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Machine Vision-based for Development a Sun Tracking using Intelligent Algorithm

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***Abstract*—**In this project, Two degree of freedom (DOF) of light tracking system using fuzzy logic control is presented in this paper. The fuzzy control for light tracking system (FLTS) uses a web-camera as a vision sensor, two PC sound cards as output signal controller, and two DC motors as a pan-tilt driver mechanism. The Fuzzy logic controller to control the camera panel angles of light tracking system is designed. Two fuzzy controllers are proposed, one for each motor to produce proper PWM in order to track the light source. A typical FLC includes three basic components, an input signal fuzzification, a fuzzy engine, and an output signal defuzzification. The Fuzzy controller input parameters (Xcp,Ycp) and variation of duty cycle output parameters are used to generate the optimal pulse-width- modulated (PWM) to track the light source, such that PWM is generated under different operating conditions to drive the motors. The motors will react accordingly when they receive signal from the sound card to make sure the camera always focuses on the centroid of the light source. The system tested at different locations. The data which were obtained by experiment were able to show a validity of the proposed controller.

***Keywords*—**DC motor, duty cycle, fuzzification, image processing, PWM, sound card, vision sensor, webcamera.

I. Introduction

INTELLIGENCE techniques are becoming useful as alternative approaches to conventional techniques. They have been used to solve complicated practical problems in various areas and are becoming more popular nowadays. They are able to deal with nonlinear problems, and once trained can perform prediction and generalization at high speed. Intelligent-based systems are being developed and deployed worldwide in a wide variety of applications, mainly because of their symbolic reasoning, flexibility and explanation capabilities [1]. Detection and tracking of light in image sequences has applications to many problems such as improve efficiency for solar cell, sun finder, robot applications and solar tracking system. Light tracking systems is an application of the Machine Vision (MV), as an instance the output of solar cells depends on the intensity of sunlight and the angle of incidence. It means to get maximum efficiency; the solar panels must remain in front of the sun during the whole day [2]. In this paper, we present a system for light tracking based on computer image processing and sound cards. FLC and pulse width modulation (PWM) methods are used to generate a pulse for drive controllable switch. In this paper we present the design of PC-based fuzzy controller that is applicable to light tracking system. It is used to operate a motor of tracking system according to change of error that is received from the image sensor (camera). Fuzzy logic control is one of the best and most successful techniques and is well known as an important tool to control non-linear, complex and ill-defined systems [3]. Fuzzy logic controller is a rule-based controller where a set of rules represents a control decision mechanism to correct the error of the object position depending on the data coming from image analysis. The fuzzy theory based on fuzzy sets and fuzzy algorithms provides a general method of expressing linguistic rules so that they may be processed quickly by a computer [4]. Furthermore, the developed technique gets rid of the inference engine and the defuzzification, defining the main parts of fuzzy controller, by applying fuzzy reasoning to crisp sets. In the present contribution, the main goal in developing a light finder and light tracking was to provide as much as capability and flexibility as possible in an affordable system that can be implemented on general-purpose systems.

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II. Overall System Presentation

The overall system of the proposed light tracking control system using FLC is shown in **Figure 1**.

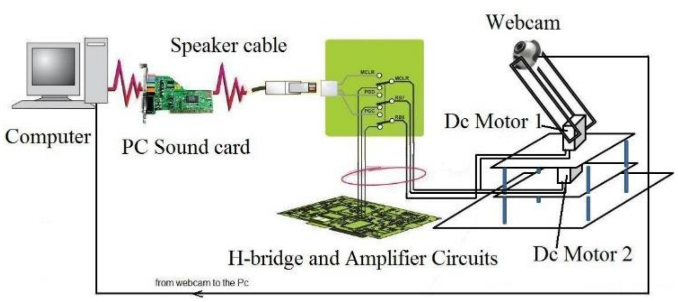


Figure 1 Components of interfacing LTS

The structure has two degree of freedom, motorized by two DC motors with incorporated camera, a PC sound card, and controller to track exactly the prescribed path of the light. The main part of the mechanical setup is a panel on top of which the camera is mounted. A feedback signal is produced from the vision sensor (Camera) since the image processing block analyses the image to determine the position of the light source.

Then, the controller delivers an output, the corresponding PWM signals, to drive the DC motors. Thus, the directions of the two dimensional camera platforms can be tuned to achieve optimal control, respectively.

III. Controller Design for LTS

In this section the goal are to design FCX (fuzzy controller for X-axis) and FCY (fuzzy controller for Y-axis) to control the PWM parameters, see **Figure 2**.

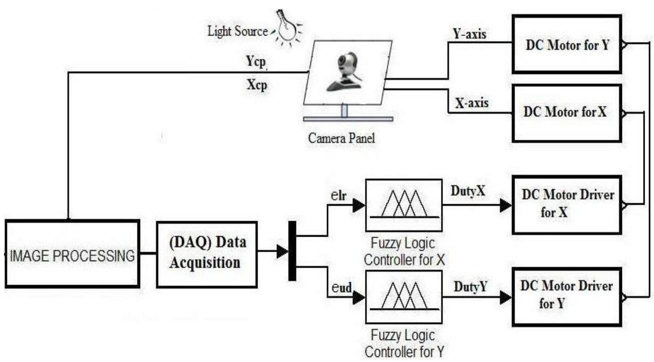


Figure 2 System architecture of the light tracking system

Figure 2 shows FCX is the controller of the X-axis and FCY is the controller of the Y-axis because two controllers must be design simultaneously. The camera is designed to detect object of the specific shape and calculates the centroid of the object in pixel coordinates. Basically, the overall system of the control program is set by the pixel of the picture. The overall pixels of the web-camera will be represented by M x N. The image will be split into four regions which is the center of the image is calculated as the total number of pixel rows and columns are divided by two, the overall pixel of the web-camera are represented by 320 x 240, see **Figure 3**.

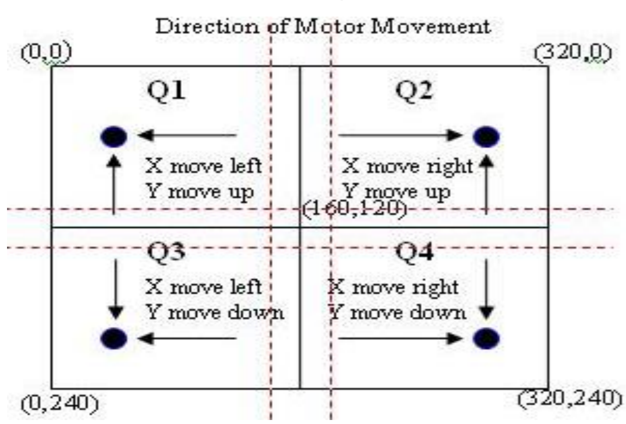


Figure 3 The quadrant approach by pixel coordinate

In non-fuzzy design, the motor has to move in certain directions when the PC receives signal from the camera and then analyses the image and send PWM through sound card to remove the error if bigger or smaller than 160 for the X direction and 120 for the Y direction. However, a major problem with this method the duty cycle to generate PWM is a fix value, it's about 40-50%. In this case, to make sure the camera always focuses on the centroid of the light source we send many pulses especially in the first time. Therefore, the system spends more power to reach to the goal. In this paper we used fuzzy controller to evaluate the duty cycle depend on the input error and then produce and send PWM through the sound card to switch circuit to drive the motor to correct the error produced from the light movement and to make sure it always focuses on the target of the light. The flow chart of the system is shown in **Figure 4**.

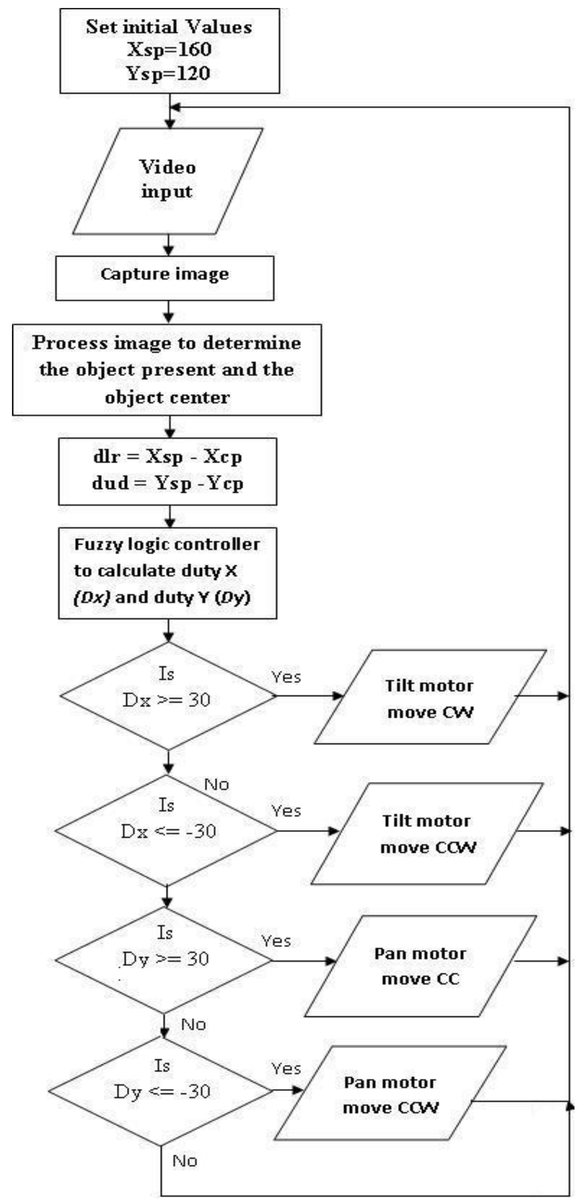


Figure 4 System's flow chart

The camera will always see the light source as video is being recorded. It will snap the image of the light source when the pulse generator is enabled and the image processing will begin. The image will be enhanced, put threshold on, eroded and dilated before it is analyzed. Then, the centroid of image is determined with the number of object present in the image. After the pixel coordinates is done to the image, the system will continue with DAQ process. **Figure 4** shows the DAQ check if the error is bigger than 30% of duty cycle than send PWM to correct the error because this value experimental is the best value to save the power consumption. By using fuzzy controller we reduced the number of pulses to one pulse or maximum two pulses to correct the error.

IV. The Fuzzy logic Control Algorithm

A fuzzy logic control algorithm for motion control systems expresses the knowledge of the system behavior in linguistic control rules and converts them into crisp control law [5]. Therefore fuzzy logic control techniques can be applied to control complex nonlinear systems with unknown dynamics. The light tracking system considered in this paper has unknown model and unknown parameters. The system dynamics can be approximately modeled by four linearized differential equations, two of them represent the electric circuit of each motor and the other equations represent the mechanical equation in the left-right and up-down directions. The moment of inertia, friction coefficient and backlash of the rotating parts are unknown. However, the system behavior is fully understood and the motor voltages (control signal) can be related to the input signal in terms of linguistic if-then rules. Therefore, in order to avoid system modeling and parameter identification, a fuzzy logic-based control algorithm utilizing the knowledge of the system behavior is investigated. Two fuzzy controllers are proposed one for each motor to produce proper PWM in order to track the light source. A typical FLC includes three basic components, an input signal fuzzification, a fuzzy engine, and an output signal defuzzification [7]. The basic structure of a fuzzy logic controller (FLC) is shown in **Figure 5**.

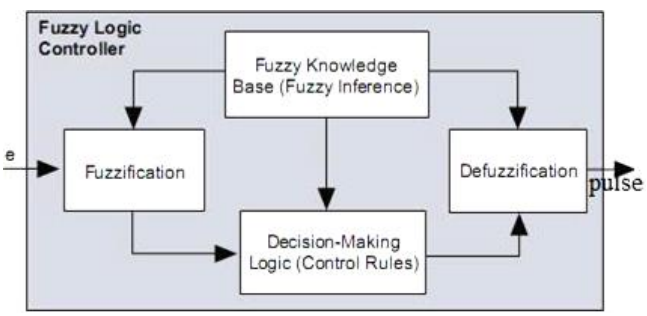


Figure 5 The basic structure of a fuzzy logic controller

In the fuzzification block, the continuous input signal is transformed into linguistic fuzzy variables. The fuzzy engine handles the rule inference where human experience can easily be injected through linguistic rules. The defuzzification module performs the mapping from a space of fuzzy control actions defined over an output universe of discourse into a space of crisp control actions that can be applied to the light tracker. The design procedure of the Fuzzy-logic controller is briefly described in the following subsections.

A. Fuzzification

Fuzzification is the process which determines the degree of membership of the input values to defined fuzzy sets (linguistic variables) [8]. In the case of the PWM to control motors, the input variables to the controller are defined as:

$$d_{\mathrm{lr}} = X_{\mathrm{sp}} - X_{\mathrm{cp}} \quad (1)$$

$$d_{\mathrm{ud}} = Y_{\mathrm{sp}} - Y_{\mathrm{cp}} \quad (2)$$

where d_{lr}, d_{ud}, X_{sp}, Y_{sp}, X_{cp}, and Y_{cp} are the position errors in the lift-right direction or clockwise (CW) and counterclockwise (CCW) for tilt motor, the position errors in the up-down direction or clockwise (CW) and counterclockwise (CCW) for pan motor, set position on x-axis (160), set position on y-axis (120), the current position on the x-axis, and the current position on the y-axis, respectively.

These variables converted to linguistic variables which may be viewed as labels of fuzzy sets. Seven linguistic variables are used for inputs, namely, positive big (PB), positive medium (PM), positive small (PS), zero (ZE), Negative small (NS), negative medium (NM) and negative big (NB). A fuzzy set is defined by assigning the grade of membership values to each element in the universe of discourse. The choice of membership function is mainly dependent on the designer preference [9].

B. Build Membership Input Functions

Based on the defined linguistic variables, we built the input membership functions. In this paper, triangular-shaped membership functions, shown in **Figure 6** are used.

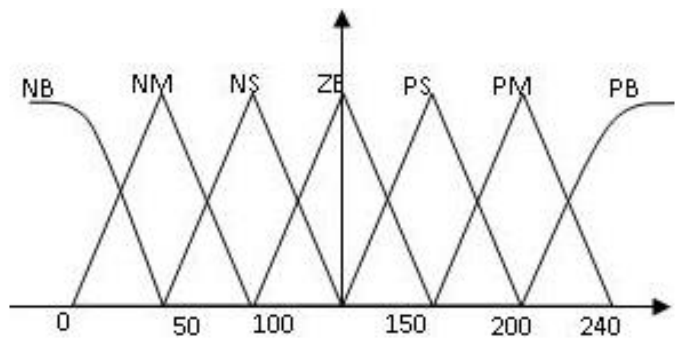


Figure 6 Triangular-shaped membership functions of input variable (X)

C. Set Up Fuzzy Rules Base

The setup of the fuzzy rules base is crucial because all states must be operated based on the rules defined in the rules base. To set up a fuzzy rules base smoothly, we adopted seven fuzzy control rules expressed with IF THEN statements. The control inputs are considered to be X_{cp} (current position on X-axis), Y_{cp} (current position on Y-axis). The linguistic variables and the membership functions for both Duty-X and Duty-Y are selected to be the opposite as those of the input variables. The following fuzzy rules are used for both motors.

Table I shows IF-Than rules for the motor PWM. It shows if the location of the light source in the tolerance zone it means the input is zero then the motor should be at rest but if the input is positive then duty cycle should be generated to drive the motor to the clockwise direction. Finally if the input is negative then duty cycle should be generated to drive the motor to the counterclockwise direction.

TABLE I FUZZY RULES FOR THE MOTOR PWM

	Inputs	outputs
Rule	***if***	***then***
	NB	PB
	NM	PM
	NS	PS
	ZE	ZE
	PS	NS
	PM	NM
	PB	NB

D. Define Fuzzy Inference Engine

There are many fuzzy inference methods and different results are inferred with different methods. In this project we use the center of gravity method proposed by Mamdani as the defuzzification tool because the method is easy and reliable.

E. Defuzzify Result

We defuzzify the result inferred by the fuzzy inference engine to convert the information into precise numbers. The aim of the defuzzification block is to produce a crisp control action that best represents the possibility distribution of an inferred fuzzy control action. Many strategies for performing defuzzification such as max criterion, the mean of max, winner takes all and center of gravity methods are available in the literature [10]. The widely used method for defuzzification is the center of gravity (COG) which is adopted in this paper. The result of the defuzzification has to be a numeric value which determines the duty factor of the PWM signal used to drive the motor. It is obtained by finding the centroid point of the function which is the result of the multiplication of the output membership function and the output vector.

$$\text{Defuz } Y = \frac{\sum_{i=1}^{n} \text{Dut } y_i \, \mu(\text{Dut } y_i)}{\sum_{i=1}^{n} \mu(\text{Dut } y_i)} \quad (3)$$

$$\text{Defuz } X = \frac{\sum_{i=1}^{n} \text{Dut } x_i \, \mu(\text{Dut } x_i)}{\sum_{i=1}^{n} \mu(\text{Dut } x_i)} \quad (4)$$

where Dut y_i and Dut x_i is the degree of membership of the output variable, it's the duty factor to produce the PWM.

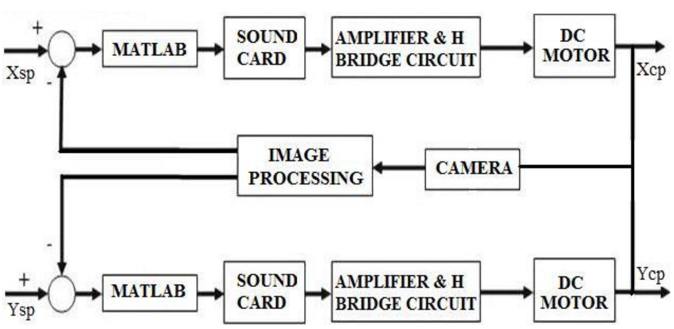


Figure 7 Flow of the hardware and software

V. HARDWARE IMPLEMENTATION

The motor and H-Bridge circuits receive a DC power supply while camera and PC uses AC power supply. This system is fully controlled by the MATLAB SIMULINK software in real time. **Figure 7** shows the flow of the LTS.

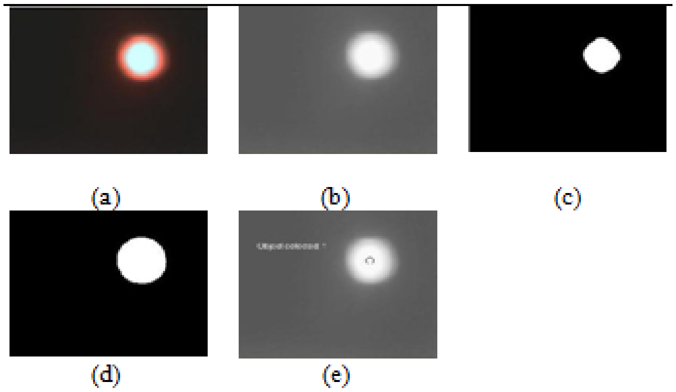
To operate the systems, the user has to click the play button in the SIMULINK browser. Before that, the time is set to infinite to make sure the systems will always running all the time. Firstly, the image will be captured, and the Video and Image Processing Blockset blocks can import the image from web camera into the Simulink environment and perform two-dimensional filtering, geometric and frequency transformation, block processing, motion estimation, edge detection, and other signal processing algorithms. Then, image will be processed in the MATLAB Simulink until the real image appears in black and white colors only. The image of camera is represented by frame and the frame can be split into four regions. The object is determined by region it detected and MATLAB sends the data from the analog output from sound card to the motor to move the camera panel. The output from sound card will pass through the op-amp to increase the voltage with the gain set and enter the H-Bridge circuit. The motor will rotate according to the output from the entire sound card and the H-bridge circuit used. Note that, one H-bridge circuit is used for one output channel from sound card. The image will be scanned again and the motor will run until the image appears at the center of the frame. The camera will always capture the image and send data to the motor if the object is not at the center of the image. Finally, the system is complete when the camera can act as an eye and the motors can run as an actuator of the system.

VI. EXPERIMENTAL RESULT

According to the quadrant approach **Figure 3**, the result of the experiment has been done at different locations. In this paper the test of the experiment that has been done for four quadrants, let us choose any quadrant to prove this system is successful to track the light source or not. In our test the frame is set to move right and up if the object appears in the Q2, also set to move right and down if the object appears in the Q4 and so forth, from this concept, the position of the camera should be at the center of the light. The result are including the measurement of the object position to calculate the error in the X-axis and Y-axis and then remove it to make sure the camera always focuses on the centroid of the light source. The data which were obtained by experiment were able to show a validity of the proposed controller.

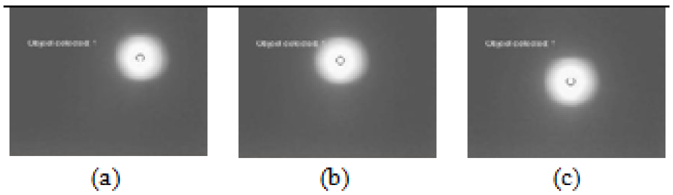
TABLE II RESULTS FOR FUZZY CONTROLLER OUTPUT BY DUTY CYCLE FOR X AND Y

location	*Time (sec)*	*DutyX (Dx)*	*DutyY (Dy)*
1	*0*	*-30.7*	*+ 31.3*
2	*1*	*-3.6*	*+ 31.3*
3	*2*	*-3.6*	*+ 3.1*



(a) Image from video input (c) Video erosion
(b) Video after enhancement (d) Video dilation
(e) Centroid detector

Figure 8 Location 1 the image after enhancement, erosion, dilation and centroid



(a) The camera detected the light source
(b) The system correct the X-axis error
(c) The sysem correct the Y-axis error

Figure 9 The camera at the center of the light after two steps

From the result shown in **TABLE II** the system at the start tries to detect and determine which quadrant the light source is in by calculating the camera current position related to the X-axis and Y-axis. The positive and negative sign in above table refer to the directions, up or down, right or left. From the above mention results, the system has to move the camera panel to right for x-axis and up for Y-axis. Also, we see that after detected the light source location, the system starts to correct the error in the X-axis and in the Y-axis in one PWM output from the sound card for each axis, which means the FLC is successful to calculate the duty cycle according to the input data from **TABLE II**. In this case, we prove that the duty cycle in this paper not fix value but a variable value.

TABLE III RESULTS FOR FUZZY CONTROLLER INPUT BY PIXELS FOR X AND Y

location	*Time (sec)*	*Xcp*	*dlr*	*Ycp*	*dud*
1	*0*	*210.3*	*-50.3*	*81.7*	*38.3*
2	*1*	*164.2*	*-4.2*	*81.7*	*38.3*
3	*2*	*164.3*	*-4.3*	*117.3*	*2.7*

Also we see in **TABLE III**, the dlr or dud decreases. It means the system tries to remove the error to enter to the tolerances range. In this experiment, we have only 2 pulses generated to control the motor. As we can see the tracing time is only 2 sec and the number of pulses is one for each axis or maximum two for each. Therefore, the good system is the system that has the low number of pulses with best accuracy, or the time of the tracking is short with small error.

VII. CONCLUSION

We present a system for a real-time visual tracking system employing a visual tracking technique using camera as a vision sensor and sound cards as an output channel to drive a motor. It offers real-time robust tracking performance as it can search all areas of an image to perform a matching operation. The theory that stated the sound card can generate the PWM that control the motor is true and we have proved in this paper. It can help make a smaller, lower cost, and lower power visual tracking system. It is easy, as required, to modify and update this circuit. When the proposed circuit is used in a system which requires the visual tracking function, only a small percentage of the system resources are allocated for visual tracking. The remainder of the resources can be assigned to preprocessing stages or to high level tasks such as recognition, trajectory interpretation, and reasoning. We have demonstrated that this real-time visual tracking system, combined with other technologies, can produce effective and powerful applications. Now we can consider the light tracking system are ready to use as a devices for efficiency improvement for solar tracking system. The unique feature to use this system as a device for solar tracking system is that it can takes the light as a guiding source.

REFERENCES

[1] Soteris Kalogirou, Kostas Metaxiotis, Adel Mellit, Artifcial Intelligence Techniques for Modern Energy Applications. IGI Global, 2010.

[2] Muhammad Faheem Khan, Rana Liaqat Ali. (2009, Nov.) seminarprojects.[Online]. VIEW

[3] U. Yolac, T. Yalcinoz, "Comparison of fuzzy logic and PID controllers for TCSC using Matlab," in Universities Power Engineering Conference, Turkey, 2004, pp. 438-442.

[4] C.Y. Won, D.H. Kim, S.C. Kim, W.S. Kim, H.S. Kim, "A New Maximum Power Point Tracker of Photovoltaic Arrays using Fuzzy Controller," in Proceedings of the IEEE Power Elec. Specialists Conference, 1994, pp. 396-403.

[5] Li, Y.F. Lau, C.C., "Development of fuzzy algorithms for servo systems," Control Systems Magazine, IEEE, vol. 9, no. 3, pp. 65-72, Apr. 1989. CrossRef

[6] K. M. Passino and S. Yurkovich, Fuzzy Control. Addison-Wesley-Longman, Menlo Park, CA, 1998.

[7] Jung-Sik Choi Do-Yeon Kim Ki-Tae Park Chung-Hoon Choi Dong-Hwa Chung, "Design of Fuzzy Controller based on PC for Solar Tracking System," in International Conference on Smart Manufacturing Application, KINTEX, Gyeonggi-do, Korea, 2008, pp. 508-513.

[8] Dr. Odry Peter, Diveki Szabolcs, Csasznyi Andor, Burany Nandor, "Fuzzy Logic Motor Control with MSP430x14x," Instruments Incorporated, Texas, Application Report SLAA235, 2005.

[9] Ying-Shieh Kung Chang-Ming Liaw, "A fuzzy controller improving a linear model following controller for motor drives," Fuzzy Systems, IEEE Transactions on, vol. 2, no. 3, pp. 194-202, Aug. 1994. CrossRef

[10] W. Pedrycz, "Fuzzy Control and Fuzzy Sysfems," Research Studies Press (RSP) ltd 0471 9231 17, 1989.