Sunlight Tracking System Using Neural Network

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Abstract

Computer-controlled systems are of great interest in today's world. These systems have spread into many areas of applications, such as environmental protections, military affairs and factory controls. Computer-controlled systems are compact and efficient to operate reducing the human effort. This paper tries to develop a computerized system that will automatically keep track of the sunlight. This system comprises Light Dependent Resistors (LDRs) that are fitted at both ends of the solar plate for sensing the light. Light sensing circuits of the system produce an analog voltage level and the analog voltage level is converted into digital level using the Analog to Digital Converter (ADC). These digital values are applied into the computer system and by means of Artificial Neural Network (ANN), it determines the width of the pulse to rotate the DC motor in order to be the solar plate face to face with the sunlight.

1. Introduction

Computer controlled systems reduce the number of components in the systems and consequently can get rid of the component malfunctioning. By means of computerized controlling the systems, compact and precise systems can be obtained. In this system, a computerized controlled light tracker system has to be constructed.

Electrical energy demand increases as the population as well as the people's intimacy with the use of electricity. At this point, the solar plates are favorites to get electricity from the free and plenty natural sunlight. The solar plate has to be fixed exactly face to face with the sun to get efficient use of sunlight.

In this paper, the computer-controlled light tracker is developed. In this system contains two light sensing circuits; the intensities of the light detected by light sensing circuits and the three-bit flash Analog to Digital Converters (ADCs) convert this into digital values. These digital values from two LDRs at both ends of the solar plate are applied into the computer system. By means of Neural Network, the computer system determines the width of the pulse to be applied into the pulse width modulation DC motor driver circuit to rotate the solar plate. Input and output operations to and from the computer system are carried out via parallel interfacing and Turbo C++ programming language is used to implement this paper.

This paper is organized with seven sections. The first section deals with introduction of the system. Related work is proposed in section two. Section three includes Artificial Neural Network. Section four explains components of the system. Section five presents design and implementation of sunlight tracking system. Section six includes conclusion and the final section express references.

2. Related Work

Automatic sun tracking system proposed a hybrid hardware/software prototype, which automatically provides the best alignment of solar panel with the sun, to get maximum output (electricity) [1]. Mehmet Karadeniz, İres İskender and Selma Yüncü presented the adaptive neural network dc motor control system using backpropagation algorithm [2]. In other system proposed to develop solar tracking by using PIC controlling system and some electrical devices [3].

3. Artificial Neural Network

A neural network has been motivated right from its inception by the recognition that the human brain computes in an entirely different way from the conventional digital computer. Today, neural networks can be trained to solve problems that are difficult for conventional computers or human beings.

This system applies multilayer feedforward networks architecture as shown in Figure 4. Typically, the network consists of a set of sensory units (source nodes) that constitute the input layer, one or more hidden layers of computation nodes, and an output layers of computation nodes. The input signal propagates through the network in a forward direction, on a layer-by-layer basis. These neural networks are commonly referred to as multilayer perceptrons (MLPs), which have been applied successfully to solve some difficult and diverse problems by training them in a supervised manner with a highly popular algorithm known as the error back-propagation algorithm. This algorithm is based on the error-correction learning rule [4].

4. Components of the System

The system is implemented by using electronic devices and circuits: light sensing circuit, Metal Oxide Semi-conductor Field-Effect Transistors (MOSFET), flash Analog-to-Digital converter, Standard Parallel Port, DC Motor.

4.1. Light Sensing Circuit

The light delivered by a light source can be detected by light sensitive device. Such a device is referred to as optical sensor. In Figure 1, this system applies Light Dependent Resistors (LDR). This is a resistor whose value changes with light level, making it vary useful sensor in the detection of light level in a variety of applications. The changes in intensity of the exposed light are transformed into the changes of resistance by the LDR. The voltage division again transforms the changes in resistance into changes of voltage [6].

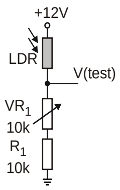

Figure 1. The Circuit to Produce the voltage to be tested

4.2. Metal Oxide Semiconductor Field-Effect Transistor (MOSFET)

Metal Oxide Semiconductor Field-Effect Transistors (MOSFETs) are the active switching elements in CMOS circuits. These devices differ greatly in construction and internal operation from bipolar junction transistors used in TTL circuits, but the switching action is basically the same: they function ideally as open or closed switches, depending on the input [5].

4.3. Flash Analog-to-Digital Converter

The simultaneous or flash method utilizes comparators that compare reference voltages with the analog input voltage. When the analog voltage exceeds the reference voltage for a given comparator, a HIGH is generated. Figure 2 shows a three-bit converter that uses seven comparator circuits: a comparator is not acceded for all zeros condition.

The reference voltage for each comparator is set by the resistive voltage-divider circuit. The output of each comparator is connected to an input of the priority encoder. The encoder is sampled by a pulse on the enabled input, and a 3-bit code representing the value of the analog input appears on the encoder's outputs. The binary code is determined by the highest-order input having a HIGH level [5].

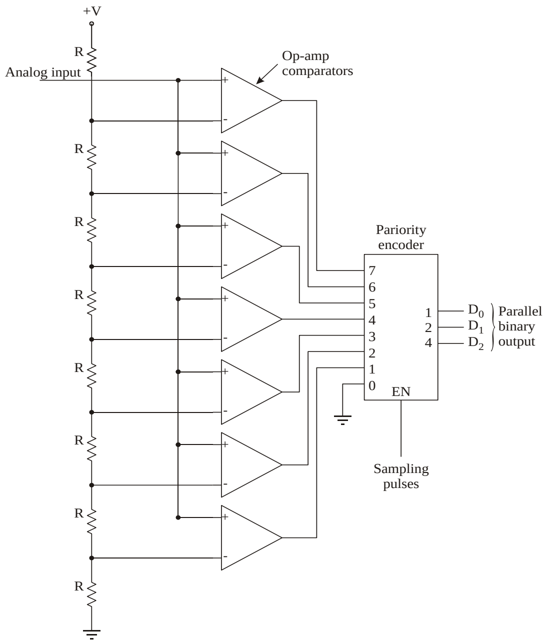

Figure 2. Three-bit flash ADC

4.4. Standard Parallel Port

The interface has three registers with which data can be transferred and control the device as well as printer. The base address, usually called the Data Port or Data Register is simply used for outputting data on the Parallel Port's data lines (Pins 2-9). This register is normally a write-only port. The Status Port (base address + 1) is a read-only port. Any data written to this port will be ignored. The Status Port is made up of 5 input lines (Pins 10,11,12,13 & 15), a IRQ status register and two reserved bits. The Control Port (base address + 2) was intended as a write-only port [7].

4.5. DC Motor

The DC motor has two basic parts: the rotating part that is called the armature and the stationary part that includes coils of wire called the field coils. The stationary part is also called the stator. The armature is made of coils of wire wrapped around the core, and the core has an extended shaft that rotates on bearings. Notice that the ends of each coil of wire on the armature are terminated at one end of armature. The termination points are called the cumulater, and this is where the brushes make electrical contact to bring electrical current from the stationary part to the rotating part of the machine. The coils are mounted inside the stator. These coils will be referred to as field coils and they may be connected in series or parallel with each other to create changes of torque in the motor. The size of wire in these coils and the number of turns of wire in the coil will depend on the effect that is trying to be achieved [8].

5. Design and Implementation of Sunlight Tracking System

The design of sunlight tracking system is shown in Figure 3 and more detailed diagram of the complete circuit as shown in Figure A of Appendix. This system can be viewed as containing the following subsystems:

- Light Sensing Circuit
- Flash Analog-to-Digital Converter
- The Neural Network design
- The Pulse Width Modulation (PWM) DC motor driver circuit

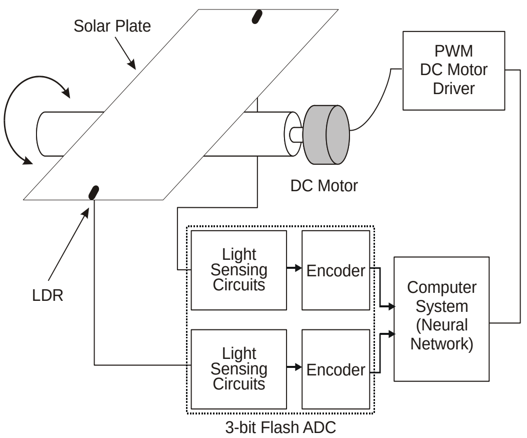

Figure 3. Design of the System

The variation of light makes the changing of LDR's resistance. The changes in intensity of the exposed light are transformed into the changes of resistance by the LDR. The voltage division again transforms the changes in resistance into changes of voltage. According to the voltage division, V (test) also changes. The light sensing circuit of the system classifying the intensity of light into seven levels.

At full light V(test) is the largest and all the positive input of the operational amplifiers are greater than all of the negative inputs and consequently the outputs of the amplifiers are at +12V making the transistors ON and the collector voltages are 0V.

When the light intensity becomes lower (a small change), the V(test) becomes also lower with a small change and reaches under the first step reference 6V. At that situation, the negative input of the operational amplifier becomes greater than the positive input and operational amplifier outputs -12V making the transistor to totally cutoff and V7 becomes at the logic 1 level (+5V) while all other collector voltages are at 0V. Therefore as the light becomes lower and lower, the collector voltages become logic 1 level correspondingly. At the smallest amount of light, all the collector voltages become logic 1. The numbers of logic 1 at the collector voltages are indicating the light intensity level.

The seven collector voltages are given at the inputs of the 74LS148 8-line-to-3-line encoder IC. The high priority property is useful for this system. All the input combinations and the corresponding outputs are listed Table 1.

Table1. Inputs and outputs Combinations of the Encoder

Light Intensity	Input Combinations							Output Combinations		
	V_7	V_6	V_5	V_4	V_3	V_2	V_1	A_2	A_1	A_0
Highest	0	0	0	0	0	0	0	0	0	0
First Drop	1	0	0	0	0	0	0	0	0	1
Second Drop	1	1	0	0	0	0	0	0	1	0
Third Drop	1	1	1	0	0	0	0	0	1	1
Fourth Drop	1	1	1	1	0	0	0	1	0	0
Fifth Drop	1	1	1	1	1	0	0	1	0	1
Sixth Drop	1	1	1	1	1	1	0	1	1	0
Lowest	1	1	1	1	1	1	1	1	1	1

In this system the status and control pins of the LPT port are used to input the two encoded 3 bits representing the light intensities on both LDRs into the computer system. Therefore, there are totally six bits to be input into the computer system. The data pins of the LPT port are used to output the fuzzy pulses and direction control bit to drive the H-bridge DC motor driver. Therefore, there are two output bits from the computer system as shown in Table 2.

Table 2. Data, Status and Control Register Utilization of the System

Register	I/O Address	Bit Positioning							
		7	6	5	4	3	2	1	0
Data	0378h	D7	D6	D5	D4	D3	D2	D1	D0
		-	-	-	-	-	-	I2	I1
Status	0379h	$\overline{BSY}$	ACK	PAP	ON/ OFF	ERR	X	X	X
		-	Encoded 3-bit code			-	-	-	-
Control	037Ah	X	X	X	X	$\overline{DSL}$	INI	$\overline{ALF}$	$\overline{STB}$
		-	-	-	-	-	Encoded 3-bit code		

Figure 4 is the architecture of system's ANN. In this system, ANN is designed with three layers: input layer, hidden layer and output layer. The input layer accepts the two voltages from the two LDRs and hence there are two input nodes. The hidden layer memorizes the system. The hidden layer is constructed with 50 neurons to get the memory improvement of the ANN. The output layer is composed of 1 neuron since there is a single control bit for the DC motor driver. This ANN is trained to achieve the desired decision power by adjusting the weight values.

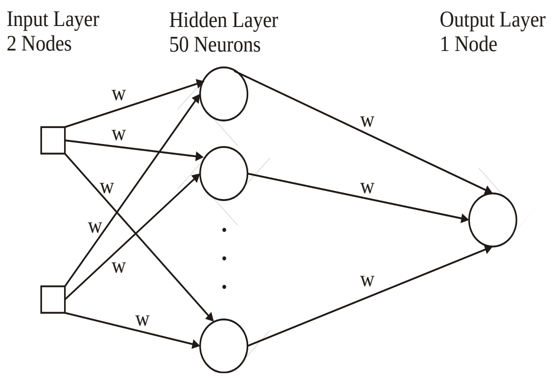

Figure 4. The architecture of system's ANN

The targeted outputs of the ANN to the plant, that is to the motor driver circuit, for all possible input combinations (two encoded voltage values of two LDRs) used to train the ANN of the system are listed in Table 3.

Table 3. Possible Input and Output Combinations used as a training set for the ANN

V2 \ V1	1	2	3	4	5	6	7
1	0	0.2	0.4	0.6	0.8	1	1
2	0.2	0	0.2	0.4	0.6	0.8	1
3	0.4	0.2	0	0.2	0.4	0.6	0.8
4	0.6	0.4	0.2	0	0.2	0.4	0.6
5	0.8	0.6	0.4	0.2	0	0.2	0.4
6	1	0.8	0.6	0.4	0.2	0	0.2
7	1	1	0.8	0.6	0.4	0.2	0

The random weight values are set with small values between -0.5 and +0.5. The total net input for each neuron in the hidden layer is calculated by the following formula:

$$v_k = \sum_{j=0}^{m} w_{kj} x_j \tag{1}$$

From the calculated total net input, the output value of each neuron in the hidden layer is calculated by means of sigmoid function.

$$\varphi(v) = \frac{1}{1+\exp(-v)} \tag{2}$$

The output of the hidden layer is applied as the input to the output layer. The total net input to the output layer as well as the output value of a neuron in the output layer are calculated out as the same for the hidden layer as described above. Then, the output values of the neurons from the output layer of ANN are obtained and these values are in the range from 0 to 1 representing the width for the PWM DC motor driver.

The error values are determined by the following formula:

$$E = T - O \tag{3}$$

If the errors are not negligible, the applying weights are needed to adjust to be the errors negligible. The changes in errors of the output neurons and hidden neurons are computed and depending upon the computed changes in errors, the weight values are adjusted. The adjusted weights are applied in the ANN and the above steps are repeated until the ANN becomes well-trained. If the errors become negligible, the ANN is said to be trained. Flowchart of the training process of ANN is shown in Figure 5.

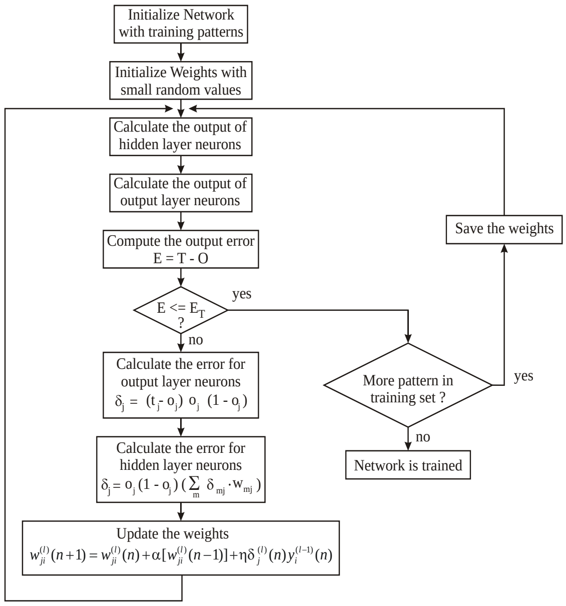

Figure 5. Flowchart of the training process of ANN

By means of Neural Network, the computer system determines the width of the pulse to be applied to the pulse width modulation DC motor driver circuit. The speed of the DC motor rotation can be controlled by the width of the pulse applied. The longer the width of the pulse, the more speed the motor rotates. The speed of the motor should be proportionate with the resistance difference of the two LDRs at both ends of the solar plate. The higher the resistance difference, the more speed the motor should rotate. The necessary width of the pulse, actually the ANN output can be obtained for the speed of the motor to rotate.

In Figure 6, this must handle the I_2 input and its value must be active pulse. The direction of the motor rotation is controlled by the I_1 input. If I_1 input is logic 0, the base of the transistors Q_1 and Q_3 gets logic 1 state by means of the NAND inverter. At that situation, the base of the transistors Q_2 and Q_4 gets logic 0. Q_1 and Q_3 are ON and Q_2 and Q_4 are OFF. The left terminal of the DC motor gets +12V reference and the right terminal of the DC motor gets the ground reference. The motor gives clockwise rotation.

If I_1 input is logic 1, the base of the transistors Q_1 and Q_3 gets logic 0 state by means of the NAND inverter. At that situation, the base of the transistors Q_2 and Q_4 gets logic 1. Q_1 and Q_3 are OFF and Q_2 and Q_4 are ON. The left terminal of the DC motor gets ground reference and the right terminal of the DC motor gets the +12V reference. The motor gives anti-clockwise rotation.

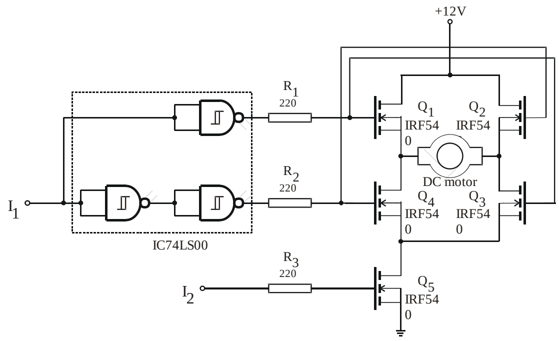

Figure 6. H-bridge DC motor driver of the system

When I_1 is 0 and I_2 is at active pulse, the motor rotates clockwise. When I_1 is 1 and I_2 is at active pulse, the motor rotates anti-clockwise. If I_2 is not at active pulse, the motor does not rotate in either direction.

The important fact is that for both clockwise and anti-clockwise rotations, the I_2 input must be at active pulse, virtually connecting the drain with the ground referenced source.

The datasheet gives the Gate to Source threshold voltage $V_{GS}^{(th)}$ to be 4 V maximum. Therefore, the logic pulse at the gate being (+5V) driving the gate of the MOSFET in this system is high enough to be the MOSFET ON.

At ON state, the data sheet gives Drain to Source resistance to be 0.057 as the maximum value, a very small value enough for virtually short the Drain and Source. Enhancement Hi-Speed Switch with this very small r_{DS} (Drain to Source resistance) value makes the H-bridge DC motor driver complete.

6. Conclusion

In this paper, the computer-controlled light tracker is developed. The conventional control systems give only the predetermined controlling functions or output values. Such control systems' output values are of only in two distinct conditions, such as, ON or OFF, +5V or 0V. The intermediate output values cannot be obtained with such control systems. The real world constraints cannot be satisfied. The skillful Neural Network can produce almost continuous output values and is suitable for interactive and real-time processing. Therefore, the system of this thesis utilizes the Neural Network.

In this system, the electrical devices are used to scan from the light and then Artificial Neural Network (ANN) controls the output of the scan process. By means of neural network, the computer system determines the width of the pulse applied into the pulse width modulation DC motor driver circuit to rotate the solar plate. To get the energy of solar from the sun, solar plate is positioned exactly right angles to the sun.

With trial and error approach, the ANN of the system is found to be best fit with the learning rate of 0.25 and momentum of 0.65.

Using ANN, a smart, intelligent and streamlined sunlight tracking is achieved compared to pure electronic sunlight tracking.

7. References

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APPENDIX

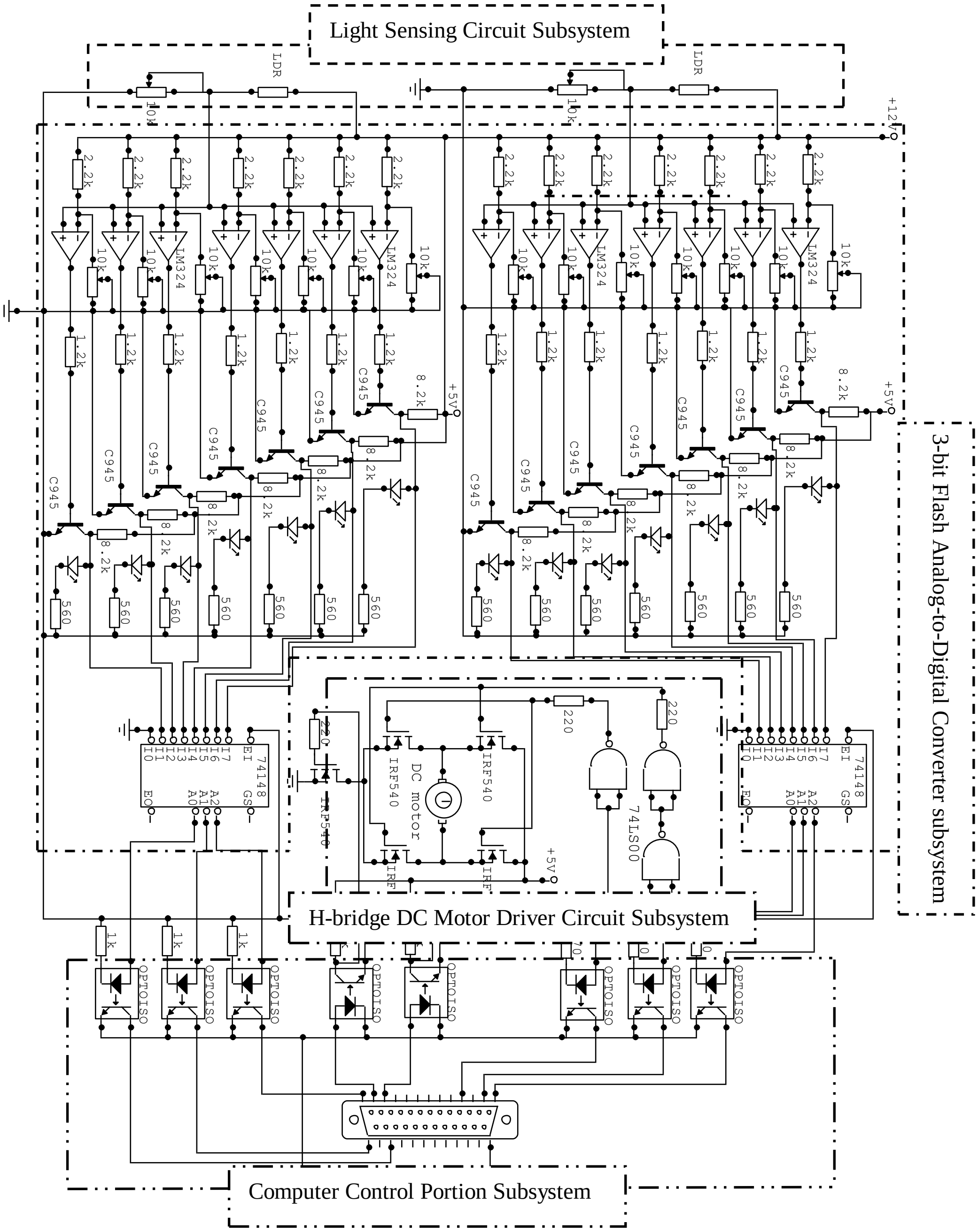

Figure A. Complete circuit of the system