An Animatronic Arm Mimicking Human-like Motions

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***Abstract* - There Human presence and movement are highly controlled at certain workplaces where significant harm to human life is anticipated, such as nuclear reactors, thermal power plants, and airtight rooms. To manipulate devices and equipment as well as for handling raw materials in such places, the use of robots that can precisely imitate human actions is widely considered a safe proposal. In this paper, we present an animatronic arm system that mimics a human hand movement, which can be deployed to work in areas that are generally unsafe for humans. Animatronic arm is the use of mechatronics to create arm movement which seems animated. The CREO software has been used to design an animatronic hand. The servo motors are used to imitate the movement of the human hand as motion actuator. The flex sensors are used to measure the bending and defection of the human fingers. An Arduino controller sends the commands to the motion actuator. MATLAB program has generated for imitation control of the robotic arm. We describe the use of this robotic arm for bomb diffusion in a defense field, wherein the robotic arm mounted on a moving platform equipped with a camera is operated from a safer distance to diffuse the bomb, without causing any potential risk to human life.**

Keywords: Human imitation, Animatronic arm, Animatronic hand, flex sensor, Arduino UNO, Robotic arm.

I. INTRODUCTION

A robotic arm with human-like performance has long drawn a considerable attention of the scientific world. While imitation is a commonly observed behavior among human beings, the development of robots to full imitate human actions is still in progress. However, in some places, a robot cannot fully replace a human scientist or a researcher. Working in airtight rooms for scientific research and dealing with radioactive devices or elements calls for significant precautionary measures. Thus, robotic arms with the ability to mimic human-like actions are a real need due to the increasing concerns of human safety in a research setting. In this paper, we present a wireless robotic arm that can be deployed and operated from a distance, thus eliminating any possible harm to human life from an imminent danger arising out of a failed attempt. For example, during bomb diffusion in the defense field, this animatronic hand, mounted on a moving platform equipped with a camera, can be operated from a safer distance, without causing any potential risk to human life. The mechanical arm that is used will replicate the motions of an operator's hands. Our prototype of the robotic arm well imitated the operator's finger actions.

Aakash K (2012) proposed the simulation of hand gestures using MATLAB. The implementation was phased into three steps, beginning with hand segmentation, followed by tracking the position and orientation of the hand to avoid errors in segmentation, and estimating the hard features to define the deterministic process of gesture [1]. S.Deshpande (2015) developed a robotic arm based on MEMS accelerometer technology. A MEMS motion sensor was used to sense the operator's finger movements. Using a preloaded code, the hand gestures were controlled. We used six motors in our robotic arm—two for shoulder and wrist motions and one for elbow and gripping motions [2]. Saurab et al.,(2015) proposed a four-finger robotic arm developed using 8-bit microcontroller sensors and wireless feedback. Fourteen commands were used to control all four fingers to open and close, wrist up and down, base clockwise & counter clockwise, pick and place, home position. This robotic arm was designed to perform a simple reflexive grasp that may be utilized to manipulate a variety of objects [3]. Agarwal A.D and Chandak M.A (2012) explains various Animatronic hand designed and implemented in various organizations such as UTAH/MIT hand, NASA Hand (Robonaut Hand), GIFU Hand [4]. G Saha et al.,(2018) has presented development of mimicking robotic arm and discussed about faced difficulties while development of the system [5].

Our system basically consists of two main parts—a transmitter with control glove and a robotic arm [9-15]. With the help of this device, the operator can safely keep a distance from an experiment while being able to execute the task remotely [16-26].

II. DESIGN OF THE ANIMATRONIC ARM

The Animatronic Arm is designed using CREO software. The fingers in the hand are designed by comparing with the force analysis required by a normal hand finger. Fig. 1 depicts the design of an animatronic hand in CREO software [27-37]. The contact area analysis of the hand with the objects is also performed using the software.

Fig.1 Design of Animatronic Arm using CREO software

III. FABRICATION OF THE ANIMATRONIC ARM

Coroplast (corrugated polypropylene sheet) was a preferred medium for the fabrication of the robotic arm. The outline was cut out from the sheet using a blade as per design. After creasing the front and back sides of the hand, a template of finger folds was obtained. The model of a human hand thus obtained resembled an actual hand. A single coroplast tube was used to make compartments for strings and elastic elements. Elastic bands were attached to one side of the robotic arm, which will allow the operator to initiate a motion with robotic arm and them bring it to rest position. Several strings were attached to the other side of the robot hand for finger motions under the control of actuators. Fig. 2 (a) shown the robotic arm with elastic elements (back view) and Fig.2 (b) shown the robotic arm with threads for actuation (front view).

Fig. 2: (a) The robotic arm with elastic elements (back view). (b) The robotic arm with threads for actuation (front view).

A. SERVO MOTOR CONNECTION

Servo motor is the actuator used to actuate the robot hand that has been made. Fig. 3 (a) shown the servo motors are mounted on a coroplast board. Fig. 3 (b) shown the servo motor attached to the hand.The servo motors are initially set in the 0-degree position and a link is coupled to the servo shaft to connect the string [38-48].The strings are connected to the servo motor in such a way that they are tightly attached to the links on the servo motor shaft. It is attached in a way that the strings are tight but the fingers are still in the rest position [49-58]. The servo motors can be set to a different offset position in order to achieve the tight string and initial rest position of the fingers.

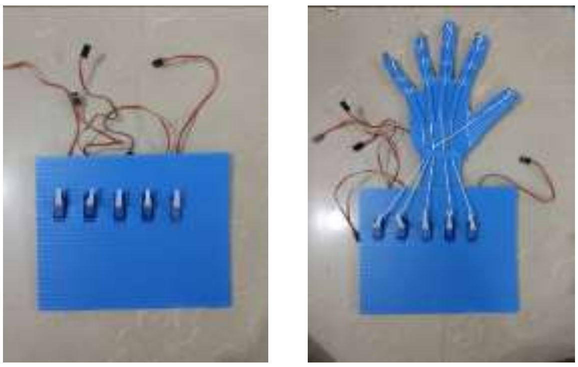

Fig. 3: (a) Servo motor connection (b) Servo motor connected with arm

B. SERVO MOTOR INTERFACE

A servo motor has a motor, a gear system, and a feedback system built-in in it. It is energized by a power line, a ground, and a control pin. The servo motor has three pins ground, power, and signal. The darkest one is usually the ground it is connected to the Arduino GND. The red one is the power pin it is connected to the 5V output on the Arduino board. Remaining pin is the signal pin which is connected to the digital pin on the Arduino board. The adjusting knob of the potentiometer is arranged with output shaft by means of another gear assembly. During rotation of the shaft, the knob also rotates and creates a varying electrical potential according to the principle of the potentiometer. Fig.5 shown the interface between servo motor and Arduino board.

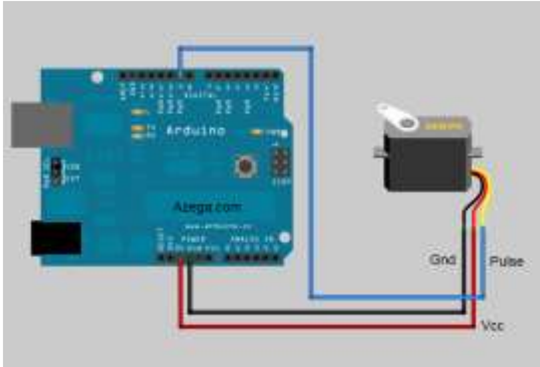

Fig.5 The interface between servo motor and Arduino board

C. FLEX SENSOR CONNECTION

Flex sensors are used to measure the bending and defection of the human fingers. There are five flex sensor sensors has been attached each finger on the glove. They are placed on the gloves in a way that each finger has a sensor on them. An insulation material is used to place the sensor in the glove and tapped using insulation tape or else the sensors are stitched to the glove. Thus the flex sensor is mounted on the gloves as shown in the Fig.6.

Fig.6 The flex sensor mounted on the glove

The flex sensor should be connected to the Analog pins in the Arduino UNO board so that the Arduino reads the signal of the sensor. The sensor signal cannot be obtained directly. A voltage divider circuit set to get the output voltage, which is then given to the Arduino as the Analog input. Usually, a flex sensor is used in voltage divider configuration.

D. INTERFACING FLEX SENSOR WITH ARDUINO

The Fig. 7 is shown the pin diagram of flex sensor. The active portion of the sensor is quite sturdy but the pin end is fragile thus it is taped or glued tightly to the active portion so that it bends along with the active portion of the sensor. The flex sensor is connected to the Arduino board using a voltage divider circuit as shown in the Fig. 8. The output of this circuit is given to the analog input on the Arduino board.

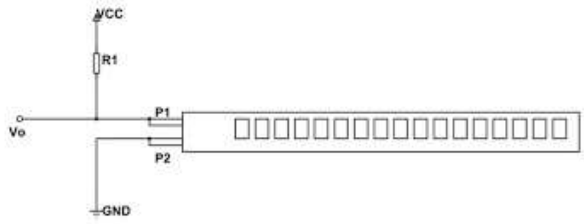

Fig.7 Pin diagram of flex sensor

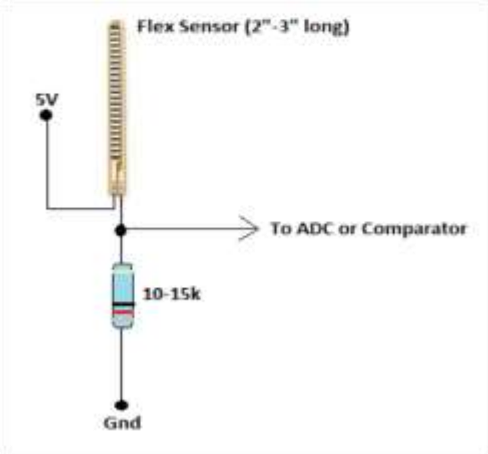

Fig.8 Flex sensor connected to Arduino

The analogRead() function will provide the sensor values.

flex = analogRead(1);

Serial.print(flex);

This will print values on the serial monitor. The serial monitor or the plotter is used to see the range of the Analog signal provided by each sensor when they are bent and when they are in the relaxed position. This Analog signal is important because they are later used to write the program for the imitation control of the robotic hand. Fig.9 shown flex sensor provided analog signal.

Fig.9 Flex sensor analog signal

E. ALGORITHM

1. Start.
2. Declare servos and variables.
3. Attach servo motors to the corresponding ports.

4. Set the initial position at 0 degrees.
5. Read Analog data from the sensor.
6. Describe respective angles of the servo motor for the corresponding Analog signal.
7. Stop.

IV. SYSTEM SETUP AND EVALUATION

In our robotic arm model, flex sensors were used to sense the motions of operator’s fingers, and analog signals were obtained using a voltage divider circuit. The analog signals were fed to the Arduino board through input ports (A0–A4). The Arduino microcontroller then read the input and provided an output (PWM signals), which was given as input to the servo motor to actuate the robotic arm. The input signals provided into the servo motor must be parallel with the physical features of the operator’s arm gestures in order for the robotic arm to precisely imitate the operator’s arm. The Fig.10 and Fig.11 Shown work flow diagram of the animatronic arm.

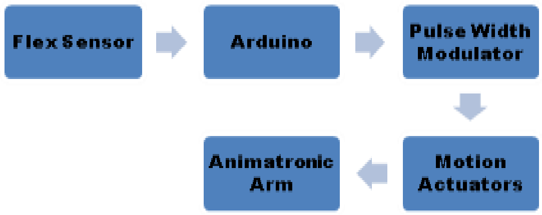

Fig.10 Work flow diagram of the Animatronic arm

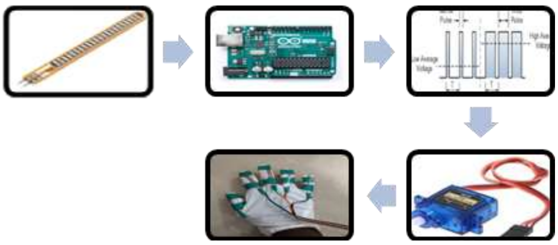

Fig.11 Work flow diagram of the Animatronic arm - pictorial view

V. RESULT

The Imitating Robotic hand was first tested with a single finger. It was observed that after bending the single flex sensor by bending a single finger, the corresponding robotic finger moved in the same direction and the same angle. Servo motor makes the fingers in the robotic hand move. With reference to this, all five servo motors moved by five flex sensors on a cotton or woolen glove. In this way, the imitation of hand movements has been achieved successfully. So, now it is possible that a man can control a robotic hand without exposing himself to hazardous regions. The Fig.12 shows the completed model of the human imitating robotic arm.

Fig.12 Animatronic arm system

VI. CONCLUSION

The proposed Animatronic arm system had designed and affordable as it was implemented using an Arduino microcontroller. It can serve many useful purposes in environments where human presence is highly restricted. Future efforts will be made to improve the device with abilities to fly over a distance or even operate underwater. In addition, by installing camera sensors, real-time image processing can be performed with an aim to improve the trajectory and locomotion of the robot arm.

REFERENCES

1. Aakash K. Sancheti, “Gesture Actuated Robotic Arm”, International Journal of Scientific and Research Publications, December 2012, Pune, India.
2. Mrs Shubhada Deshpande”Wireless Animatronic Hand Using Control Glove”, IJIERE International Journal of Innovative and Emerging Research in Engineering, 2015, Mumbai, India.
3. Saurabh A. Khajone , Dr. S. W. Mohod , V.M. Harne, “Implementation of a Wireless Gesture Controlled Robotic Arm” ,in International Journal of Innovative Research in Computer and Communication Engineering , January 2015, Amravati, India.
4. Agarwal A.D and Chandek M.A (2012) Animatronic Hand. Word Research Journal of Biologically-Inspired Computing, ISSN: 2278-8492 & E-ISSN: 2278-8506, Volume 1, Issue 1, pp.12-15.
5. G Saha., S Das., A Ghosh, J Rakshit, K Hasan, A D Roy, N Das and A Paul, “Mimicking Robotic Arm”, Fourth International Conference on Research in Computational Intelligence and Communication Networks (ICRCICN), IEEE, 2018.
6. J. Dhanasekar, P. Sengottuvel, G.Manikandan, M. Deepa “Development of a Robotic Arm for Dangerous(Explode) Object Disposal”, International Journal of Innovative Research in Science, Engineering and Technology (ISSN(Online): 2319 – 8753& ISSN (Print) :2347 – 6710) Vol. 4, Issue 6, June 2015, Page no. 4058- 4065 DOI:10.15680/IJIRSET.2015.04061198
7. Manikandan G, Dhanasekar J, Sridevi S and Sengottuvel P “Dynamic Ball Tracking and Hitting Robot Using Vision System”, International Journal of Innovative Research in Science, Engineering and Technology,(ISSN(Online): 2319 – 8753& ISSN (Print) :2347 – 6710) Vol. 4, Issue 7, July 2015,Page no. 6148 – 6153. DOI:10.15680/IJIRSET.2015.0407286.
8. S.Sridevi, G.Manikandan, J.Dhanasekar, P.Sengottuvel “Design of Fire Fighting Robot” International Journal of Innovative Research in Science, Engineering and Technology,(ISSN(Online): 2319 – 8753& ISSN (Print) :2347 – 6710) Vol. 3, Issue 11, November 2014, Page no.17141 – 17144. DOI: 10.15680/IJIRSET.2014.0311094.
9. Ganesh Babu Loganathan, Praveen M., Jamuna Rani D., “Intelligent classification technique for breast cancer classification using digital image processing approach” IEEE Xplore Digital Library 2019, Pp.1-6.
10. M. Viswanathan, Ganesh Babu Loganathan, and S. Srinivasan, “IKP based biometric authentication using artificial neural network”, AIP Conference Proceedings (2020), Volume 2271, Issue 1, pp 030030.
11. Mohammed Abdulghani Taha and Ganesh Babu Loganathan, “Hybrid algorithms for spectral noise removal in hyper spectral images” AIP Conference Proceedings (2020), Volume 2271, Issue 1, pp 030013.
12. Dr.Idris Hadi Salih, Ganesh Babu Loganathan, ”Induction motor fault monitoring and fault classification using deep learning probablistic neural network” Solid State Technology(2020), Volume 63, Issue 6, PP No. 2196-2213.
13. Ganesh Babu Loganathan “Design and analysis of high gain Re Boost-Luo converter for high power DC application”, Materials Today: Proceedings(2020), Volume 33, Part 1, PP 13-22.

14. Ganesh Babu Loganathan, Dr.E.Mohan, R.Siva Kumar, “ Iot Based Water And Soil Quality Monitoring System”, International Journal of Mechanical Engineering and Technology (IJMET)(2019), Vol.10 Issue No.2, P.No. 537-541.
15. Suganthi K, Idris Hadi Salih, Ganesh Babu Loganathan, and Sundararaman K, “A Single Switch Bipolar Triple Output Converter with Fuzzy Control”, International Journal of Advanced Science and Technology, (2020), Vol. 29, No. 5, (2020), P.No.. 2386 – 2400.
16. Ganesh Babu Loganathan, “Can Based Automated Vehicle Security System”, International Journal of Mechanical Engineering and Technology (IJMET)(2019), Vol.10 Issue No.07, P.No. 46-51.
17. Ganesh Babu L 2019 Influence of benzoyl chloride treatment on the tribological characteristics of Cyperus pangorei fibers based nonasbestos brake friction composites Mater. Res. Express 7 015303.
18. Qaysar Salih Mahdi, Idris Hadi Saleh, Ghani Hashim, Ganesh Babu Loganathan, “Evaluation of Robot Professor Technology in Teaching and Business”, Information Technology in Industry, Volume 09, Issue 01, PP 1182-1194.
19. Ellappan Mohan, Arunachalam Rajesh , Gurram Sunitha , Reddy Madhavi Konduru , Janagaraj Avanija, Loganathan Ganesh Babu, “A deep neural network learning-based speckle noise removal technique for enhancing the quality of synthetic-aperture radar images”, Concurrency And Computation-Practice & Experience, https://doi.org/10.1002/cpe.6239.
20. Ganesh Babu Loganathan, Idris Hadi Salih , A.Karthikayen, N. Satheesh Kumar, Udayakumar Durairaj. (2021). EERP: Intelligent Cluster based Energy Enhanced Routing Protocol Design over Wireless Sensor Network Environment. International Journal of Modern Agriculture, 10(2), 1725 - 1736. Retrieved from http://www.modern-journals.com/index.php/ijma/article/view/908
21. BABU LOGANATHAN, GANESH; E.MOHAN, Dr.. High Quality Intelligent Database Driven Microcontroller Based Heartbeat Monitoring System. **International Journal of Engineering & Technology**, [S.l.], v. 7, n. 4.6, p. 472-476, sep. 2018. ISSN 2227-524X.
22. Loganathan, Ganesh Babu, Vanet Based Secured Accident Prevention System (September 10, 2019). International Journal of Mechanical Engineering and Technology, 10(6), 2019, pp. 285-291,
23. S Priyadharsini, TS Sivakumaran, C Kannan, ”Performance analysis of photovoltaic-based SL-quasi Z source inverter” International Journal of Energy Technology and Policy, Volume 1, Issue 3, Pages 254-264.
24. Dr.A.Senthil Kumar, Dr.G.Suresh, Dr.S.Lekashri, Mr.L.Ganesh Babu, Dr. R.Manikandan, “Smart Agriculture System With E – Carbage Using Iot”, International Journal of Modern Agriculture, Volume 10, No.1, 2021 pp 928-931.
25. Muthukumaran, S., Ganesan, M., Dhanasekar, J. and Loganathan, G.B. (2021). Path Planning Optimization for Agricultural Spraying Robots Using Hybrid Dragonfly – Cuckoo Search Algorithm. Alinteri Journal of Agriculture Sciences, 36(1): 412-419. doi: 10.47059/alinteri/V36I1/AJAS21062.
26. Muthuramalingam, T., Saravanakumar, D., Babu, L.G. et al. Experimental Investigation of White Layer Thickness on EDM Processed Silicon Steel Using ANFIS Approach. Silicon 12, 1905–1911 (2020). https://doi.org/10.1007/s12633-019-00287-2
27. G, Sai Krishnan and Loganathan, Ganesh Babu and K, Selva Ganapathy and N, Srivathsan and M, Vasanth and G, Venkatateja, Development of Superhydrophobic Nanocomposite Coatings on FRP Sheet Surface for Anti-Icing and Wear-Resistance Applications (August 5, 2019). Proceedings of International Conference on Recent Trends in Computing, Communication & Networking Technologies (ICRTCCNT) 2019, Available at SSRN: https://ssrn.com/abstract=3432305 or http://dx.doi.org/10.2139/ssrn.3432305
28. S.P. Sundar Singh Sivam, Ganesh Babu Loganathan, K. Saravanan, S. RajendraKumar, “Outcome of the Coating Thickness on the Tool Act and Process Parameters When Dry Turning Ti–6Al–4V Alloy: GRA Taguchi & ANOVA”, International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-8, Issue-4, February 2019 PP. 419-423.
29. Sivam S.P.S.S., Loganathan G.B., Saravanan K., Dinesh Guhan S., Banerjee A. (2021) Effects of Drilling Process Parameters Using ANOVA and Graphical Methods. In: Kumaresan G., Shanmugam N.S., Dhinakaran V. (eds) Advances in Materials Research. Springer Proceedings in Materials, vol 5. Springer, Singapore. https://doi.org/10.1007/978-981-15-8319-3_35
30. Muthuramalingam T., Ganesh Babu L., Sridharan K., Geethapriyan T., Srinivasan K.P. (2020) Multi-response Optimization of WEDM Process Parameters of Inconel 718 Alloy Using TGRA Method. In: Sattler KU., Nguyen D., Vu N., Tien Long B., Puta H. (eds) Advances in Engineering Research and Application. ICERA 2019. Lecture Notes in Networks and Systems, vol 104. Springer, Cham. https://doi.org/10.1007/978-3-030-37497-6_56
31. BABU, L. G. (2020). INFLUENCE ON THE TRIBOLOGICAL PERFORMANCE OF THE PURE SYNTHETIC HYDRATED CALCIUM SILICATE WITH CELLULOSE FIBER. In Journal of the Balkan Tribological Association (Vol. 26, Issue 4, pp. 747–754).
32. Sai Krishnan G., Shanmugasundar, Pradhan R., Loganathan G.B. (2020) Investigation on Mechanical Properties of Chemically Treated Banana and Areca Fiber Reinforced Polypropylene Composites. In: Praveen Kumar A., Dirgantara T., Krishna P.V. (eds) Advances in Lightweight Materials and Structures. Springer Proceedings in Materials, vol 8. Springer, Singapore. https://doi.org/10.1007/978-981-15-7827-4_27
33. Abdulghani Taha, Mohammed and Şah, Melike and Direkoğlu, Cem and Babu Loganathan, Ganesh (2020) *Adaptive Wiener Filter And Non Linera Diffusion Based Deblurring And Denoising Images*. Journal of critical reviews, 7 (3). pp. 908-915. ISSN 23945125

34. T. Muthuramalingam, S. Vasanth, L. G. Babu, D. Saravanakumar and P. Karthikeyan, "Flushing Pressure Automation for Efficient Machining in EDM Process," 2019 7th International Conference on Control, Mechatronics and Automation (ICCMA), 2019, pp. 232-236, doi: 10.1109/ICCMA46720.2019.8988592.
35. Sivam, S.P.S.S., Loganathan, G.B., Kumaran, D., Saravanan, K., Rajendra Kumar, S., 2019. Performance Evaluation of Yield Function and Comparison of Yielding Characteristics of SS 304 in Annealed and Unannealed Conditions. MSF 969, 637–643. https://doi.org/10.4028/www.scientific.net/msf.969.637.
36. Babu Loganathan, Ganesh (2020) Activated Carbon Production From Biowaste Materials - Properties and Applications: A Review. Indian Journal of Environmental Protection, 40 (5). pp. 507-511.
37. Manikandan Ganesan, K.R. Ishwarya, Demoz Lisanework, Ganesh Babu Loganathan, "Design and Implementation of Single Phase to Three Phase Drive System Using Space Vector Modulation", REVISTA GEINTEC-GESTAO INOVACAO E TECNOLOGIAS, Vol. 11, No. 2 (2021) , pp 2221-2239. https://doi.org/10.47059/revistageintec.v11i2.1870
38. Ganesh Babu Loganathan, Dr. Mohammad M. Othman, Elham Tahsin Yasin, "An Analysis on Garbage Removal Process by WSN thorugh Global System for Mobile Communication Media" , REVISTA GEINTEC-GESTAO INOVACAO E TECNOLOGIAS, Vol. 11, No. 3 (2021) , pp 493-505. https://doi.org/10.47059/revistageintec.v11i3.1952.
39. BABU, LG (2021). MICROSTRUCTURE AND WEAR BEHAVIOR OF A356-TIB2 NOVEL METAL MATRIX COMPOSITES. In Journal of the Balkan Tribological Association (Vol. 27, Issue 3, pp. 417–425).
40. G Shanmugasundar etal 2020, Fabrication and analysis of mechanical properties of PVC/Glass fiber/graphene nano composite pipes, Mater. Res. Express **7** 115303.
41. Loganathan, G., Saravanan, K., Rajendran, R., Sivam Sundarlingam Paramasivam, S. et al., "Investigation of Setting Input Process Parameters for Getting Better Product Quality in Machining of AM60 Magnesium Alloy - TOPSIS and ANOVA Approach," SAE Technical Paper 2019-28-0136, 2019, https://doi.org/10.4271/2019-28-0136.
42. Sivam Sundarlingam Paramasivam, S., Loganathan, G., Kumaran, D., Saravanan, K. et al., "Taguchi Based Vikor Method for Optimization of Cutting Parameters for Improving the Efficiency in Machining Process by Considering the Effect of Tool Nose Radius," SAE Technical Paper 2019-28-0138, 2019, https://doi.org/10.4271/2019-28-0138.
43. Sai Krishnan, G. Shanmugasundar, Pradhan, Raghuram Loganathan, Ganesh Babu, Praveen Kumar, A., Dirgantara, Tatacipta Krishna, P. Vamsi, 2020,"Investigation on Mechanical Properties of Chemically Treated Banana and Areca Fiber Reinforced Polypropylene Composites ", Advances in Lightweight Materials and Structures, PP 273 280,Springer Singapore, Singapore
44. Loganathan, G., Kumaran, D., Sivam Sundarlingam Paramasivam, S., Saravanan, K. et al., "Improvement of Mechanical Properties, and Optimization of Process Parameters of AISI 1050 Spheriodized Annealed Steel by Ranking Algorithm," SAE Technical Paper 2019-28-0143, 2019, https://doi.org/10.4271/2019-28-0143.
45. Sivam Sundarlingam Paramasivam, S., Kumaran, D., Loganathan, G., Saravanan, K. et al., "Development and Influence of Setting Process Variables in Single Point Incremental Sheet Metal Forming of AA 8011 Using Complex Proportional Assessment and ANOVA," SAE Technical Paper 2019-28-0064, 2019, https://doi.org/10.4271/2019-28-0064.
46. Loganathan, G., Sivam Sundarlingam Paramasivam, S., Kumaran, D., Saravanan, K. et al., "Experimental Study on Verification of Alloy ASTM A510 High-Speed Micro Turning by Parameters Validation through Ranking Algorithm," SAE Technical Paper 2019-28-0071, 2019, https://doi.org/10.4271/2019-28-0071.
47. Sivam Sundarlingam Paramasivam, S., Loganathan, G., Saravanan, K., Kumaran, D. et al., "A Study on Mechanical Properties and Multi Response Optimization of Process Parameters for Showing Signs of Improvement Product Quality in Drilling $AlSi_7Cu_4$ Utilizing GRA in Taguchi Method," SAE Technical Paper 2019-28-0058, 2019, https://doi.org/10.4271/2019-28-0058.
48. AHMED AMEER ARSALAN HADI , KARAM DHEYAA JIRJEES, G. B. L. I. H. S. (2021) "AN ANALYSIS OF TOPOLOGY OPTIMIZATION ON ROBOT BY FINITE COMPONENT", DESIGN ENGINEERING, PP. 7336-7351. HTTP://WWW.THEDESIGNENGINEERING.COM/INDEX.PHP/DE/ARTICLE/VIEW/3246 .
49. S DHANRAJ ET AL 2019, "AN EFFICIENCY STUDY ON WATER EXTRACTION FROM AIR USING THERMOPHORESIS METHOD" IOP CONF. SER.: MATER. SCI. ENG. **574** 012003.
50. Dr.A.Senthil Kumar, Dr.Venmathi A R ,L.Ganesh Babu, Dr.G. Suresh, "Smart Agriculture Robo With Leaf Diseases Detection Using IOT", European Journal of Molecular & Clinical Medicine, Volume 07, Issue 09, PP 2462-2469.
51. Babu Loganathan, Ganesh (2021) A Study on Data Analysis and Electronic Application for the Growth of Smart Farming. Alinteri Journal of Agriculture Sciences, 36 (1). pp. 209-218. ISSN 2564-7814
52. B.K. Patle, Ganesh Babu L, Anish Pandey, D.R.K. Parhi, A. Jagadeesh,A review: On path planning strategies for navigation of mobile robot, Defence Technology, Volume 15, Issue 4, August 2019, Pages 582-606.
53. Elham Tahsin Yasin, Nawroz I. Hamadamen, Ganesh Babu Loganathan, Manikandan Ganesan, "Recent Scope for AI in the Food Production Industry Leading to the Fourth Industrial Revolution", Webology, Volume 18, Issue-Number 2, December, 2021, PP 1066-1080. DOI: 10.14704/WEB/V18I2/WEB18375.
54. Ganesh Babu Loganathan, K. I. M. G. (2021). CROWD CONTROL ROBOT FOR CONGESTION CONTROL. *Design*

Engineering, 3377- 3391. Retrieved from http://thedesignengineering.com/index.php/DE/article/view/5286.

55. Mr.Vishwa Deepak, S.Nithish, D. V. B. M. B. L. M. (2021). Static Stress Analysis of an Addendum Modified Spur Gear Pair using FRP Material. *Design Engineering*, 3562-3573. Retrieved from https://thedesignengineering.com/index.php/DE/article/view/5301.
56. P. Jeevitha, K. S. Elango, Ganesh Babu L, J. Ranjitha, S. Vijayalakshmi," Glycerol as a Key Reactant in the Production of 3-Hydroxypropanoic Acid using Engineered Microbes", AIP Conference Proceedings 2396, 030004 (2021). https://doi.org/10.1063/5.0066423
57. Mahdi, Q.S., & Loganathan, M.G.B. (2021). Modelling of Radar Targets and Radar Cross Section for Air Traffic Control Radars. EFFLATOUNIA-Multidisciplinary Journal, 5(2), 664 – 674.
58. Mahdi, Q.S., & Loganathan, M.G.B. (2021). Classification of Web Page by Using Neural Networks. EFFLATOUNIA-Multidisciplinary Journal, 5(2), 650 – 663.
59. Manikandan Ganesan, Ganesh Babu Loganathan, J.Dhanasekar, K. R. Ishwarya, Dr.V.Balambica. (2021). IMPLEMENTING INDUSTRIAL ROBOTICS ARMS FOR MATERIAL HOLDING PROCESS IN INDUSTRIES. *Harbin Gongye Daxue Xuebao/Journal of Harbin Institute of Technology*, *53*(9), 17–27. Retrieved from http://hebgydxxb.periodicales.com/index.php/JHIT/article/view/704