EcoScan: AI-Driven Waste Segregation System

L.Glarida Amala*, A.Subramaniyan**, G.Sree Ganesh Ram**, A.Deenathayalan**, S.Karthi**
*Assistant Professor, Department of Electrical and Electronics Engineering, M.A.M College of Engineering and Technology, Siruganur, Trichy, Tamilnadu.
** UG Student, Department of Electrical and Electronics Engineering, M.A.M College of Engineering and Technology, Siruganur, Trichy, Tamilnadu.

Abstract - Waste segregation is a critical aspect of efficient waste management systems, ensuring that different types of waste are properly sorted for appropriate disposal or recycling. In modern implementations, advanced technologies such as cameras are employed to automatically identify and separate various types of waste materials. These cameras capture images of the waste as it moves along a conveyor belt, utilizing image processing algorithms to categorize the waste into different groups based on predefined criteria such as material type or recyclability. Once identified, the waste is directed along separate conveyor belts corresponding to its respective category, facilitating efficient sorting. To streamline the process further, conveyer setups are often employed to transfer the waste from the segregation point to designated bins or collection areas. These conveyors are designed to transport the segregated waste swiftly and accurately, minimizing manual handling and maximizing operational efficiency. Servo motors are utilized within the setup to precisely control the movement and direction of the waste as it is transferred to the appropriate bins

Key Words: Artificial Intelligence (AI), Deep Learning, Waste Detection, CNN, Arduino UNO, Web Camera, Power Supply, Servomotor, Conveyor Belt, Waste Management System.

I. INTRODUCTION

Effective waste management is crucial for environmental sustainability, prompting the development of innovative solutions like waste segregation with camera-based sorting and conveyor setups. In today's world, where population growth and urbanization lead to increased waste production, traditional waste management methods are proving insufficient. Thus, there's a pressing need to adopt advanced technologies to streamline the process, reduce environmental impact, and promote sustainable practices. This introduction sets the stage for understanding the purpose, necessity, and implementation of such systems. The purpose of implementing waste segregation with camera-based sorting and conveyor setups is twofold. Firstly, it aims to improve the efficiency of waste management systems by automating the segregation process. By employing cameras capable of identifying different types of waste materials, the system can categorize them accurately and efficiently.

II. LITERATURE SURVEY:

Survey Paper 1: “A Comparative Analysis of Algorithms for Effective Waste Classification (2023)”- Ms. Deepika Kamboj; Madhavi Singh; Maaz Usmani;-This research paper presents a comparative analysis of various algorithms used for waste classification, highlighting their strengths, limitations, and performance metrics.

Survey Paper 2: “Developing Smart Trash Management System using IoT and Machine Learning (2023)”- M. Aldiki Febriantono ; Andi Pramono-The aim of this research is to address the ineffectiveness of current trash management systems.

Survey Paper 3: “Waste Classification Using Support Vector Machine with SIFT-PCA Feature Extraction (2020)”- Adita Putri Puspaningrum; Sukmawati Nur Endah-This research proposes waste image classification to support automatic waste sorting using Support Vector Machine (SVM) classification algorithm and SIFT-PCA (Scale Invariant Feature Transform - Principal Component Analysis) feature extraction.

Survey Paper 4: “Waste Management of Residential Society using Machine Learning and IoT Approach (2020)”- Sonali Dubey ; Murari Kumar Singh-A small scale waste management is also adding same potential as large scale waste management. IoT and machine learning based waste management system for residential society are aimed to enhance the same concern as the waste management of smart city.

Survey Paper 5: “Recyclable Waste Classification Using Computer Vision And Deep Learning (2019)”- Nadish Ramsurrun1 , Geerish Suddul2 , Sandhya Armoogum,-Our work proposes a Deep Learning approach using computer vision to automatically identify the type of waste and classify it into five main categories: plastic, metal, paper, cardboard and glass.

Survey Paper 6: “Waste Segregation Using Image Processing (2022)”- Prof. Yuvaraj , Likhith N Gowda , Manavi, Priya P Rao,-The captured image is processed by a certain image processing algorithm which consists of image segmentation, image classification and object detection.
Survey Paper 7: “Waste Segregation Using Image Detection and IOT (2023)”- Rizwana S, Abinaya J, Harshada G,-The system uses Python, YOLOv8, and OpenCV for image processing and classification.
Survey Paper 8: “Automated Waste Segregation System using Image Processing (2023)”- Haritha K N, 2Gopika S Pillai, 3Jyothi Krishnan M-By automating the segregation process using image processing techniques, the system aims to reduce the reliance on manual sorting, which can be hazardous to human health and inefficient.
Survey Paper 9: “An Analytical Approach for Waste Segregation Using Machine Learning Techniques (2019)”- Rutuja Thakre, Minakshi Gahalyan, Anjali Jaiswal, shron Jadhao,-The proposed CNN-based image classifier has the potential to significantly improve the efficiency of waste segregation processes by automating the identification and categorization of different types of waste materials.
Survey Paper 10: “Waste Segregation using Deep Learning Algorithm (2018)”- R.S.Sandhya Devi, Vijaykumar VR , M.Muthumeena-This paper proposes an automated waste classification system using Convolution Neural Network (CNN) algorithm, a Deep Learning.

III. EXISTING SYSTEM:

This research proposes waste image classification to support automatic waste sorting using Support Vector Machine (SVM) classification algorithm and SIFT-PCA (Scale Invariant Feature Transform Principal Component Analysis) feature extraction. SIFT-PCA is a combination of SIFT to extract feature data and PCA to reduce the dimensionality of the resulting feature data. The data used in this research is Trash net datasets.

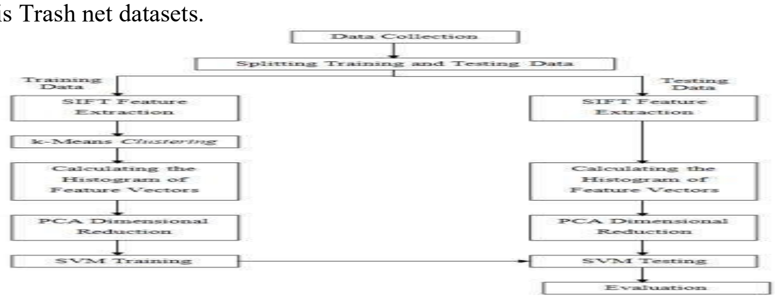


Figure3: Existing System Block Diagram

3. Proposed System:

The proposed waste segregation system integrates advanced technologies such as cameras and image processing algorithms to automate the sorting process. As waste moves along a conveyor belt, cameras capture images and algorithms analyze them to categorize the waste based on predefined criteria. This automated identification directs waste along separate conveyor belts, streamlining sorting and minimizing manual intervention. Conveyer setups efficiently transfer the segregated waste to designated bins using servo motors for precise control, further enhancing operational efficiency and reducing the risk of errors or contamination. This system optimizes waste management practices, promoting environmental sustainability through improved segregation and recycling processes.

Soft Ware Block Diagram:

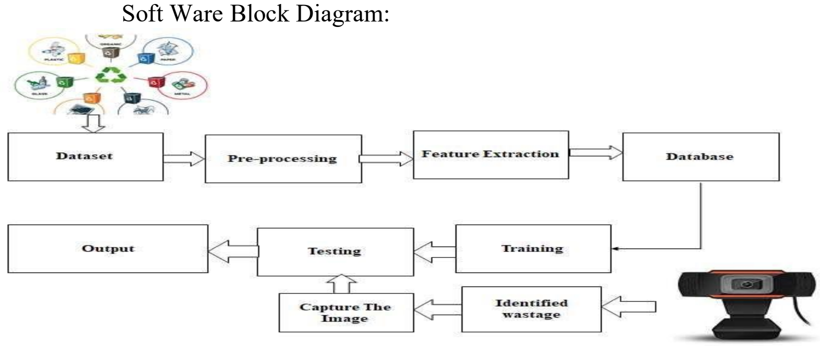


Figure4.1: Software Block Diagram

Hard Ware Block Diagram:

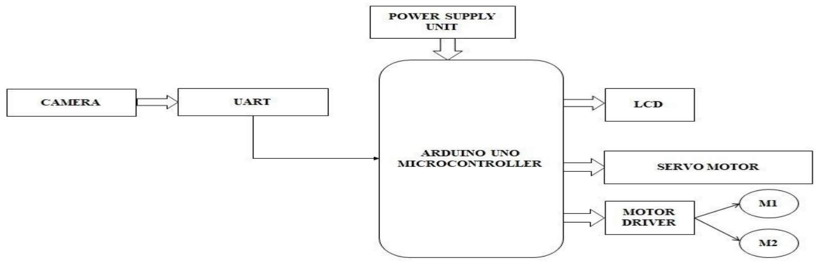


Figure4.2: Hardware Block Diagram

IV. SYSTEM REQUIREMENTS:

3.1 Soft Ware Requirements H/W System Configuration:

- Processor - Pentium – IV
- RAM - 4 GB (min)
- Hard Disk - 20 GB

S/W System Configuration:

- Operating System : Windows 7 or 8
- Frontend :HTML,CSS
- Backend: python, Arduino IDE

3.2 Hard Ware Requirements

- POWER SUPPLY UNIT
- ARDUINO UNO
- LCD
- MOTOR DRIVER
- DC MOTORS
- SERVO MOTOR

4. Hard Ware Specifications:

Arduino UNO

The Arduino Uno is a popular microcontroller board widely used for prototyping and developing electronic projects due to its simplicity and versatility. At its core, the Arduino Uno features an ATmega328P microcontroller unit (MCU), which acts as the brain of the system. The MCU is responsible for executing the code uploaded to the board, interacting with various hardware components, and controlling external devices through input and output pins.

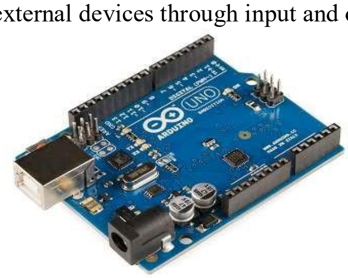


Figure6.1: Arduino UNO

Servo Motor:

A servo motor is a type of rotary actuator that allows for precise control of angular position. It consists of a motor coupled with a sensor for feedback, typically a potentiometer or encoder, and a control circuit. Servo motors operate by receiving a control signal, usually in the form of a pulse-width modulation (PWM) signal, which determines the desired position of the motor shaft.

Figure6.2 Servo Motor

6.3 Web Camera:
A webcam, short for "web camera," is a digital camera device typically integrated into computers or external peripherals that captures video and images in real-time. These cameras consist of an image sensor, optics (such as lenses), and electronics for processing and transmitting data. When in use, the webcam is connected to a computer via USB or another interface, and software applications interact with it to access the video feed and control camera settings.

Figure6.3: Web Camera
6.4 Power Supply Unit:
A power supply unit (PSU) is an essential component in electronic devices that converts electrical power from a source into usable voltage levels required by the device's components. PSUs are commonly found in various applications, including computers, appliances, industrial equipment, and electronic systems. The primary function of a PSU is to deliver stable and reliable power to the device, ensuring its proper operation. PSUs can be categorized based on their output voltage and current characteristics. Linear power supplies regulate output voltage by dissipating excess power as heat, while switching power supplies use high-frequency switching circuits to achieve efficient voltage regulation.
6.5 LCD:
An LCD (Liquid Crystal Display) is a type of flat-panel display commonly used in electronic devices such as computer monitors, television screens, smartphones, and digital watches. LCDs utilize the properties of liquid crystals to modulate light and produce images or text. The basic structure of an LCD consists of two polarized glass panels with a layer of liquid crystal solution sandwiched between them. The liquid crystals are arranged in a grid pattern, and their orientation can be controlled electrically. When an electric current is applied to specific regions of the liquid crystal layer, the crystals change orientation, altering their ability to rotate polarized light passing through them. The LCD also includes a backlight, typically composed of LEDs (Light Emitting Diodes) or CCFLs (Cold Cathode Fluorescent Lamps), positioned behind the liquid crystal layer.
6.6 Motor Driver:
A motor driver is an electronic device or circuit that controls the movement and direction of an electric motor. It serves as an interface between the motor and a microcontroller or other control system, providing the necessary power and signals to drive the motor according to desired specifications. The primary function of a motor driver is to regulate the electrical current flowing through the motor windings, thereby controlling its speed and direction of rotation. Motor drivers typically incorporate power transistors or MOSFETs (Metal-Oxide-Semiconductor Field-Effect Transistors) to switch the current on and off rapidly, allowing precise control over the motor's behavior. Motor drivers also often include protective features such as overcurrent protection, thermal shutdown, and reverse polarity protection to prevent damage to the motor or driver circuitry in case of electrical faults or overload conditions.
6.7 DC Motor:
A DC (Direct Current) motor is an electromechanical device that converts electrical energy into mechanical motion. It operates on the principle of Lorentz force, where a current-carrying conductor placed in a magnetic field experiences a force perpendicular to both the current direction and the magnetic field lines. In a DC motor, this force causes the motor's rotor, typically a coil of wire or permanent magnet, to rotate. The direction of rotation is determined by the polarity of the applied voltage and the orientation of the magnetic field. By controlling the magnitude and polarity of the applied voltage, the speed and direction of the motor can be adjusted. DC motors are widely used in various applications due to their simplicity, reliability, and ease of control, including in automotive systems, industrial machinery, robotics, and consumer electronics.

Hard Ware Design And Implementation:

According to the design of the system, a conveyor belt ismade to convey the waste from one end to another end. Initially, it was planned to take as 15 feet but due to the budget limitation, it has been structured as 10 feet using DC gear motor. Afterwards, a physical infrastructure is made to hold the camera module, ultrasonic sensor and all the servomotors.There are six types of waste collection bins to collect differenttypes of classified waste. In addition, a GSM-based communication medium is used to monitor the waste level inside the bins and the time to trash out the bins filled with garbage. Finally, this device has been made in such a way sothat it can aid the dumping process remotely via an android controlled app based on Bluetooth communication. The inserted picture in Fig:demonstrates the overall hardware implementation of the system.

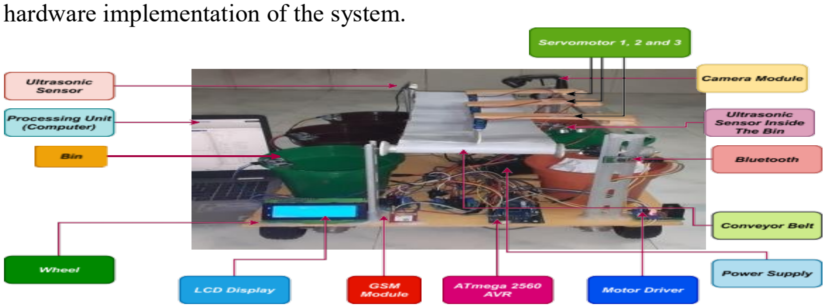
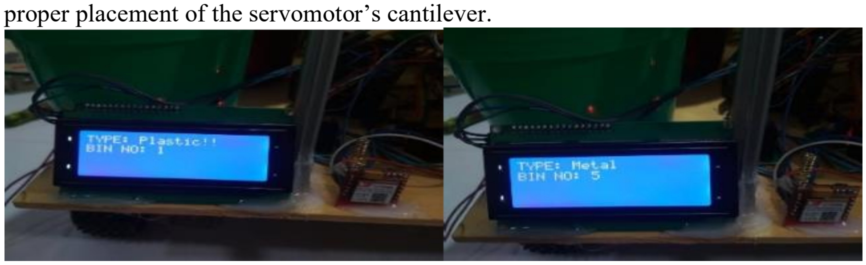


Figure7: Overall Hardware Implementation of the System

V. RESULT ANALYSIS

The overall detection and separation of the system are quite satisfactory. When an object is detected, a signal is sentto the servomotor controller from the processing unit (Computer) to separate the detected waste inside the corresponding bin. Afterwards, the cantilever of the servomotor comes to its initial position to be ready for the nextdetected waste. The depicted pictures in Fig. 8.1 (a) and (b) show the proper placement of the servomotor's cantilever.



A) B)

Figure: 8.1 (a) and (b). Integration of display module with the system.

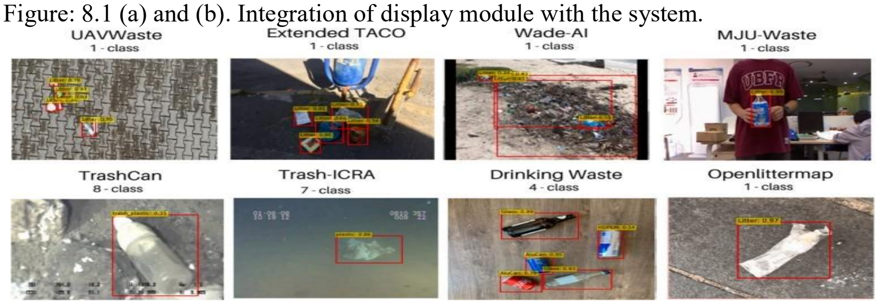


Figure8.2: Waste Segregation of Image Detection

Inferences drawn:

In modern waste management systems, advanced technologies such as cameras and image processing algorithms are employed to automatically identify and segregate different types of waste materials. These systems use conveyor belts to transport the waste to designated bins or collection areas, minimizing manual handling and maximizing efficiency. Servo motors are integrated into the setup to precisely control the movement and direction of the waste, further enhancing the speed and accuracy of segregation. This automation not only improves waste management practices but also promotes environmental sustainability by reducing errors and contamination.

Proposed solution:

The proposed waste segregation system integrates advanced technologies such as cameras and image processing algorithms to automate the sorting process. As waste moves along a conveyor belt, cameras capture images and algorithms analyze them to categorize the waste based on predefined criteria. This automated identification directs waste along separate conveyor belts, streamlining sorting and minimizing manual intervention.Conveyer setups efficiently transfer the segregated waste to designated bins using servo motors for precise control, further enhancing operational efficiency and reducing the risk of errors or contamination. This system optimizes waste management practices, promoting environmental sustainability through improved segregation and recycling processes.

Scope for future continuation of this work:

Although people fear that the use of AI is going to affect their jobs, the are some issues that require immediate action and efficient methods to tackle them. Waste management has become a colossal issue, that needs automation of the process along with swift and efficient methods to tackle it. Here, AI can contribute by reducing time and effort through automation. The proposed system can automate the process of segregation and separate waste into Dry and Wet classes.This system can be efficiently used on a large scale in waste treatment plants and large garbage bins to treat the waste.The automation of model training by lobe application can be further applied in classifying medical waste, Electronic waste, Industrial waste, etc.Through the use of IoT and AI, the segregation and treatment of waste becomes through and efficient, leading us towards a safer, cleaner and greener environment.

VI. CONCLUSION

In conclusion, the implementation of an advanced waste segregation system incorporating technologies such as cameras, image processing algorithms, conveyor belts, and servo motors presents a significant leap forward in modern waste management practices. By automating the sorting process, this system offers unparalleled efficiency, accuracy, and scalability across various sectors, including municipal waste management, industrial recycling, and construction sites. Furthermore, the system's ability to minimize contamination, reduce manual handling, and optimize resource utilization underscores its pivotal role in promoting environmental sustainability and advancing towards a circular economy. With its numerous benefits ranging from improved recycling outcomes to reduced landfill waste, the proposed waste segregation system represents a transformative solution poised to revolutionize waste management practices and foster a more sustainable future for generations to come.

Future Enhancement:

Integration of Artificial Intelligence (AI): Incorporating AI algorithms can further enhance the system's ability to recognize and classify diverse waste materials with greater accuracy and efficiency. Machine learning techniques could enable the system to continuously improve its sorting capabilities over time, adapting to new waste streams and evolving recycling requirements.

Robotics and Automation: Expanding the use of robotics and automation beyond conveyor systems could enable more sophisticated handling and sorting of waste materials. Robotic arms equipped with advanced gripping mechanisms could selectively extract valuable recyclables from mixed waste streams, further reducing the need for manual labor and increasing operational efficiency.

Modular Design and Scalability: Designing the system with modular components and scalability in mind would facilitate its deployment in diverse settings and accommodate varying waste management needs. This flexibility would enable seamless integration with existing infrastructure and support future expansion or customization as demand for waste segregation solutions grows.

REFERENCES

[1] K. N. Sami, Z. M. A. Amin and R. Hassan, "Waste management using machine learning and deep learning algorithms", Int. J. Perceptive Cogn. Comput., vol. 6, no. 2, pp. 97-106, Dec. 2020. 2) S. Shahab, M. Anjum and M. S. Umar, "Deep learning applications in solid waste management: A deep literature review", Int. J. Adv. Comput. Sci. Appl., vol. 13, no. 3, pp. 381-395, 2022

[2] S. S. A. Rajjak and A. K. Kureshi, "Object Detection and Tracking using YOLO v3 Framework for Increased Resolution Video", International Journal of Innovative Technology and Exploring Engineering (IJITEE), vol. 09, no. 06, pp. 118-125, 2020.

[3] L. J. J. Meijer, T. van Emmerik, R. van der Ent, C. Schmidt and L. Lebreton, "More than 1000 rivers account for 80% of global riverine plastic emissions into the ocean", Science Advances, vol. 7, no. 18, Apr. 2021.

[4] X. Li, M. Tian, S. Kong, L. Wu and J. Yu, "A modified YOLOv3 detection method for vision-based water surface garbage capture robot", vol. 17, no.3, june, 2020.

[5] Ma. B. L. D. Diola, M. A. N. Tanchuling, D. R. G. Bonifacio and M. J. N. Delos Santos, "Characterization of Plastic Pollution in Rivers: Case of Sapang Baho River Rizal Philippines", EGUGA, pp. 22467, 2020.

[6] S. Bhandari, Automatic waste sorting in industrial environments via machine learning approaches, Tampere, Finland, Oct. 2020.

[7] C.Nagarajan and M.Madheswaran - 'Experimental verification and stability state space analysis of CLL-T Series Parallel Resonant Converter' - Journal of ELECTRICAL ENGINEERING, Vol.63 (6), pp.365-372, Dec.2012.

[8] C.Nagarajan and M.Madheswaran - 'Performance Analysis of LCL-T Resonant Converter with Fuzzy/PID Using State Space Analysis'- Springer, Electrical Engineering, Vol.93 (3), pp.167-178, September 2011.

[9] C.Nagarajan and M.Madheswaran - 'Stability Analysis of Series Parallel Resonant Converter with Fuzzy Logic Controller Using State Space Techniques'- Taylor & Francis, Electric Power Components and Systems, Vol.39 (8), pp.780-793, May 2011.

[10] C.Nagarajan and M.Madheswaran - 'Experimental Study and steady state stability analysis of CLL-T Series Parallel Resonant Converter with Fuzzy controller using State Space Analysis'- Iranian Journal of Electrical & Electronic Engineering, Vol.8 (3), pp.259-267, September 2012.

[11] Nagarajan C., Neelakrishnan G., Akila P., Fathima U., Sneha S. “Performance Analysis and Implementation of 89C51 Controller Based Solar Tracking System with Boost Converter” Journal of VLSI Design Tools & Technology. 2022; 12(2): 34–41p.

[12] C. Nagarajan, G.Neelakrishnan, R. Janani, S.Maithili, G. Ramya “Investigation on Fault Analysis for Power Transformers Using Adaptive Differential Relay” Asian Journal of Electrical Science, Vol.11 No.1, pp: 1-8, 2022.

[13] G.Neelakrishnan, K.Anandhakumar, A.Prathap, S.Prakash “Performance Estimation of cascaded h-bridge MLI for HEV using SVPWM” Suraj Punj Journal for Multidisciplinary Research, 2021, Volume 11, Issue 4, pp:750-756

[14] G.Neelakrishnan, S.N.Pruthika, P.T.Shalini, S.Soniya, “Perfromance Investigation of T-Source Inverter fed with Solar Cell” Suraj Punj Journal for Multidisciplinary Research, 2021, Volume 11, Issue 4, pp:744-749

[15] C.Nagarajan and M.Madheswaran, “Analysis and Simulation of LCL Series Resonant Full Bridge Converter Using PWM Technique with Load Independent Operation” has been presented in ICTES’08, a IEEE / IET International Conference organized by M.G.R.University, Chennai.Vol.no.1, pp.190-195, Dec.2007

[16] M Suganthi, N Ramesh, “Treatment of water using natural zeolite as membrane filter”, Journal of Environmental Protection and Ecology, Volume 23, Issue 2, pp: 520-530,2022

[17] M Suganthi, N Ramesh, CT Sivakumar, K Vidhya, “Physiochemical Analysis of Ground Water used for Domestic needs in the Area of Perundurai in Erode District”, International Research Journal of Multidisciplinary Technovation, pp: 630-635, 2019

[18] T. Yang, J. Xu, Y. Zhao, T. Gong, R. Zhao, M. Sun, et al., "Classification technology of domestic waste from 2000 to 2019: A bibliometrics-based review", Environ. Sci. Pollut. Res., vol. 28, no. 21, pp. 26313-26324, Jun. 2021.

[19] F. Zhang, C. Cao, C. Li, Y. Liu and D. Huisingh, "A systematic review of recent developments in disaster waste management", J. Cleaner Prod., vol. 235, pp. 822-840, Oct. 2019.

[20] J. Bobulski and M. Kubanek, "Deep learning for plastic waste classification system", Appl. Comput.

[21] Intell. Soft Comput., vol. 2021, pp. 1-7, May 2021.

[22] F. A. Azis, H. Suhaimi and E. Abas, "Waste classification using convolutional neural network", Proc. 2nd Int. Conf. Inf. Technol. Comput. Commun., pp. 9-13, Aug. 2020.

[23] Y. Wu, X. Shen, Q. Liu, F. Xiao and C. Li, "A garbage detection and classification method based on visual scene understanding in the home environment", Complexity, vol. 2021, pp. 1-14, Nov. 2021.

[24] Y. Chen, W. Han, J. Jin, H. Wang, Q. Xing and Y. Zhang, "Clean our city: An automatic urban garbage classification algorithm using computer vision and transfer learning technologies", J. Phys. Conf. Ser., vol. 1994, no. 1, Aug. 2021.

[25] F. Liu, H. Xu, M. Qi, D. Liu, J. Wang and J. Kong, "Depth-wise separable convolution attention module for garbage image classification", Sustainability, vol. 14, no. 5, pp. 3099, Mar. 2022. 15) A. Patil, A. Tatke, N. Vachhani, M. Patil and P. Gulhane, "Garbage classifying application using deep learning techniques", Proc. Int. Conf. Recent Trends Electron. Inf. Commun. Technol. (RTEICT), pp. 122-130, Aug. 2021.