

# An innovative approach in modelling and design of smart washing machine with automatic drying with estimating energy and water consumption using AI

Narender Chinthamu,  
MIT (Massachusetts Institute of  
Technology) CTO Candidate,  
Enterprise Architect  
narender.chinthamu@gmail.com

Priya Kohli,  
Assistant Professor, School of  
Computing,  
Graphic Era Hill University,  
Dehradun, R/S, Graphic Era Deemed  
To Be University, Dehradun, 248002,  
pkohli@gehu.ac.in

Vigilson Prem M,  
Professor, Department of Computer  
Science and Engineering,  
R.M.K. College of Engineering and  
Technology,  
vigiprem@gmail.com

Rajeev Kudari,  
Assistant Professor, Department of  
Computer Science and Engineering,  
Koneru Lakshmaiah Education  
Foundation,  
Vaddeswaram, Guntur-522502,  
Andhra Pradesh, India,  
krajeev@kluniversity.in

Rupinder Singh,  
Associate Professor, Chitkara  
University Institute of Engineering and  
Technology, Chitkara, University,  
Punjab, India,  
dca.rupinder@gmail.com  
rupinder.1153@chitkara.edu.in

Khunt Abhay,  
Student, Department of Computer  
Science and Engineering,  
Lovely Professional university,  
khuntabhay2001@gmail.com

**Abstract**—The automations in smart appliances play a vital role. The evolution of automation is the adoption of smart machines and appliances for industrial and domestic purposes. This helps to obtain smart home. They are implemented through artificial intelligence with optimization techniques. To replace the convention washing machine, the proposed system is introduced. This is functioned through adopting artificial intelligence to operate automatically through various devices. The smart washing machine is designed through machine learning techniques with sensors. This helps to adopt a newer way in washing that helps to reduce energy consumption through estimating the power utility. This is accompanied with automatic drying techniques. The system is completely automatic to perform the washing process. It is enhanced through internet of things to enable the two way communication system. The smart meter is used to record the energy consumption. The efficiency and performance parameter are higher when compared to conventional washing machines. Thus the proposed system enhances automation in washing machines with automatic drying and estimates the amount of energy consumption.

**Keywords**—Washing machine, smart machines, artificial intelligence, induction motor drives, microgrids, energy management system, smart meters

## I. INTRODUCTION

The rise of artificial intelligence play a versatile role in the sophistication and development of human lives through improvement in various fields ranging from industry and domestic applications. The control and monitoring of these appliances are complex and hence they are done through automation through artificial intelligence [1]. The artificial intelligence is defined as the progression of training the machines to function as similar to that of human intelligence. This helps to solve various complex problems

to achieve the obtained results. They are functioned without human interference. These artificial intelligences are used to obtain the decision-making techniques rapidly. The advancement of artificial intelligence from the past decade is due the increase in demand. This includes machine learning, artificial neural network and deep learning techniques. The application of artificial intelligence helps in agriculture, industry, education and energy management system. They play a significant role in various fields through improving automations and performing the functions without the assistance of humans [2]–[4].

Hence this helps to reduce the computational time and hence helps to obtain reduction in cost parameter. This is accomplished through the data monitoring and integration, smart control system with communication system helps to the rise of artificial internet of things. The automations also helps in load forecasting. This is done through the machine learning with artificial intelligence to enhance energy consumption. This is done through the optimization techniques. This includes long term and short term load forecasting techniques [5]–[7].

The load forecasting helps to predict the power consumption and thus leads to the reduction of power utility. The load forecasting is done through analyzing the physical parameters such as weather, climatic conditions and consumers need at the particular period of time. This plays an important role in the complex systems. These automations and advanced innovations helps to determine the performance efficiency and helps in the reduction of carbon emission in the ecosystem. The adoption of automations in the renewable energy system helps to improve a greener environment. They are highly reliable and much efficient in performance. The control and

functioning of the system are enhanced through the optimization techniques. They help to monitor and control the system based upon the priority and interest of the user. They are largely used in complex problems to obtain an accurate results [8]–[10]. Thus the automation in diverse field are achieved through the artificial intelligence techniques. These techniques are largely used in the hybrid renewable energy system to control and monitor. Thus utilizing it in an efficient way. These artificial intelligence paved way for the development of introduction of digital platform. It includes the evolution of virtual technology. They are formed through the virtual and augmented reality through the internet of things. In automation in the domestic appliances, the machine learning plays a vital role. They are implemented with forecasting mechanism to adopt automation in the functioning system [11]–[13].

This helps to increase the efficiency of the system through various control parameters. They are accompanied with the internet of things to achieve the two way communication systems. This helps to provide the monitored information to the user at other the end even at the remote places [14]–[16].

Thus the domestic appliances are controlled to achieve much sophistications in day to day life. Thus the appliances in the home are tend to completely automated through the machine learning and optimization algorithms that takes in to another world. The advancement in the technology are increasing largely due to the various sophistications and it helps to make lives easier. The machine learning provides a different approach in the functioning of the washing machine. The washing machine is an electrical and electronic system used to wash clothes. The washing machines are classified into top load and front load categories. The washing machine includes washing drum, sensors and inner drum. The washing machine are controlled through the control mechanism [17]–[19].

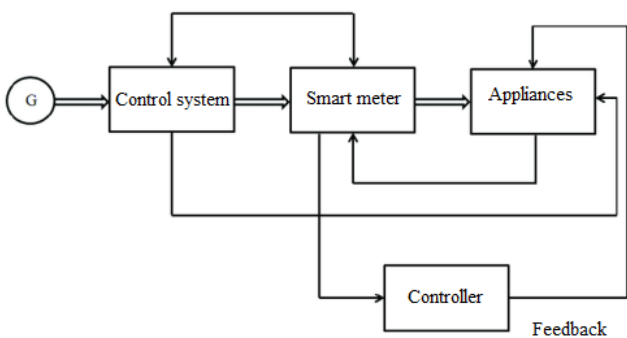


Fig 1: Smart meter drives

The figure 1 demonstrates the smart meter drives. This includes control system, smart meter, appliances and controller. This electronic control mechanism is denoted as programmer. This is done through the microcontroller through sensors and actuators. It includes ultrasonic cleaners for enhancing numerous functions. The real time operating system is used to function the washing machines. They are classified into hard real time and soft real time operating

systems. These are classified based upon their functioning properties. The microprocessors and the microcontrollers are functioned and programmed using 2<sup>nd</sup> language programming languages. The various topographies of washing machine includes spin settings, washing types based upon the material of the cloths and capacity of the load. This helps in various advantages through adopting faster washing speed. This leads to obtain a newer way in washing the cloths with automatic drying. This also helps to determine the water quantity and energy consumption[27]. These helps to develop the overall home energy managements system. Due to the demand in the electricity, these artificial intelligence techniques helps to eliminate the increasing demand.

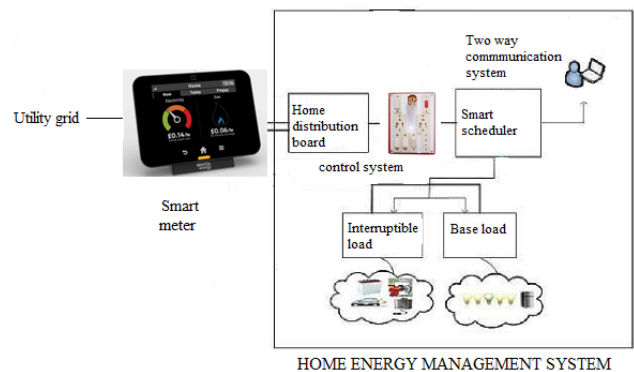


Fig 2: Home energy management system

The figure 2 represents the home energy management system. The expansion of the smart machines leads to the implementation of smart home and smart grid. This helps in diverse ways through communication system. The development of smart washing machine includes the two way communication to monitor and provide instruction to the washing machine through remote places.

The complete washing of clothes are done through the smart washing machine. This includes image processing techniques with feature extraction techniques. The washing machine used in the industry are highly profited through the machine learning techniques. They are tend to function much faster and hence helps to save time. The overall functioning of the washing machines are instructed externally using the smart touch screen which provides various options for washing. They are provides with various visual effects and automations. This helps to create an interest to operate and function the washing machines. This helps to reduce the manual efforts. Thus the proposed system is used to replace the use of the conventional washing machine. The smart washing machine involves the detection of clothes through which the quantity of water, detergent quantity and the time of washing is estimated and provides. The functioning of the washing machine includes four stages such as water consumption, soaking, washing process and drying [20]–[22].

This also helps to determine the amount of power consumption. This helps to maintain the usage thereby saving the power consumption. The energy consumption of the electrical utilizations are estimated independently

through the energy disaggregation. This helps to determine and estimate the power consumed by the each and each appliances in the home and industry. These data are collected and processed to complete the smart functioning of the washing machine. This includes numerous data that are need to be stored. This is done through the internet of things with cloud computing techniques. They are also beneficial in the analysis and detection of fault and its performance. Thus the automations leads to improve the home energy management system [26].

The energy disaggregation plays a prominent role. They are classified into two categories based upon the intrusive and non-intrusive load balancing and monitoring system. The intrusion load balancing and monitoring is the hardware approach in which the smart meters and externally attached to the appliances to measure the performances. The non-intrusion load balancing and monitoring is the software approach. These energy segregation plays an important role in the large scale industrial sectors to estimates the consumption of power with estimating individually.

## II. PROPOSED SYSTEM

The smart washing machine is introduced to enhance innovation in the home automation system. This is developed through the energy decomposition techniques to improve smart home automation system. The smart washing machines are the innovative approach that are implemented through digital platform. The washing machine is the integration of electrical and electronic equipment's used for rapidly washing the clothes. This washing process includes soaking of clothes in combination of water and soapy solution to remove the dirt particles through the process of spinning. Then it is allowed to drain the water after the completion of the spinning process. This overall process is implemented through fully automatic manner using artificial intelligence adopting machine learning techniques. This helps in automatic drying of clothes after the specified spinning time based upon the loads. The complete functioning of the machine are intimated to the user through internet of things [23]–[25].



Fig 3: Smart washing machine

The figure 3 represents the smart washing machine. The components of washing machine includes hot water inlet valve, cold water inlet valves, door, inner drums, outlet water hose, filter and outlet line. These smart washing machine helps in analysis of clothes based on material and then initialise the washing process. They are differentiated through the image processing techniques. The sensors are used to sense the temperature of water used in the operation process. This automatically detects the quantity of water and detergents that are needed for the particular amount of loads.

## III. FUNCTIONING OF SMART WASHING MACHINE

The operation of the smart washing machine includes two way communication system that seems the complete functioning process to the user. This internet of things play a prominent role in the monitoring and controlling the operation. The first step involved in the washing machine includes the processing the command to the machine through smart screen display unit.

Here the detailed information regarding the number of clothes are initiated. The machine itself recognised the amount of water and detergent needed for the prescribed loads. Then it automatically fetches the water from the water inlet valve. This includes both the hot water valve and cold water valve based upon the requirements. The clothes are dumped into the inner steel tub in which the process takes place. The diamond drum used inside the washing machines are highly efficient and gives best results. The quick wash is more reliable and fastest wash cycle with higher energy saving mode of functioning. The smart motion technology is employed. The smart motion technology are differentiated into three types. This rotating movement helps the clothes to remain tangle free and protects the clothes from earlier fading without causing any torn. The advanced techniques employed in smart washing machine involves the improved drum with twinwash process, wash technology with  $O_2$ , automatic dispenser technology with internet of things.

The smart washing machine tends to provide sophistication through automatic on and off through the instruction provided by the user through their mobile phone. This helps to function rapidly. This includes sending and receiving of instructions to mobile phone during the working conditions of the washing machine. This also helps to pause the functioning and can able to revine later. The functioning of washing machines includes top load and front load washing machines. They are classified based upon the operation and designing parameters. In which the top load washing machine is the efficient way to utilize. This includes the use of impellers that helps to achieving minimum quantity of water for washing purposes. Hence it helps to save water. The drying process is proceeded after washing the clothes. The drying process depends upon the rpm. This determines the spin speed in washing machines. The increased rpm leads to faster drying of clothes. The spin cycle ranging between 300-500 rpm is usually used for drying the clothes. This varies based upon the material and colour of the clothes. Thus the overall progression is done through the integration of machine learning with

optimization algorithm. Here genetic algorithm used for optimize the overall functions.

#### IV. SMART WASHING MACHINE THROUGH ARTIFICIAL INTELLIGENCE

The combination of machine learning with internet of things constitute the functioning of smart washing machines. This helps to adopt the decision making techniques similar to human intelligence. This helps to obtain well-organized functioning through adopting comfort in operation, advanced design parameters, safety and easier maintenance. These parameters helps in efficient energy saving. The energy saving includes the demand side management. This is accompanied with image processing and feature extraction techniques. This includes sensors for sensing the external physical parameters. The various sensor used in functioning of washing machine includes pH sensor, light sensor, temperature sensor and heat sensor. They helps to indicate the appropriate functioning in washing the clothes. The image processing techniques are used to identify the material of clothes based upon the predefined data. They are proceeded through the feature extraction techniques. This helps to convert the obtained raw data into numerical data to perform the functioning. These data are used for the optimization techniques that performs the overall functioning in washing machines.

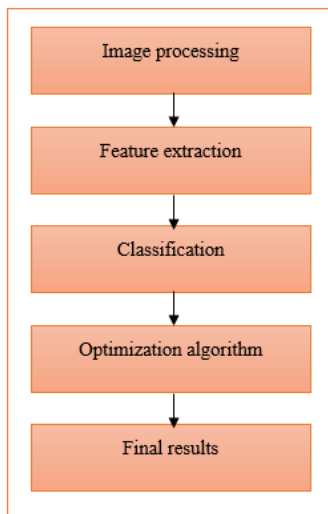


Fig 4: Smart washing machines through optimization techniques

The figure 4 demonstrates the functioning of smart washine machines. Here genetic algorithm is used to program the functioning based upon the needs and priority of the users with enhancing instructions to control and monitor the functioning of the washing process. They are implemented through the pre-processed information in the dataset. This stores the complete information regarding the material of clothes, detergent amount and water level dependent upon the load. This is employed through the testing and training process which helps to make the system fully automatic. The speed of the rotating drum determines the drying process and it is regulated based upon the fabrics.

The higher rpm leads to faster performance in washing and drying process. This also helps to reduce the occurrence of noise occurred in washing machine. The noise can be neglected through active casting technique. This includes the feedforward structure to control the noise parameter. The noise level of low frequency upto 500hz is acceptable. Increase in the noise level need to be reduced. The increase in noise leads to vibrations in the machine. These vibrations are caused due to the improper suspension of the drum inside the machine.

#### V. MATHEMATICAL MODEL ANALYSIS AND FUNCTIONING OF WASHING MACHINE

The suspension co-ordination of the drum in washing machine is refered as spring damping system. The vibrations occurred in the machines are obtained through the differential equations. Some of the assumptions are denoted as disregarding the mass of spring and damper and avoiding the deformation in the system.

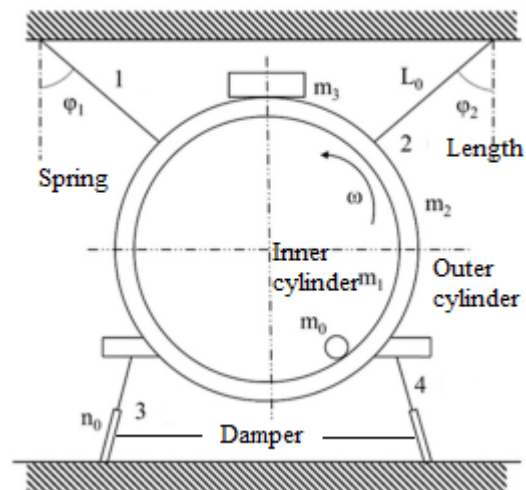


Fig 5: Mathematical model

The figure 5 demonstrates the mathematical model of suspension system. According to Lagrange equation, the dynamic equation is states as follows,

$$\frac{d}{dt} \left( \frac{\partial T}{\partial \dot{q}_j} \right) - \frac{\partial T}{\partial q_j} + \frac{\partial P}{\partial q_j} + \frac{\partial L}{\partial q_j} = Q_j(t)$$

T is the kinetic energy of the system,

P is the potential energy,

L is denoted as energy dissipation function

The kinetic energy of system is denoted as,

$$T = \frac{1}{2} m_1 |v_G|^2 + \frac{1}{2} I_1 (\dot{\theta} + \omega)^2 + \frac{1}{2} m_2 |v_G|^2 + \frac{1}{2} I_2 \dot{\theta}^2 + \frac{1}{2} m_0 |v_{m0}|^2 + \frac{1}{2} m_3 |v_{m3}|^2 + \frac{1}{2} I_3 \dot{\theta}^2 + \frac{1}{2} J_1 \omega_1^2 + \frac{1}{2} J_2 \omega_2^2$$



where  $v_g$  is the centroid velocity of the inner and outer cylinder respectively. The interconnection between the box and the inner cylinder are immovable in nature. There are two types of cylinders inside the machine namely inner and outer cylinder. They are inflexible in nature.

TABLE I. MOMENT OF INERTIA

Moment of inertia kg-mm <sup>2</sup>	
Motor shaft	$2.27 \times 10^4$
Inner cylinder	$4.6 \times 10^5$
Outer cylinder	$1.01 \times 10^4$
Counterweight	$2.4 \times 10^4$
Damping of spring	1.98
Suspension of spring	6.1

The table 1 represents the moment of inertia of the components of washing machine. The vibrations in the system are neglected through magnetorheological dampers. This is used to interconnect with the drum and cabinet. This reduces the vibrations adopted with control strategies. The control strategies includes adoption of fixed (current) values through a constant spin operating condition. This includes when a constant spinning condition, the training stage is initiated in multiple times with reduced ramp signal. The vibration and noise of the machine are identified and examined at the training phase [25].

The logical understanding of the functioning of washing machine is demonstrated as follows,

D = 0 (Door open condition), D = 1 (Door closed condition)  
 L = 0 (Low water level), L = 1 (Higher water level)  
 T = 0 (Low temperature), T = 1 (Higher temperature)

The motor operates when the value of D, L and T are higher.

The heater functions when the D and L are higher and T is lower.

The water valve operates when D and T are higher and reduced value of L.

TABLE II. LEVEL OF FUNCTION

Door (D)	Level (L)	Temperature (T)	Valve (V)	Motor (M)	Heater (H)
0	0	0	0	0	0
0	0	1	0	0	0
0	1	0	0	0	0
0	1	1	0	0	0
1	0	0	1	0	0
1	0	1	1	0	0
1	1	0	0	0	1
1	1	1	0	1	0

The table II represents the logical functioning parameters for operation and functioning of washing machines. The washing machine consists of three sensors namely the temperature sensor, door sensor and water sensor. They forms the basics for the operation of the drum. Thus the mathematical model determines the functioning of the system to neglect vibrations and to achieve higher efficiency. Through a smoothing of current vibration map, it helps to determine the current value at which the vibration responds during the training phase. This helps to find out the

optimum solution thus maintaining the constant spin functioning condition. This helps to enhance reduction in the power consumption. The overall process is optimized through genetic algorithm. The genetic algorithm is a tool for resolving both the controlled and unconfined problems. These complex problems are solved to obtain optimum results.

Algorithm 1: Genetic Algorithm for flexible Load shaping in Demand Side Management (GADSM)

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Take load types 'L', total number of matrices 'n', number of devices 'T', current matrix 'm' and power consumption 'p' from the table of load data
while  $I < L < n$  do
    while  $0 < I < m$  do
        (1) Calculate the total 'p' consumption of 'T' no. of devices
        (2) Compute the fitness function
            (a) Fitness function – without GA-DSM
            (b) Fitness function – with GA-DSM
                i. Population initialization
                ii. best optimal fitness function selection based on the minimal 'p' during peak hour 'ph'
                iii. Crossover is carried out on 'I' based on the minimal 'p' for time slot 't' < crossover >
                iv. After analyzing the behavior of the new population, mutation is done on 'I' based on 't' during 'ph' < mutation >
                v. The fitness function matrix of the 'I' with minimal 'p' during 'ph' is taken as the best fitness function for each 'L' < optimal solution >
    end while
    Same process is repeated for each 'L' and the best optimal fitness function is chosen.
end while
123
    
```

Fig 6: Genetic algorithm

The figure 6 represents the genetic algorithm for control and functioning of the machine learning. They are obtained through the process of crossover and mutation. This helps to optimize the system to achieve optimum solutions.

## VI. SIMULATION RESULTS

The proposed smart washing machine using artificial intelligence is implemented in proteus platform. This helps to analyse and estimate various functioning parameters of washing machines.

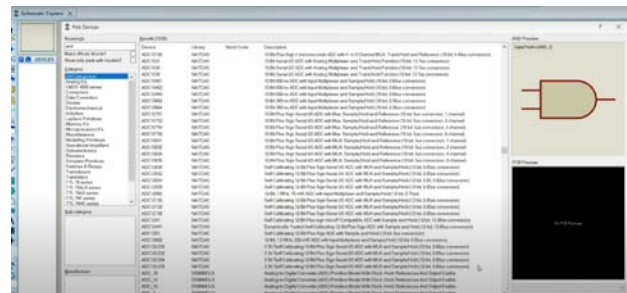


Fig 7: Simulation through Proteus

The figure 7 demonstrates the proteus simulation model to estimate the energy and water consumption. The simulation results are functioned through the logic functioning.

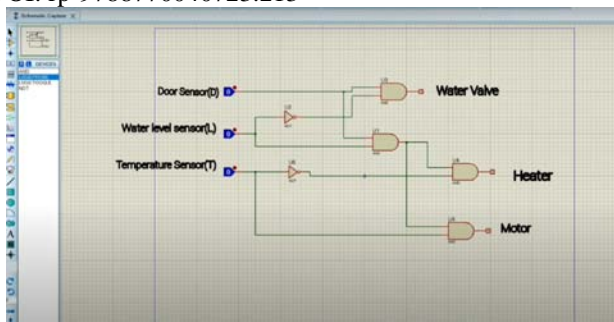


Fig 8: Simulation model and results

The figure 8 demonstrates the simulation model. This helps to analyze the accurate solution to various constraints in the functioning of washing machines. The output results are evaluated through the simulation model. Thus the proposed system provides 100% outcome in achieving automatic drying with efficient energy and water consumption through the aid of machine learning techniques.

## VII. CONCLUSION

The proposed system helps to obtain automation in washing machine through artificial intelligence. This includes control and monitoring of the system through machine learning techniques with internet of things. Thus the two way communication system helps to provide the information to the user even at remote places to monitor and visualise the functioning. Thus the smart washing machine helps to estimate the energy consumption through smart meters. Various smart techniques are inculcated to improve automations and smartness in functioning of the washing machine. This supports to decrease the energy consumption thus maintaining the demand side management.

## REFERENCES

- [1] A. Polenghi, L. Cattaneo, and M. Macchi, "A framework for fault detection and diagnostics of articulated collaborative robots based on hybrid series modelling of Artificial Intelligence algorithms," 2023.
- [2] Z. Zou, X. Xu, Z. Zhu, and X. Tu, "An improved demodulation scheme for FH-MFSK underwater acoustic communications," Program Book - OCEANS 2012 MTS/IEEE Yeosu: The Living Ocean and Coast - Diversity of Resources and Sustainable Activities, no. 1, pp. 2–5, 2012, doi: 10.1109/OCEANS-Yeosu.2012.6263513.
- [3] A. Kishore, M. Aeri, A. Grover, J. Agarwal, and P. Kumar, "Measurement: Sensors Secured supply chain management system for fisheries through IoT," Measurement: Sensors, vol. 25, p. 100632, December 2023, doi: 10.1016/j.measen.2022.100632.
- [4] S. C. Sethuraman, V. Vijayakumar, and S. Walczak, "Cyber Attacks on Healthcare Devices Using Unmanned Aerial Vehicles," Journal of Medical Systems, vol. 44, no. 1, 2020, doi: 10.1007/s10916-019-1489-9.
- [5] S. Tyszbrowicz and D. Faitelson, "Emergence in cyber-physical systems: potential and risk," Frontiers of Information Technology and Electronic Engineering, vol. 21, no. 11, pp. 1554–1566, 2020, doi: 10.1631/FITEE.2000279.
- [6] A. Chougule, V. K. Jha, and D. Mukhopadhyay, "Ontology Based System for Pests and Disease Management of Grapes in India," Proceedings - 6th International Advanced Computing Conference, IACC 2016, pp. 133–138, 2016, doi: 10.1109/IACC.2016.34.
- [7] K. L. Keung et al., "Edge intelligence and agnostic robotic paradigm in resource synchronisation and sharing in flexible robotic and facility control system," Advanced Engineering Informatics, vol. 52, January, 2022, doi: 10.1016/j.aei.2022.101530.

- [8] N. Venu et al., "Energy Auditing and Broken Path Identification for Routing in Large-Scale Mobile Networks Using Machine Learning," Wireless Communications and Mobile Computing, 2022, doi: 10.1155/2022/9418172.
- [9] J. F. Rajotte, R. Bergen, D. L. Buckeridge, K. El Emam, R. Ng, and E. Strome, "Synthetic data as an enabler for machine learning applications in medicine," iScience, vol. 25, no. 11, p. 105331, 2022, doi: 10.1016/j.isci.2022.105331.
- [10] Sitharthan, R., Vimal, S., Verma, A., Karthikeyan, M., Dhanabalan, S. S., Prabakaran, N., ...&Eswaran, T. (2023). Smart microgrid with the internet of things for adequate energy management and analysis.Computers and Electrical Engineering, 106, 108556.
- [11] J. Xu, B. Gu, and G. Tian, "Review of agricultural IoT technology," Artificial Intelligence in Agriculture, vol. 6, pp. 10–22, 2022, doi: 10.1016/j.aiaa.2022.01.001.
- [12] J. H. Song, C. Kim, and Y. Yoo, "Vein visualization using a smart phone with multispectral wiener estimation for point-of-care applications," IEEE Journal of Biomedical and Health Informatics, vol. 19, no. 2, pp. 773–778, 2015, doi: 10.1109/JBHI.2014.2313145.
- [13] L. Njomane and A. Telukdarie, "Impact of COVID-19 food supply chain: Comparing the use of IoT in three South African supermarkets," Technology in Society, vol. 71, p. 102051, June, 2022, doi: 10.1016/j.techsoc.2022.102051.
- [14] S. Zhang, Y. Feng, B. Li, J. Deng, T. Geng, and J. Zhang, "Fracture development during disposal of hazardous drilling cuttings by deep underground injection: A review," Journal of Rock Mechanics and Geotechnical Engineering, May 2022, doi: 10.1016/j.jrmge.2022.05.001.
- [15] Z. Liu, R. N. Bashir, S. Iqbal, M. M. A. Shahid, M. Tausif, and Q. Umer, "Internet of Things (IoT) and Machine Learning Model of Plant Disease Prediction-Blister Blight for Tea Plant," IEEE Access, vol. 10, pp. 44934–44944, 2022, doi: 10.1109/ACCESS.2022.3169147.
- [16] R. Verma, "Smart City Healthcare Cyber Physical System: Characteristics, Technologies and Challenges," Wireless Personal Communications, vol. 122, no. 2, pp. 1413–1433, 2022, doi: 10.1007/s11277-021-08955-6.
- [17] K. B. Mutyalu, V. V. Reddy, S. U. M. Reddy, and K. L. Prasad, "Effect of machining parameters on cutting forces during turning of EN 08, EN 36 & mild steel on high speed lathe by using Taguchi orthogonal array," Materials Today: Proceedings, no. xxxx, 2021, doi: 10.1016/j.matpr.2021.06.374.
- [18] Y. V. Kistenev, D. A. Vrazhnov, E. E. Shnaider, and H. Zuhayri, "Predictive models for COVID-19 detection using routine blood tests and machine learning," Heliyon, vol. 8, no. 10, p. e11185, 2022, doi: 10.1016/j.heliyon.2022.e11185.
- [19] L. J. L. S. V. S. M. R, and M. R., "Automated food grain monitoring system for warehouse using IOT," Measurement: Sensors, vol. 24, p. 100472, July, 2022, doi: 10.1016/j.measen.2022.100472.
- [20] S. Zhang et al., "Graphene/ZrO2/aluminum alloy composite with enhanced strength and ductility fabricated by laser powder bed fusion," Journal of Alloys and Compounds, vol. 910, p. 164941, 2022, doi: 10.1016/j.jallcom.2022.164941.
- [21] D. A. Gzar, A. M. Mahmood, and M. K. A. Al-Adilee, "Recent trends of smart agricultural systems based on Internet of Things technology: A survey," Computers and Electrical Engineering, vol. 104, no. PA, p. 108453, 2022, doi: 10.1016/j.compeleceng.2022.108453.
- [22] J. L. Vilas-Boas, J. J. P. C. Rodrigues, and A. M. Alberti, "Convergence of Distributed Ledger Technologies with Digital Twins, IoT, and AI for fresh food logistics: Challenges and opportunities," Journal of Industrial Information Integration, vol. 31, p. 100393, June 2022, doi: 10.1016/j.jii.2022.100393.
- [23] V. Rajesh Kumar, K. Pradeepan, S. Praveen, M. Rohith, and V. Vasantha Kumar, "Identification of Plant Diseases Using Image Processing and Image Recognition," 2021 International Conference on System, Computation, Automation and Networking, ICSCAN 2021, pp. 0–3, 2021, doi: 10.1109/ICSCAN53069.2021.9526493.
- [24] R. Shukla, N. K. Vishwakarma, A. R. Mishra, and R. Mishra, "Internet of Things Application: E-health data acquisition system and Smart agriculture," International Conference on Emerging Trends in Engineering and Technology, ICETET, pp. 12–16, April, 2022, doi: 10.1109/ICETET-SIP-2254415.2022.9791834.

- [25] T. Lei, Z. Cai, and L. Hua, "5G-oriented IoT coverage enhancement and physical education resource management," *Microprocessors and Microsystems*, vol. 80, p. 103346, September 2021, doi: 10.1016/j.micpro.2020.103346.
- [26] D. Sumit, S. Gupta, A. Juneja, Y. Nauman, I. Hamid, T. Ullah, Kim, E.M.Tag eldin, and N.A. Ghamry, Energy Saving Implementation in Hydraulic Press Using Industrial Internet of Things (IIoT). *Electronics*, vol. 11, p. 4061, 2022. <https://doi.org/10.3390/electronics11234061>
- [27] Moshika, A., Thirumaran, M., Natarajan, B., Andal, K., Sambasivam, G., &Manoharan, R. (2021).Vulnerability assessment in heterogeneous web environment using probabilistic arithmetic automata. *IEEE Access*, 9, 74659-74673..
- [28] R. Kaushal, R. Bhardwaj, N. Kumar, A. A. Aljohani, S. K. Gupta, P. Singh, N. Purohit, "Using Mobile Computing to Provide a Smart and Secure Internet of Things (IoT) Framework for Medical Applications", *Wireless Communications and Mobile Computing*, Article ID 8741357, vol. 13 p, 2022. <https://doi.org/10.1155/2022/8741357>.