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Natural language based smart garbage management system using Artificial Intelligence

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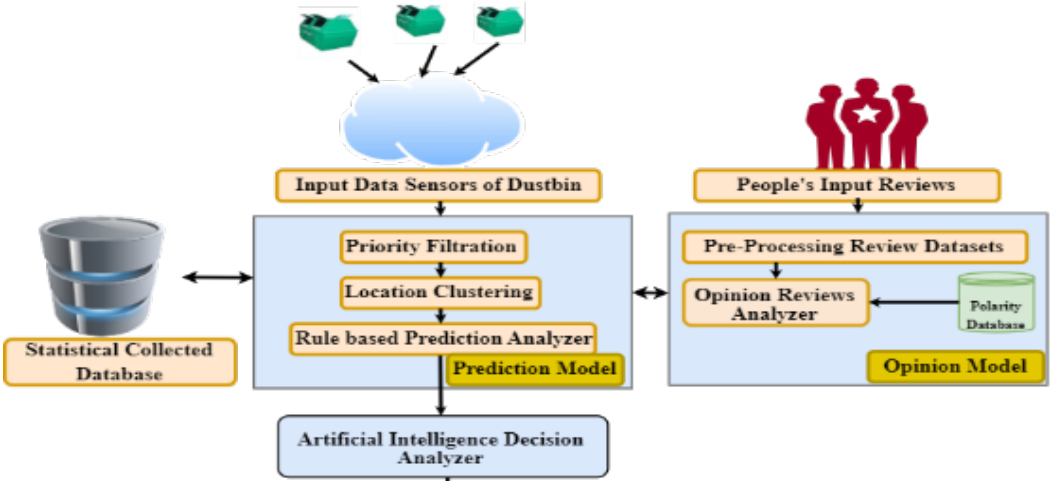
Article

ABSTRACT



The tremendous growth in population around the globe has leads to the society in an unclean and unhygienic environment. This problem then converts to various diseases and other symptoms that affects the human kind in all phases of work. The traditional and conventional approaches used for waste management are not quite enough to manage the generated waste. The traditional system also lags the people's feedback that provide valuable suggestions in terms of complaints etc. that are necessary parameters for the system upgradation. The use of opinion analysis for upgradation of the existing system has been found very effective in the service oriented sector as it deals with the real time problems of the user. This paper introduces a novel management methodology that combines the Internet of Things (IOT) domain along with the opinion analysis module for predicting and summarizing the user opinions for effective decision making. The evaluation of the system depicted an overall improvement in the waste management.

Keywords: Opinion Analysis, IoT, Waste management, artificial intelligence, machine learning.

INTRODUCTION

Urbanization and technological advancement in world has provided the people with advance functionality and King-Size life for each and every section of the people of society at affordable rates. The advancement and technological growth has given the world with many useful things that are handy to use,[1] easy to carry and solve all the basic problems of the society and livelihood. As it is rightly said that. A coin has two face one good and one bad, likewise development in technological growth has raised the problems of waste, which are generated in large quantity from the things that are used.

Waste collection, management and degradation have become major problems in every country of the world.[2–5] The advance methods are used for the efficient waste management but they are not enough for it as the waste degradation systems are very less as compared to unwanted generation. The gathering of waste garbage is a major problem due to tremendous increase in the population in the last few decades.[6] The waste garbage if not collected properly from the area and is left in the open surrounding then it leads to various health problems and epidemic's diseases. The municipal

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corporations in India which are situated in very city are responsible for waste garbage management.[7]

The conventional techniques are used for garbage collection from the area, as they keep the dump of garbage bin at every corner of the city. Mostly the dump of garbage bin are not cleared at proper time, due to poor management,[8] early fill of the bin during festival session, public holiday and weekends as most of the people clear their house garbage in this free time that leads to collection of more waste garbage in the dump bin as compared to normal collection and the overflow of the dump leads to scattering of waste around the dumps, results in creating the unhealthy environment for the society.[1,9–13] the process lacks user opinions towards the system as it provides a valuable suggestion towards the improvement of the system. The opinion,[5] module deals with extraction of meaningful summary from the unstructured opinion given by the user and also defining the granularity of the stated problems.

The main contribution of this paper

- Optimising resources based on real-time sensor values and data from the Stastical databases requires an approach that integrates IoT devices with rule-based prediction models.
- Designing an opinion analysis model for resolving the people's problem with the system by taking the quick and evidence based real time decision upon the result generated from the model.
- The suggested methodology has been the subject of analytical results to attain accuracy and efficiency in comparison to alternative approaches.

Many researchers have proposed various collection methods that were considerably aim to solve the problem of waste garbage collection but they were not enough sufficient to achieve the overall efficiency.

LITERATURE REVIEW

The development of technology has created the various ways for the efficient waste management by employing many out of the box ideas proposed and developed by many researchers from academia and company.[1] The IOT (Internet of things) has provided the automation system and reduces manual efforts for waste management. The combination of IOT with computing facility has provided a boost for the advancement.

Ishaq, et al.(2023),[6] aims to investigate the potential of Internet of Things (IoT) technology in enhancing the management of biomedical waste in healthcare facilities, with a specific concentration on the Kaduna region of Nigeria. A system for intelligent refuse bin monitoring utilising IoT sensors and actuators is proposed by the author. Sensors attached to waste bins track fill levels, waste types, and environmental conditions. This data is transmitted wirelessly and analyzed in the cloud to optimize waste collection and disposal. The research suggests further research on integrating AI and machine learning for waste classification and optimizing collection routes. The effectiveness of the system on a larger scale and different regions needs further investigation.

Xiangru Chen(2022),[14] has proposed an AMLWRF system that integrates IoT devices with a machine learning framework to automate waste collection in smart cities. This system aims to enhance the efficacy of both the current and proposed methods. The author divided the system in three different steps for carrying out the system implementation. The various ML algorithm like DTs, ML-CNN,[9] and YOLOV3,[10] were compared in order to test the efficiency of the proposed work.

Attrah et al.(2022),[15] delves into a comprehensive review of medical waste management. Medical waste poses unique challenges due to its hazardous nature, and the paper likely covers various aspects of its treatment, recycling, and disposal options. The author faces various challenges in medical waste management this could include advancements in technology, and modern AI approaches for efficient waste management.

Gondal et al.(2021),[1] Presented a Multilayer neural network using convolution as a solution for the challenges faced in the management of smart cities. The traditional management methods have been shown to be ineffective as they were unable to achieve the required level of precision and effectiveness in dealing with the increasing population, leading to a chaotic situation. Implementation of an automated waste categorization and administration strategy is necessary to address such situations.

Kumar et al.(2020),[10] suggested and showed the YOLOv3 method for sorting trash into two groups: biodegradable and non-biodegradable. The suggested method cuts down on the time needed for detection and has a high chance of predicting correctly, which helps make the best use of resources.

Kellow Pardini and et al.(2019),[12] in their research findings "IoT-Based Solid Waste Management Solutions: A Survey" examine the issue of garbage management in rapidly expanding urban areas. The author emphasises the need of employing an Internet of Things (IoT) to investigate diverse characteristics and facets of intelligent waste management systems. The author demonstrates the utility of IOT management in addressing waste management issues by enabling the tracking of waste container locations, monitoring garbage levels, identifying areas with high demand, and suggesting the most efficient collection routes for solid waste optimisation.

Mdukaza and et al.(2018),[13] in their research presented a state of art IOT enabled solutions for smart cities waste management. The author objectives towards these findings were to enhanced and improve the system for it. The author demonstrated the comparison of various research findings and identified the pros and cons of the methods and illustrated the need of further enhancement in the system.

Dung D. Vu and Georges Kaddoum(2017),[16] In their research on waste management, they proposed a dynamic and efficient approach to waste collection. This approach involves predicting the location of waste, identifying the placement of trash bins, calculating the quantity of waste, and determining the shortest path for delivery. The proposed method underwent evaluation on several parameters, with particular emphasis on optimising resource utilisation and efficiency.

Jose M. Gutierrez and et al.(2015),[17] proposed an smart waste collection and controlling method based on location for reading, collecting and transmitting the live status,[17] of the garbage bin over the internet to the management system. The research work proposed the use of graph theory algorithms for the prediction of shortest route for the collection of waste. The proposed system was evaluated in real time scenarios,[18] for the efficiency prediction and future enhancement.

The above literature review explained the many methods that are developed and implemented by many researchers by considering different technological growth and combination. The survey helps to understand that researchers has focused on collection of data via sensors,[10,18,21] and using internet of things for transformation of data. The Artificial Intelligence and Opining mining, of reviews from users experienced was not explored for the waste management problems, the use of this methods along with IOT can prove an efficient overcome above the listed methods and helps in increasing the complete effectiveness of the system

ARCHITECTURAL FRAMEWORK IMPLEMENTATION

Waste management has become an important constraint, as the cities around the globe is getting crowded day by day. The exponential growth of trash coupled with insufficient resources for waste management has resulted in the world's most pressing and intricate environmental challenges. It is imperative to augment the system by integrating the different AI modules, which will enable the system to independently process and increase the outcomes of the current system.

The designed waste management system architectural framework shown in figure 1 depicts the granularity of the designed module. The different module is combined together in order to enhance the system capability. The system composed of IOT Module,[3,17] Prediction Module, Opinion Module, Artificial Analyzer and stastical database module for processing the input and generation of summarized result.

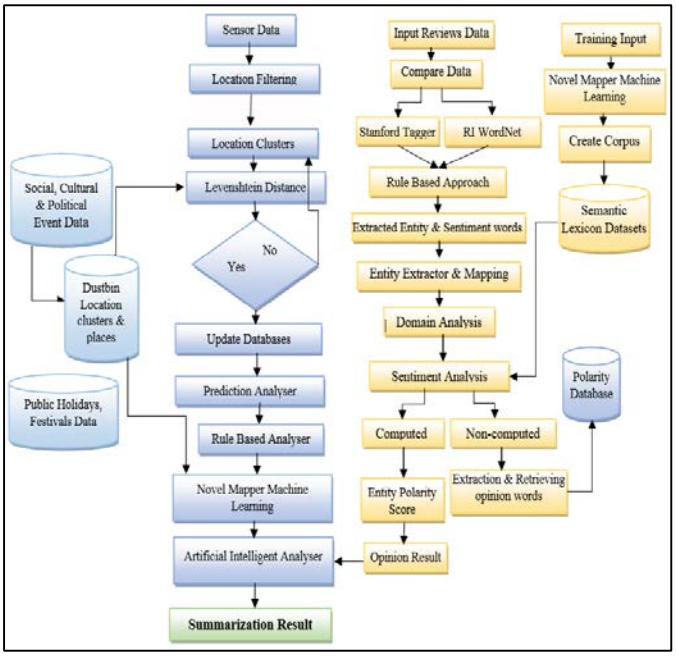

Figure 1. Designed system Architectural Framework

Input Sensor Data Module

The garbage bins are incorporated with IOT based sensors that facilitate with the real time information of waste collected in the bin. This real time information helps in decision making process for the smart and effective way of waste garbage collection. The real time data generated by the sensors are filtered based upon the priority of filling and other aspects. The threshold value for the garbage bins are set from the information received from the prediction model. The IR & Ultrasonic sensor are positioned in the bin, Number of sensor used depends upon the size of dustbin. The multiple sensor is used in the dustbin to predict the actual fulfilment.

Consider the figure 2 a) the size & surface area of the dustbin is small and within the range of one IR sensor to easily detect the fulfilment now in fig b) & fig c) the size & surface area of the dustbin is larger and multiple opening are provided so in order to detect the actual capacity multiple sensor are placed and depending upon the threshold value bin capacity is determined. The Sensor block collects the sensor data with the help of cloud server the data is received and filtered upon the location. The Location filter fragment the complete area upon the clusters and Stastical data. The processed data is forwarded to predication model.

Figure 2. Different shapes and size of Bins

Statistical Database Module

The statistical database is a backbone of complete process as the complete decision are made upon this data in the system. The invention focuses on the geographical location considering the Indian society were large no of diversity is observed depending upon social cultural and political ground.

The garbage waste management is a major problem as the population spike is more and literacy rate in less in India as compared to other developing countries and multiple times the waste are generated in any social cultural and political programme. The Stastical database is a combination of three types of data.

Social Cultural and Political activities carrying out in particular location

The information related to this data is collected from the collector office and Municipal Cooperation where permission is provided for such activities. The multiple gathering of the people at one location for the concern activity will generate a lot of waste. The frequency of garbage bin filling will also be more as less time will be required to fill it up. This information collaborated with waste management system will guide them to update the no of frequency for garbage collection and also to increase the number of garbage bin at a particular location for temporary use.

Festival, Public holidays and population count in particular location

The data related to this database will be collected from the collector election office. The count of population will give an insight about the count of bin that need to place at a particular cluster location, and this will also help to predict the festival celebration and public holidays were people cleaned their house

from scratch generating the multiple amount of waste as compared to the normal days and the bin get flooded easily within unexpected normal time and this leads to over thrashing of waste in public places. The information gathered will be helpful for the system to predict the festival time and IOT sensor in bin will help to predict the number of frequency that need to be carried out more from the normal days.

Number and location of Dustbin placed in particular clusters at public procession area, community hall, auditorium, marriage hall and public garbage dumping location etc.

This database will contain the information about the existing bin placed data in the particular location also information about the places were events can take place so placing the bin at that location will be helpful for the people to place garbage properly in the bin.

Prediction Model for analysing Statistical Data

The inputted data from the sensor is filtered based on the particular location is clustered according to the region. The distance between the bin in the clusters are compared continuously with the provided site by the system with the help of the Levenshtein distance, based on the calculated real time value the place of the bin are updated in the database if any change occurred in placing the bin due to site issue, construction work etc. The prediction analyzer takes the updated bin location data and Stastical data of the particular location and analysis the amount of tariff and priority and set the particular rule based preferences for the updating of the collection frequency that need to be carried out.

Example: Consider a situation where more than one bin is placed in a particular clusters say B1, B2, B3 and all are providing the threshold value for collection.

The collection vehicle can collect one bin at a time and require some N times to transport the existing bin to dumping location and come back again to second location B2 for collection. In the meantime, N the B2 bin is over flooded with garbage as the threshold value reaches the maximum level in very less time that was anticipated due to some social event occurring at that point and garbage collection was more than the specified level.

Whereas at location B1 bin no such activity was present.

In order to cope up with this type of problem where multiple bin is not to be compared. The designed algorithm will work and can provide a better insight for the same. The algorithm will take the bin location threshold value and Stastical data for the location in step 1. The step 2 & 3 will be used for comparison of the bin data with the statistical data of location to predict the event occurring at particular site. The bin location near the event will be matched and priority for that will be set to high among all the three bin and preference will be given first for the collection. In this way the collection frequency will be calculated on the filling time and this will be updated in the system in step 4 & 5.

The algorithm developed for the same is present below:

Step 1: I/P Data ☐ Sensor Data from IOT of particular location
Database ☐ Stastical data for the particular location

Step 2: Comparing the location bin data with the Stastical data

Step 3: Take the bin location and map it with the event and activities

Step 4: For Bin 1 to N present:

Match with Database:

If (Match Found):

Set as priority and updated the bin frequency

Else:

Normal frequency for collection

Continue for all the bin from the particular location available

Step 5: Compare bin threshold value and data the one with maximum priority is given the first preference for collection and same is updated.

Opinion Sentiment Analysis Module

The Real time structured and unstructured opinion or feedback collected is further analysed for pre-processing, for extracting the keywords and applying the rule based approach for the entity and feature word .The extracted entity and opinion words are categorized based upon different level, entity extractor is used for extracting only those which matches the system semantic lexicon, which consist of list of all entity that are related to the system and domain cluster area for the particular entity is predicted. The entity those who are related to system and are not updated are considered in training data and novel mapper algorithm are used to predict the matching of it with the specified entity and if matches corpus is created for particular entity and same is updated in semantic lexicon database.

The sentiment analysis model takes the domain analysis data from and compute the polarity for the entity that are expressed with the compute polarity with the help of knowledge dictionary and if matches they are updated in the polarity database in for improving more efficiency by reconsidering the polarity. The Entity polarity score is calculated and if the entity performance is below threshold value then it is considered for updation based on the parameters and the detailed result is placed in opinion result of the system for further decision making process.

The objective of the current work is to create an opinion module that operates effectively across multiple domains.

The following describes the process and methodology for the opinion analysis module:

1. It involves retrieving the classified words from the pre-processing module, including adjectives, verbs, and adverbs.
2. Establishing the Rule-based Approach for conjunction execution, polarity modification of verb and adverb phrases, non-negative term usage, and so forth.
3. Developing the Polarity databases for positive, negative, and impartial words across all domains is the third step.
4. In the fourth step, the non-computed polarity words are matched with the word net dictionary or an online query to retrieve and extract opinion words. The fundamental polarity of these words is then determined and appended to the polarity databases.
5. Determining the Polarity Index of the computed terms and extracting user-provided suggestions constitutes the fifth step.

In this way, the Module computes the polarity score of every feature by updating its database at real time for efficient analysis of every feedback.

The invention helps in real time updation of the feature semantic lexicon Datasets of the particular domain and polarity database of the sentiment words.

All the feedback that is relevant to the domain is processed successfully for carrying out proper decision making.

The operations specified within the block diagram, flowcharts or examples can be implemented by a combination of hardware software and thereof, including software running on a single system or on a server in the form of website or mobile applications.

Artificial Intelligent Analyser Module

The prediction rule framed and opinion suggestion data are further taken as an input. The AI Analyzer uses the Novel Mapper Machine learning algorithm to predict the roadmap for the placement of the number of bin in particular location prior and helps in efficient management of the system

The algorithm uses the supervised nave bases machine learning algorithm to match the particular location clusters with the Stastical data. The information available in the block 106 helps us to identify the key location where maximum garbage can be collected for the specified time so prior arrangement of increase in bin, extra collection unit and all additional action can be forth taken.

Example: Consider a Social gathering taking placed at R1 Location of particular clusters, the accumulation of garbage taking place is more than the normal value and this leads to over flooding of bin as the assumed statistics fails due to the occurrence of the event. The real time event happening at places for which prior information is not provided also deals with similar problem.

The opinion analysis carried out in block 108 specifies the people's suggestions and complaints about the particular part or entity in the system with which they are facing major issues as well as the suggestions or requirement that is placed should also be addressed earlier before they convert into a problem all this things are monitored and given to the AI Analyzer for efficient decision making process and at the same time action should be taken to update it.

The specified algorithm takes the sensor placed data and Stastical database in step 1. The location corpus are designed from the location data in step 2. The Novel Machine Learning Mapper in step 3 maps the location clusters of bin with the event Stastical data and based upon the training data calculates the additional resources required and updated the status to the system earlier for possible management. The same analysis is done for all the location clusters prior and hence the efficiency can be gradually increased. The Step 6 consider the opinion result calculated in block 108 and based upon it decision making process is carried out and same is updated in the system in step 7.

The algorithm for the same is as follows:

Step1: Initialize:
Data Sensor Data, Opinion data
Database Statistical Database
Step 2: Apply Novel Mapper,
Create Location corpus;
Step 3: Compare Calculated location corpuses with Stastical database corpuses using supervised machine learning algorithm.
Step 4: If Event is detected
Location corpus is updated with additional resources,
Update location bin and frequency,
Else:
Continue;
Step 5: Continue for all the location clusters.
Step 6: Apply Decision making process on opinion data
If positive decision is made
Entity or part of the system is updated
Else:
Consider for further decision making process.
Step 7: System is updated with the additional resources in particular location.

RESULTS AND DISCUSSION

The suggested architecture is incorporated with machine learning and opinion analysis in order to predict the real time bin level and as well as summarizing the public opinion and upgrading the system based on the inputs are the key role that need to carried out. This model was tested by monitoring and interpreting the length of time the bin was appropriately filled without being overwhelmed. This information is saved and analysed in an IOT modules for predictions and summary. Data calculations can range from simple predictions to more complex differential formulas, depending on the level of precision required. The accuracy estimate has been identified by the comparison of the various existing method on the designed one. The result and analysis show the comparison results between the implemented system and that of the existing system. The designed system uses the AI approach and the existing system uses the normal conventional techniques.[16,19]

The evalaution is carried out on the two part one for the opinion analysis model for correctly predicting the public reviews and categorzing and summarizing it as per the system entites, The result of the opinion model will be critical in enhancing the system.

Datasets

The Datasets is collected by the conventional method and one to one interaction as it is observed that the people opininon was a combination of multiple entitites. The size of the datasets collected includes 25000 opinions of the people residing in the particular area. The Digital campagin was enumerated for collecting the opinions.

The Precison and Recall are the evaluation metrices that are most commonly used in the evalaution of the NLP model for assessing the effectiveness of the designed part. The datasets is divded in the P1- P5 in an increamental order for assessing the correctness as from the literature review it is analyzed that as the size of the data goes on increasing the effectivenss and accuracy of the system retards.

Table 1: Precision Calculation on Varied Datasets

Datasets	Data Scale Size	Naïve Bayes	LSTM	Designed Model
P1	4000	79.23	81.21	85.11
P2	8000	80.43	82.32	84.14
P3	16000	80.73	82.43	84.22
P4	20000	80.83	82.74	83.92
P5	25000	80.84	82.80	83.71

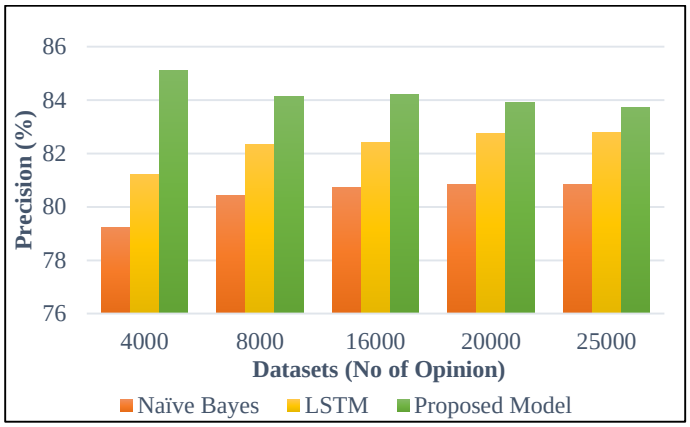

Figure 2. Precision Score Graphical Representation

The Table 1 and Figure 2, provides an interactive understanding that the precision, i.e correct identification of the entity from the opinion and their summarization of socre meets an effective accuracy. The size of the data ranging from 4000 to 25000 in an increamental order has moved the accuracy paramters to a liitle extent but overall accuracy of precision is considerably effective. The opinion module results represented in the part give an clear indetifaction for its use with the other model for overall improvement in the designed model.

The parameters for evaluation of results are as follows:

Accuracy: The designed methodology's accuracy is measured by how accurately the dustbin is filled and emptied.

$$Accuracy\ Percentage\ = \frac{DB}{EM} * 100 \qquad (1)$$

Where DB denotes the number of correctly completed dustbin emptied, EM represents the total number of time dustbin filled.

The dustbin is arranged according to the location clusters from A- E, the location are decided as per the population count in the particular area in an incremental order and also away from the dumping zone, the number of dustbins are determined as per the number of people in the area mapped and garbage generated per Day/kg for the particular bins. The manual simulation is carried out by incorporating a 1 month survey analysis for monitoring the bins emptied properly.

Table 2: Accuracy Calculation on Varied Datasets

Location	Number of Dustbin	No of times the dustbin filled/day	No of time the Dustbin emptied properly		Percentage Accuracy	
			Existing System	Designed AI System	Existing System	Designed AI System
A	12	52	41	47	79%	90%
B	14	67	49	59	73%	88%
C	18	72	56	61	78%	85%
D	20	121	79	98	65%	81%
E	25	143	103	126	72%	88%

The conventional mechanism/ existing methodology for collecting garbage bins is employed along with AI based Natural language processing model for designed system to estimate the efficiency of the system.[20]

The average accuracy is carried out in getting the system known the dustbin filled and time calculation from source to destination. The accuracy parameters is an important part of system evaluation that justified the use and effectiveness of the designed model. The precision and recall parameters of the opinion analysis model have significantly contributed to the enhancement of the component. The values are given in Table 2.

The table below shows the accuracy comparison between the designed and implemented system employed in the particular area.

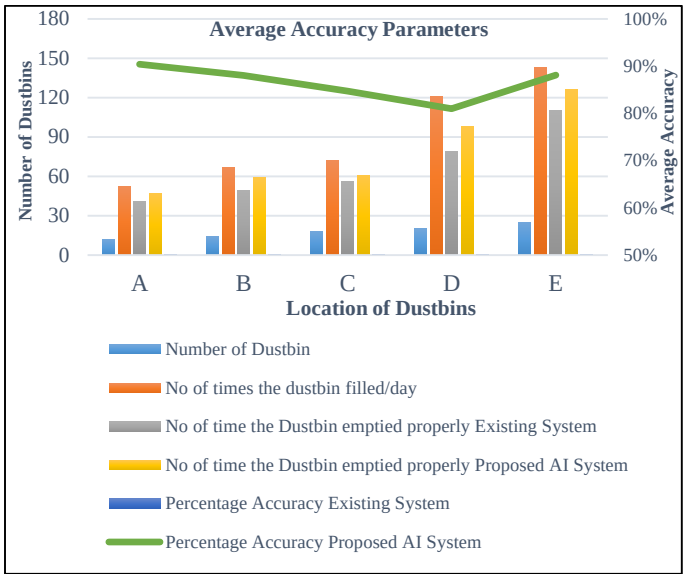

Figure 3. Average Accuracy Graphical Representation

The average delay is determined by the overall time taken by the method to compute the job completed within the shortest possible period.

$$Average\ Delay\ = (TT - PT) \qquad (2)$$

TT represents the total duration required by the system to do the task and PT represent the designed time that the system should complete the work, in a real time situation there can be many reasons for the system to encounter a delay with respect to the time designed. The Traffic on the area, delay in decision making all hampers the efficiency of the system. The delay parameters was addressed quite in the system.

Table 3: Average Delay Calculation on Varied Datasets

Location	Number of Dustbin	No of times the dustbin filled/day	No of time the Dustbin emptied properly		Average Delay(min)	
			Existing System	Designed AI System	Existing System	Designed AI System
A	12	52	41	47	22 min	15 min
B	14	67	49	59	28 min	25 min
C	18	72	56	61	40 min	35 min
D	20	121	79	98	52 min	45 min
E	25	143	103	126	57 min	46 min

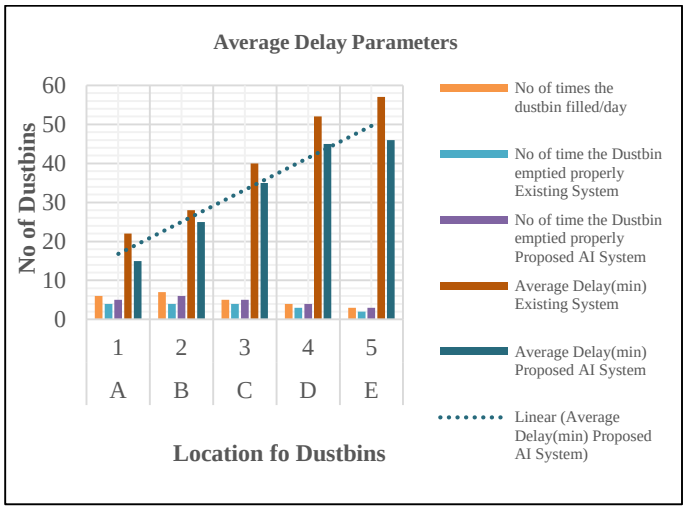

Figure 4. Average Delay Graphical Representation

CONCLUSION

Managing waste in smart cities has demonstrated to be a difficult issue for the establishments, especially considering the limited resources that are available today. The advancement of technology components has made it possible to give an effective mechanism that offers an extra improvement on the standard ways that are already in use. The public evaluations that were utilized for the purpose of improving the system have shown to be an extra advantage that has resulted in the enhancement of particular parameters of the system, resulting in a reduction in the amount of latency experienced in the process of updating. The suggested methodology in prediction, opinion, and artificial intelligence analyst modules has been brought together for the purpose of evaluating the bin that has been placed in a variety of geographical areas. The Result and Discussion section enumerate the extensive evidence of the improvement from the existing to conventional approaches. The Artificial Intelligence module is a self-learning based module that improves the overall efficiency as the module is trained with the varied and different size data ranging from one entity to another. As part of the ongoing development, the IOT sensors, opinion module will be further improved in terms of their efficiency in a variety of climates, and the system will be strengthened to accommodate a variety of working situations.

CONFLICT OF INTEREST STATEMENT

The author declared no conflict of interest for the publication of this work.

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