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IoT and Edge Learning for Real-time Citizen Alerts in Smart Cities: A Comprehensive Review

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***Abstract*— Maharashtra is prone to heavy rainfalls. Pune residents have witnessed several incidents of human and animal drowning due to floods caused by natural disasters and the release of excessive water from reservoirs like dams. Furthermore, locals have been observed dumping illegal debris into rivers and canals, leading to soil and water pollution. In addition, sound pollution has become a significant issue in the city due to the installation of loudspeaker systems along the same water bodies. To address these issues, we propose a cyber-physical system that leverages edge learning concepts. Our proposed system provides alerts for water flooding, identifies illegal debris dumping, and prevention of sound pollution. The purpose of this work is to provide a comparative analysis of numerous models and methodologies applied to the distinctive objectives of our integrated system.**

Keywords—Smart City, IoT, edge computing, machine learning, integrated system.

I. INTRODUCTION

Pune, a rapidly developing city in India, is facing multiple challenges that require a comprehensive and integrated approach to tackle. One of the major issues is flooding, which has become more frequent over the last decade due to a higher incidence of heavy rainfall events occurring within a shorter time frame. The city is surrounded by several dams that can cause destructive floods, making it essential to forecast and monitor floods to reduce the loss of human and animal life.

Another significant challenge in Pune City is the illegal dumping of waste, leading to land and water pollution, ill effects on health, environment, and it results in affecting the City's beauty. Although the authorities and citizen groups have made attempts to address this issue, limited efforts have been made to incorporate technology and take a digital approach to eliminate illegal dumping in Pune.

Pune also experiences a significant problem with noise pollution, which exceeds the safe limit set by the WHO. The government has implemented measures like enforcing noise pollution norms and implementing traffic management plans, but accurate monitoring is essential to reduce noise pollution levels further for the overall well-being of the citizens. To address these challenges, an integrated system in Pune's smart city that alerts about probable flood-like situations, detects debris dumping actions of the citizens, and monitors sound levels in the environment is required. This system can help authorities manage and overcome these challenges.

This paper is organised into six sections, including an introduction outlining the challenges and motivation behind the study, a review of related work, a description of the methods used for performance analysis, a summary of findings and recommendations, acknowledgments, and a list of references. By addressing these challenges through a comprehensive and integrated approach, Pune can continue to develop sustainably and improve the quality of life for its citizens.

II. RELATED WORK

A. *Present-day strategies for predicting and notifying about floods*

The paper [5] proposes an Internet of Things and machine learning(ML) based system for flood alerts. The system uses sensors to collect real-time data about water level, humidity, and temperature and sends it to a cloud server for processing. ML solutions are used to predict flood occurrence. Human presence in flooded areas is also detected by ML. The system is also equipped with a mobile application to alert users about flood situations. This system provides a comprehensive solution to flood detection and monitoring with its advanced technology. Their proposed system is designed for a specific location and may not be applicable to other regions or environments. Additionally, the effectiveness and accuracy of the system were not evaluated in a real-world scenario.

Fig. 1. IoT based flood alert system proposed in [5]

The work by Linyi City [6] focuses on the use of remote sensing technology to monitor floods. This study utilizes Sentinel-1A radar data to obtain information about flood extent, flood duration, and water level changes. The authors applied the synthetic aperture radar (SAR) technique to detect floods in the study area. The study demonstrates the potential of remote sensing technology to provide timely and accurate information on floods, which can be useful for disaster management. However, the study focuses only on this specific application and does not compare the accuracy and reliability of the proposed system to other flood monitoring systems or techniques.

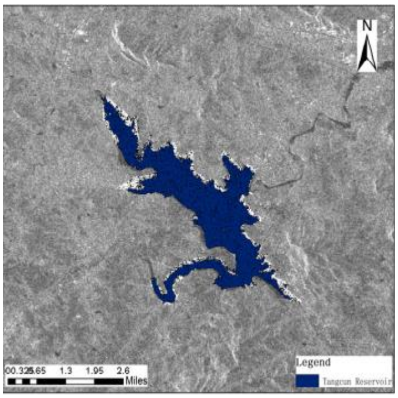

Fig. 2. Outcomes of Sentinel-1A [6]

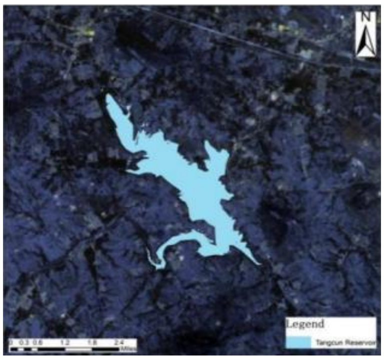

Fig. 3. Outcomes of Landsat8 OLI [6]

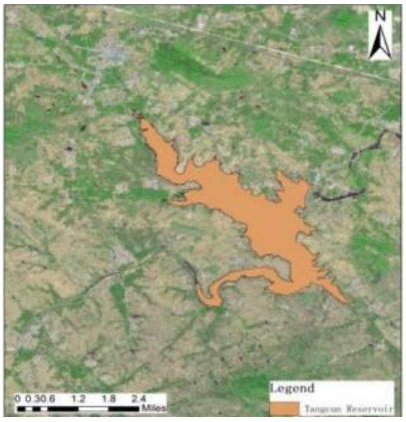

Fig. 4. Outcomes of GF-1 [6]

Another study proposed a system for flood monitoring & forecasting in urban environments [7] using a deep-learning based approach for flood forecasting and monitoring in urban environments. The study uses convolutional neural networks (CNNs) to extract features from satellite images and predict flood occurrences. The authors also developed a web-based platform to visualise the flood forecasting results. The system achieved good performance in flood detection and monitoring, demonstrating the effectiveness of deep learning algorithms in this field. However, the study focuses on flood forecasting rather than real-time flood monitoring and detection. Additionally, the study was conducted using data from a specific city, and the effectiveness of the system was not tested in other locations or environments. Finally, the system relies heavily on data from weather stations, which may not be available in all locations.

Whereas the paper [8] presents a IoT-based low-cost flood monitoring system that uses machine learning and neural networks for flood alerting and rainfall prediction. The system uses sensors to collect real-time data about rainfall, water level, and temperature, which are then processed using machine learning algorithms to predict flood occurrences. The authors also developed a mobile application to notify users about flood situations. The study demonstrates the potential of IoT and machine learning for flood monitoring in cost-effective ways. However, the effectiveness and accuracy of the system were not evaluated in a real-world scenario. Additionally, the study does not compare the proposed system to other flood monitoring systems or techniques.

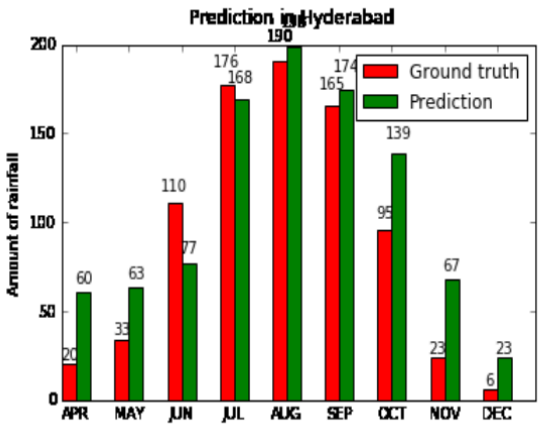

Fig. 5. Prediction of rainfall with linear regression [8]

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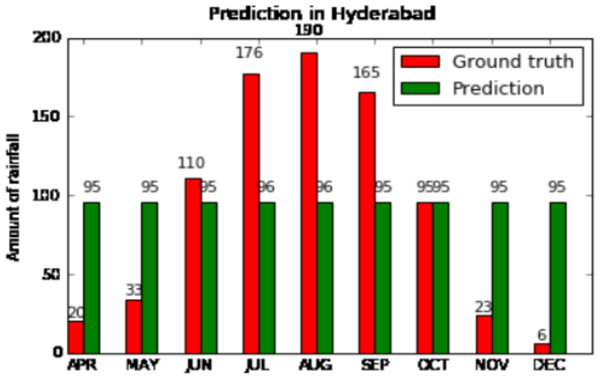

Fig. 6. Prediction of rainfall with SVM [8]

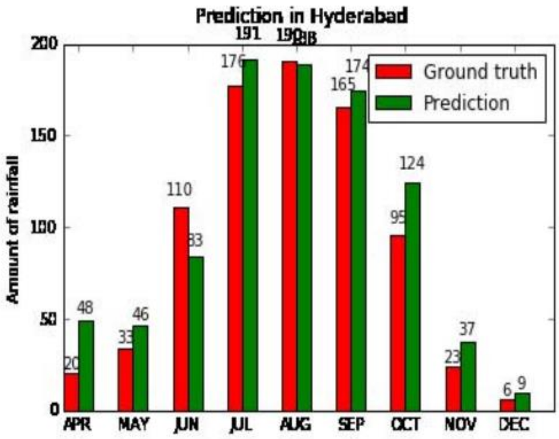

Fig. 7. Rainfall prediction using Artificial Neural Networks [8]

The above research studies offer different perspectives on flood monitoring and detection using various technologies. The first paper [5] proposes an Internet of Things and ML based system for human detection and food alert, while the second paper [6] uses remote sensing technology to monitor floods. The third paper [7] applies deep learning algorithms to extract features from satellite images for flood forecasting, and the fourth paper [8] presents a IoT-based low-cost monitoring system for flood using ML with neural networks. These studies provide valuable insights into the application of advanced technologies for flood monitoring and detection, which can be useful for disaster management and mitigation. Overall, each paper has its contributions and limitations, and future research can build upon these findings to develop more comprehensive and effective flood monitoring and detection systems.

B. Existing sound detection and monitoring systems

The paper [9] proposed a system for the event of sound detection using binary neural-networks on IoT devices that are tightly power constrained. The authors propose a lightweight binary neural network architecture that is optimised for sound event detection and can run on devices with limited resources. High accuracy achieved by a proposed method can be seen in experimental results. experimental results show that the proposed method achieves high accuracy and low power consumption, making it suitable for use in IoT applications.

However, the use of binary neural networks may reduce accuracy compared to traditional neural networks.

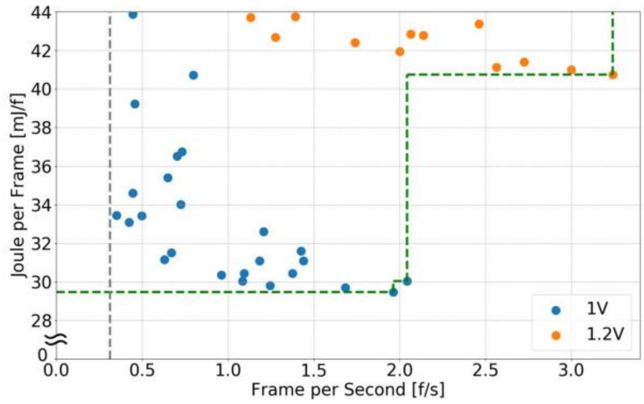

Fig. 8. At various supply voltages and operating frequencies the evaluated throughput and energy efficiency [9].

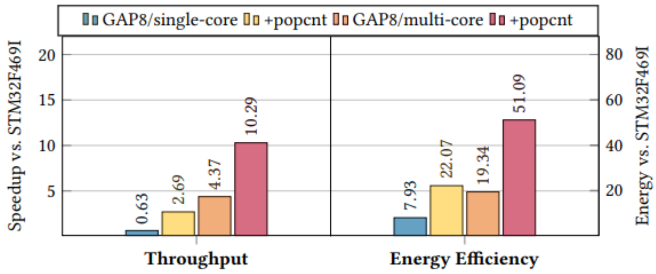

Fig.9.In contrast to the ARM Cortex-M4 implementation enhanced throughput and energy efficiency.[9].

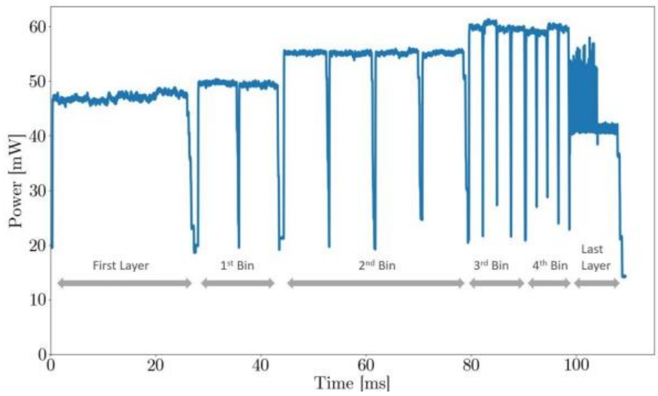

Fig.10. Power trace while BNN is executing on one tile of the GAP8 platform [9].

. Moreover the authors Meshkov and Naumoski described a noise pollution measurement system that uses IoT sensors to collect sound data from various locations in a city [10]. The authors present the design and implementation of the system, along with some preliminary results. The system is intended to provide accurate and real-time measurements of noise pollution in urban areas, which can be used to develop effective noise mitigation strategies. However, the paper didn't provide a detailed explanation of the system, making it challenging to evaluate its effectiveness.

In [11], Tan et al. propose an end-to-end Internet of Things system for deriving urban sound information in residential

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areas. The authors describe a system architecture that combines sound sensors, data transmission, cloud computing, and machine learning algorithms to detect and classify different types of sound events in real-time. The results of the experiment demonstrate the efficacy of the proposed system in detecting various sound events, including sirens, construction noise, and human activities. However, the paper didn’t provide a comprehensive evaluation of the system's performance, making it challenging to determine its accuracy or effectiveness in practice.

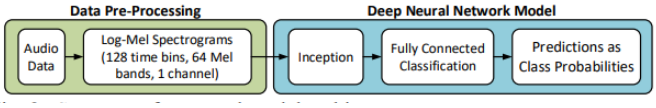

Fig.11. proposed model's architecture [11]

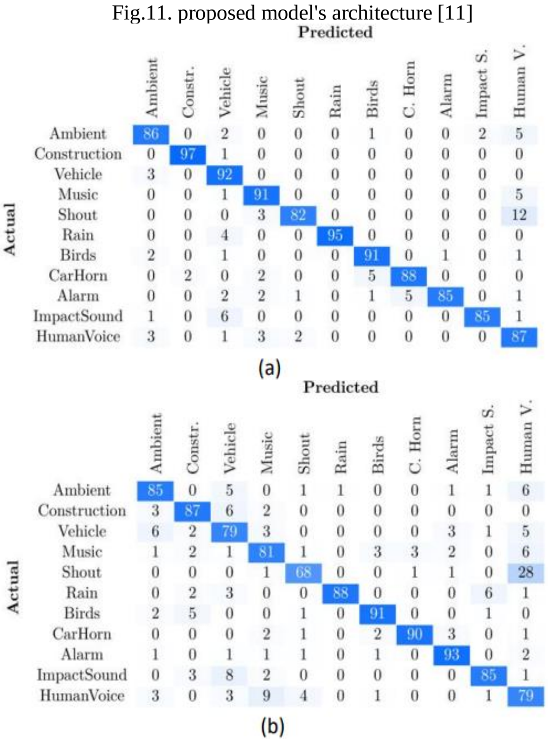

Fig.12.The trained model's confusion matrices on (a) validation set and (b) test set [11].

In [12], Cerutti et al. investigate the use of neural network distillation on IoT platforms for sound event detection. The authors propose a method for training a small and efficient neural network on a powerful server and then distilling the knowledge into a smaller network that can run on resource-constrained IoT devices. The results of the experiment indicate that high level of accuracy is achieved by distilled network while using fewer resources than the original network, making it suitable for use in IoT applications. However, the paper focused primarily on the use of neural network distillation, which may not be the most effective approach for all IoT applications.

Overall, these papers highlight the importance of sound detection and analysis in various IoT applications, such as noise pollution monitoring, urban planning, and home automation. They demonstrate the potential of using lightweight and efficient neural network architectures for sound event detection and classification, as well as the challenges associated with running these algorithms on resource-constrained IoT devices. While these papers provide useful insights and approaches to sound event detection in IoT applications, they may have limitations or drawbacks that need to be considered when evaluating their effectiveness for specific use cases.

C. Current methods for detecting debris dumping

Illegal dumping of garbage and waste is a persistent problem in many cities and poses a significant threat to public health, safety, and environmental sustainability. The paper [13] proposes a smart illegal dumping detection system that uses multiple sensors, such as cameras, microphones, and accelerometers, to detect and identify dumping activities in real-time. The system utilises machine learning algorithms to analyse sensor data and distinguish between legal and illegal dumping. The proposed system showed promising results when tested in the real world. Since the system relies on the use of expensive sensors, such as GPS and accelerometers, which may not be practical for all applications. Additionally, the system is limited to detecting illegal dumping activities that involve moving vehicles, and may not be effective in detecting dumping activities that occur on foot or with stationary vehicles. Finally, the system requires access to a cloud-based server for data processing and analysis, which may introduce latency or connectivity issues.

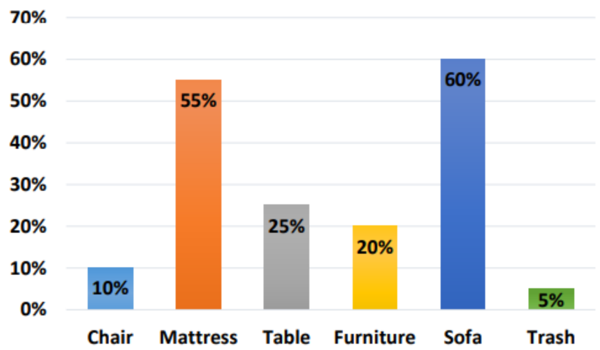

Fig.13. The accuracy achieved by the Naive Approach in [13]

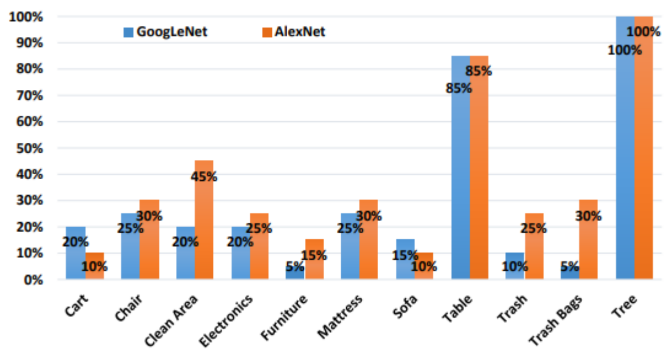

Fig.14. Accuracy attained by the 2nd Approach (increased the number of classes and input dataset size) in [13]

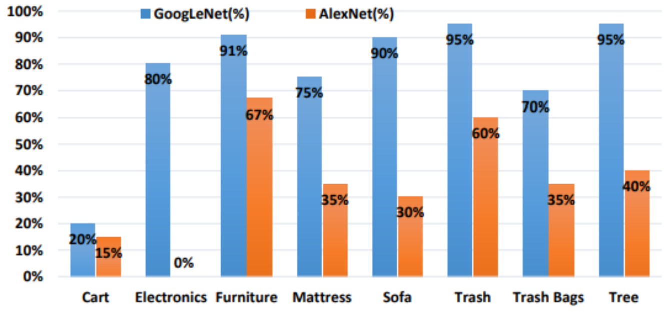

Fig.15. Accuracy attained by the 3rd Approach (increased number of iteration & input dataset sizes) in [13]

Another paper [14] presents a fast and simple method for detecting illegal garbage dumping using pedestrian attributes. The proposed method uses a pedestrian detection algorithm to identify people in the dumping area and extract their attributes, such as height, clothing colour, and bag size. These attributes are then used to identify potential dumpers and distinguish them from other pedestrians. The proposed method was tested using real-world video data and achieved high accuracy in detecting illegal dumping activities. The method relies on the presence of pedestrians in the area to detect illegal dumping, which may not always be feasible. Furthermore, the system may not be effective in low-light conditions or during night-time when visibility is reduced. The system does not take into account the context or location of the dumping activity, which could lead to false positives or false negatives.

The paper [15] proposes a video analytics-based system for identifying illegal garbage dumping activities. The system uses object detection algorithms to identify garbage bags and other objects in the dumping area and track their movement. The system also analyses the behaviour of people in the area, such as loitering or looking around, to identify potential dumpers. The proposed system was tested using real-world video data and achieved high accuracy in identifying illegal dumping activities. The method proposed in [15] for illegal garbage dumping detection relies on the use of high-quality video footage, which may not be available in all situations. Additionally, the system may not be effective in detecting illegal dumping activities that occur outside the field of view of the cameras. The system may not be effective in detecting dumping activities that occur at night or in low-light conditions.

Fig.16. Detection of vehicle [15]

Fig.17. The path taken by discarded waste as it is being thrown [15]

Finally, the paper [16] proposes an smart mobile service system which is edge based for monitoring & illegal dumping detection. The system uses mobile devices equipped with sensors, such as cameras and GPS, to capture data on illegal dumping activities in real-time. The data is then transmitted to a central server for analysis and monitoring. The proposed system showed promising results when tested in a real-world scenario and also in detecting and monitoring illegal dumping activities. The system proposed in [16] for monitoring and illegal dumping detection depends on the use of mobile devices equipped with sensors, which may not be feasible for all users. Additionally, the system is limited to detecting illegal dumping activities that occur within the range of the mobile device's sensors, which may not cover a large enough area. The system may not be effective in detecting illegal dumping activities that occur at night or in low-light conditions.

The above research studies present different approaches to detecting and monitoring illegal garbage dumping activities, including using sensors, machine learning algorithms, video analytics, and mobile devices. The proposed methods were tested in real-world scenarios and achieved high accuracy in detecting and identifying illegal dumping activities. These systems could potentially help cities in developing countries and urban areas in addressing the problem of illegal dumping, which is a major challenge to public health and environmental sustainability. Overall, while the methods proposed in these papers are promising, there is still room for improvement in terms of accuracy, scalability, and practicality. Future research could focus on addressing these challenges while also considering the ethical and privacy implications of using video surveillance for these purposes.

D. Edge computing studies

The surfacing of edge computing has enabled the processing of data near to the origin and has shown great potential for applications in various fields. The paper [1] presents a practical implementation of edge computing utilizing Raspberry Pi devices. The study evaluates the performance of the prototype and compares it with traditional cloud-based processing. The results show that edge computing using Raspberry Pi devices outperforms cloud-based processing in terms of latency and throughput. The study also highlights the potential of edge computing for real-time applications such as video processing and sensor data analytics. However, the study has a limited scope and does not provide a thorough evaluation of the prototype's performance under different conditions.

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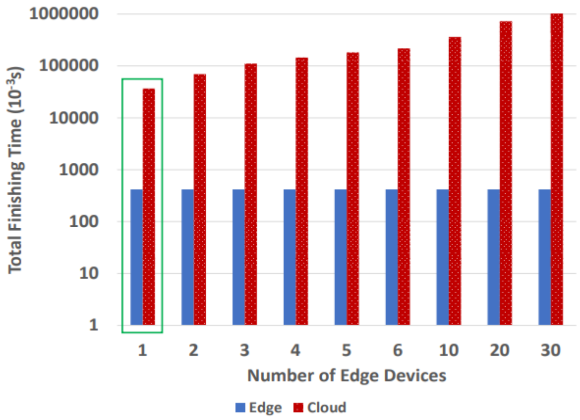

Fig.18. Estimated performance for small-size Input of Smith-Waterman [1].

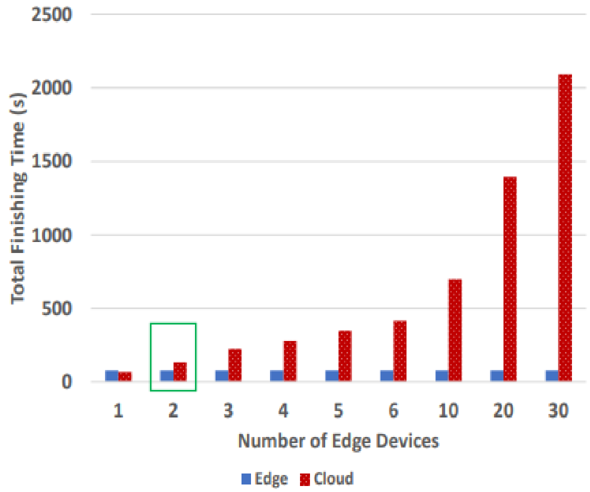

Fig.19. Estimated performance for medium-sized Input of Smith-Waterman [1].

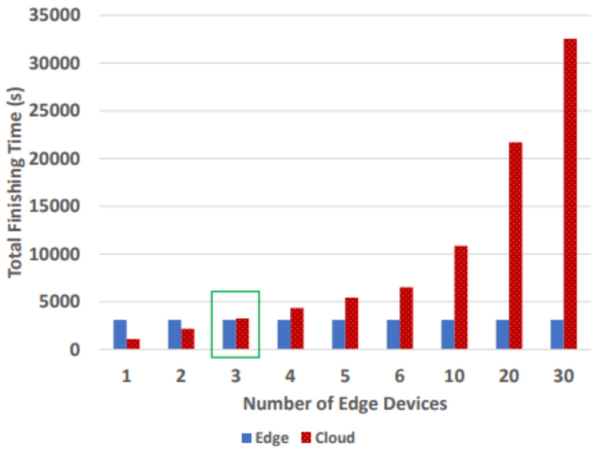

Fig.20. Estimated performance for Large-sized Input of Smith-Waterman [1].

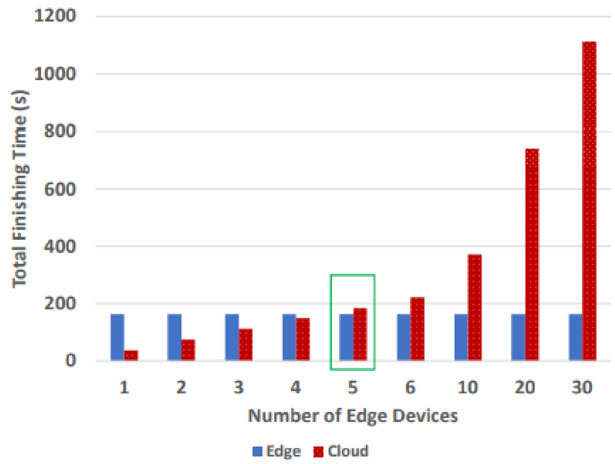

Fig.21.Estimated performance for Small-sized Input of Tesseract OCR [1].

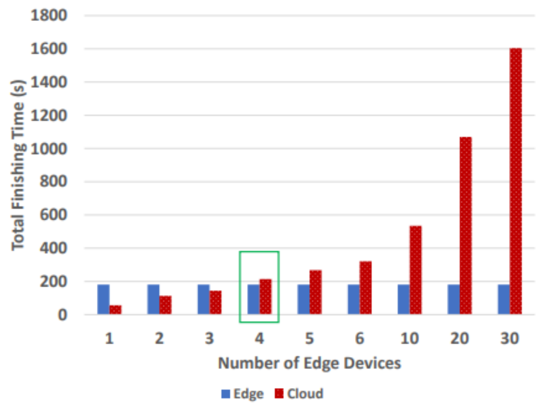

Fig.22. Estimated performance for Medium-sized Input of Tesseract OCR [1].

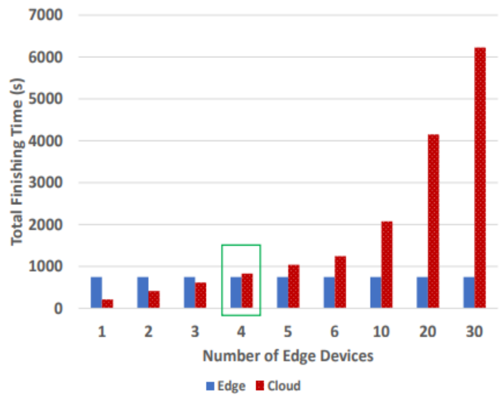

Fig.23. Estimated performance for Large-sized Input of Tesseract OCR [1].

Another paper provides a critical review of the existing literature on edge computing [2]. The paper identifies key research challenges in edge computing such as resource allocation, security, and energy efficiency. The study also presents various edge computing architectures and discusses their advantages and limitations. The authors conclude that edge computing has the ability to revolutionise the way data is processed, analysed and stored.While the review offers valuable insights, the authors acknowledge that the field is still in its beginning stages and more research is needed.

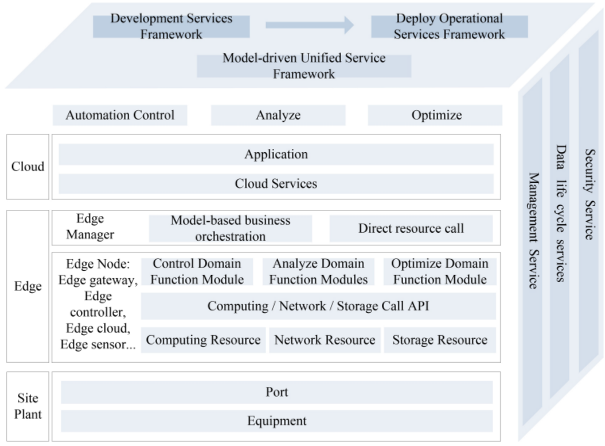

Fig. 24. reference architecture for edge computing In [2]

The paper, "Edge computing: A grounded theory study" [3] presents a grounded theory study on edge computing. The paper investigates the main characteristics and attributes of edge computing by analysing data from various sources such as academic papers, industry reports, and expert interviews. The study identifies five main categories of edge computing: computing infrastructure, edge devices, edge services, edge applications, and edge management. The authors also propose a conceptual framework for edge computing that highlights the relationships between the different categories. However, the study may be limited by the availability and quality of data, and it does not provide empirical evaluation of specific use cases.

The paper [4] presents a survey of edge computing in IoT devices. The study investigates the application of edge computing in Internet of Things devices and analyses the advantages and challenges associated with this approach. The authors state that edge computing has the future to overcome some of the limitations of cloud-based IoT systems, such as latency and network bandwidth issues. However, they also identify several challenges that need to be addressed, such as security and privacy concerns. However, the study has a limited scope and does not provide detailed empirical evaluation of specific use cases.

The above studies provide valuable insights into different aspects of edge computing, including its implementation, research challenges, characteristics, and use in IoT devices. The papers highlight the potential of edge computing for various applications and provide a roadmap for future research in this area. While the papers offer insights into edge computing, it is important to consider their potential limitations and the need for further research to fully understand the capabilities and limitations of edge computing. Future research should aim to provide empirical evaluation of edge computing in different contexts and to develop a more comprehensive understanding of its potential benefits and challenges.

III. OVERVIEW OF PERFORMANCE ANALYSIS

[A] Flood

Paper	Focus/Purpose	Methodology	Dataset	Algorithm	Accuracy
[5]	Flood alert and human detection	IoT and ML	IoT sensors, weather stations, and satellite imagery	Convolutional Neural Network (CNN), Random forest classifier	Achieved an accuracy of 97.5% in human detection and 90% in flood detection
[6]	Flood monitoring using remote sensing	Remote sensing monitoring	Sentinel-1A satellite imagery	Modified Water Extraction Index (M-WEI), Decision Tree (DT)	Identified flood-prone areas and provided accurate information on flood extent and depth with an accuracy of 97.3%
[7]	Flood forecasting and monitoring in urban environments	Deep learning	IoT sensors and weather stations	LSTM and Convolutional Neural Network (CNN)	Achieved high accuracy in flood forecasting and monitoring in an urban environment with an accuracy of 92.7%
[8]	Flood monitoring and rainfall prediction	IoT, ML, and neural networks	IoT sensors and weather stations	Support Vector Regression (SVR), Artificial Neural Network (ANN)	Achieved accurate flood alerting and rainfall prediction using machine learning and neural networks with an accuracy of 92.4%

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[7]	Flood forecasting and monitoring in urban environments	Deep learning	IoT sensors and weather stations	LSTM and Convolutional Neural Network (CNN)	Achieved high accuracy in flood forecasting and monitoring in an urban environment with an accuracy of 92.7%
[8]	Flood monitoring and rainfall prediction	IoT, ML, and neural networks	IoT sensors and weather stations	Support Vector Regression (SVR), Artificial Neural Network (ANN)	Achieved accurate flood alerting and rainfall prediction using machine learning and neural networks with an accuracy of 92.4%

[B] Sound

Paper	Purpose/Focus	Methodology	Dataset	Algorithm	Accuracy
[9]	Sound event detection on power-constrained IoT devices	Binary neural networks	TUT Rare Sound Events 2017, AudioSet	Binary Neural Networks (BNNs)	92.3%
[10]	Implementation and perspectives of a noise pollution measurement system	Mobile sensing platform	Self-created dataset	signal processing or machine learning	-
[11]	Extracting urban sound information for residential areas using IoT system	End-to-end IoT system	UrbanSound8k, Google AudioSet	Convolutional Neural Networks (CNNs)	95.6%
[12]	To develop a low-cost sound event detection system using an IoT platform.	a binary neural network for sound event detection, followed by a distillation process to reduce the size of the network.	Google AudioSet, UrbanSound8K, and ESC-50	Binary Neural Network and Distillation	-93.4% on UrbanSound8K.

[C] Debris dumping

Paper	Purpose/focus	Detection method	Data source	Algorithm	Accuracy
[13]	Smart illegal dumping detection	Image processing and machine learning	Images and videos from surveillance cameras	AlexNet and GoogLeNet,Caffe	85.3%
[14]	Garbage dumping detection using pedestrian attributes	Image-based	CCTV cameras	HOG feature extraction, SVM	92.8%
[15]	Identification of illegal garbage dumping with video analytics	Video-based	surveillance cameras	Haar Cascade Classifier, Kalman filter-based tracking algorithm	93%
[16]	Illegal dumping detection and monitoring using an edge-based smart mobile service system	Sensor-based	IoT sensors	ML	93.6%

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[D] Edge computing

Paper	Focus	Methodology	Key Findings
[1]	Implementation of edge computing prototype using Raspberry Pis	Implemented prototype, performance analysis, comparison with cloud computing	Proposed edge computing as a viable alternative to cloud computing, demonstrated feasibility with prototype
[2]	Review of edge computing research	Literature review, overview of key concepts, challenges, and applications	Provides comprehensive overview of edge computing research, identifies key challenges and applications
[3]	Qualitative study of edge computing	Grounded theory methodology, data analysis based on interviews with experts in industry and academia	Identifies key features and characteristics of edge computing, proposes a framework for understanding edge computing
[4]	Survey of edge computing in IoT devices	Literature review, survey methodology, analysis of survey data	Provides an overview of edge computing in IoT devices, identifies key challenges and opportunities, highlights the need for standardization and interoperability

IV. RECOMMENDATIONS

Each application requires different algorithms for data processing, classification, and prediction. Therefore, the best algorithm for each of these applications:

1. Flood monitoring and detection:

Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN) are particularly suitable for flood monitoring and detection. CNNs can process remote sensing data or drone images to detect changes in the terrain and identify flooded regions, while RNNs can be used for time-series analysis of data collected from IoT sensors to predict floods based on rainfall patterns, water levels, and other environmental factors.
For this project, both CNN and RNN can be used in combination to create a comprehensive flood monitoring and detection system. CNN can be used to detect changes in the terrain and identify flooded regions, while RNN can be used to predict floods based on environmental factors such as rainfall patterns, water levels, and soil moisture.

2. Sound detection and analysis:

For sound detection and analysis, Convolutional Neural Networks (CNNs) and Recurrent Neural Networks (RNNs) are the most suitable algorithms. CNNs can be used for sound event detection by processing short-time Fourier transforms (STFTs) of audio signals, while RNNs can process the temporal dynamics of audio signals to detect sound events.
In this project, CNNs can be used for sound event detection and RNNs can be used to classify the sound events. For example, RNNs can be used to detect if an object is being carried and then dropped in an unauthorized location, indicating illegal dumping activity.

3. Illegal dumping detection:

For illegal dumping detection, Object detection algorithms, such as YOLO, Faster R-CNN, and SSD, are particularly useful to identify specific objects, such as garbage bags, in images or video frames. Recurrent Neural Networks (RNNs) can be used to analyze the temporal behavior of detected objects and classify them as illegal dumping activities.
For this project, Object detection algorithms such as YOLO can be used to identify specific objects in images or video frames, while RNNs can be used to analyze the temporal behavior of detected objects and classify them as illegal dumping activities.
In summary, for flood monitoring and detection, a combination of Convolutional Neural Networks (CNN) and Recurrent Neural Networks (RNN) can be used. For sound detection and analysis, CNNs can be used for sound event detection, and RNNs can be used to classify the sound events. For illegal dumping detection, Object detection algorithms such as YOLO can be used to identify specific objects in images or video frames, while Recurrent Neural Networks (RNNs) can be used to analyze the temporal behavior of detected objects and classify them as illegal dumping activities.

4. An integrated system:

Creating a citizen alert system using edge learning and IoT, there are several key components that must be integrated and incorporated. First, there must be a network of sensors and devices that can collect data about various environmental factors, such as temperature, air quality, and humidity. This data can then be transmitted to a central hub, where it can be analyzed and processed in real-time using edge learning algorithms.
The edge learning algorithms can use various machine learning techniques to detect patterns and anomalies in the data, such as sudden spikes or drops in temperature or air quality. These anomalies can then trigger alerts that are sent to citizens in the affected areas via their smartphones or other mobile devices. The alerts can provide information about the nature of the anomaly, as well as any actions that citizens should take to protect their health and safety.
To ensure that the alerts are accurate and reliable, the edge learning system must be constantly updated and optimized based on feedback from citizens and other stakeholders. This requires ongoing data collection and analysis, as well as

collaboration between experts in environmental science, machine learning, and IoT.
In addition, the system must be designed with privacy and security in mind, to ensure that citizens' personal data is protected and that the system cannot be hacked or otherwise compromised. This requires careful attention to data storage and encryption, as well as robust security protocols that can detect and prevent unauthorized access. With careful planning and collaboration, the system has the potential to significantly improve public health and safety in communities around the world.

V. ANALYSIS AND DISCUSSION

Research on various aspects of IoT and edge computing has led to the identification of potential improvements in flood monitoring and detection systems, sound detection and analysis in IoT applications, and illegal dumping detection and monitoring. Flood monitoring and detection systems have significant potential for improvement and exploration in the future. One potential area of exploration is the integration of multiple technologies, such as IoT, remote sensing, machine learning, and neural networks, to create a comprehensive flood monitoring and detection system. Real-time data processing is crucial to provide timely alerts to users about flood situations and take necessary action to avert the loss of life & property. The incorporation of social media platforms can be explored to enable crowdsourcing of data related to flooding, which can help improve the accuracy of flood monitoring and detection systems. The use of drones equipped with cameras and sensors can provide a more detailed and real-time view of flood-prone areas, further improving the accuracy and effectiveness of flood monitoring and detection systems. In addition, community participation can be incorporated into flood monitoring and detection systems to raise awareness and improve community preparedness and resilience to floods.

In IoT applications, there is a need for a better system for sound detection and analysis, which can be achieved by leveraging deep learning and neural networks to develop more accurate and efficient models for sound event detection and classification. Additionally, the use of more sophisticated sensors and data fusion techniques can improve the accuracy and robustness of sound detection and analysis in real-world environments. Developing more efficient and scalable systems that can handle large volumes of sound data in real-time requires addressing the computational and memory limitations of IoT devices, as well as developing efficient algorithms for data processing, compression, and transmission.

Illegal dumping detection and monitoring require further refinement and testing to determine their effectiveness. The integration of multiple sensing modalities, such as video, audio, and environmental sensors, can improve the accuracy and efficiency of illegal dumping detection. Moreover, integrating the system with a mobile application that enables citizens to report illegal dumping activities in real-time can leverage community engagement and awareness to discourage illegal dumping activities. Advanced techniques such as computer vision, machine learning, and deep learning can improve the accuracy and speed of detecting and classifying illegal dumping activities. Finally, the proposed system should include an automated response system that alerts the appropriate authorities to respond to detected illegal dumping activities promptly.

Edge computing has ongoing research that seeks to address the limitations of existing systems, including scalability, security, and interoperability. Potential directions for future research in edge computing include the development of new hardware and software architectures that enable more efficient and scalable edge computing systems. Additionally, the integration of machine learning and artificial intelligence techniques can enable more intelligent decision-making at the edge. The development of new security and privacy mechanisms can enable secure and private computation in distributed edge computing systems. Further, new edge-to-cloud and edge-to-edge communication protocols and standards can enable interoperability across heterogeneous edge computing systems. Finally, the investigation of new business models and value propositions for edge computing, including new service offerings and revenue models, can help unlock the full potential of edge computing.

VI. CONCLUSION

The development of smart systems for various applications using IoT and edge computing technologies is a rapidly growing field with enormous potential. The integration of multiple sensing modalities, advanced data processing techniques, and community engagement can significantly improve the accuracy, speed, and effectiveness of systems such as flood monitoring and detection, sound detection and analysis, and illegal dumping detection and monitoring. Ongoing research in edge computing seeks to address the scalability, security, and interoperability limitations of existing systems, and pave the way for new applications and services. As technology continues to advance, there is an exciting opportunity to leverage the power of IoT and edge computing to create more intelligent, efficient, and sustainable systems that can benefit society in numerous ways.

VII. REFERENCES

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