OUTDOOR POLLUTION MEASUREMENT USING IOT SYSTEMS

[1]Yoheswari S
[1] Department of Computer Science & Engineering, K.L.N College of Engineering, Pottapalayam – 630612, Tamilnadu, India
[1]yoheswari1988@gmail.com

Abstract: Air pollution is a significant environmental concern that affects human health, ecosystems, and climate change. Effective monitoring and management of outdoor air quality are crucial for mitigating its adverse effects. This paper presents an advanced approach to outdoor pollution measurement utilizing Internet of Things (IoT) technology, combined with optimization techniques to enhance system efficiency and data accuracy. The proposed framework integrates a network of IoT sensors that continuously monitor various air pollutants, such as particulate matter (PM), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ozone (O_3), across different geographic locations. The data collected by these sensors are transmitted to a centralized system where optimization algorithms, such as Genetic Algorithms (GA), Particle Swarm Optimization (PSO), and Simulated Annealing (SA), are applied to optimize sensor placement, data transmission, and processing efficiency. This ensures accurate, real-time pollution monitoring and data analysis, providing actionable insights for policymakers, environmental agencies, and the general public. The system's performance is evaluated through simulations and real-world experiments, demonstrating its capability to deliver reliable and timely pollution data. Future work will explore the integration of machine learning techniques for predictive analytics and the expansion of the sensor network for broader coverage.

Key words: Outdoor Pollution Measurement, Internet of Things (IoT), Optimization Techniques, Air Quality Monitoring, Environmental Sensing

Corresponding Author: Yoheswari S
K.L.N. College of Engineering, Pottapalayam, Tamil Nadu, India
Mail: yoheswari1988@gmail.com

Introduction:

Outdoor air pollution has become one of the most pressing environmental challenges of the 21st century, with severe implications for public health, biodiversity, and climate stability. As urbanization and industrialization continue to rise, so does the emission of harmful pollutants into the atmosphere. These pollutants, which include particulate matter (PM), carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), and ozone (O_3), are linked to respiratory and cardiovascular diseases, premature death, and environmental degradation.

Therefore, continuous monitoring and accurate measurement of outdoor air pollution are imperative for effective environmental management and public health protection.

Traditional methods of pollution measurement, which rely on stationary monitoring stations, are limited in their coverage and often fail to provide real-time data. The emergence of the Internet of Things (IoT) offers a promising solution to these limitations by enabling the deployment of a network of low-cost, interconnected sensors that can monitor air quality across vast geographic areas in real time. IoT-based pollution measurement systems allow for the collection of large amounts of data, which can be used to identify pollution hotspots, assess the effectiveness of pollution control measures, and inform policy decisions.

However, the deployment of IoT systems for pollution monitoring presents several challenges, including the need for optimal sensor placement, efficient data transmission, and real-time data processing. These challenges can be addressed through the application of optimization techniques, which aim to improve the performance and accuracy of IoT-based pollution measurement systems. Optimization algorithms such as Genetic Algorithms (GA), Particle Swarm Optimization (PSO), and Simulated Annealing (SA) can be employed to determine the optimal placement of sensors, minimize energy consumption, and enhance data processing efficiency.

This paper presents a comprehensive framework for outdoor pollution measurement using IoT, enhanced by optimization techniques. The proposed framework aims to provide accurate, real-time pollution data that can be used for environmental monitoring and decision-making. The remainder of this paper is organized as follows: Section II reviews the existing literature on IoT-based pollution measurement systems and optimization techniques. Section III describes the proposed framework, detailing the IoT architecture, sensor network, and optimization strategies. Section IV presents the experimental results, demonstrating the effectiveness of the framework in real-world scenarios. Finally, Section V discusses the implications of this research and outlines potential directions for future work.

IoT Sensor Network Design and Deployment:

The first step in the proposed framework involves designing and deploying an IoT sensor network for outdoor pollution measurement. The network consists of a distributed array of sensors, each capable of detecting specific air pollutants such as PM, CO, SO_2, NO_2, and O_3. These sensors are strategically placed across different geographic locations to ensure comprehensive coverage of the monitored area. The placement of sensors is optimized using Genetic Algorithms (GA), which evaluate various placement configurations based on factors such as pollution sources, terrain, and population density. This optimization ensures that the sensors are placed in locations where they can capture the most relevant pollution data, while also minimizing the number of sensors needed and the associated costs.

Data Collection and Transmission:

Once the IoT sensor network is deployed, it begins the continuous collection of pollution data. Each sensor measures the concentration of specific pollutants in the air and transmits this data to a central server for processing. To optimize the efficiency of data transmission, Particle Swarm Optimization (PSO) is employed. PSO is used to determine the optimal communication paths between the sensors and the central server, minimizing energy consumption and ensuring that data is transmitted quickly and reliably. The data is transmitted via wireless communication protocols such as LoRaWAN, Zigbee, or cellular networks, depending on the network's requirements and the geographic area being monitored.

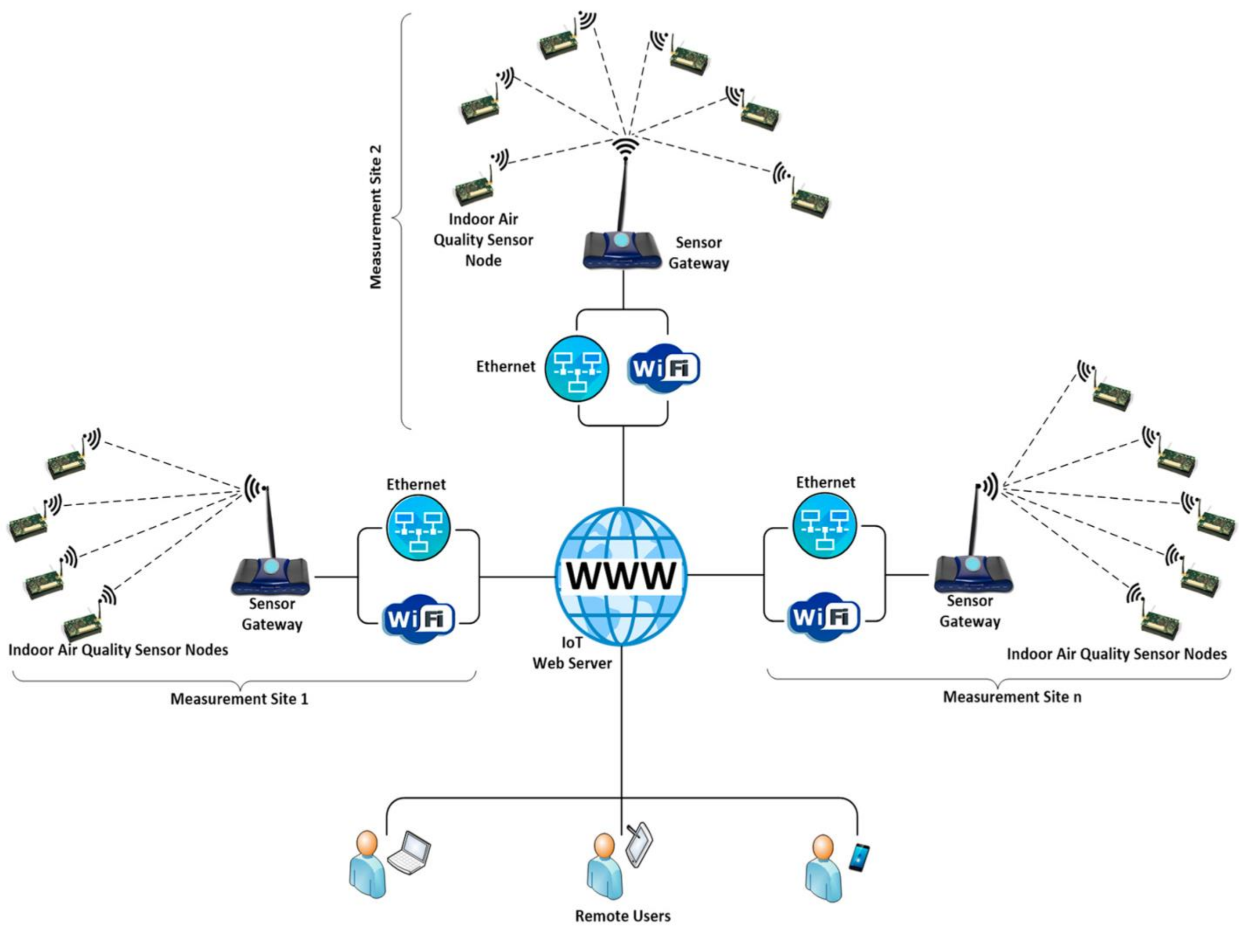

Fig.1. IAQM system architecture:

Data Processing and Analysis:

The collected pollution data is then processed and analyzed in real time. The central server employs data processing algorithms to filter out noise and correct for any errors or anomalies in the data. Following this, the data is analyzed to identify pollution patterns and trends. Simulated Annealing (SA) is used to optimize the data processing pipeline, ensuring that the analysis is conducted as efficiently as possible. The processed data is then visualized on a user-friendly dashboard, where stakeholders can monitor air quality in real-time and make informed decisions. The dashboard also provides historical data and trend analysis, allowing for long-term monitoring and assessment of pollution levels.

Conclusions:

The proposed IoT-based framework for outdoor pollution measurement, enhanced by optimization techniques, offers a robust and efficient solution for real-time environmental monitoring. By optimizing sensor placement, data transmission, and processing, the system ensures that accurate and reliable pollution data is provided to stakeholders. The experimental results demonstrate the system's effectiveness in various real-world scenarios, highlighting its potential to significantly improve air quality monitoring and management. The integration of IoT with optimization techniques represents a significant advancement in the field of environmental monitoring, offering new opportunities for research and development. Future enhancements to the proposed framework may include the integration of machine learning algorithms for predictive analytics, enabling the system to forecast pollution levels based on historical data and real-time inputs. Additionally, expanding the sensor network to cover larger geographic areas or different types of environments, such as urban, suburban, and rural areas, would enhance the system's applicability and effectiveness. Another potential enhancement is the incorporation of additional sensors to monitor other environmental parameters, such as temperature, humidity, and noise levels, providing a more comprehensive assessment of environmental conditions. Finally, further research into energy-efficient IoT devices and communication protocols could reduce the system's overall power consumption, making it more sustainable and cost-effective.

Reference:

1. Selvan, M. A. (2024). Deep Learning Techniques for Comprehensive Emotion Recognition and Behavioral Regulation.
2. Selvan, M. A. (2024). SVM-Enhanced Intrusion Detection System for Effective Cyber Attack Identification and Mitigation.
3. Selvan, M. A. (2024). IoT-Integrated Smart Home Technologies with Augmented Reality for Improved User Experience.
4. Selvan, M. A. (2024). Multipath Routing Optimization for Enhanced Load Balancing in Data-Heavy Networks.
5. Selvan, M. A. (2024). Transforming Consumer Behavior Analysis with Cutting-Edge Machine Learning.

6. FELIX, A. S. M. M. D., & KALAIVANAN, X. D. M. S. Averting Eavesdrop Intrusion in Industrial Wireless Sensor Networks.
7. Selvan, M. A. (2021). Robust Cyber Attack Detection with Support Vector Machines: Tackling Both Established and Novel Threats.
8. Selvan, M. A. (2023). INDUSTRY-SPECIFIC INTELLIGENT FIRE MANAGEMENT SYSTEM.
9. Selvan, M. A. (2023). FIRE MANAGEMENT SYSTEM FOR INDUTRIAL SAFETY APPLICATIONS.
10. Selvan, M. A. (2023). CONTAINMENT ZONE ALERTING APPLICATION A PROJECT BASED LEARNING REPORT.
11. Selvan, M. A. (2023). A PBL REPORT FOR CONTAINMENT ZONE ALERTING APPLICATION.
12. Rajagopal, R. K. P. M. T. K. R., Karthick, R., Meenalochini, P., & Kalaichelvi, T. (2023). Deep Convolutional Spiking Neural Network optimized with Arithmetic optimization algorithm for lung disease detection using chest X-ray images. *Biomedical Signal Processing and Control*, *79*, 104197.
13. Karthick, R., & Sundararajan, M. (2021). SPIDER-based out-of-order execution scheme for Ht-MPSOC. *International Journal of Advanced Intelligence paradigms*, *19*(1), 28-41.
14. Karthick, R., & Meenalochini, P. (2020). Implementation of data cache block (DCB) in shared processor using field-programmable gate array (FPGA). *Journal of the National Science Foundation of Sri Lanka*, *48*(4), 475.
15. Karthick, R., & Sundararajan, M. (2017). Design and implementation of low power testing using advanced razor based processor. *International Journal of Applied Engineering Research*, *12*(17), 6384-6390.
16. Karthick, R., & Sundararajan, M. (2018). A novel 3-D-IC test architecture-a review. *International Journal of Engineering and Technology (UAE)*, *7*(1), 582-586.
17. Karthick, R., Senthilselvi, A., Meenalochini, P., & Senthil Pandi, S. (2022). Design and analysis of linear phase finite impulse response filter using water strider optimization algorithm in FPGA. *Circuits, Systems, and Signal Processing*, *41*(9), 5254-5282.
18. Karthick, R. R. M. A. M. V. K. R., Ramkumar, R., Akram, M., & Kumar, M. V. (2021). Overcome the challenges in bio-medical instruments using IOT–A review. *Materials Today: Proceedings*, *45*, 1614-1619.
19. Karthick, R., & Sundararajan, M. (2017). PSO based out-of-order (ooo) execution scheme for HT-MPSOC. *Journal of Advanced Research in Dynamical and Control Systems*, *9*(6), 1969-1986.
20. Karthick, R., & Sundararajan, M. (2017). A Reconfigurable Method for TimeCorrelatedMimo Channels with a Decision Feedback Receiver. *International Journal of Applied Engineering Research*, *12*(15), 5234-5241.

21. Meenalochini, P., Karthick, R., & Sakthivel, E. (2023). An Efficient Control Strategy for an Extended Switched Coupled Inductor Quasi-Z-Source Inverter for 3Φ Grid Connected System. *Journal of Circuits, Systems & Computers*, *32*(11).
22. Karthick, R., Senthilselvi, A., Meenalochini, P., & Senthil Pandi, S. (2023). An optimal partitioning and floor planning for VLSI circuit design based on a hybrid bio-inspired whale optimization and adaptive bird swarm optimization (WO-ABSO) algorithm. *Journal of Circuits, Systems and Computers*, *32*(08), 2350273.
23. Reka, R., Karthick, R., Ram, R. S., & Singh, G. (2024). Multi head self-attention gated graph convolutional network based multi-attack intrusion detection in MANET. *Computers & Security*, *136*, 103526.
24. Vijayalakshmi, S., Sivaraman, P. R., Karthick, R., & Ali, A. N. (2020, September). Implementation of a new Bi-Directional Switch multilevel Inverter for the reduction of harmonics. In *IOP Conference Series: Materials Science and Engineering* (Vol. 937, No. 1, p. 012026). IOP Publishing.
25. Jasper Gnana Chandran, J., Karthick, R., Rajagopal, R., & Meenalochini, P. (2023). Dual-channel capsule generative adversarial network optimized with golden eagle optimization for pediatric bone age assessment from hand X-ray image. *International Journal of Pattern Recognition and Artificial Intelligence*, *37*(02), 2354001.
26. Sabarish, P., Karthick, R., Sindhu, A., & Sathiyanathan, N. (2021). Investigation on performance of solar photovoltaic fed hybrid semi impedance source converters. *Materials Today: Proceedings*, *45*, 1597-1602.
27. Nagarani, N., Karthick, R., Sophia, M. S. C., & Binda, M. B. (2024). Self-attention based progressive generative adversarial network optimized with momentum search optimization algorithm for classification of brain tumor on MRI image. *Biomedical Signal Processing and Control*, *88*, 105597.
28. Suresh, H. R., Vinitha, V., Girinath, N., & Karthick, R. (2021). Suppression of four wave mixing effect in DWDM system. *Materials Today: Proceedings*, *45*, 2707-2712.
29. Sabarish, P., Raj, L. H. T., Ramprakash, G., & Karthick, R. (2020, September). An Energy Efficient Microwave Based Wireless Solar Power Transmission System. In *IOP Conference Series: Materials Science and Engineering* (Vol. 937, No. 1, p. 012013). IOP Publishing.
30. Roald, N. G. (2013). *Estimation of vital signs from ambient-light non-contact photoplethysmography* (Master's thesis, Institutt for elektronikk og telekommunikasjon).
31. Karthick, R., Prabaharan, A. M., & Selvaprasanth, P. (2019). Internet of things based high security border surveillance strategy. *Asian Journal of Applied Science and Technology (AJAST) Volume*, *3*, 94-100.

32. Suja, S. (2012). WOMEN EMPOWERMENT THROUGH SELF-HELP GROUP-AN EVALUATIVE STUDY. *Global Management Review*, *6*(3).
33. Cavaliere, L. P. L., Khan, R., Sundram, S., Jainani, K., Bagale, G., Chakravarthi, M. K., ... & Rajest, S. S. (2021). The Impact of customer relationship management on customer satisfaction and retention: The mediation of service quality. *Turkish Journal of Physiotherapy and Rehabilitation*, *32*(3), 22107-22121.
34. Sundram, S., Venkateswaran, P. S., Jain, V., Yu, Y., Yapanto, L. M., Raisal, I., ... & Regin, R. (2020). The impact of knowledge management on the performance of employees: The case of small medium enterprises. *Productivity Management*, *25*(1), 554-567.
35. Sundram, S., Chauhan, H., Muda, I., Effendy, F., Choubey, S., & Patni, I. (2022). The effects of electronic word-of-mouth (E-WOM) on integrated results and destination picture of traditional image of tourists. *Webology*, *19*(1), 4847-4866.
36. Venkateswaran, P. S., & Sundram, S. (2021). Impact of Retail Service Quality and Store Service Quality on Patronage Intention towards Organized Retail Industry. *Turkish Journal of Computer and Mathematics Education Vol*, *12*(3), 1462-1471.
37. Sundram, D. S., & Kavitha, D. P. (2021). A Review On Customer Service Quality in Big Bazaar Tirupur. *Int. J. of Aquatic Science*, *12*(3), 1867-1876.
38. Sundram, S., Raman, M. S., & Balamuralitharan, S. (2023). Influence of process parameters on machining studies on stir casted MMCs with AA6351 and TiO2 by grey and desirability approaches. *Materials Today: Proceedings*, *77*, 551-556.
39. Shankari, L., & Suja, S. (2008). Benchmarking on HR Scorecard in the hospitality industry. *Management and Labour Studies*, *33*(1), 80-102.
40. Taderera, F., Al-Nabhani, S., Bhandari, V., Kirubakaran, P. S., Al Rahbi, H. H. A., Karedza, G., ... & Sundaram, S. (2014). Marketing excellence: myth or reality in oman. *International Journal of Arts & Sciences*, *7*(04), 195-206.
41. Suja Sundram, M. W. M. A. O. (2022). Consumer Perspectives On Grocery Retail Shopping In Saudi Arabia. *Journal of Positive School Psychology*, 2816-2828.
42. Sundram, S., Kumar, V. R., Muthukrishnan, K. B., Naved, M., Dani, R., & Khatri, E. (2022). The Impact of Entertainment Amenities Availability on Hotel's Performance. *Webology*, *19*(1), 3989-4005.
43. Sundram, S. (2020). Green Marketing–A Novel Path to create meaningful Social Marketing Mix Strategy. *TEST Engineering and management*, *7*, 8.
44. Anjani, P. K., Sundram, S., & Abinaya, V. (2020). The impact of COVID-19 on work force in the information technology sector. *European Journal of Molecular & Clinical Medicine*, *7*(2), 3660-3674.
45. Waghmare, G., Sundram, S., Kumar, B., Raman, M. S., Yagnam, N., Motekar, H. S., & Kaushik, D. (2023). Blockchain in Supply Chain Management Prevailing in Smart Cities:

Prospects and Approaches. In *Handbook of Research on Data-Driven Mathematical Modeling in Smart Cities* (pp. 117-137). IGI Global.

46. Sundram, S., Tambvekar, S. E., Sekar, S., Tiwari, S. K., & Gopinathan, R. (2022). The effect of service quality on patient loyalty mediated by patient satisfaction. *Journal of Pharmaceutical Negative Results*, 1393-1400.
47. Raj, K. B., Somasundari, K. M., Sundram, S., Sreerekha, U., Agarwal, V., & Pillay, D. R. (2023, September). Systematic Novel Ai Approach For Business Success Model In Small And Medium Enterprises. In *2023 6th International Conference on Contemporary Computing and Informatics (IC3I)* (Vol. 6, pp. 1427-1432). IEEE.
48. Sundram, S., & Abubshait, F. A. A. (2023). A STUDY ON CUSTOMER SATISFACTION TOWARDS MASALA PRODUCTS IN SHRI KANNAN DEPARTMENTAL STORES, COIMBATORE. *Journal of Pharmaceutical Negative Results*, *14*(2).
49. Bhowte, Y. W., Sundram, S., Parthiban, K., Ramachandran, S., Sharma, N., & Sumaira, Z. (2023). The Influence of Social Media Marketing on Consumer Buying Decision Through Brand Image in The Fashion Apparel Brand. *RES MILITARIS*, *13*(3), 256-264.
50. Bhowte, Y. W., Sundram, S., Parthiban, K., Ramachandran, S., Sharma, N., & Sumaira, Z. (2023). A Study On Impact Of Service Quality In Customer Satisfaction In E-Commerce. *resmilitaris*, *13*(2), 5891-5899.
51. Khemraj, S., Thepa, P., Chi, A. P. D. H., Wu, W., & Samanta, S. (2022). Sustainable Wellbeing Quality of Buddhist Meditation Centre Management During Coronavirus Outbreak (COVID-19) in Thailand Using the Quality Function Deployment (QFD), and KANO Analysis. *Journal of Positive School Psychology*, 845-858.
52. Thepa, P. C. A., Khemraj, S., Khethong, P. K. S., Saengphrae, J., Chi, A. P. D. H., & Wu, W. Y. (2022). The Promoting Mental Health through Buddhadhamma for Members of the Elderly Club in Nakhon Pathom Province, Thailand. *Turkish Journal of Physiotherapy and Rehabilitation*, *32*(3), 33334-33345.
53. Khemraj, S., Thepa, P. C. A., Patnaik, S., Chi, H., & Wu, W. Y. (2022). Mindfulness Meditation and Life Satisfaction Effective on Job Performance. *NeuroQuantology*, *20*(1), 830-841.
54. Khemraj, S., Thepa, P. C. A., Chi, H., Wu, W. Y., Samanta, S., & Prakash, J. (2021). Prediction of world happiness scenario effective in the period of COVID-19 pandemic, by artificial neuron network (ANN), support vector machine (SVM), and regression tree (RT). *NVEO-NATURAL VOLATILES & ESSENTIAL OILS Journal| NVEO*, 13944-13959.
55. Khemraj, S., Pettongma, P. W. C., Thepa, P. C. A., Patnaik, S., Wu, W. Y., & Chi, H. (2023). Implementing Mindfulness In The Workplace: A New Strategy For Enhancing Both Individual And Organizational Effectiveness. *Journal for ReAttach Therapy and Developmental Diversities*, *6*(2s), 408-416.

56. Khemraj, S., Pettongma, P. W. C., Thepa, P. C. A., Patnaik, S., Chi, H., & Wu, W. Y. (2023). An Effective Meditation Practice for Positive Changes in Human Resources. *Journal for ReAttach Therapy and Developmental Diversities*, *6*(3s), 1077-1087.
57. Trung, N. T., Phattongma, P. W., Khemraj, S., Ming, S. C., Sutthirat, N., & Thepa, P. C. (2022). A Critical Metaphysics Approach in the Nausea Novel's Jean Paul Sartre toward Spiritual of Vietnamese in the Vijñaptimātratā of Yogācāra Commentary and Existentialism Literature. *Journal of Language and Linguistic Studies*, *17*(3).
58. Khemraj, S., Thepa, P. C. A., & Chi, H. (2021). Phenomenology In Education Research: Leadership Ideological. *Webology (ISSN: 1735-188X)*, *18*(5).
59. Bhujell, K., Khemraj, S., Chi, H. K., Lin, W. T., Wu, W., & Thepa, P. C. A. (2021). Trust in the Sharing Economy: An Improvement in Terms of Customer Intention. *Indian Journal of Economics and Business*, *20*(1), 713-730.
60. Khemraj, S., Wu, W. Y., & Chi, A. P. D. H. (2024). Evolution of Marketing Strategies in the Tourism Industry. *Intersecta Minds Journal*, *3*(2), 44-61.
61. Chen, Y. M., Huang, K. C., & Khemraj, S. (2024). Praxis International Journal of Social Science and Literature.
62. Patnaik, S., Selvanayagam, N., Khemraj, S., Sadiq, F. U., Wu, W. Y., & Chi, H. (2023). Anxiety And Performance: An Insight From Cognitive Behavioral Angle. *Journal for ReAttach Therapy and Developmental Diversities*, *6*(3s), 785-795.
63. Khemraj, S. (2023). Enhancing Competitive Advantage through Learning Capabilities and Innovative Human Resource Management. *Intersecta Minds Journal*, *2*(1), 26-41.
64. Khemraj, S., Wu, W. Y., & Chi, A. P. D. H. (2023). Analysing The Correlation Between Managers' Leadership Styles And Employee Job Satisfaction. *Migration Letters*, *20*(S12), 912-922.
65. Khemraj, S., Chi, H., Wu, W. Y., & Thepa, P. C. A. (2022). Foreign Investment Strategies, Performance and Risk Management in Emerging Economy. *resmilitaris*, *12*(6), 2611-2622.
66. Khemraj, S., Wu, W. Y., & Chi, H. Social Science, Arts and Humanities, Business, Management, and Education. *Dr. Sharma Khemraj*.
67. KHEMRAJ, S., THEPA, P. C. A., CHI, H., CHATTOPADHYAY, S., & WU, W. Y. AN OVERVIEW ON THE ROLE OF CRYPTOCURRENCIES IN BUSINESS AND FINANCE.
68. Khemraj, S., Thepa, P., Chi, A. P. D. H., Wu, W., & Samanta, S. (2022). Sustainable Wellbeing Quality of Buddhist Meditation Centre Management During Coronavirus Outbreak (COVID-19) in Thailand Using the Quality Function Deployment (QFD), and KANO Analysis. *Journal of Positive School Psychology*, 845-858.

69. Singh, V., Sharma, M. P., Jayapriya, K., Kumar, B. K., Chander, M. A. R. N., & Kumar, B. R. (2023). Service quality, customer satisfaction and customer loyalty: A comprehensive literature review. *Journal of Survey in Fisheries Sciences*, *10*(4S), 3457-3464.
70. Chatterjee, R., Singh, A., & Singh, V. (2022). Ethical and Sustainable Perceptions on Cloud Kitchen Business-A Study of Consumers and Stakeholders during the Covid-19 Pandemic. *International Journal of Hospitality and Tourism Systems*, *15*(COVID-19 Issue), 76.
71. Mishra, R., Sharma, M. P., Seth, K., & Singh, V. (2023). A study on consumers' travel purchase intention through travel apps. *Prabandhan: Indian Journal of Management*, *16*(7), 25-42.
72. Singh, V., & Tharakan, Y. G. (2020). Marketing Trends in Food Tourism to Attract International Tourists in Delhi Hotels. *Studies in Indian Place Names (UGC Care Journal) ISSN*, 2394-3114.
73. Mishra, R., & Singh, V. (2022). A study on destination loyalty of tourists at the UNESCO world heritage site: A case study of old Goa in India.
74. Sakhuja Sharma, A. (2022). An Empirical Study To Assimilate The Perceptual Gaps Among The Hospitality Stakeholders Regarding The Academic Learning Processes Followed By The Private Hotel Management Colleges In Karnataka. *Webology (ISSN: 1735-188X)*, *19*(2).
75. CARE, A. U. A STUDY OF FOOD PROTECTION AND SANITATION AWARENESS AND PRACTICES BY HOTEL MANAGEMENT STUDENTS IN DELHI NCR.
76. Sundram, S., Kushwaha, A., Mylapalli, S., Latwal, G. S., Singh, V., & Jaswal, R. INVESTIGATING THE RELATIONSHIP BETWEEN ATTACHMENT STYLE AND MANNER OF MOBILE PHONE USAGE AMONG STUDENTS.
77. Kumari, M. J. P. Community Perception of Initiatives Promoting Community-Based Tourism.
78. Singh, C. V., & Sharma, H. The Impact and Challenges of Hospitality Sector Post Covid-19. *Perspectives, Patterns and Practices*, 207.
79. Sharma, H., & Singh, C. V. Operational Considerations for Hotel Industry Post COVID-19. *Perspectives, Patterns and Practices*, 183.
80. Thakur, S., Kulshrestha, R., & Singh, C. V. Perspectives, Patterns and Practices.
81. Saravanan, V., Rajakumar, S., Banerjee, N., & Amuthakkannan, R. (2016). Effect of shoulder diameter to pin diameter ratio on microstructure and mechanical properties of dissimilar friction stir welded AA2024-T6 and AA7075-T6 aluminum alloy joints. *The International Journal of Advanced Manufacturing Technology*, *87*, 3637-3645.
82. Saravanan, V., Banerjee, N., Amuthakkannan, R., & Rajakumar, S. (2015). Microstructural evolution and mechanical properties of friction stir welded dissimilar

AA2014-T6 and AA7075-T6 aluminum alloy joints. *Metallography, Microstructure, and Analysis*, *4*, 178-187.

83. Abdulkarem, W., Amuthakkannan, R., & Al-Raheem, K. F. (2014, March). Centrifugal pump impeller crack detection using vibration analysis. In *2nd International Conference on Research in Science, Engineering and Technology* (pp. 206-211).
84. Amuthakkannan, R., Kannan, S. M., Selladurai, V., & Vijayalakshmi, K. (2008). Software quality measurement and improvement for real-time systems using quality tools and techniques: a case study. *International Journal of Industrial and Systems Engineering*, *3*(2), 229-256.
85. Vijayalakshmi, K., Ramaraj, N., & Amuthakkannan, R. (2008). Improvement of component selection process using genetic algorithm for component-based software development. *International Journal of Information Systems and Change Management*, *3*(1), 63-80.
86. Amuthakkannan, R. (2012). Parameters design and performance analysis of a software-based mechatronics system using Taguchi robust design–a case study. *International Journal of Productivity and Quality Management*, *10*(1), 1-24.
87. Amuthakkannan, R., Kannan, S. M., Vijayalakshmi, K., & Ramaraj, N. (2009). Reliability analysis of programmable mechatronics system using Bayesian approach. *International Journal of Industrial and Systems Engineering*, *4*(3), 303-325.
88. Saravanan, V., Banerjee, N., Amuthakkannan, R., & Rajakumar, S. (2015). Microstructure and mechanical properties of friction stir welded joints of dissimilar AA6061-T6 and AA7075-T6 aluminium alloys. *Applied Mechanics and Materials*, *787*, 350-354.
89. Senthilkumar, M., Somasundaram, S., & Amuthakkannan, R. (2009). Power aware multiple QoS constraints routing protocol with mobility prediction for MANET. *International Journal of Information Systems and Change Management*, *4*(2), 156-170.
90. Amuthakkannan, R., Kannan, S. M., Vijayalakshmi, K., & Jayabalan, V. (2007). Managing change and reliability of distributed software system. *International Journal of Information Systems and Change Management*, *2*(1), 30-49.
91. Amuthakkannan, R., Babu, C. K., & Kannan, S. M. (2010). An approach to the minimisation of makespan in the textile industry using ant colony optimisation. *International Journal of Services and Operations Management*, *7*(2), 215-230.
92. Jose, J., & Amuthakkannan, R. (2014). Design, Development and Analysis of FDM based Portable Rapid Prototyping Machine. *International Journal of Latest Trends in Engineering and Technology (IJLTET)*, *4*(4), 324-232.

93. Babu, V. S., Amuthakkannan, R., Kumar, S. S., & Muruganandam, A. (2013). Optimal cutting parameters estimation to improve surface finish in turning operation in AISI 1045 using Taguchi's robust design. *International Journal of Industrial and Systems Engineering*, *15*(1), 19-36.
94. Vijayalakshmi, K., Ramaraj, N., Amuthakkannan, R., & Kannan, S. M. (2007). A new algorithm in assembly for component-based software using dependency chart. *International Journal of Information Systems and Change Management*, *2*(3), 261-278.
95. Al Tobi, M. A. S., Ramachandran, K. P., Al-Araimi, S., Pacturan, R., Rajakannu, A., & Achuthan, C. (2022). Machinery faults diagnosis using support vector machine (SVM) and Naïve Bayes classifiers. *Int. J. Engi. Trends Technol.*, *70*(12), 26-34.
96. Amuthakkannan, R., Kannan, S. M., Vijayalakshmi, K., & Ramaraj, N. (2009). Reliability analysis of programmable mechatronics system using Bayesian approach. *International Journal of Industrial and Systems Engineering*, *4*(3), 303-325.
97. Amuthakkannan, R., Vijayalakshmi, K., Al Araimi, S., & Ali Saud Al Tobi, M. (2023). A review to do fishermen boat automation with artificial intelligence for sustainable fishing experience ensuring safety, security, navigation and sharing information for Omani fishermen. *Journal of Marine Science and Engineering*, *11*(3), 630.
98. Al Tobi, M. A. S., K p, R., Al-Araimi, S., Pacturan, R., Rajakannu, A., & Achuthan, G. (2022, July). Machinery Fault Diagnosis using Continuous Wavelet Transform and Artificial Intelligence based classification. In *Proceedings of the 2022 3rd International Conference on Robotics Systems and Vehicle Technology* (pp. 51-59).
99. Saravanan, V., Banerjee, N., Amuthakkannan, R., & Rajakumar, S. (2014). Effect of Heat Input on Tensile Properties of Friction Stir Welded AA6061-T6 and AA7075-T6 Dissimilar Aluminum Alloy Joints. *Int. J. of Multidisciplinary and Scientific Emerging Research*, *3*(1).
100. Guo, J. F., Chen, H. C., Sun, C. N., Bi, G., Sun, Z., & Wei, J. (2014). Friction stir welding of dissimilar materials between AA6061 and AA7075 Al alloys effects of process parameters. *Materials & Design (1980-2015)*, *56*, 185-192.
101. Palaniappan, A., Muthiah, R., & Sundaram, M. T. (2023). ZigBee enabled IoT based intelligent lane control system for autonomous agricultural electric vehicle application. *SoftwareX*, *23*, 101512.
102. Anbu, S., Senthilkumar, M., & Murugesh, T. S. (2022). Design of a multiloop controller for a nonlinear process. *International Journal of Advanced Computer Science and Applications*, *13*(4).
103. Arunkumar, P. L., Ramaswamy, M., & Murugesh, T. S. (2022). IoT based speed control for semi-autonomous electric on-road cargo vehicle. *International Journal of Advanced Computer Science and Applications*, *13*(3).

104. Mohanraj, S., Murugesh, T. S., & Senthilkumar, M. (2021). Design of decentralized controller for coupled tank system using BLT method. *Materials Today: Proceedings*, *46*, 11198-11201.
105. Akshay, B. R., Pulari, S. R., Murugesh, T. S., & Vasudevan, S. K. (2024). *Machine Learning: A Comprehensive Beginner's Guide*. CRC Press.
106. Ramakrishnan, A. B., Murugesh, T. S., Pulari, S. R., & Vasudevan, S. K. (2024). Cognitive Analytics-Based Diagnostic Solutions in Healthcare Infrastructure. *Cognitive Analytics and Reinforcement Learning: Theories, Techniques and Applications*, 239-252.
107. Jayanthi, S., Raja, P., Elangovan, M., & Murugesh, T. S. (2024). Single ended 12T cntfet sram cell with high stability for low power smart device applications. *e-Prime-Advances in Electrical Engineering, Electronics and Energy*, *7*, 100479.
108. Vasudevan, S. K., Murugesh, T. S., Narassima, M. S., Dantu, N. V., Pulari, S., & Muralidharan, S. (2023). A Deep Learning Approach for the Sales Prediction in Retail Stores: An End-to-End Analysis and Implementation. In *Internet of Everything for Smart City and Smart Healthcare Applications* (pp. 17-34). Cham: Springer Nature Switzerland.
109. Ramakrishnan, A. B., Vasudevan, S. K., Murugesh, T. S., & Pulari, S. R. (2023). Enhancing multiclass classification of knee osteoarthritis severity grades using oneDNN. *International Journal of Bioinformatics Research and Applications*, *19*(3), 200-212.
110. Chegu, S. K., Murugesh, T. S., & Sivaraman, E. (2023). Grey wolf optimization based controller design for a two tank system. *Energies*, *12*(7), 4019-4028.
111. Mohanraj, S., Murugesh, T. S., & Sivaraman, E. (2023). A novel meta-heuristic grey wolf optimization algorithm for a coupled tank system. *Journal of Data Acquisition and Processing*, *38*(1), 925.
112. Juluru, A., Vasudevan, S. K., & Murugesh, T. S. (2022). *Let's Get IoT-fied!: 30 IoT Projects for All Levels*. CRC Press.
113. Narmatha, R., Murugesh, T. S., & Krishnan, J. (2014). Design of an Intelligent Control Scheme for Synchronizing Two Coupled Van Der Pol Oscillators. *International Journal of ChemTech Research*, *6*(12), 5033-5048.
114. Murugesh, T. S., Vasudevan, S. K., & Pulari, S. R. (2024). *Python: A Practical Learning Approach*. CRC Press.
115. Pulari, S. R., Murugesh, T. S., Vasudevan, S. K., & Ramakrishnan, A. B. (2024). Reinforcement Learning for Demand Forecasting and Customized Services. *Cognitive Analytics and Reinforcement Learning: Theories, Techniques and Applications*, 123-134.
116. Anudeep, J., Vasudevan, S. K., & Murugesh, T. S. (2024). Machine learning based wearable sensor module for human fall detection-a fully functional solution. *International Journal of Medical Engineering and Informatics*, *16*(4), 350-362.

117. Thaiyub, A., Ramakrishnan, A. B., Vasudevan, S. K., Murugesh, T. S., & Pulari, S. R. (2024). Predictive Modelling for Employee Retention: A Three-Tier Machine Learning Approach With oneAPI. In *Multidisciplinary Applications of AI Robotics and Autonomous Systems* (pp. 195-205). IGI Global.
118. Vasudevan, S. K., Murugesh, T. S., Pulari, S. R., Dantu, N. V., & Muralidharan, S. (2024). Smart multilayer architecture for cyber-physical agricultural systems with Intel oneAPI. In *Agri 4.0 and the Future of Cyber-Physical Agricultural Systems* (pp. 115-133). Academic Press.
119. Kavitha, V., Malaisamy, K., Murugesh, T. S., & SenthilKumar, M. (2023). Design and development of jeans textile antenna for wireless broadband applications. *Journal of Industrial Textiles*, *53*, 15280837231215374.
120. Vasudevan, S. K., Dantu, N. V., Pulari, S. R., & Murugesh, T. S. (2023). *Machine Learning with OneAPI*. CRC Press.
121. Sharma, M., & Kadyan, S. (2013). Marketing of Financial Products and Services.
122. Sharma, M., & Kadyan, S. (2014). Reaching The Customers: Role Of Multiple Delivery Channels In Banking Industry. *Trinity Journal of Management, IT & Media (TJMITM)*, *5*(1), 12-20.
123. Kadyan, S., Sharma, Y., Agnihotri, A. K., Singh, V. B. P., Kothari, R., & Kunwar, F. B. (2024). Human-Centric AI Applications for Remote Patient Monitoring. In *Blockchain and IoT Approaches for Secure Electronic Health Records (EHR)* (pp. 117-137). IGI Global.
124. Bhasin, N. K., Kadyan, S., Santosh, K., Ramya, H. P., Changala, R., & Bala, B. K. (2024, March). Enhancing Quantum Machine Learning Algorithms for Optimized Financial Portfolio Management. In *2024 Third International Conference on Intelligent Techniques in Control, Optimization and Signal Processing (INCOS)* (pp. 1-7). IEEE.
125. Prakash, C., Yadav, R., & Kadyan, S. (2021). Effect of the price drop on customer's perceived evaluation across selected product categories. *Journal of Revenue and Pricing Management*, *20*, 204-210.
126. Verma, R., Kadyan, S., & Gupta, S. (2022). Evolving dimensions of managerial effectiveness in export oriented/internationalizing firms in turbulent post pandemic world: A student’s perception-based validation approach. *Transnational Marketing Journal*, *10*(3), 473-482.
127. Kadyan, S., Sharma, Y., Agarwal, K., Gujrati, R., & Koul, M. K. (2023). Linking workplace incivility with employee turnover intention & job satisfaction: The mediating role of selfefficacy of employees in telecom sector in NCR. *Journal of Information and Optimization Sciences*, *44*(8), 1595-1611.

128. Kadyan, S., Bhasin, N., & Madhukar, V. (2022). Impact of claim settlement procedure of health insurance companies on customer satisfaction during the pandemic: A case of third-party administrators. *Insurance Markets and Companies*, *13*(1), 66-80.
129. Ahamed, S. K., Naidu, M. M., & Reddy, C. S. R. (2015). Outliers in data envelopment analysis. *International Journal of Computer Science and Security (IJCSS)*, *9*(3), 164-173.
130. Ahamed, S. K., Naidu, M. M., & Subba, R. R. C. (2016). Outliers: most influential observations in variable returns to scale data envelopment analysis. *Indian Journal of Science and Technology*, *9*(2), 1-7.
131. Ahamed, S. K., Krishna, B. V., & David, D. B. (2021). Brain Tumor Segmentation and Classification based on Deep Learning-Based Inception Networks. *Annals of the Romanian Society for Cell Biology*, 5210-5219.
132. Ahamed, S. K., Naidu, M. M., & Reddy, C. S. R. (2015). Most influential observations-Super efficiency. *International Journal on Computer Science and Engineering*, *7*(9), 82.
133. Sirajuddin, M., Ravela, C., Krishna, S. R., Ahamed, S. K., Basha, S. K., & Basha, N. M. J. (2024). A Secure Framework based On Hybrid Cryptographic Scheme and Trusted Routing to Enhance the QoS of a WSN. *Engineering, Technology & Applied Science Research*, *14*(4), 15711-15716.
134. Balasubramaniam, P. M., Satheesh, N., Guhathakurta, R., Ahamed, S. K., Sharma, D. K., Rangasamy, R., & Sengan, S. (2022). Design of Automotive Accident-Avoidance System at Speed Limit Zone Using GPS. In *Innovations in Computer Science and Engineering: Proceedings of the Ninth ICICSE, 2021* (pp. 271-279). Singapore: Springer Singapore.
135. Singuluri, P. K., Basha, S. L. J., Ahamed, S. K., & Nithya, M. (2021, July). An Educated Peer Discovery Expanding Blockchain Framework. In *Journal of Physics: Conference Series* (Vol. 1964, No. 4, p. 042091). IOP Publishing.
136. Rekha, V., Reddy, L. V., Chaudhari, S. V., Gopi, A., Nithiya, C., & Ahamed, S. K. (2023, January). Automated Deep Learning with Wavelet Neural Network based Rice Plant Classification. In *2023 International Conference on Intelligent Data Communication Technologies and Internet of Things (IDCIoT)* (pp. 345-350). IEEE.
137. Nair, J., Prasad Kumar, P., Thakur, A. K., Samhita, S., & Aravinda, A. (2021, February). Influence on emissions and performance of CI engine with graphene nanoparticles blended with Karanja biodiesel. In *AIP Conference Proceedings* (Vol. 2317, No. 1). AIP Publishing.
138. Dhana Raju, V., Nair, J. N., Venu, H., Subramani, L., M. Soudagar, M. E., Mujtaba, M. A., ... & Fattah, I. M. (2022). Combined assessment of injection timing and exhaust gas recirculation strategy on the performance, emission and combustion characteristics of algae biodiesel powered diesel engine. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, *44*(4), 8554-8571.

139. Nair, J. N., & Murthy, Y. V. S. (2021). Impact of Tamarindus Indica biodiesel blends on performance and exhaust emissions characteristics of light duty compression ignitionengine. *Materials Today: Proceedings*, *45*, 2697-2701.
140. Raju, V. D., Veza, I., Venu, H., Soudagar, M. E. M., Kalam, M. A., Ahamad, T., ... & Rahman, S. A. (2023). Comprehensive Analysis of Compression Ratio, Exhaust Gas Recirculation, and Pilot Fuel Injection in a Diesel Engine Fuelled with Tamarind Biodiesel. *Sustainability*, *15*(21), 15222.
141. Nair, J. N. (2021). Mitigation of Emissions through Injection Strategies for CI Engine. *Internal Combustion Engine Technology and Applications of Biodiesel Fuel*, 103.
142. Y. W. Bhowte, A. Roy, K. B. Raj, M. Sharma, K. Devi and P. LathaSoundarraj, "Advanced Fraud Detection Using Machine Learning Techniques in Accounting and Finance Sector," 2024 Ninth International Conference on Science Technology Engineering and Mathematics (ICONSTEM), Chennai, India, 2024, pp. 1-6, doi: 10.1109/ICONSTEM60960.2024.10568756.
143. V. Chavan, K. Bhavana Raj, N. S, A. K. Bhunia, A. Dadhich and H. Pallathadka, "Integrated Portfolio Management Strategies: Harnessing IoT and Machine Learning for Enhanced Decision-Making," 2024 International Conference on Science Technology Engineering and Management (ICSTEM), Coimbatore, India, 2024, pp. 1-6, doi: 10.1109/ICSTEM61137.2024.10560711.
144. K. Bhavana Raj; Kamakshi Mehta; Someshwar Siddi; M.K. Sharma; Dilip K. Sharma; Sunil Adhav; José L.A. Gonzáles, "Optimizing Financial Transactions and Processes Through the Power of Distributed Systems," in Meta-Heuristic Algorithms for Advanced Distributed Systems, Wiley, 2024, pp.289-303, doi: 10.1002/9781394188093.ch17.
145. Grover, R., Raj, K. B., Tiwari, A., Sumant, M., & Naqvi, S. R. (2024). Statistical Quality Control in Manufacturing and Managing Processes for Continuous Improvement of Organisation. International Journal of Central Banking, 20(1).
146. J. R, S. H. Krishna, M. G.M, S. Mohammed, K. B. Raj and G. Manoharan, "Fuzzy Evaluation Method on the Financing Efficiency of Small and Medium-Sized Enterprises," 2023 International Conference on Artificial Intelligence and Knowledge Discovery in Concurrent Engineering (ICECONF), Chennai, India, 2023, pp. 1-7, doi: 10.1109/ICECONF57129.2023.10083731.
147. Bommisetti, R. K., Raj, B. K., Subbalakshmi, A. V. V. S., Shehryar, M., & Hoang, S. D. (2022). Blockchain in Trust with Reputation Management for Financial Stock Market Using Distributed Ledger Technology and Bayesian Theory Based on Fault Tolerance Model. Global Business Review, 1-21. https://doi.org/10.1177/09721509221110371.
148. G. Revathy, K. Bhavana Raj, Anil Kumar, Spurthi Adibatti, Priyanka Dahiya, T.M. Latha, Investigation of E-voting system using face recognition using convolutional neural

network (CNN), Theoretical Computer Science, Volume 925, 2022, Pages 61-67, ISSN 0304-3975, https://doi.org/10.1016/j.tcs.2022.05.005.

149. Girish Santosh Bagale, Sudhakar Sengan, Arodh Lal Karn, Bhavana Raj Kondamudi., Deepesh Kumar Srivastava, and Ravi Kumar Gupta. (2022). Measuring the Determining Factors of Financial Development of Commercial Banks in Selected SAARC Countries. Journal of Database Management. Vol. 33, No. 1, pp. 1–21. ISSN: 1063-8016, E-ISSN: 1533-8010. EISBN13: 9781799893301. https://doi.org/10.4018/JDM.311092.
150. Chaubey PK, Arora TK, Raj KB, Asha GR, Mishra G, Guptav SC, Altuwairiqi M, Alhassan M. (2022). Sentiment Analysis of Image with Text Caption using Deep Learning Techniques. Computational Intelligence and Neuroscience. pp. 1-11. ISSN: 1687-5265, E-ISSN: 1687-5273. https://doi.org/10.1155/2022/3612433 .
151. Dr. K. Bhavana Raj . (2022). "Industry 4.0: Smart Manufacturing in Industries - The Future".(2022). Machine Learning and Data Science: Fundamentals and Applications, John Wiley and Sons, Scopus, Web of Science, Library of Congress, 30 July 2022, Chapter 4,pp. 67-74. ISBN 9781119775614, E-ISBN 9781119776499. DOI: https://doi.org/10.1002/9781119776499.ch4 , DOI:10.1002/9781119776499.
152. Madhan, E. S., Kannan, K. S., Rani, P. S., Rani, J. V., & Anguraj, D. K. (2021). A distributed submerged object detection and classification enhancement with deep learning. Distrib. Parallel Databases, 1-17.
153. Kumar, V. S., & Naganathan, E. R. (2015). Segmentation of Hyperspectral image using JSEG based on unsupervised clustering algorithms. ICTACT Journal on Image and Video Processing, 6(2), 1152-1158.
154. Sakthivela, M., Balakrishnab, N., Kannanc, K. S., & Devabaland, P. (2021). An Analysis of Load Balancing Algorithm Using Software-Defined Network. Turkish Journal of Computer and Mathematics Education Vol, 12(9), 578-586.
155. Padmanaban, K., Kannan, K. S., Rajan, D. P., & Divya, P. (2021). A Novel Groundwater Resource Forecasting Technique for Cultivation Utilizing Wireless Sensor Network (WSN) and Machine Learning (ML) Model. Turkish Journal of Computer and Mathematics Education, 12(2), 2186-2192.
156. Kanna, D. K., Devabalan, D. P., Hariharasitaraman, S., & Deepa, P. (2018). Some Insights on Grid Computing-A Study Perspective. International Journal of Pure and Applied Mathematics, 118(8), 47-50.