DESIGN OF A NEW GENERATION “SOLAR ANTBOT” FOR MANKIND

Bidrohi Bhattacharjee^{1*}, Pradip Kumar Sadhu¹, Ankur Ganguly²
and Ashok Kumar Naskar²

¹*Department of Electrical Engineering, Indian Institute of Technology (Indian School of Mines), Dhanbad, Jharkhand-826004, India*

²*Department of Electrical Engineering, Techno International Batanagar, Kolkata-700141, India*

**onlybidrohi@gmail.com*

Abstract— The world is constantly going on the path of automated technology day by day and robotics is having a vital role in it (plays a vital role in this section as well). Hence, this robot called, "Solar AntBot" is made to automatically pick and place different objects with different colours by scanning ArUco markers by using its mechanical arm. Two microcontrollers are used in this case, Arduino and Raspberry Pi and serial communication is done between them to perform its job. It is designed in such a way that it is charged automatically when the charge percentage drops below a certain level. Power bank has been used as a backup device. In this particular model the Bot is charged using solar charger to make it eco-friendly, apart from that it can also be charged by any means of electrical power of same voltage and ampere rating. The main application area is autonomous based vehicles and restaurant food delivery system.

Keywords— Solar AntBot, Raspberry Pi, Power bank, Battery, Ant Hill

1. INTRODUCTION

The Solar AntBot [1]-[4] technology states the need of automation and robotics as well as renewable energy [5]-[7] source in modern days and to give an example of automation with renewable energy source [8]-[10], this robot, called "Solar AntBot" [11]-[15] is constructed keeping in mind to reduce human labor, time taken to complete a task and use the renewable energy [16]-[17] for its operation. It moves in its way following a black line which leads it to the source of blocks and as well as to the destination to place the blocks. The black line is also stretched to the place to keep the garbage blocks from the destination part. It is powered by solar panel which is controlled by a charge controller. This robot [18]-[20] can be used as a waiter in restaurants or as a substitute of man labor in material loading and unloading in go down or stores etc. With the use of this automated method with minimum running cost [21], it is possible to deliver food from restaurant in less time. Besides this, car control would be much easier. This AntBot technology is much better than the AntBot of the past. The homing and outdoor recital of the solar AntBot when its pathway incorporation mode was set to the auto mode, which means that it computed both the distance travelled and its orientation on the basis of stride integration alone. The whole system is portable as AntBot has its own power supply and it is possible to extend the working time of AndBot by selecting the ampere-hour capacity of the battery. Moreover it does not have any effect during power supply

Received: September 15, 2019
Reviewed: November 21, 2019
Accepted: December 2, 2019

failure or shut down. This technology very useful in those places where there is no global positioning system (GPS) available, such as transporting goods to remote locations, automatic crop growers and maintenance, autonomous marine navigations.

2. SOLAR ANTBOT TECHNOLOGY

In case of the first generation robots, the main sensor was made up of three pairs of polarization-sensitive units (POL-units) with a spectral sensitivity in the visible range. The pole units were arranged in different orientation like 0^0 , 60^0 and 120^0 [22] accordingly. The polarization sensor was composed of three pairs of photo diodes joined with linear polarizes [23] and concomitantly with a bio-inspired. Bio-inspired approaches have also been adopted with cameras in the visible range [23]. The major drawback of those technologies is that, negation capacity is very poor with high initial cost.

The main inspiration for the solar AntBot has been found from desert ants. They go out for food in the desert and return to their destination in the perfect way. Following the desert ants, the solar AntBot has been created in the same way with appropriate navigation, so that they can move without GPS. Solar AntBot technology is a fully automated system that allows complex tasks to be completed in a relatively short time, in a coherent way. By reducing its running cost using green energy, it brought into the hands of common people. The walking robots move without global positioning system (GPS) by the help of appropriate programmable circuit with wireless communication. Solar AntBot navigation systems differ from those of other AntBot. The robot is made fully of Aluminum and it has mainly three parts - base, arm and catcher, roof or carrier. At the lower surface of the Bot, the line following the sensor is fitted at the opposite surface. The Arduino Nano, Raspberry Pi, L98N motor driver are connected through a single piece of Vero board. At the lower surface, the D.C battery is also connected and at the opposite surface, the power bank is kept and connected with Raspberry Pi. The arm is moved by the Standard servo and the catcher is moved by micro servo. The movement of the arm is along 'Y' axis and catcher along 'X' axis. The arm is moved over 120 degree with the help of one mechanical support and one rubber band. The arm is required to move 120 degree only when the robot carries two blocks at a time; otherwise, the arm is only moved 90 degree. The Vero board consisting of Raspberry Pi, Arduino Nano, L298N motor driver is mounted at a certain small distance from the body surface so that the heat released by each component is easily dissipated into the air. The roof is supported by four metal supports which are tall enough to lift the roof over the whole circuit mentioned previously. Over the roof, an extra place is there to carry the second block picked up by the robot and that is tilted at an angle of 15 degree so that the block is helped to be picked up by the catcher at the time of placing the block to its final position. The design of power circuit based on solar energy. The arms of AntBot move vertically ups and downs up to 120^0 and used to lift and drop the object or load when required. The catcher is located at the very front of the arms. The two separate parts of the catchers acts horizontally to catch or release the load. The wheel section used to give mobility to the AntBot. Power circuit built with solar panel, solar charge controller and power bank with proper rating. The tenor of AntBot is determined by the rating of the power bank. Robotics function is controlled by the Stride integration methods. The robot goes step by step towards destination and the overall distance to the walkway depends on the number of steps. Total moving distance D_i is calculated depending on the number of steps walked.

$$\text{Therefore, The moving distance - } D_i = S_T \times d_s \quad (1)$$

Where, d_s = Average distance covered per stride, depending on the step parameters

S_t = Number of strides performed.

The entire journey is guided by the relentless function of its components.

3. LIST OF MATERIALS

Table I. Component specification

Name of the component	Specification
Microcontrollers	1. Raspberry Pi 3B . 230mA (1.13W) 400% CPU load - 730mA (3.7W) 2. Arduino Nano 7W, (5V-7V)
Actuators	1. Micro Servo (0.55A, 2.75A) 2. Standard Servo (0.8A , 5V ,4W) 3. Two number of Johnson motors (4.3A, 12V, 51.6W)
Driver	L298N Motor driver (5V, 0.2W)
Else	1. Digital Buzzer (0.15A,5V) 2. RGB LED 3. Line following sensor (0.75A, 2.47W) 4. 1K Potentiometer 5. Vero board 6. Solar Charge controller (15W,12V) 7. Pi cam 8. Solar panel of 15W, 12V 9. Power bank 12V ,25000mAh.
Connecting wire	2m single core

4. ELECTRICAL CONNECTIONS

Electrical connections - All the electrical connections are made on Vero board, apart from that they can also be done through PCB's.

Table II. Connections Between L298N And Raspberry 3B

L298N Motor Driver	RPI 3B
EN-A	PIN 37
IN1	PIN33
IN2	PIN35
IN3	PIN36
IN4	PIN38
EN-B	PIN40
+5V	PIN2
GND	PIN39
EN-A	PIN 37

Fig. 1 Connections between L298N and RPI 3B

Table III. Connection between L298N and dc motors

MOTOR 1 AND MOTOR 2	L298N
M1	OUT1
M2	OUT2
M1	OUT3
M2	OUT4

Table IV. Connection between rpi3b, li-ion battery and L298N

L298N	Connected To
12V	12V(LI-ION)
GND	GND(LI-ION AND RPI3B)
5V	RPI3B PIN 3

Table V. Connections between Arduino Nano and standard servo motors.

Arduino Nano Pin	Standard Servo Pin
D3	DATA PIN(WHITE)
GND	GND PIN(BLACK)
5V	VCC PIN(RED)

Table VI. Connections between Arduino Nano and micro servo

Arduino Nano Pin	Micro Servo Pin
D6	DATA PIN(ORANGE)
GND	GND PIN(BROWN)
5V	VCC PIN(RED)

Table VII. Connections between Arduino Nano and line following sensor

Line Following Sensor Pin	Arduino Nano/ Potentiometer Pin
1	ARDUINO(A0)
2	POTENTIOMETER (VARIABLE END)
4	POTENTIOMETER (VARIABLE END)
5	ARDUINO(A4)
6	POTENTIOMETER (VARIABLE END)
15	ARDUINO GND
16	ARDUINO GND
17	ARDUINO GND
18	ARDUINO GND
19	ARDUINO 3V3
20	ARDUINO 3V3

Table VIII. Connections between Arduino Nano And Buzzer

Arduino Nano Pin	Buzzer Pin
5V	VCC
D13	I/O
GND	GND

Table IX. Raspberry Pi3b to RGB LED Connections

RASPBERRY PI3B	RGB LED (Cmmn. Cathode)
PIN NO. 11	1 st PIN
GND	GND PIN OF LED(2 nd)
PIN NO. 13	3 rd PIN

Connections between RPI 3B, L298N, Motor (1&2) and DC battery.

Fig. 2 Connections between Arduino Nano and L298N

Fig. 3 Connections between Raspberry PI3B, Arduino Nano and Power bank

Fig. 4 Connections between Arduino Nano, L298N, Whiteline sensor, Standard Servo and Micro Servo

Fig. 5 Internal connections between Standard Servo and Sensor Circuit

Fig. 6 Connection diagram of Solar panel with charge controller, battery and load

The 15 W, 12V solar panel is connected to the AntBot's power circuit through a charge controller. The cells of the solar panel produce electricity directly from sun light. The generated DC voltage available at the terminal points of the panel. But the generated DC voltage is unregulated, because the amount of voltage depends on the intensity of the sun light and the intensity of sunlight changes throughout the solar hours. One of the main functions of the charge controller is to convert the unregulated DC voltage to the regulated DC voltage and another task is to charge the battery. Charge controller consists of six numbers of terminals. 15W Solar panel connected in between the S⁺ and S⁻.

Fig. 7 Different component of Solar AntBot

Fig. 8 Front view of Solar AntBot

5. POWER CALCULATION

The power calculation for this project is shown step by step-

5.1 TOTAL POWER CONSUMED FROM POWER BANK

In this project, the power consumed is –

Raspberry pi3b - Idle - 230mA (1.13W)

400% CPU load - 730mA (3.7W)

When connected to a power meter, average 4.7W power is consumed by it.

1.7W is consumed by Arduino itself in an average.

Standard Servo – $(0.8A \times 5V = 4W)$

White line sensor – $(0.75A \times 3.3V = 2.47W \text{ approximate})$

Buzzer – $(0.015A \times 5V = 0.09W)$

Micro Servo – $(0.55A \times 5V = 2.75W)$

5.2 TOTAL POWER CONSUMED FROM BATTERY

The two Johnson motors and the L298N motor driver are connected to DC battery.
Here, the power consumed is –

$$\text{Johnson motors} - 2 \times (4.3A \times 12V) = 51.6W \quad (2)$$

$$\text{L298N} - (0.004A \times 5V = 0.02W)$$

Hence, the power bank will last long for:

$$\begin{aligned} \text{Total Power} &= (4.7 + 1.7 + 4 + 2.47 + 0.09 + 2.75) W \\ &= 15.91W \end{aligned}$$

$$W = V \times I \quad (3)$$

$$\text{or, } 15.91 = 5 \times I$$

$$\text{or, } I = 3.182 A.$$

Therefore, the power bank will last up to

$$(10.000Ah) \div 3.182A = 3.142h. \quad (4)$$

Yet, all the sensors and actuators do not work all the time together. Hence, from practical experience, the Power bank gives battery backup for average 20 hours.

The DC battery gives battery backup up to 5 hours.

The DYI voltmeter in Arduino to measure voltage of the battery:
It is basically a voltage divider circuit–

Fig. 9 Equivalent Circuit of Battery port to Arduino

As, Arduino cannot measure greater than 5V with its analog pins, a voltage divider circuit is needed.

In the above picture, R_1 & R_2 are two resistors in $k\Omega$ range. One end of the voltage divider is to be connected to the 12V battery voltage and other end to GND. Between the two resistors, the voltage measured appears in the desired range which is 5V in this case.

The formula is:

$$V_i = V_m \times R_2 / (R_1 + R_2) \quad (5)$$

[In this case, $V_m = 12V$]

or, $5 = 12 \times R_2 / (47000 + R_2)$ [$R_1 = 47000 \Omega$, approx.]

or, $R_2 = 33000\Omega$

Hence, $R_2 = 33K\Omega$.

It is fact that all the components of the AntBot do not work at the same time during working period. The components are activated depending on the type of work.

When the robot has to move, its wheel and line following sensor starts to work actively. The amount of power consumption during that time:

For Arduino Nano – 1.7 W.

For Line following sensor – 2.47 W

For two numbers of Johnson motors – 51.6 W

For L298N motors driver – 0.02 W

For Raspberry PI3B – 4.7 W

During moving period the total consumed power 60.49 W. In fact both the arm and catcher cannot work together.

Whenever the AntBot stops moving, and lifts an weight up or down then the wheel, L298N and line following sensor will not be working actively. The amount of power consumption during that time:

For Raspberry PI3B – 4.7 W

For Arduino Nano – 1.7 W.

For Standard servo motor – 4 W

For Micro servo motor – 2.75 W

Total power required 13.15 W.

6. STRUCTURE OF THE CHARGER MODULE

The charger module is a solar charger-based charging system. Considering the present situation of the world, the world must move forward towards renewable energy sources. It consists a solar panel, a charge controller and two leads to charge the battery coming from the load terminals of the controller. The two input terminals of charge controller are connected to the two output terminals of solar panel. The two battery terminal points of charge controller are connected to the battery.

7. SOFTWARE PROGRAMS

Abbreviations used in this project given below:-

Table IX. Abbreviations and their full forms

Sr. No.	Abbreviations	Full Forms
1	AB	Ant Bot
2	AH	Ant Hill
3	BB	Blue Block
4	CN	Central Node
5	GB	Green Block
6	W	Wood
7	H	Honeydew
8	L	Leaves
9	T	Trash
10	TDZ	Trash
11	QAH	Deposition
3	BB	Blue Block
4	CN	Central Node
5	GB	Green Block
6	W	Wood
7	H	Honeydew
8	L	Leaves
9	T	Trash
10	TDZ	Trash Deposition Zone
11	QAH	Queen Ant Hill
12	RAH	Regular Ant Hill
13	RB	Red Block
14	RN	Regular Node
15	S	Supply
16	SIM	Service and Identification Marker
17	TR	Trash Removal

7.1 FLOWCHART

Fig. 10 Operation of AntBot by flowchart

Following the above flowchart (Fig. 10.), AntBot will complete its tasks correctly. The following pictures are the methodological output of Solar AndBot's Work. With the help of a train of programming Solar AndBot has been working in real life. Following the next pictures consistently illustrates the AndBot's way of working in real life for mankind. Not only this, the output of the program is known for its control mechanism.

Press Enter

Fig. 11 Observation 1 (Configuration command)

On pressing enter, a configuration screen will appear with various configurable properties of the RPi3 as shown:

Fig. 12 Observations 2

The up-down + enter keys are to be used to select the configurable property.
The following steps are to be performed:

7.2 .EXPAND FILE SYSTEM

Expand File system is the main tools, available in raspi-config. The size of the Raspbian root file system is generally 2GB. To expand the root file system, firstly highlight the Expand Files stem operation and after that press Enter key. The process of extending the partition being immediately. No confirmation dialogs available here. In this case, the device can be rebooted and the expansion process lasts for a couple of minutes.

Fig. 13 Observations 3

Enter is pressed

The following screen will appear:

```
pi@raspberrypi ~$ sudo fdisk /dev/mmcblk0p2
fdisk: 2.11.16-2
Created a new partition 2 of type "linux" and of size 14.8 MiB.
Partition is not bootable. No boot signature.

Command (m for help):
Disk /dev/mmcblk0p2: 14.8 GiB, 15931538456 bytes, 31116288 sectors
Units: sectors of 1 * 512 = 512 bytes
Sector size (logical/physical): 512 bytes / 512 bytes
I/O size (minimum/optimal): 512 bytes / 512 bytes
Disklabel type: dos
Disk identifier: 0x13029002

Device            Boot Start      End  Sectors  Size Id Type
/dev/mmcblk0p1    6192      93814   88623  41.9M  a W95 FAT32 (LBA)
/dev/mmcblk0p2    94708    31116287 31021580 14.8G 83 Linux

Command (m for help): The partition table has been altered.
Calling ioctl() to re-read partition table.
WARNING: Re-writing the partition table to disk is dangerous!
The kernel still uses the old table. The new table will be used at the next reboot
or after you run partprobe(8) or kpartx(8).
```

Fig. 14 Observations 4 (Expanding the file system)

This following screen will appear after that:

Fig. 15 Observations 5

“OK” is pressed to finish configuration.

7.3. ENABLE PICAMERA

In order to enable Picam, “Interfacing options” is selected.

Fig. 16 Observations 6

Then the following steps are to be followed:

Fig. 17 Observations 7

On selecting the “Camera” option, “Yes” is pressed:

Fig. 18 Observations 8

Then “OK” is pressed

Fig. 19 Observations 9

7.4 EXPAND MEMORY ALLOCATION

For Picamera to work with Raspberry Pi 3B, the following steps are to be followed:

Fig. 20 Observation 10 (Advanced option is Chosen)

Then the option “Memory Split” is chosen

Fig. 21 Observations 11(Memory split is chosen)

Then, “256” is written in the text box given.

“OK” is pressed

Fig. 22 Observations 12

Finally, “Finish” is pressed to finish the configuration of Raspberry Pi3B.

The tasks to be done by AB across the arena are same as the first ant i.e. collecting leaves, honey, wood from the Shrubs Area (SA) and store for winter and/or remove trash from its Ant Hills (AH). One of the Ant Hills, the Queen Ant’s Hill (QAH) is always given preferential treatment while doing the service.

Ant Hill (AH):Ant Hill (AH) is defined as the area where ants live. They carry required Supplies to the AH and remove Trash from the AH. There are 4 such AHs depicted in the arena as Ant Hill 0 (AH0), Ant Hill 1 (AH1), Ant Hill 2 (AH2) and Ant Hill 3 (AH3). One of the AH is a Queen Ant Hill (QAH) which is a priority AH for providing Services while other are Regular AH (RAH) and are always of less priority than QAH. The information regarding which AH is QAH is present in Service and Identification Marker (SIM) (discussed in further points).

Note: There can be a maximum of ONLY one QAH.

Node (N):A Node is a small Black square of dimension 3cm x 3cm. The Node present in the centre of arena is called as the Central Node (CN). All AHs are equidistant from the Central Node (CN). All Nodes other than the CN are called as a Regular Node (RN).

Service and Identification Marker (SIM): A Service and Identification Marker (SIM) i.e. an ArUco marker is associated with each AH. Ant Bot identifies the Ant Hill number (AH0/AH1/AH2/AH3), its category (RAH or QAH) and the type of Service required by Ant Hill from the SIM. As shown in Figure 1, SIM 0 is associated with AH0, similarly, SIM 1 with AH1, SIM 2 with AH2 and SIM 3 with AH3.

Service Location (Serv):A Service location is defined as the place where AH requires Service such as placing Supply (S) or Trash Removal (TR). For a given AH there are two Service locations, Service Location 1 (Serv 1) and Service Location 2 (Serv 2).

Supply (S):An Ant Hill may have Supply Requirements as a Service requirement. These Supplies are present in the Shrubs Area (SA). There are total of 3 types of Supply as Honeydew (H), Leaves (L) and Wood (W). Supplies are denoted by blocks of Red, Green and Blue colour where, Red Block (RB) denotes Honeydew (H), Green Block (GB) denote Leaves (L) and Blue Block (BB) denotes Wood (W).

Shrubs Area (SA): This area contains supplies.

Trash Deposition Zone (TDZ):This is an area denoted by a black patch of 30 cm x 15 cm where Trash from AH is deposited for AH having Trash Removal as a Service requirement.

Trash Removal (TR): An AH may have Service requirement as Trash Removal (TR). The Trash (T) may be present in an AH at either Serv 1 or Serv 2 and is denoted by a Yellow Block (YB). Trash has to be removed from the AH and deposited in the Trash Deposition Zone (TDZ).

SIM: SIM is an ArUco marker that contains the information about the AH it is associated with. It is an ArUco marker belonging to dictionary DICT_7X7_1000. The ID of the marker (decimal number of the ID) contains the following data bit-wise:

- i. Bit-7: If this bit is "1", it denotes AH to be QAH. Otherwise, AH is RAH.
- ii. Bit-6 and Bit-5: These bits denote the AH number as per the following table:

Table X. BIT-6, BIT-5 and AH NO

BIT-6	BIT-5	AH NO.
0	0	AH0
0	1	AH1
1	0	AH2
1	1	AH3

- iii. Bit-4 and Bit-3: These bits denote the Serv 2 supply requirements as:

Table XI. BIT -4 , BIT-3 and Supply Frequency

BIT-4	BIT-3	SUPPLY REQUIRED
0	0	No Supply required
0	1	Honey dew (H)
1	0	Leaves (L)
1	1	Wood (W)

- iv. Bit-2 and Bit-1: These bits denote the Serv 1 Supply requirements as:

Table XII. BIT -2 , BIT-1 and Supply Frequency

BIT-2	BIT-1	SUPPLY REQUIRED
0	0	No Supply required
0	1	Honey dew (H)
1	0	Leaves (L)
1	1	Wood (W)

- v. Bit-0: If this bit is “1”, it denotes TR is required at the AH. Otherwise, TR is not required.
- vi. Thus, for example, an ArUco marker with ArUco ID as 5 denotes AH0 as RAH with a TR requirement. Here, Serv 1 requirements is Leaves and thus Serv 2 requirements becomes TR. Here, ArUco ID 5 is 0x05 in Hex value which in binary is 0x05 = 0000 0101 and is depicted in the bit Table below:

ArUco ID Bits							
7	6	5	4	3	2	1	0
QAH Bit	AH Bit	AH Bit	Serv 2 Bit	Serv 2 Bit	Serv 1 Bit	Serv 1 Bit	TR Bit
0	0	0	0	0	1	0	1

Fig. 23 Observation 13

- vii. Elaborating the above example further, the AB is supposed to pick the Green Block from the Shrubs Area. The Green Block is then to be deposited in the Ant Hill 0's Service Location 1. Also, the Yellow Block depicting Trash is to be picked from Ant Hill 0's Service Location 2 and deposited in Trash Deposition Zone.

8. COST ANALYSIS

1. 2200 mAh Li-ion DC battery - 350 INR
2. 10000 mAh power bank - 700 INR
3. RGB LED with register 10 INR
4. Micro Servo - 200 INR
5. Standard Servo - 350 INR
6. Digital Buzzer - 50 INR
7. 1K potentiometer - 15 INR each
8. Charge Controller - 600 INR
9. Solar Panel(15W, 12V) -600 INR
10. Wheel , Catcher – 200 INR
11. Raspberry Pi – 2950 INR
12. Others accessarys – 550 INR

The total cost of the Solar AntBot project is 6575 INR is equal to 92.93 USD .So, in real life, the benefits are much greater than the cost of the Solar AntBot project.

9. SOLAR ANTBOT FOR MANKIND

With the help of modern technology, people are constantly increasing their standard of living. Technology is the main tool to reduce the work time and the running costs in people's daily life. The main advantages of Solar Antbot technology is that, firstly the running cost is very low due to the use of solar power and the technology is not so

complicated. Secondly, the time required for the use of robotics technology is comparatively much shorter than the manual technology. This project can be directly used in real life by making some technological improvement. The cost of the project is not so high. Solar AntBot can be used for a long time, even after the solar hours because it has a power bank with its circuit. By using raspberry Pi, the board is portable with low cost. The Raspberry Pi uses an SD card for storage, has no moving part here so noise level is almost negligible, moreover, it works as a normal computer at low cost server to handle web traffic.

10. CONCLUSION

The Design has been looking into the market for future scope. Solar automation will become the main technology in future research work. If implemented properly this project will lead the way in agricultural and so many others technical fields. Using this technology, there will not be any delay in work even if the power is deficient. Moreover the running cost of this project is very low because this project is related with solar energy, thereby improving the quality of life of people associated with this work. Simultaneous development of the area is possible. Proper application of this technology will bring out radical changes in the field of automated cars and restaurant catering system in future. Using the automated system has many benefits in the vehicles control area and using this technology will lead to a drastic change in the catering system in restaurant.

REFERENCES

- [1] Soni, B. and Hingston P (2008). "Bots trained to play like a human are more fun," in Neural Networks, IEEE International Joint Conference on, 2008, pp. 363–369.
- [2] Bauckhage, C., Thureau C. and Sagerer G (2003) "Learning human-like opponent behavior for interactive computer games," in Lecture notes in Computer Science 2781, pp. 148–155.
- [3] Fernandez Leiva, A. and O'Valle Barragan J (2011) "Decision tree-based algorithms for implementing bot ai in ut2004," Lecture Notes in Computer Science, vol. 6686 LNCS, no. PART 1, pp. 383–392.
- [4] Martinez, A. and Espacia A(2010) "Evolving bot ai in unrealTM ," Lecture Notes in Computer Science, vol. 6024 LNCS, no. PART 1, pp. 171–180.
- [5] Miric, S. and Nedeljkovic M (2015) "The Solar Photovoltaic Panel Simulator," Rev. Roum. Sci. Techn. Électrotechn. et Énerg., vol. 60, no. 3, pp. 273–281.
- [6] Kumar, R. and Singh B (2014) "Buck boost converter fed BLDC motor drive for PV array based water pumping," IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), pp.1–6, 16–19.
- [7] Wang, H. and Zhang D (2010) "The stand-alone PV generation system with parallel battery charger," Proc. Int. Conf. Elect. Control Eng. (ICECE'10), pp. 4450–4453.
- [8] Kolhe, M (2009) "Techno-economic optimum sizing of a stand-alone solar photovoltaic system," IEEE Trans. Energy Convers., vol. 24, no. 2, pp. 511–519.
- [9] Debnath, D. and Chatterjee K (2015) "A two stage solar photovoltaic based standalone scheme having battery as energy storage element for rural deployment," IEEE Trans. Ind. Electron., vol. 62, no. 7, pp. 4148–4157.
- [10] Krithiga, S. and Gounden N. G. A (2014) "Power electronic configuration for the operation of PV system in combined grid-connected and stand-alone modes," IET Power Electron., vol. 7, no. 3, pp. 640–647.
- [11] Gallagher, M. and Ryan A (2003) "When will a genetic algorithm outperform hill climbing?" in Proceedings of the IEEE Congress on Evolutionary Computation, pp. 2462–2469.
- [12] Lucas, S (2005) "Evolving a neural network location evaluator to play Ms. Pac-Man," in IEEE Symposium on Computational Intelligence and Games, pp. 203–210
- [13] Szita, I. and Lőrincz A (2007) "Learning to play using low-complexity rule-based policies: illustrations through Ms. Pac-Man," Journal of Artificial Intelligence Research, vol. 30, no. 1, pp. 659–684.
- [14] Wirth, N. and Gallagher M (2008) "An influence map model for playing Ms. Pac-Man," in IEEE Symposium on Computational Intelligence and Games, pp. 228–233.

- [15] Campanhol, L., Silva, S., Junior, A. and Bacon V (2017) "Dynamic performance improvement of a grid-tied PV system using a feed-forward control loop acting on the NPC inverter currents," IEEE Trans. Ind. Elec., vol. **64**, no. 3, pp. 2092–2101.
- [16] Radwan, A. and Mohamed Y (2016) "Power Synchronization Control for Grid-Connected Current-Source Inverter-Based Photovoltaic Systems," IEEE Trans. Energy Conv., vol. **31**, no. 3, pp. 1023–1036.
- [17] Thawonmas, R. and Matsumoto H (2009) "Automatic controller of Ms. Pac- Man and its performance: Winner of the IEEE CEC 2009 software agent Ms. Pac-Man competition," in Proceedings of Asia Simulation Conference.
- [18] Lo'pez, E. G., Swafford, J. M., O'Neill, M. and Brabazon, A (2010) "Evolving a ms. pacman controller using grammatical evolution." in *Evo Applications (1)*, ser. Lecture Notes in Computer Science, vol. **6024**. Springer, pp. 161–170.
- [19] Wittkamp, M., Barone, L. and Hingston P (2008) "Using NEAT for continuous adaptation and teamwork formation in Pacman," in *Computational Intelligence and Games, 2008. CIG '08. IEEE Symposium On*, dec., pp. 234 –242.
- [20] Dai, J.-Y., Li, Y., Chen, J.-F. and Zhang F (2011) "Evolutionary neural network for ghost in Ms. Pac-Man," in *Machine Learning and Cybernetics (ICMLC), 2011 International Conference on*, vol. 2, pp. 732–736.
- [21] P. Singh, N.M. Ravindra, Temperature dependence of solar cell performance—an analysis, *Solar Energy Materials & Solar Cells*, 101, pp. 36–45 (2012)
- [22] T. Labhart, Polarization-opponent interneurons in the insect visual system. *Nature*. **331**, 435–437 (1988).
- [23] H. G. Krapp, Ocelli. *Curr. Biol.* **19**, R435–R437 (2009).