VISUAL-BASED INTELLIGENT SOLAR TRACKING SYSTEM

BY

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ABSTRACT

Global warming and the drive to minimise greenhouse gas emissions has put the focus on how to make the most of natural energy sources. The sun is freely available almost everywhere in the world and intelligent solar tracking can help improve the exploitation and efficiency of these sustainable sources of energy. Two degree of freedom (DOF) visual-based intelligent solar tracking system using fuzzy logic control is presented in this project. The fuzzy control algorithm for solar tracking system is implemented using a webcamera as a vision sensor, two PC soundcards as output signal controller, and two DC motors as a pan-tilt driver mechanism. Two Fuzzy logic controllers are designed to control the camera panel angles of the proposed solar tracking system. The fuzzy controller input parameters (light source pixel coordinate) and output parameters (variation of duty cycle) are used to generate the optimal pulse-width- modulated (PWM) under different operating conditions to drive the motors. The motors will react accordingly when they receive signal from the sound card to ensure the camera always focuses on the centroid of the light source. The major issue addressed in this project is the reduction of the number of pulses that are sent through the soundcards to move the motors. This will significantly reduce the power consumption required to drive the camera panel to the desired location. Also using a webcamera and a sound card reduces the circuitry required when compared with conventional solar tracking systems, hence, minimizing the number of components, such as xPC target, encoder, tachometer, analog to digital converter (ADC) or digital to analog converter (DCA) and others. In short intelligent solar tracking is an obvious way to improve the efficiency of solar power plants. As the sun moves across the sky, an electric actuator system ensures that the solar panels automatically follow and maintain optimum angle in order to collect the most of the sunbeams. The proposed system in this study still has some points that need to be improved, so far, the most important limitation lies in the fact that it is not recommended to use this system for small solar panels because of high energy losses in the driving systems. The system was tested at different locations; the results of this project indicate that it is obvious that the intelligent sun tracking system is more effective in collecting solar energy compared with stationary solar panel. It can increase the voltage, current, surface temperature and power of the solar cell. The power increase gained and the efficiency over a stationary array was in excess of 67% and 40%, respectively. The data obtained by experiment such as voltage received, current, power, surface temperature and others justify the validity of the proposed controller.

خلاصة البحث

ان لإرتفاع درجة الحرارة في الكرة الأرضية والتداعيات الى تقليل انبعاثات غازات الاحتباس الحراري وضعت التركيز على كيفية الاستفادة القصوى من مصادرالطاقة الطبيعية. ولان الشمس متاحه في كل مكان في العالم تقريبا فان لاستخدام التتبع الذكي للطاقة الشمسية دورا في تحسين كفاءة استغلال مصادر الطاقة المستدامة هذه. في هذا البحث, نقدم نظام تتبع الطاقه الشمسيه الذكي ثنائي حريه الحركه معتمدا على الرؤيه الصوريه لموقع الشمس مستخدما نظريه المنطق الضبابي للتحكم. ان خوارزميه التحكم الضبابي لنظام تعقب الطاقه الشمسيه طبقت باستخدام ويب كاميرا كمتحسس للرؤيا, بطاقتان للصوت في الكومبيوتر كمخرج لاشارة التحكم ومحركان يعملان بالطاقه المستمرة لميكانيكة الحركه. في هذا النظام تم تصميم متحكمين بمنطق ضبابي للسيطرة على زوايا لوحة الكاميرا. ان وظيفه المتحكم الضبابي في هذا النظام هو توليد النبضه الامثل (PWM) المرسله الى المحركات بالاعتماد على معاملات الادخال (حسب احداثيات موقع مصدر الضوء) وذلك لادارة حركه واتجاه المحاور طبقا لاختلاف مواقع مصدر الضوء. المحركات تستجيب وفقا لطول الموجه المحددة من المتحكم الضبابي عند استلام الاشارة من كارت الصوت من اجل ضمان ان الكاميرا دائما موجه باتجاة مركز الضوء. ان من اهم الاهداف المطروحه في هذا المشروع هو تقليل عدد النبضات المرسله خلال بطاقه الصوت وهذا من شأنه ان يساهم بتقليل كبير لاستهلاك الطاقه اللازمه لتحريك لوحه الكاميرا للاتجاه المطلوب. وكذلك ان لاستخدام الويب كاميرا وبطاقه الصوت دور في تقليل الدوائر الكهربائيه بالمقارنه مع انضمه التتبع التقليديه, وعليه تم تقليل الاجزاء الالكترونيه المستخدمه مثل ال Xpc target , المشفر, والتاكوميتر, DAC , ADC وغيرها. من هذا كله نرى ان نظام التتبع الذكي هذا له اثرة لتحسين كفائه الخليه الشمسيه من خلال توجيه هذا الخليه عموديا وبصورة مستمرة مع اشعه الشمس. ومع ذلك فان هذا النظام لازل بحاجه لتحسين بعض النقاط وعليه فان من اهم المحددات هي ان هذا النظام لا يوصى باستخدامه كنظام تتبع اذا كان عدد الخلايه قليل لسبب ارتفاع الطاق المستهلكه نسبيا. تم اختبار هذا النظام في مواقع وازمان مختلفه ومن النتائج تبين ان نسبه الزيادة في الطاقه والكفائه كانت 67% و 40% على التوالي وعليه فان النتائج المستحصله من التجارب مثل الفولتيه المستلمه, التيار, القدرة, ودرجه حرارة سطح الخليه وغيرها اثبتت صحه نظام السيطرة المقترح.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Mechatronics Engineering).

Rini Akmeliawati
Supervisor

Riza Muhida
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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Mechatronics Engineering).

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Amir Akramin Shafie
Dean, Kulliyyah of Engineering

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Samir A. Abdul Kareem

Signature .... Date ....

INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

DECLARATION OF COPYRIGHT AND AFFIRMATION OF FAIR USE OF UNPUBLISHED RESEARCH

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Signature Date

My beloved parents, wife & this humble effort is fully dedicated to the Islamic nation

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All praise to Almighty Allah (SWT) and salutation upon the Prophet Muhammad (PBUH). All creations are blind without His guidance.

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LIST OF ABBREVIATIONS

ADC	Analog to Digital Converter
CCW	Counter Clockwise
CW	Clockwise
DAC	Digital to Analog Converter
DAQ	Data Acquisition
DOF	Degrees Of Freedom
FCX	Fuzzy Controller for X-Axis
FCY	Fuzzy Controller for Y-Axis
FIS	Fuzzy Inference System
FLC	Fuzzy Logic Control
ISTS	Intelligent Solar Tracking Systems
MV	Machine Vision
NB	Negative Big
NM	Negative Medium
NS	Negative Small
N-S	North-South
PB	Positive Big
PLC	Programmable Logic Controller
PM	Positive Medium
PS	Positive Small
PV	Photovoltaic
PWM	Pulse Width Modulation
STS	Solar Tracking System
UV	Ultra Violet
VR	Virtual Reality
W-E	West-East
ZE	Zero

LIST OF SYMBOLS

dx Position errors in lift-right direction.

dy Position errors in up-down direction.

X_{sp} Set position on x-axis.

Y_{sp} Set position on y-axis.

X_{cp} Current position on x-axis

Y_{cp} Current position on y-axis.

dlr Position errors in clockwise (CW) and counter clockwise (CCW) for tilt motor.

dud Position errors in (CW) and (CCW) for pan motor.

Xsp set position on x-axis

Ysp set position on y-axis

Xcp Current position on x-axis

Ycp Current position on y-axis

$\mu(Duty_i)$ The degree of membership of the output variable y-axis

$\mu(Dutx_i)$ The degree of membership of the output variable x-axis

$DutX$ The duty cycle factor to produce the PWM for X-axis

$DutY$ The duty cycle factor to produce the PWM for Y-axis

CHAPTER ONE

INTRODUCTION

1.1 OVERVIEW

Visual-based intelligent systems are being developed and deployed worldwide in a wide variety of applications, mainly because of their symbolic reasoning, flexibility and explanation capabilities (Kalogirou and Soteris, 2007). Solar energy is rapidly advancing as an important means of renewable energy resource (Barsoum and Nader, 2009). Moreover in remote areas the sun is a cheap source of electricity using solar cells to produce electricity. While the output of solar cells depends on the intensity of sunlight and the angle of incidence, therefore to get maximum efficiency the solar panels must facing the sun during the whole day. But due to rotation of earth those panels unable maintain their position always facing the sun (Khan and Ail, 2009). As well as intelligence techniques are becoming useful as alternate approaches to conventional techniques or as components of integrated systems. They have been used to solve complicated practical problems in various areas and are becoming more popular nowadays. They can learn from examples, are fault tolerant in the sense that they are able to handle noisy and incomplete data, are able to deal with nonlinear problems and once trained can perform prediction and generalization at high speed. Therefore, intelligent solar tracking systems have received a lot of attention in recent times.

1.2 SUN-TRACKING METHODS

When tracking objects, which are moving in the sky, there is a number of tracking techniques that can be used. The two most common techniques which can be used for tracking objects, such as the sun, are the:

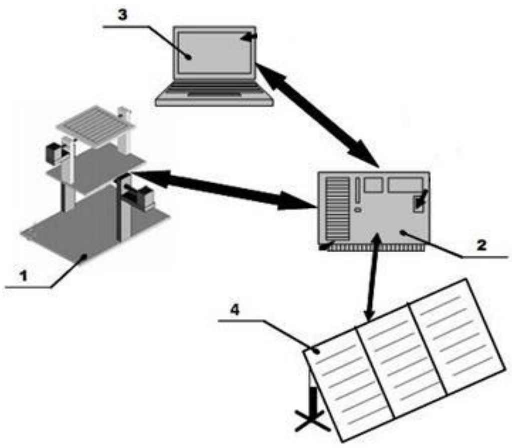
1. Fixed control algorithm method
2. Dynamic method

The main difference between these two methods is the way the position of the sun is determined. The fixed control algorithm method determines the path of the sun by referencing an algorithm that calculates, for each time period, the position of the sun. This method does not actually “find” the sun in the sky, but instead works out the position of the sun from specific, given data. This data is usually the current time, day, month and year.

The dynamic method is a system that actually finds the position of the sun based on sensory input. That is, data from light sensitive sensors is used such that the system can actively “find” the sun. Since the sensory data is continuous, the system can follow (track) the sun’s movement across the sky (Scott J. Hamilton, 1999).

1.3 OVERALL SYSTEM PRESENTATION

The overall system is presented in Figure1.1. The complete system is composed of 4 sub-systems (Figueiredo and Costa, 2008):



1) Electro-Mechanical Structure   2) Control Unit
3) Supervisory System   4) Photovoltaic (PV).

Figure 1.1: Overall system presentation

The structure has two degrees of freedom (DOF); it will be managed by MATLAB® image processing program. This is programmed to detect the sunlight through the camera and then actuate the motor to position the solar panel where it can receive sunlight. It motorize by two DC motors with incorporated camera in order to track exactly the prescribed path of the light.

The camera is the vision sensor to perform machine vision method, it is the main sensor to play the main role to detect object of the specific shape also to ensure the object always in the centre of the picture. The main task performed by the system is to control the two DC motors of the pan-tilt mechanism.

The second part from the system is a control unit. It is containing a control circuits, main program, sound card, DC motor and camera. The main tasks should be performed by the system are to control the two DC motors of the pan-tilt.

1.4 PROBLEM STATEMENT AND ITS SIGNIFICANCE

To get maximum output power from the solar cells the solar panels must be facing the sun during the whole day because the output of solar cells depends on the intensity of sunlight and the angle of incidence, but due to rotation of earth those panels unable maintain their position always facing the sun. This results in decrease of their output power. Thus, to improve the output power, an automated system is required to constantly rotate the solar panel. In addition, almost of the sunlight tracking approaches introduced system based design which used light sensing device, light following according to the calendar and others. To develop new approach in designing tracking system using camera and sound card as well as to make visual tracking system intelligent in a way that it performs monitoring of the sunlight to increase photovoltaic energy production are challenging problem to be studied. Therefore, visual-based intelligent solar tracking systems (ISTS) have received a lot of attention in recent times.

1.5 RESEARCH OBJECTIVES

1. To construct a two degree of freedom (DOF) mechanical structure of the solar tracking system (STS).
2. To design and implement visual-based control system to locate the sun position by using camera and sound card as the alternative sensory devices.
3. To detect and track the light using intelligent tracking system hence reduced the power consumption.
4. To increase the efficiency of solar tracking system and sensory devices.
5. To analyse the performance of the intelligent visual tracking system.

1.6 RESEARCH METHODOLOGY

The entire tasks for this project have been stated in the below list:

1. Literature review.
2. Primary data/information collection.
3. Possible modification or improvements have accomplished to enhance the efficiency and effectiveness of the webcamera to see the sun.
4. Hardware selection and acquisition the most suitable motors, gears, coupling, camera and sound cards to be use.
5. Software design which has been implemented in to the intelligent solar tracking system (ISTS).
6. Hardware design which has been fabricated the mechanical design, built control circuits and study on how sound card produces pulse width modulation (PWM) to send control signal depend on data from camera.
7. Simulate system in MATLAB™ – SIMULINK®.
8. Design implementation.
9. Testing and measure its responses.

1.7 SCOPE OF RESEARCH

The scope of this project encompasses both hardware and software design and implementation. In other words this project is focused to design and build the prototype of intelligent solar tracking system to track the sun position in real time. As for the hardware, designing and construction of mechanical structures are needed. The designed intelligent control system should track the movement of sun (light radiation) to maximize the output of the solar panel by using webcamera as a vision sensor to determine the sun position so far send PWM through the two PC sound cards to move two DC motors to ensure that the sun is in the center of image at a clear day under MATLAB™ program environment.

1.8 DISSERTATION OUTLINE.

This thesis will be presented in seven chapters. Chapter Two describes the literature survey of sunlight tracking system. Also previous works by some of researcher on the STS are explored and elaborated. The overview of energy gain in tracking systems, sun-tracking techniques, solar cell theory, motor and motor driver theory, fuzzy logic control theory, and machine vision theory are presented. Chapter Three explains the methodology used and the design considerations undertaken in this project. The chapter also explains the design procedure of intelligent and non intelligent controller that will be used in the tracking system. Chapter Four explains solar tracking system design and implementations. It also contains descriptions of the overall system (hardware and software).

Chapter Five discusses the development of control software and data acquisition (DAQ). It explains the steps of control program design for intelligent STS and non intelligent STS.

Chapter Six gives an analysis of the data obtained during testing our system.

Chapter Seven summarizes the entire work explained in previous chapters. Suggestions and future works are also presented.

CHAPTER TWO

LITERATURE SURVEY

2.1 INTRODUCTION

In today's high-tech environment, energy has become the impetus for socio-economic development. Since the Industrial Revolution, humans have used fossil fuels as their primary energy source. However, the amount of fossil fuels on the earth is limited, and their use has caused unprecedented changes to the global ecological environment and climate. Gases from burning fossil fuels can build up in the atmosphere, becoming thicker and thicker to produce greenhouse effects such as rising global temperature and sea level. These effects will dramatically alter our living environment. Fortunately, humans are becoming more conscious of environmental protection, and are seeking new energy sources that cause less pollution and do not threaten the environment. As a free, non-polluting, inexhaustible energy, solar energy is ideal for generating electricity. The construction of a mechanism which follows the sun is not a new problem. The first attempt in Chile was completely mechanical, done by Finster in 1962 (Finster C., 1962). Saavedra A. S., (1963) presented a mechanism with automatic electronic control. It was used to orient an Eppley pyrheliometer. Currently, generating electricity by solar energy is inefficient; this project focuses on how to improve its efficiency. A solar panel receives the most sunlight when it is perpendicular to the sun's rays, but the sunlight direction changes regularly with changing seasons and weather. Currently, most solar panels are fixed, i.e., the solar array has a fixed orientation to the sky and does not turn to follow the sun. To increase the unit area illumination of sunlight on solar panels, solar tracking electricity