size of the acrylic plate used is 15x15 cm, 2 mm thick. The distance between the plate and the camera is 15 cm. Figure 2 displays the position of the object, acrylic plate, and the camera.

![Position of laying of objects, acrylic plates, and camera.](image2)

After the object's image is captured and processed to produce an angle, a microcontroller is needed to control the motion of the servo motor. The microcontroller used is Arduino Uno. The servo motor used is MG966r. MG966r servo motor has a large torque that reaches 23 kg.cm. Servo motor movement functions to move the solar panel along with the acrylic plate. Figure 3 shows the hardware design of the solar panel position control system.

![Solar panel position control system hardware design.](image3)
2.2. **Image processing**
The object's shadow image is then processed to produce an angle. Figure 4 shows the image processing that was carried out. Shadow image processing of the trunk object is useful for separating the shadow from the background. The initial image comes from the webcam in the form of an RGB image, then changes to a grayscale image. Change from RGB to a grayscale image is done to change the image according to the degree of gray. The next process is to change grayscale into the binary image so that the image converted into patterns of numbers 0 and 1. The last process is the segmentation process. The segmentation process used is using Otsu segmentation. Otsu method is a segmentation method that done by finding the boundary value so that the distribution of foreground and background has the most minimal value [12]. The most appropriate boundary value is searched by an iteration process using the possible boundary value. The segmentation process in Matlab is enough to use the code \( T = \text{graythresh}(I) \). \( T \) is the threshold value, while \( I \) is a segmented image.

![Figure 4. Image processing.](image)

2.3. **Angle calculation**
The angle calculation process is done after the image processing. The angle referred to in this case is the angle formed between the object's point and its shadow. Shadow objects can be created due to the direction of sunlight that hits them. When sunlight hits an object perpendicular to or 90°, then the shadow of the object is not formed. So that what seen on the camera is only a dot. However, if the sun's rays are not perpendicular to the object, shadows will form. If a shadow forms on the right side of the object, then the sun's rays come from the left of the object. Vice versa, if the shadow formed on the left side of the object, then the sun's rays come from the right side of the object. The proposed system is to control the position of the solar panel so that it is always perpendicular to sunlight. Then the angle must be calculated from the farthest point of the shadow to the center point of the object. The angular calculation used is to use the trigonometric formula. Figure 5 shows the angle calculation method.

![Figure 5. Angle calculation method.](image)

3. **Results and discussion**
System testing was done by two methods, namely testing using lights and testing using direct sunlight. Testing using lights is done by moving the lamp at a certain angle. The purpose of this test was to determine the ability of the system to calculate angles and control its position. Lamp angle tested from 0° to 57°. Figure 6 displays a graph of the direction angle of the lamp compared to the angle read by the
system. From this test, it is known the value of $R^2 = 0.99$. This value states that the system can read the angle of the lamp following the angle set. Besides, the servo motor can move according to the given angle input.

![Figure 6](image1.png)

**Figure 6.** The actual angle vs the angle calculated by system.

The second system testing is direct testing using sunlight. Direct sunlight testing was carried out on the N building at Telkom University (Figure 7). The test is carried out for 90 minutes from 11:15 to 12:45 WIB. Azimuth and altitude obtained from the calculation of the object's shadow angle compared to the azimuth and altitude values displayed on SunCalc. SunCalc is a web that shows the position of the sun at a location. A comparison between the value of the measurement results of the system with the value on SunCalc aims to determine the accuracy of the calculation of angles based on the direction of sunlight from the system made. Figure 8 displays an example of the SunCalc display.

![Figure 7](image2.png)

**Figure 7.** Location of data collection [13].
The results of azimuth calculation and altitude for 90 minutes compared to Suncalc displayed on the graph in Figure 9 and Figure 10. Azimuth, at the beginning of the test obtained by the system, was 23°, then at the end of the test obtained 77°. Altitude, at the beginning of the test, the system gets a value of 65°, and at the end of the test gets 70°. Compared with the azimuth shown on Suncalc at the beginning of the test, 23.64°, and the end of the test at 75.43°. Then, for the altitude displayed on Suncalc at the beginning of the test, 65.07° and at the end of the test 64.11°. Based on testing for 90 minutes taken data every 1 minute, the accuracy of the system to get the azimuth (x-axis) is 95%, and the altitude (y-axis) is 96%. The results of this test show that the system can calculate the angle of the shadow of the object formed and move the system so that it is always perpendicular to sunlight.
4. Conclusions
In this research, a solar panel position control system has been developed based on image processing. The shadow image of objects in the form of bars used to determine the angle of incidence of sunlight. The results of our study are systems capable of tracking sunlight and following them with 95% azimuth (x-axis) calculation accuracy and 96% altitude (y-axis) calculation accuracy. The continuation of this research is the development of the system so that it can be used for a longer duration and different weather conditions.

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