A Robotic arm based automatic solar-tracking system

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Abstract. The automatic sun-chasing panel can effectively improve the utilization of solar energy by adjusting the robotic arm that keep a right angle towards the sunlight. The new tracking system searches the position of the sun by analyzing the video stream captured by the camera and then binarization and edge detection methods are adopted to prevent the interference of other light sources. In the contemporary world with the shortage of energy resource, automatic sun-chasing panels can effectively improve the utilization of solar energy, so that the photoelectric conversion rate stays at the peak at every moment, effectively alleviating the problem of energy shortage.

1. Introduction

In the contemporary world, solar energy is considered as an important renewable energy. The amount of solar energy reaching the surface of the Earth is enormous, equivalent to about twice the total amount of non-renewable resources such as the energy from coal, oil, natural gas and uranium harvested in a year.¹ The United Nations Development Programmer’s 2000 World Energy Assessment found that the annual potential of solar energy is 1,575-49,837 joules (EJ), which is several times more than the total energy consumption in the world.²³ At present, solar energy has become an increasingly attractive source of electricity among the countries in the world.

The potential solar energy that humans can use is different from the amount of solar energy present on the surface of the earth. In fact, currently, utilization of solar energy is pretty low. Factors such as geography, time changes, cloud cover and land available to humans affect our use of solar energy. Conventional solar panels are fixed to one direction, especially when they are used on moving objects that are not normally reversible in real time, such as cars or small vessels, which greatly reduces the use ratio of solar energy.

For solar installations, automatic chasing is an effective means to improve solar energy utilization. According to the study, compared with the fixed one, single-axis tracking can increase the power generation by more than 20%, dual-axis tracking can increase by more than 30%, and fully automatic can increase the power generation by 35%.⁴ Of course, the accuracy of tracking light will also affect the power generation efficiency. Nowadays, many solar brackets that can automatically adjust the angle also have problems such as complicated measuring device, high cost, inflexible adjustment of mechanical devices, poor stability, etc.,⁵ and are mainly used for large-scale power generation. Our goal is to use the camera, combined with image recognition technology, to achieve real-time effective control of the robot arm, so that to ensure the solar panels are perpendicular to the sunlight, and filter other sources of light, guarantee the max area of light received.
2. The constitution and working principle of solar-tracking system

2.1 Overall introduction of solar-tracking system

Each frame is divided into 100 areas of 10X10 and the brightest area is selected by comparing the average brightness of each area. By judging both color and shape of the light source, system can accurately select the sunlight and meanwhile, the binarization method is combined to reduce the deviation. When the test is done the position of the solar light source in the real-time image taken back by the camera can be found. Finally, the manipulator is manipulated to turn the solar panel to the direction of the light source to obtain the max light received area, thereby effectively improving the utilization rate. The proposed solar-tracking system is shown in figure 1.

![Figure 1](image1.png)

Figure 1. The overall flow chart of the solar-tracking system.

2.2 Algorithm for processing captured video of the solar-tracking system

As for the image analysis, first, pictures are got through the video stream, then converted into grayscale pictures, and finally binary method will be used to find the brightest area. Since the solar light source is an approximately circular white light, it is judged whether the two requests are fulfilled, and if not, the next brightest area is selected. In this way, the deviation can be effectively reduced and the position of the sunlight source can be accurately found.

 Originally, each frame is divided into 25 areas of 5X5 each frame is divided into 100 areas of 10X10 at first, but in this case, when part of the light source falls in the corner of some areas, due to the small area of the light, even though the gray value of that small part is high, the average brightness of the whole area may be small. In this way, the system is likely to select out a few brightest areas, unable to effectively manipulate the arm to turn the solar panel to the position of the solar light source. Further subdivision is taken to solve this problem. Then, the frame is divided into 100 areas of 10X10, but in this case, when the light source is large or the light source is close to the camera, light sources are likely to be distributed into several areas. In order to eliminate this error, the image is processed by a binarization method. The figure below shows the flowchart algorithm of the binarization.

![Figure 2](image2.png)

Figure 2. Algorithm of the binarization.

Step 1: Pixels with the largest and smallest gray value in the image will be selected and then their average value will be calculated and initially set as Q.

Step 2: The gray value of other pixels will be compared with Q, the gray value greater than Q is recorded as foreground, and the gray value smaller than Q is recorded as background.
Step 3: The average of all foregrounds and backgrounds will be calculated in this step, then the average of the two averages will be calculated and set as K.

Step 4: If K is not approximately equal to Q, Q will be superseded by K and then above steps are supposed to repeated.

Step 5: If K is approximately equal to Q, then Q at this time is the final value. Then, the gradation value of the pixel points whose gradation value is smaller than Q is set to 0, and the gradation value of the pixel point whose gradation value larger than Q does not change.

Step 6: In this case, segment the image to find the brightest area.

As shown in the figure below, the result of the binarization processing which prove that this method can effectively eliminate the error.

In order to determine whether the detected light source is circular light, the image is pre-processed first, the edges of the detected light source are connected to form an area, and then the areas are reprocessed. Divide the area of all these areas by the perimeter and see if the result is less than or close to the pie divided by two. If this condition is met and the area at this time is greater than the present value, then this area can be considered as circular light. Figure 4 shows the result of edge detection.
3. **hardware of solar-tracking system**

3.1 **Partial design of the mechanical bracket system**
We fix the camera on the top of the robot arm, processing the frame from the camera with a computer, and then turned the arm to the appropriate direction based on the results of the computer analysis.

![Image after preprocessing](image1.png) ![Edge detection result](image2.png)

Figure 4. Edge detection.

The solar panels and camera support use the six-axis robotic arm Sainsmart as shown in the picture above. Compatible with the Arduino, this robotic arm simulates a true palletizing robotic arm structure with durable PVC material and a range of servo systems, including four MG996 servos and two SG90 servo systems. It can be run on six axes, it can be programmed to move to every direction and it can very accurately turn the solar panel to the position of the sunlight source.

![Image of Arduino 101](image3.png)

Figure 5. The six-axis robotic arm Sainsmart.

3.2 **Electronic control part design (model of single chip microcomputer)**
The electronic control part uses the Arduino 101 microcontroller (figure 6), which includes the Intel® Curie module, which is designed to integrate the core's low power consumption and good performance with the ease of use of the Arduino. Compared with other microcontroller, it has Bluetooth low-power function and has an on-board 6-axis accelerometer/gyroscope, which can be effectively used with the Sainsmart six-axis robot arm.

![Arduino 101 microcontroller](image4.png)

Figure 6. Arduino 101 microcontroller.
4. Conclusion
In this paper, the new solar-tracking system has been designed and successfully implement, which can prevent the interference of other light sources and improve the photoelectric conversion. At present, solar energy accounts for an increasing proportion of global energy consumption. In the first quarter of this year, global solar power generation reached 12 GW, and power generation is still increasing. Most fixed solar panels have a photoelectric conversion rate of about 10%. Due to their low usage rate in the morning and evening, a few solar panels have a photoelectric conversion rate of 20%. However, by tracking and rotating, the photoelectric conversion rate can reach a peak at each moment, greatly improving the solar energy utilization rate, thereby bringing huge economic benefits. In addition, as a renewable and clean energy source, solar energy will also contribute to environmental protection. Therefore, it is clear that the wide promotion of automatic chasing solar systems can bring great rewards.

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