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Household Waste Management System Using IoT and Machine Learning

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Abstract

IOT and machine learning based household waste management system for Green smart society are aimed to make management of waste from the every apartment of the society more efficient using the most upcoming technology IOT. This paper discusses the collection and decomposition of waste in the smart way so that benefit from the waste is maximized and the actual waste is minimized efficiently. This paper focus on the segregation of the waste at two levels: the first level of segregation is on the individual house of the society and the second level of segregation is at the society. Author, discuss the recycling of the biodegradable waste for making compost. The machine learning technique such as KNN is used to generate an alert message for various combinations of three sensor values like level of bio and non biodegradable waste,concentration of poisonous gas. The overall impact of this research is in the upliftment of the green technologies by reducing pollutants, conserving, resourcing and reusing the energy through the use of technology.

Keywords: IoT, smart city; waste management; biodegradable; sensor; machine learning

1. Introduction

The Internet of Things (IoT) and machine learning is a technological development where each device is assigned a unique identity (IP address) and is fortified with the capability to automatically allocate data over the network without human-human or human-computer interaction. Therefore, any entity in the physical world which could referred with an IP address to empower data transmission over a network, can be the part of the IoT system by establishing them with electronic hardware such as sensors, software and networking equipment.IoT provides advanced connectivity of diverse type of equipment, various services, numerous protocols and different application; moreover, IoT is characterized with the vision of heterogeneity [1]. IoT is not only proven effective in home automation, smart city, but also admiring in social issues [2].

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The notion of smart city is now-a-days very important topic in terms of improving living conditions. Government of India has taken initiative to set up 100 smart cities. A smart city is equipped with innovative technology enriching with a sensor network, cameras, wireless devices, fast network like 5G, IT infrastructure and data centers to proficiently offer necessary services like electricity, water supply, sanitation, recycling, transportation, etc. and certify their effective management. Waste management is a vital part of city management—particularly where it has become significant to rethink cities for environmental sustainability. One cannot imagine a smart city without a smart waste management system. A city consists of market, offices, institutions and various small or large scale homes and societies. The major sources of waste are collected from households. The organic or inorganic waste materials produced out of commercial or household activities [3]. Dustbin is the only way to collect the waste of household and wait for municipal corporations. Most of the time, the garbage bins or dustbins are placed in public places or in front of household /societies in the cities are overfull due to escalation in the waste every day. Improper waste management makes a serious health risk and lead to the spread of infectious diseases and also polluted the surrounding environment [4]. The various biodegradable waste combinations produces poisonous gases like methane if dustbin left unattended for many days which need immediate action. The main issue with rapidly increasing population in the urban area is day to day biodegradable and non-biodegradable waste segregation and waste management to have a healthy environment. There must be required a system that can provide prior information about the filling of the dustbin that alerts the concern authority so that they can clean the bin on time and safeguard the environment. Moreover, a city can be smart when a society having household, is also smart in term of waste management, energy saving, water saving and environment saving etc.. These societies are usually referred as a smart green society. The component of green society is represented in Fig. 1.

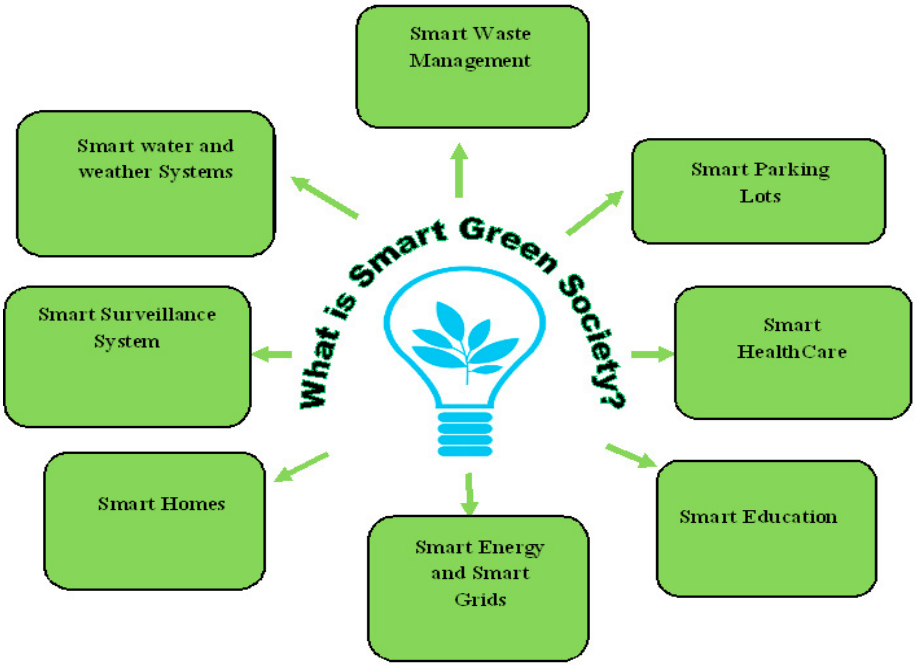

Fig. 1.components of green society

According to Rewind 2018 [5] India has policies to deal with all kinds of waste, but implementation is weak and not maintained effectively. Only Delhi produces 10000 metric tons of garbage every day and space to dump this is a major problem. The municipal corporation spends a good amount of money to collect, transport, treatment and disposal of this garbage. There is facility of only collection of garbage at the societal level, but segregation, reuse and recycle of household waste at society level is still not present in India.Machine learning and IoT based solution is promosing research direction in order to make smart city.The number of connected devices are rising due to IoT applications and their usage in all aspect of smart city. As the volume of the collected data increases due to variety of connected devices, then Machine Learning (ML) techniques are realistic to enrich the intelligence and the capabilities of an application [6].

In this paper, author propose a smart dustbin to segregate household waste and reuse the waste for making bio compost based on machine learning and IoT technique. The main contribution of this paper is to send alert messages to concern authority on the basis of decision taken from the combination of three parameters received from the sensors value. First parameter is related to level of biodegradable waste in the dustbin, second parameter is being related to non biodegradable waste in the dustbin and the third parameter is a concentration of poisonous gases. The decision whether to send alert message or not is based on getting data from sensors. Supervised machine learning algorithm: KNN is used for classification and prediction of alert message based on sample data. The proposed model has two modules. The module one has smart dustbin with two compartments, one for biodegradable waste and the other compartment is for non-biodegradable household waste. It is designed for the every house in the society as a first level of segregation.While module 2 is implemented at the society level, which deals with the second level of segregation where segregated non-biodegradable waste from level 1 is further segregated to separate different types of non-biodegradable waste and send the alert messages to the municipal corporation. Level 2 is also used for making the compost using segregated biodegradable waste from level 1 and system system sent the alert messages to the municipal corporation.

The rest of the paper is structured as follows Section2 presents the work related to the IOT based waste management systems in the Smart societies. Section3 will describe the proposed framework its features. Section4 presents the components used for the proposed research. Section 5 describes the machine learning approach for the proposed model. Section 6 presents the result and discussion and section 7 concludes the paper with the future work.

2. Related work

From last two decades, there is rapid growth in urbanization, industrialization and population in India, which leads the problem of waste management. A review of common waste management model supported by it is discussed in references [7] [8]. The World Bank reports, municipal corporations spend 20 to 50 percent of the total available budget on maintaining the management of the solid waste. The author proposed the document called ISWM plan which includes baseline information, proposed targets, concern issues, management system responses, strategy for implementation, monitoring and also feed the system [9]. Reference [10] had developed an electronic monitoring system with GSM, which sends SMS to the supervisor informing that the dustbin if completely filled so that system can send the truck for the collection of trash. Again the SMS is sent to the supervisor to inform of waste collection. In that paper the author had used the ultrasonic sensor for sensing the level of trash in the dustbin and GSM module was used for messaging purpose which gives information about the status of the dustbin whether it was filled or cleaned.A similar method was proposed in [11] for the collection of waste with the help of Arduino UNO board interfaced with GSM module and ultrasonic sensor and the author concluded the paper with the issues of smart dustbin like affordability, its maintenance and also its durability.A waste management system that deals with the collection of garbage inaccessible areas of the city by using a camera, Arduino UNO, Wi-Fi module which accesses the internet using Blynk application which handles all the communication between the involved people [2]. The ultrasonic sensor monitors the level of garbage and ensures immediate cleaning of the dustbin when filled to the reference level [12] [13]. An intelligent wastebin was proposed by [14] in 2017 based on the IoT prototype for the

city Pune in the country India. IoT is not only used in homes, but also has major advantages in Healthcare Applications [15].

Machine learning is playing powerful and important role in making decisions, identifying specific pattern and also in analyzing the vast amount of data from the sensors used in various IoT devices, wearable gadgets and smart technologies. Machine learning is thus tool to take actions based on data [16]. Machine learning techniques such as KNN is a simple approach for classification of user 'type' decision in wireless network and other area [17][18]. Agarwal et al. presented the deep knowledge about the waste management initiatives in India for human well being. Author revealed the scope for improvement in the management of waste for the welfare of the society [3]. In order to make smart city waste management is necessary but it is not just collection and disposal of waste.Household products are also releasing toxic gases into the air due to improper disposed of old batteries, pesticides, paints, car oil etc. which must be managed appropriately.The unattended bio degradable items such as food waste also contribute in production of poisonous gas like methane[19]. A proper waste management includes: collection, segregation, reduce, reuse, and recycle of waste. Most of the literature available related to smart dustbin which is mostly placed in a common place of the city. However, management of household waste is still a challenging problem.

There are very few research papers on segregation of biodegradable and non-biodegradable waste as well for the reusing of the biodegradable waste to make compost. Further, poisonous gases due to household products also creating problem in environment. This motivates us to design the system which can segregate the household waste at two levels on the basis whether it is biodegradable or non-biodegradable and send alert message using machine learning approach on the basis of data collected from sensors. The segregated biodegradable waste is reused for making the compost and non-biodegradable waste after further segregation at society level is being collected by the Municipal Corporation.

3. Proposed framework for green and smart society

The concept of smart city could not be fulfilled without the intention of people and society. In this paper, author proposed the waste management system for a green society with advance features such as it automatic open and close the lid when any one reach near the dustbin,detection of poisonous gas. Two level segregation of biodegradable and non-biodegradable household waste, making compost using the biodegradable waste, intimation to the supervisor of the society as well as to the municipal corporation by the Google messenger. Proposed smart dustbin could be able to identify biodegradable and non-biodegradable waste and segregated in two different compartments. The proposed model for waste management system for the green society is implemented at two levels: level one is for the every house of the society and level 2 works at the societal level as shown in Fig. 2.

3.1. Level 1: House Level

At the house level, smart dustbin comprises with two compartments. The steps to achieve level one is represented below:

- Opens the lid of dustbin automatically when anyone reaches near the dustbin.
- There are two buttons: Green button is for biodegradable waste and Red button is for Non-biodegradable waste.
- Rotation of the inner drum of the dust bin on the basis of biodegradable and non-biodegradable waste.
- Intimation to facility supervisor when the dustbin is filled to the predefined level or if any poisonous gas is detected by using the alert message.
- Move the dustbin outside the home when either biodegradable or non-biodegradable compartment of the dustbin filled up to reference level and then bring it inside when it is empty using line follower.

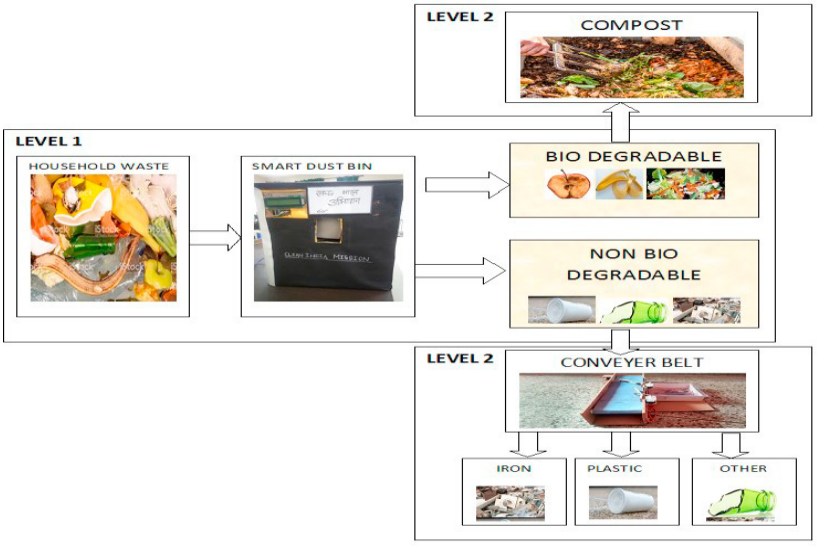

Fig. 2.Proposed model for waste management

3.2. Level 2: Society Level

- Non-biodegradable waste from the level 1 which has different types of non-biodegradable waste, is spread on the conveyer belt for second level segregation.
- The Inductive proximity sensor on the conveyer belt is responsible for the segregation of Metal waste. As it senses metal and is moved to the metal collecting box.
- The capacitance proximity sensor on the conveyer belt is responsible for the segregation of plastic and wooden waste. As it senses plastic and is moved to the plastic and the wooden collecting box.
- Remaining waste is the non-biodegradable waste which cannot be further segregated with this model.
- When this segregated non-biodegradable waste reaches the threshold level (90% filled) then an alert message is sent to the municipal corporation for its collection.
- For making compost, the biodegradable household waste from level 1 is mixed with fallenleafs from the society green area, leftover roots, earthworms, etc.

3.3. System assumptions and parameter description:

The following assumptions are taken into consideration in the proposed model:

- *'flag'* is used to represent the current status of whether the biodegradable or non biodegradable compartment is present at the lid.Initially, it is 1 and shows biodegradable compartment is present at the lid.
- Parameter *'b'* is used to show whether the Green button for biodegradable waste is pressed or not and parameter'*nb'* is used to show whether the red button for nonbiodegradable waste is pressed or not.
- Variable 'ir_{user}' is used to monitor current distance of the user from dustbin which stores the value of 'ir' sensor reading and we assume that if it is less than and equal to 40mm then open the lid.
- A constant 'th_{level}'is used for the threshold waste level for both biodegradable as well as for non biodegradable. Initially, it is set as 20 cm.
- Variable *blevel* and *nblevel* are used to monitor the present/current level of biodegradable and non biodegradable waste.

- Variable *'pg_{level}'* is used to monitor the current concentration of poisonous gas like methane.

Figure 3(a) and (b) is the simple flow chart of the proposed work with level 1 and level 2 implementation.

Algorithm 1: Working of smart dustbin at Level1

1. Initialize flag=1 , th_{level} =20 cm ,th_{plevel}=0.3
2. If ir_{user}< 40mm
   "open the lid"
3. if b=1 then
   if flag=1
   "No Rotation"
   else
   "180 degree Rotation"
   flag=1
   endif
   endif
4. if nb=1 then
   if flag=1
   "180 degree Rotation"
   flag=0
   else
   "No Rotation"
   endif
   endif
5. "close the lid after delay of 30 sec"

end if

6. if blevel>= th_{level} || nblevel>= th_{level}|| pg_{level}>= th_{plevel}
   "Move the dustbin outside home"
   "Send message to the facility supervisor"
   endif
7. if blevel== 0 || nblevel== 0
   "Move the dustbin inside home "
   endif
8. goto step 2.

3.4. Components used in Proposed Model

This model in the real world is indeed beneficial to sustain the clean environment of the society by recycling and reusing the household waste which leads to make the society as Green and Smart society. According to the proposed framework, the IR sensor on the front side of the smart dust bin senses the proximity of the user and opens and closes the lid automatically. Actuators are used to control the linear motion required to open and close the lids of the smart dust bin.The two ultrasonic sensor on the inner side of the lid continuously monitor the level of garbage in biodegradable as well as non biodegradable compartment ofthe dustbin at level 1.The distance between the sensor and the object can be calculated by using Time is taken by sonic waves to strike the object and bounces back to the sensor (T) and the sonic speed(C) using the formula (1)

$$\text{Distance}=1/2*T*C \quad (1)$$

MQ-4 gas sensor is used to detect poisonous gas like Methane in biodegradable compartment under the lid at level 1.Segregation of non-biodegradable is monitored by proximity inductive sensors and capacitance proximity sensor fixed under the conveyer belt of level 2.The inductive proximity sensor detects the metal object without any physical contact with the object which is fixed under the coveyer belt at level2 and the capacitance proximity sensor can be used for sensing the plastic as well as wood and is located below the conveyer belt at level 2

The data from the various sensors is collected by Raspberry pi as well as send on the Adafruit IO free web service using Wi-Fi which connects IFTTT (If This Then That) service and the Facebook messanger and also send messages according to the programming and perform the required action. The data at various stages is also monitored on the mobile as well as adafruit IO GUI.Adafruit.io is a cloud service and can be connected to the Internet. It is used for storing and then retrieving data.It connect the two web services.It also makes storing data useful. With the help of dashboard feature we can visualize the data. Messanger service is used to send the alert message to the concern facility supervisor.

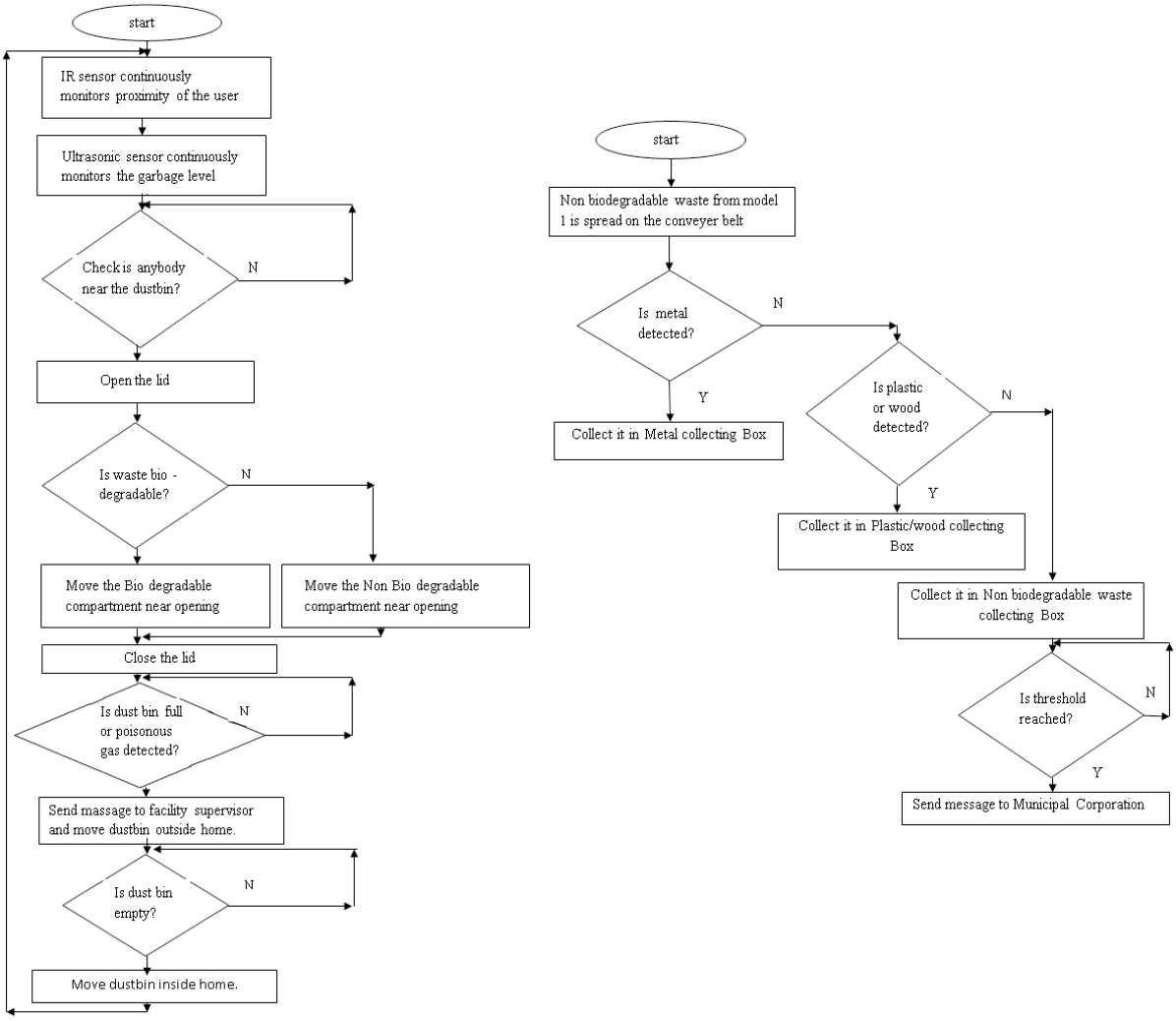

Fig. 3.(a) Level 1 implementation (b). Level 2 implementation

4. Machine Learning Approach for Proposed Model:

After implementing the algorithm the next task is to collect data set of three sensor valueS_i .These sensor values areDustbin Level (DL), Metal Level (ML), Poisnous Gas Value (PG) in a comma separated file (csv). These values are normalized between 0 to 1 according to the equation 2[17].

$$N(S_i)=\frac{S_a}{S_{\max}} \qquad S_a \leq S_{\max} \tag{2}$$

Where S_a is actual value collected by sensorvalue and S_{max} is the maximum expected value of that parameter. Maximum expected value can be set by different service providers. On the basis of combinations of N (S_i), the 'decision' has taken automatically that weather alert message is sent or not. As a test case it is assumed that there are four dustbin in a society that will send the alert messages or not on the basis of supervised learning. Author used K-nearest neighbor (KNN) approach to predict 'decision' directly from the training data set. KNN is used for classification, estimation and prediction algorithm in the area of data mining [20]. In this paper, author utilized K-nearest neighbor (KNN) approach to predict 'decision' directly from the training data set.

For building the simulation environment for classification author imported panadas library to import csv file and sklearn or Scikit-Learn to use machine learning library for technique like KNN classifier using python . Scikit-Learn support various algorithm like SVM, KNN, random forest etc., and also support numerical and scientific libraries like NumPy and SciPy. The author has taken following parameter value for a KNN classifier[21].

KNeighborsClassifier(algorithm='auto', leaf_size=30, metric='minkowski',metric_params=None, n_jobs=1, n_neighbors=2, p=2, weights='uniform')

The data set consists of 100 samples of class'Decision'= {'$blevel_i$', '$nblevel_i$', 'pg_{level_i}'}. Out of 100 samples, 70 samples are for training purpose and 30 samples is for testing purpose. KNN classfier is used to predict '*decision*' directly from the training data set.Predictions are made for a new instance A{'$blevel_i$', '$nblevel_i$', '$pg_{level\ i}$'}by searching through the entire training set for the K most similar instances (the neighbors) and summarizing the output variable for those K instances. For comparative analysis only '*n neighbors'* or '*K'* parameter has taken into consideration in present work. The average accuracy of the KNN classifier has plotted for different value of n_neighbors (K). Fig. 4, is plotted for various value of K which range 1 to 16. From the figure 4, accuracy of KNN classifier is performaing well at k=3, 4 and 6 compare to rest of the values of K. Data associated with figure 4 is shown in table 1.

Table 1. Acuuracy Comparison for different values of K

K (n_neighbors)	Accuracy
1,2	0.87
3,4,6	0.93
5	0.90
7,8,9	0.83
10,11,12,13,14,15	0.87

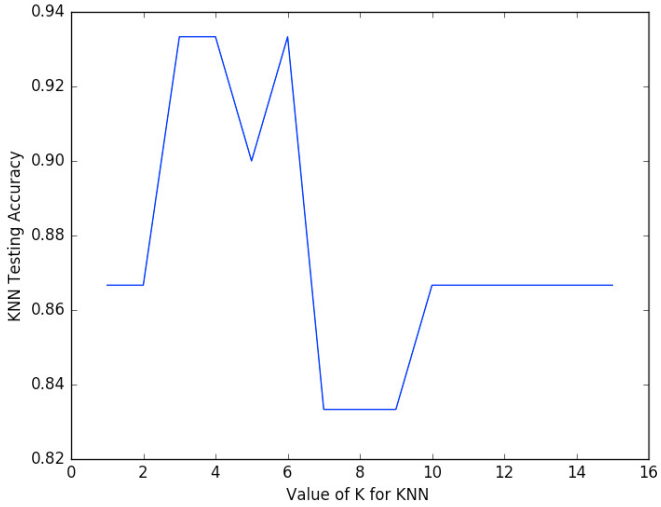

Fig. 4: KNN Testing Accuracy

5. Result and Discussion

The proposed model is very helpful for maintaining the health, hygiene and clean environment of societies through the machine learning approach. The overall accuracy of KNN model is 93.3% at K = 3, 4 and 6. The manufactured bio composts from waste at society level can be used in the maintenance of greenery of the society as well as it can be used to generate revenue by selling the compost. The segregated non biodegradable waste can also be sold or Municipal Corporation can also collect it.The proposed framework works efficiently at society level by collection, segregation of biodegradable and non biodegradable household waste and decomposition of waste in making compost. This is useful to maintain the cleanliness, hygiene, and clean environment of the society in the smart way. This helps to make the society green smart society which is helpful to make city as smart city.

6. Conclusion

The objective of this research is to make the society as a smart green society which is environmentally sound and healthy.This model continuously monitors the level of waste in the biodegradable and non biodegradable compartment of the dustbin and also the concentration of poisonous gases. This model uses machine learning technique (KNN) to send alert messages to concern society authority with 93.3 % accuracy. This model segregate the household waste at level1 and minimizes the actual waste by recycling biodegradable waste to make compostat level2. This model is a remarkable achievement in upgrading the household waste management system of the society.

The future work will simulate the model and find out the suitability of the proposed model. The proposed model could also use the GPS for navigation instead of line follower for sending the dustbin in and out. The proposed model can be used at multi specialty hospitals, at various public places and in industries for segregation of different types of waste by adding more sensors which could further be recycled or reused.

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