TELKOMNIKA Telecommunication, Computing, Electronics and Control
Vol. 18, No. 5, October 2020, pp. 2682~2689
ISSN: 1693-6930, accredited First Grade by Kemenristekdikti, Decree No: 21/E/KPT/2018
DOI: 10.12928/TELKOMNIKA.v18i5.15338

Design and implementation of robot control system for multistory buildings

Naqaa Luqman Mohammed[1], Mothanna Sh. Aziz[2], Omar Ibrahim AlSaif[3]
[1]Computer Technical Engineering, Northern Technical University, Iraq
[2]Medical Instrumentation Technology Engineering, Northern Technical University, Iraq
[3]Computer Systems Technical, Institute of Technical Mosul, Northern Technical University, Iraq

Article Info

Article history:

Received Jan 19, 2020
Revised Apr 17, 2020
Accepted May 1, 2020

Keywords:

Arduino
Control
Proteus
Robot
Stepper motor

ABSTRACT

The advancement of technology, make robots have more attention from researchers to make life of mankind comfortable. This paper deals with the design of an itemized control system prepared for window cleaning/maintenance of towers and multistory buildings which can be aided to simulating human activities. These activities (washing, coating, wiping, climbing, and maintenance events) normally achieved by specialized personal. The designed control system was prepared to guide the units of the required job to move freely along the outside surface of a window with a fairly enough area and mediate time for achieving the desired goal. The system design is implemented using Arduino kit, due to facilities in program and control of cleaning windows through infer the stepper motor movement and rotation. The controller has been achieved as real time system (30 msec.), it is done throw control of three stepper motor by taken in consideration the speed of the motors (π/3000 rad/sec) and the time can be adjustable within the cleaning area that the device covering it.

Corresponding Author:

Mothanna Sh. Aziz
Department of Medical Instrumentation Technology Engineering
Northern Technical University, Mosul, Iraq.
Email: mothanna.sh.aziz@ntu.edu.iq

1. INTRODUCTION

In the recent years, robots have been used for various cleaning purposes. Robots have various cleaning expertise like mopping, picking up the waste, wet floor cleaning and dry vacuum cleaning. Depending on the cleaning mechanism, these robots may have some advantages and disadvantages [1]. Now a days cleaning of windows from outside on tall and multi-story buildings is commonly done manually by special skill workers and that process put them in a dangerous or risky situation where it is not easy as from inside of the room. In addition, it needs expensive lifting machine [2]. As it is known windows normally remain dirty from outside especially in a dusty atmosphere of desert countries which might block the room occupant's view and looks not comfortable. Cleaning window for the building is one of the important aspects in building maintenance activities which has been carried out regularly. The cleaning jobs are done by human might involve high risk [3, 4].

The designed system in this paper is represent by construction of a control unit arranged to assist the process executed by the workers for cleaning, coating, and maintenance activities of window collection system which is used along the outdoor surface of a window with an objectively enough zone [5]. The aim of the designed system is covering the whole window area in a perfect manner and shortest possible time. Multi

applications (devices) such as hard disk drives, medical equipment, printers, automotive and many others applications in which needs controlling in speed, position and rotation angle, so that according to the pervious applications whenever controlled movement is required stepper motor will be use [6, 7]. In this paper microcontroller is used for fast implementation and quick hardware verification. A major benefit of using Arduino Due is the fact that is small size with large speed. C language used for programming the control of three stepper motors by giving it the array of area which needs to clean it [8, 9].

2. LITERATURE REVIEW

A robotic vacuum cleaner is an autonomous electronic device that is intelligently programed to clean a specific area through a vacuum cleaning assembly. Some of the available products can brush around sharp edges and corners while others include a number of additional features such as wet mopping and UV sterilization rather than vacuuming. Some of the available products are discussed below [10, 11].

3. RESEARCH METHOD

3.1. Stepper motor

Conversion into rotational motion of inputs either angel or direction of multiple change (steps) is done through electromechanical devices called stepper motors [12]. Each step is known by the construction of the motor.4-phase unipolar stepper motor (ULN2XX3 which is stander) is simply to be direct by two ways Stamp or Javelin Stamp at the point when supported with a fitting high-current driver (ULN2003 or similar is highly recommended) [13, 14].

3.1.1. The driver circuit

The chip (ULN2003) as shown in Figure 1 is applied as driver to order the stepper motor (for multiple outputs it's important to be aware of the ULN2x03 sink capability through assuring of the motor current requirements) [15].

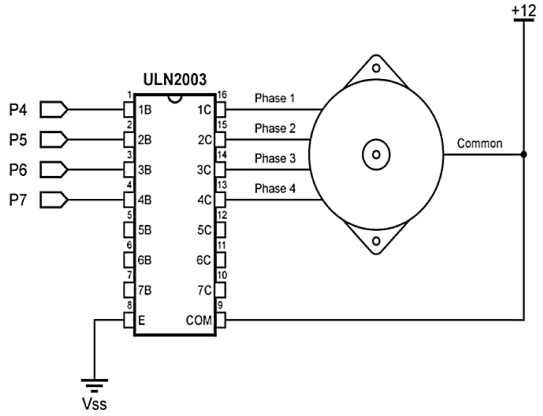

Figure 1. ULN2003 with stepper motor

3.1.2. Motors movements

The kinematic of the device window cleaner is made simple due to the fact that the device is Cartesian. The sign convention for these motions is shown in Figure 2 [16]. The device of window cleaning moves right and left along the "X" axis, and move up and down along the "Y" axis, while the machine's movement from one window to others is assigned as the "Z" axis [17, 18]. The movement is controlled by stepper motors, the degree of stepper motor is 7.5˚ so to complete one rotational it needs 48 step (360˚÷7.5˚= 48) that means the stepper motor rotates 48 step to move 2 mm (dimension of the shift) , these are for high degree of resolution [19, 20]. For cleaning 1×1 meter of window, the motor at X and Y access must rotate with number of durations can be calculating as below:
1 duration of motor moved 2 mm, so for 1 meter.

$$\frac{1\,m}{2\,mm} = 500\,duration \quad (1)$$

The practical circuit of connecting stepper motor with arduino and driver is shown in Figure 3 [21].

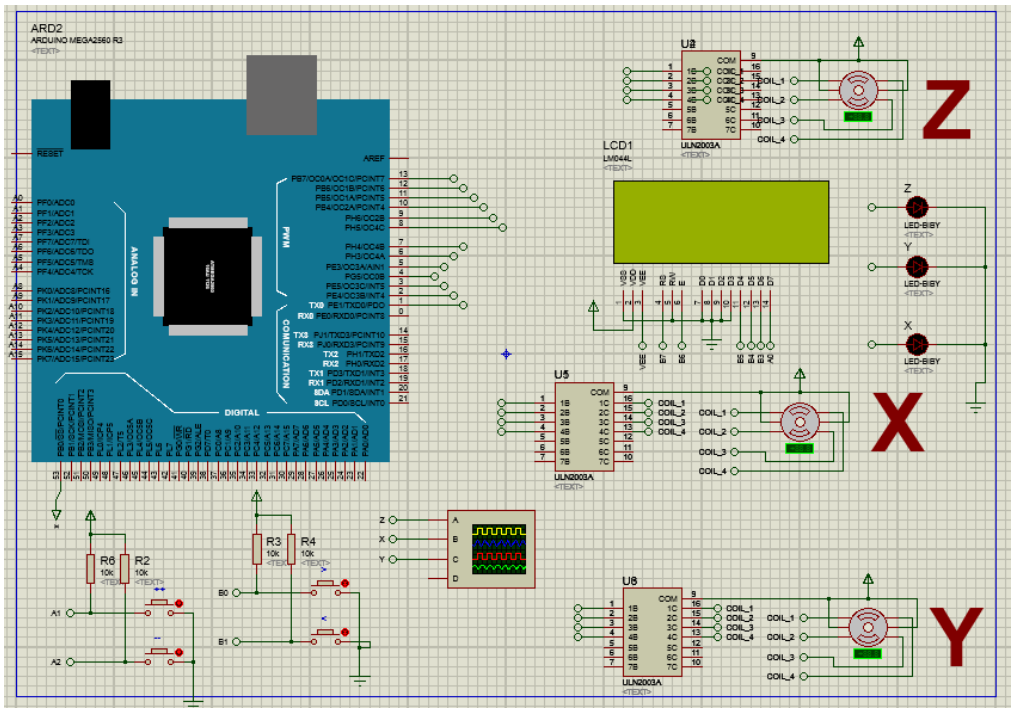

Figure 2. Motor motion control axis with proteus [10]

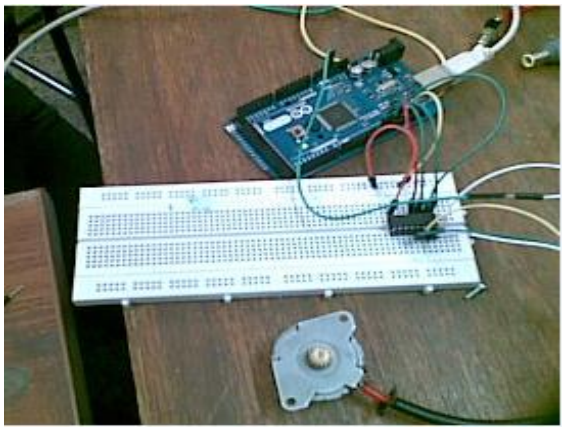

Figure 3. The practical circuit of stepper motor connection with arduino

3.2. Cleaning operation

The cleaning operation for this work is establish according to building windows glasses pans is like chess board as shown in Figure 4 [22]. So after entering the required cleaning area dimension x1 and y1 of whole building in addition the x2 ,y2 and z for one of windows glass pan that will give information about the required cleaning area for each pan and the number of steppes in which that robot required to move it around x axis to cover the cleaning of one pan, y axis of one pan represent the destines of the second motor to move the robot arm up and down to clean in column way of the pan regarding one step of x axis it also can be programed for 1 or 2 or 3 cycle if the pan is very dirty, z axis is in mm movement that pull away the cleaning arm about 300mm so it represent the distance for movement the arm away from the glass to the second position to start another cleaning cycle of new pan or position [23]. This operation will be continuous until finish the whole building pans. It is important for the robot supervisor to insure doing the required calculation of x1, y1, x2, y1 and z then entering the required information also in addition add the required arms of the y1 axis that needed to reach to the first start pan to that will start cleaning from it as explain in the Figure 5 [24].

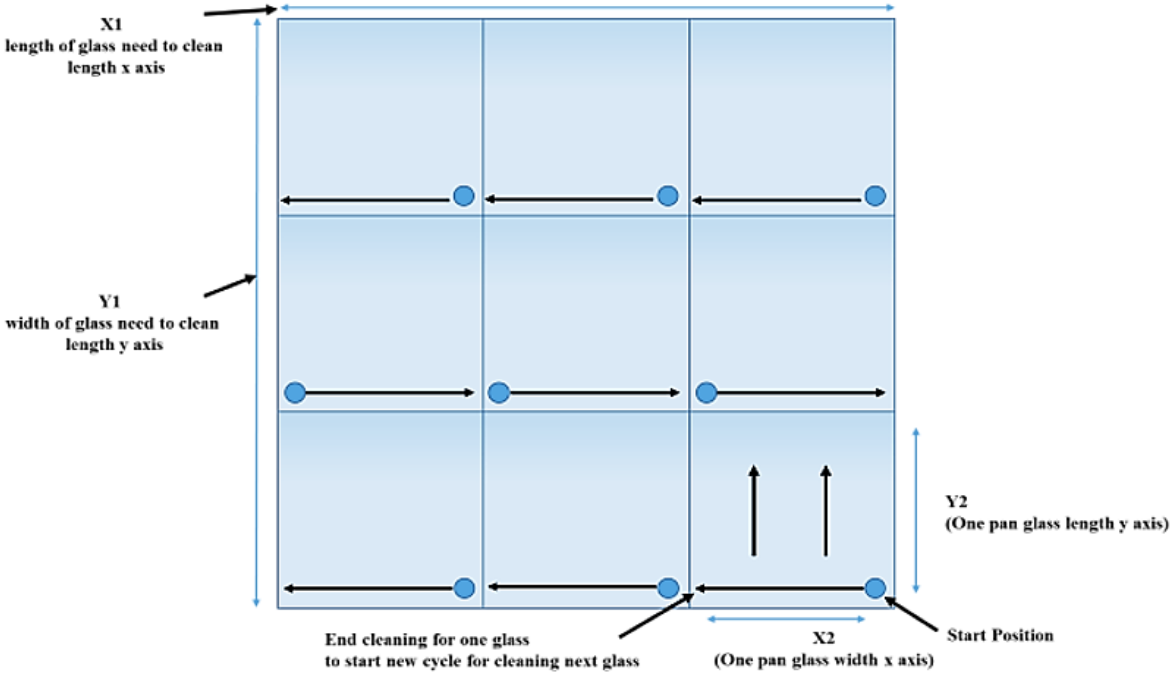

Figure 4. Cleaning glass pans

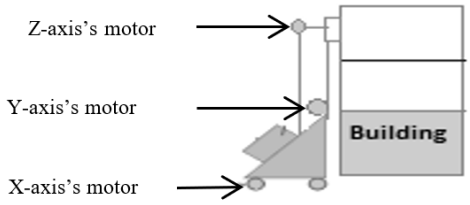

Figure 5. Description the robot components

3.3. Hardware design units and operations

- Elevation units that represent the distance from the robot base to the first glass pan of the building which add by the supervisor to the total elevation of the building glasses [16].
- Control unit which can be classify as two controller the first one that will control the movement of the arm about the y axis which is repeated for any required times to insure cleaning of the one pan according to counter L, the second one is to control the movement around the x axis and here required two counters (I) to control how many x axis will be repeated according to the number of raw pans y axis for one front side of building, the second counter is to count (I1) the steps needed to clean one pan this will be repeated till the counter of the one raw pan will finish, Third one is the z axis control to control the distance when the arm pull out from glass pan to move to the next step of cleaning [25].
- Calculation unit this unit demonstrate the required calculation for the control unit I which summarize with its parameters in details in Table 1.

Table 1. Parameters of the calculation unit

Parameters	Description
A1	Destines in which will be add to Y axis
X	The total distance of the raw pans
Y	The total distance of width
X1	The length of on pan
Y1	The distance the arm needed to move up-down to clean on pan
L	Counter represent times repeated for one cleaning operation
I	Counter of the number of raw pan regarding Y axis
I1	Counter of steps to cover cleaning of one pan regarding X1

3.4. Flow chart

The operating of three stepper motors is shown in, Figure 6 and the declaration of parameters found in Table 2 [26]. The parameters are used for determine the speed, the direction of motors, and the number of rotations for each motor. In the program if statement is used for determine the start and end of motor operation. The flowchart for the cleaning operation is demonstrate in Figure 7 [19, 27].

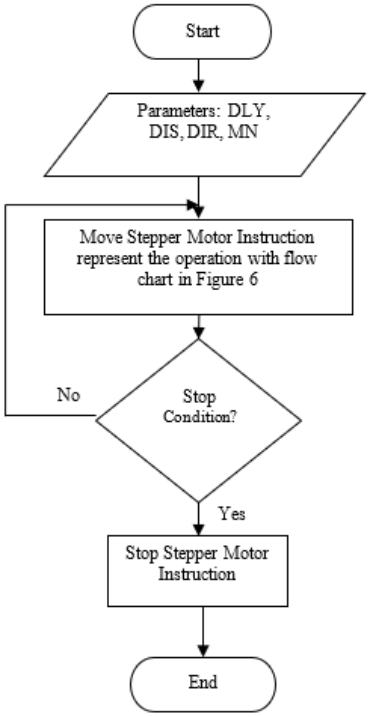

Figure 6. Flow chart of robot motors operation

Table 2. Parameters of the flow chart of Figure 5

Parameter's Mnemonic	Parameter's Name	Description	Parameter's Value
DLY	Delay	This parameter represents the speed of the sequence codes that sent to the driver of the stepper motor through the arduino output pins	Slow (100) Normal (50) Fast (30)
DIS	Distance	This parameter represents how much the robot must move, the DIS parameter may be a specific distance measured in meters (X, Y, X1, Y1, L, I and I1)	L, I and I1 =? (counter)
DIR	Direction	The rotation's direction of the stepper motor will be to the clock wise direction (CW) or to the counter clock wise direction (CCW), if it is CW the code sequence that will be sent to the driver of the stepper motor will be as: (6, C, 9, 3) or if it is CCW the sequence will be reversed as: (3, 9, C, 6)	CW (also = up, right) CCW (also = down, left)
MN	Motor number	The MN parameter means which stepper motor must move, this robot contains three stepper motors so the value of this parameter will be a number between 1 and 3	1, 2, 3

4. RESULTS AND ANALYSIS

The objective of this project is to make a cleaning robot for multistory buildings, which is fully autonomous and manual featured with user friendly interface. In this work the output (sequence signals for motor) from Arduino kit are used to drive the gate drive circuits of three stepper motor through digital output pins, each output pin is connected to one of the gate drive circuit. The speed of the device is one of the most important issues in the work field, the device's speed depends on the speed of the stepper motors which can be changed by the delay parameter in the program. The weight of the device's body as well as the torque of the stepper motors that affects the device 's speed, so the results that have been measured and calculated here are the speed values with different magnitudes of the delay parameter. The output signal of the motor's driver is shown in Figure 8 as it is seen in oscilloscope.

This signal represent the output of two pins at the kit which go to the driver of the motor, Figure 8 (a) shows that the duty cycle of the signal is equal to 2.5 square time pulses-scale and each scale represents 50 ms (this is when the stepper motor steps delayed by 30 step) and the Figure 8 (b) shows that the duty cycle of the signal is equal to 4 square time-scale and for the same scale time (this is when the stepper motor steps delayed by 50 step), so the speed of motor can be increased when the delay between motor steps is decreased. The speed of motor can be calculated as below:

$$\alpha = 2\pi/spr \qquad rad \tag{2}$$

$$w = \alpha/t \qquad rad/sec \tag{3}$$

where:
α: step angle
spr: no. of steps per round
w: speed
t: time delay between stepper pulses
The motor which used is 7.5-degree step, so the spr. equal to 48.

$$\alpha = 2\pi/48$$
$$w = (2\pi/48)/125 \quad (when\ delay\ = 30)$$
$$= \pi/3000 \quad rad/sec$$

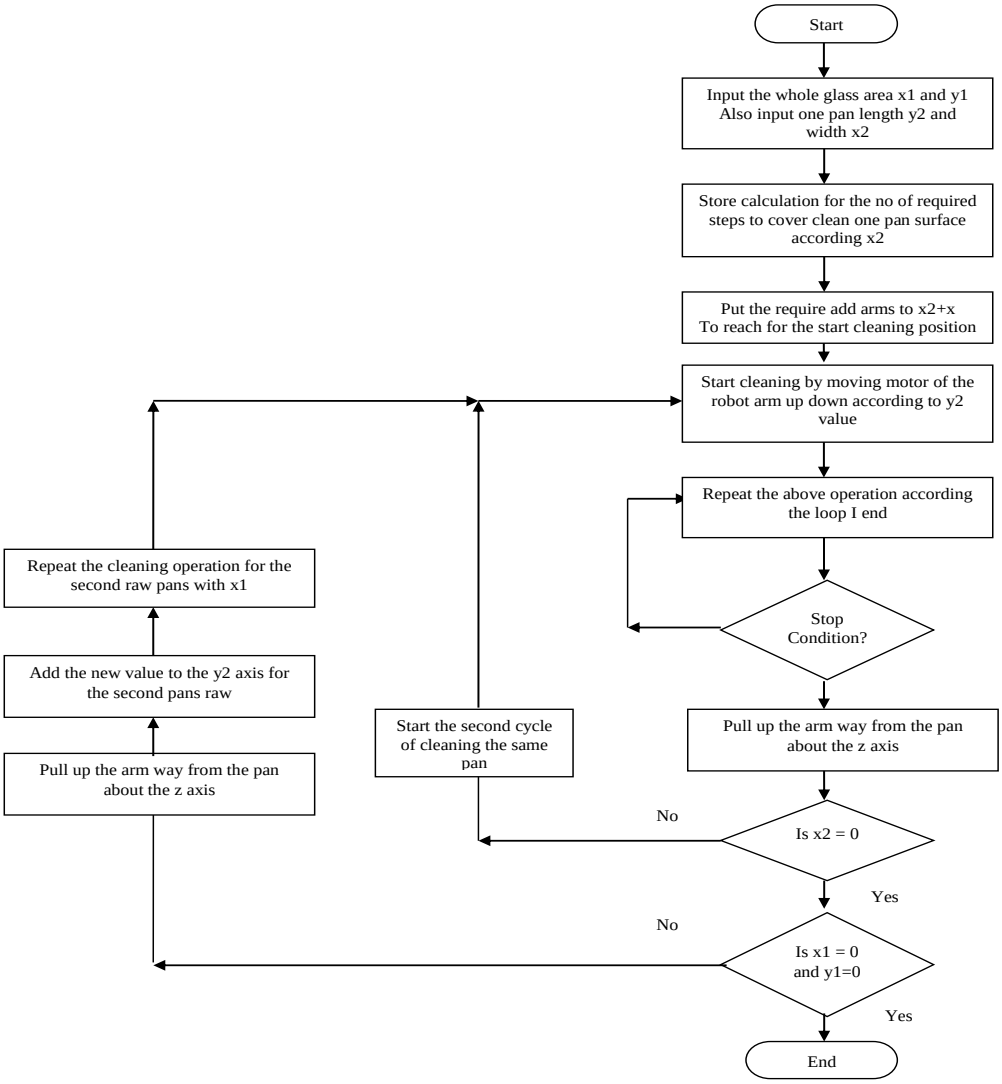

Figure 7. Flow chart of robot cleaning and moving operation

(a) (b)

Figure 8. Frequency of two-phase stepper pulses; (a) low speed and (b) high speed

5. CONCLUSION

This research paper presents that multistory buildings cleaning process can be done in an easier manner and more efficiently by robotic system. The designed system of cleaning windows is developed to give the system ability to wipe and clean common windows panes. The controller is modified in which it can be extended for cleaning different size of windows. Furthermore, the usage of the Arduino microcontroller board gives flexibility to the device due to the ability of update the program that controls the device. This means the ability to develop and improve the function of the device by modification software only without need to change hardware.

REFERENCES

[1] S. Monika, K. Aruna Manjusha, S. V. S. Prasad, B. Naresh," Design and Implementation of Smart Floor Cleaning Robot using Android App", *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, vol. 8, no. 4S2, 2019.

[2] Syamsul Syamsul, Rudi Syahputra, Suherman Suherman, Zamzami Zamzami, "Control System Based on Fuzzy Logic in Nutmeg Oil Distillation Process", *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 16, no. 5, pp. 2254-2262, 2018.

[3] M. A. Viraj J. Muthugala , Manuel Vega-Heredia , Rajesh Elara Mohan and Suresh Raj Vishaal," Design and Control of a Wall Cleaning Robot with Adhesion-Awareness", *Symmetry journal*, vol. 12, no. 122, 2020.

[4] Y Luo, M. J. Er, and L. P. Ong, "Design and development of a glass cleaning robot," *2013 Fourth International Conference on Intelligent Systems Design and Engineering Applications*, pp. 225–228, 2013.

[5] M. Farsia, K. Ratcliffi, P. J. Johnson, C. R. Allen', K.Z. Karam', R. Pawsonb, "Robot control system for window cleaning," *Proceedings of 1994 American Control Conference - ACC '94*, 1994.

[6] Kifaa Hadi Thanoon, "Morphological Properties for Feature Extraction of Geometrical shapes," *International Journal of Engineering and Innovative Technology (IJEIT)*, vol. 7, no. 6, pp. 43-49, 2017.

[7] Ade Silvia Handayani, Siti Nurmaini, Irsyadi Yani, Nyayu Latifah Husni, "Analysis on swarm robot coordination using fuzzy logic," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 13, no. 1, pp. 48-57, 2019.

[8] Omar I. Alsaif, I Saleh, Dia Ali, "Evaluating The Performance of Nodes Mobility For Zigbee Wireless Sensor Network", *2019 International Conference on Computing and Information Science and Technology and Their Applications (ICCISTA)*, 2019.

[9] N. Naresh, T. S. Sirish, Dr. K. S. Sivanandan, "Design And Implementation Of Driving Circuits For Stepper Motor Control Using PIC," *International Journal of Emerging Trends in Engineering and Development*, vol. 2, no. 2, pp. 106–112, 2012.

[10] Ismyuzri Bin Ishak, "Small Cleaning Robot for Office Window," Faculty of Mechanical Engineering, Universti Malasia Pahang, Nov 2008.

[11] Mohamad Taib Miskon, "PCB Design using Proteus," Scribd. [Online]. Available: https://www.scribd.com/doc/116885739/PCB-Design-using-Proteus.

[12] Catherine O. Sereati, Arwin D. Sumari, Trio A. Adang Suwandi Ahmad, "Architecture design for a multi-sensor information fusion processor," *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 17, no. 1, pp. 362-369, 2019.

[13] KI Alsaif, IA Saleh, OI Alsaif, "Design and Analysis WLAN Nodes Performance Based on Roaming Technique," *Journal of Education for Pure Science*, vol. 4, no. 1, pp. 228-235, 2014

[14] S. Nansai and R. Mohan, "A Survey of Wall Climbing Robots: Recent Advances and Challenges," *Robotics*, vol. 5, no. 3, pp. 1-14, 2016.

[15] Diyaa M. Faris, Naqaa L. Mohammed "Circuit Design and Implementation of 3-D Programmable Position Controller Based on FPGA," *2014 15th International Carpathian Control Conference (ICCC)*, 2011.

[16] Essa Ibrahim Al-juborie, Khalil I Al-saif, "Optical Ring Architecture Using 4-Nodes WDM Add/Drop Multiplexer Based SSMF," *Advanced Research in Electrical and Electronic Engineering*, vol. 2, no. 1, pp. 66-68, 2014.

[17] Siti Nurmaini, Bambang Tutuko, Kemala Dewi, Velia Yuliza, Tresna Dewi, "Improving Posture Accuracy of Non-Holonomic Mobile Robot System with Variable Universe of Discourse," *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 15, no. 3, pp. 1265-1279, 2017.
[18] B. Aranjo, P. K. Soori, and P. Talukder, "Stepper motor drives for robotic applications," *2012 IEEE International Power Engineering and Optimization Conference Melaka*, Malaysia, pp. 361–366, 2012.
[19] Ifrah Jaffri, Zeeshan Nafees, Shoaib Zaidi, Oliver Faust, "BlueSteps: A Bluetooth Based Stepper Motor Control System," *Journal of Embedded Systems*, vol. 3, no. 1, pp. 21-27, 2015.
[20] Nazim Mir-Nasri, et al., "Portable Autonomous Window Cleaning Robot," *Procedia Computer Science*, vol. 133, pp. 197-204, 2018.
[21] Mehadi Saki, "Simulation of Arduino Based CNC-Arduino+ GRBL+ Proteus 8," Instructables Circuits. [Online]. Available: http://www.instructables.com/id/Simulation-of-Arduino-Based-CNC-Arduino-GRBL-Prot.
[22] Uman Khalid, Muhammad Faizan Baloch, et al., "Smart Floor Cleaning Robot (CLEAR)" Institute of Engineering Sciences and Technology, Pakistan Hamdard Institute of Engineering & Technology, Hamdard University, Karachi, Pakistan, 2015.
[23] Manreet Kaur, Preeti Abrol, "Design and Development of Floor Cleaner Robot (Automatic and Manual)," *International Journal of Computer Applications*, vol. 97, no. 19, July 2014.
[24] Zainab G. Faisal, Maysam S. Hussein, Amany M. Abood, "Design and realization of motion detector system for house security," *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 17, no. 6, pp. 3211-3217, 2019.
[25] Andi Adriansyah, Yudhi Gunardi, Badaruddin Badaruddin, Eko Ihsanto, "Goal-seeking Behavior-based Mobile Robot Using Particle Swarm Fuzzy Controller," *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 13, no. 2, pp. 528-538, 2015.
[26] Hany Ferdinando, Handry Khoswanto, Djoko Purwanto, "Performance Evaluation of MMA7260QT and ADXL345 on Self Balancing Robot," *TELKOMNIKA Telecommunication Computing Electronics and Control*, vol. 11, no. 1, pp. 1-10, 2013.
[27] S. S. Mohammedsheet and M. S. Aziz, "Design and implementation of digital heart rate counter by using the 8051microcontroller," *2018 International Conference on Engineering Technology and their Applications (IICETA)*, pp. 107-111, 2018.

BIOGRAPHIES OF AUTHORS

Naqaa Luqman Mohammed, Assist. Lecturer, Msc. in Computer Technical Engineering in 2012 , College of Engineering Technical, North Technical University, Mosul. Iraq She has some publications research in different place such as "Circuit Design and Implementation of Dental System Controller Based on FPGA" in Journal of Babylon University, "Controlling Directivity of Solar Cells Array Based on FPGA" in Al Altaqani Journal, "Mobile Base Program for Drug-Drug Interactions (MBPDDIs) in Engineering and Technology Journal. Ass .Lec. Mohammed,work in Computer Technical Engineering Dept./ Engineering Technical College.

Mothanna Sh. Aziz, I am an electrical engineer, I have two degrees in electrical power engineering BEng.in 2005 and MEng in 2008 from Northern Technical University, Iraq. Currently, I am an assistant lecturer in Northern Technical University with full time position. I am interested in research area related to power electronic, electrical power systems engineering and control.

Omar. Alsaif. He received his B.Sc. in electrical engineering from University of Mosul, Mosul, Iraq, in 1992. He received his M.Sc. and Ph. D degrees in electrical and microelectronic engineering from Mosul University, in 2005 and 2018 respectively. He is currently a lecturer in the Mosul Technical Institute/Northern Technical University in Mosul, Iraq.His research interests include microelectronic and solid-state systems, renewable energy and solid-state devices.