A Machine Learning Approach for Smart Waste Management Systems that is Automated

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Abstract: A waste management system is the concept in an organization that is used to dispose, reduce, reuse, and prevent waste. Some of the waste disposal methods are recycling, composting, incineration, landfills, bioremediation, waste of energy, and waste minimization. Traditional waste management system operates based on daily schedule which is highly inefficient and costly. Numerous data-driven methods for solving the problem are investigated in a realistic setting where most of the events are not actual emptying. Waste management is a daily task in urban areas, which requires a large amount of labour resources and affects natural, budgetary, efficiency, and social aspects. Many approaches have been proposed to optimize waste management, such as using the nearest neighbour search, colony optimization, genetic algorithm, and particle swarm optimization methods. The isolation of waste is done by unskilled workers which are less effective, time-consuming, and not plausible because of a lot of waste. So, proposing an automated waste classification problem utilizing Machine Learning algorithms. The use of machine learning allows improving the classification accuracy and recall of the existing manually engineered model.

Keywords: Machine Learning, Waste Management, Automation, Classification, Smart System.

1. INTRODUCTION

The waste management system predominantly corroborates the disposal and treatment of different types of waste. Thus, it safeguards human beings, animals, and surroundings [1]. Adequate waste management techniques can save much money, which will lead to improved air quality and less environmental pollution. Waste management requires necessary processes and activities to dominate from its inception to demolition. Waste comes in solid, liquid, or gaseous form, and every type of waste demands a different method of classification, disposal, and management. Waste management deals with every waste category, including household, organic, industrial, municipal, biomedical, organic, biological, and radioactive waste. Any unnecessary substance or substance with no use is called “waste”. Waste management involves the collection of the waste and its transport and disposal to appropriate locations. Machine learning is an area with a huge potential for the transformation of many areas of life and science including industrial informatics. In order to hasten the application of machine learning to real-world problems, the automated machine learning (AutoML) approach has been proposed. This article extends the AutoML approach with the data-driven methodology applied to industrial problems with existing (e.g., model-based) solutions. The methodology includes five steps:

- Collection of data, which can be used during the development and evaluation of solutions;
- The collected data are used to evaluate the existing solution to the problem;
- Parameters of the existing solution are optimised and evaluated based on the data;
- Conventional machine learning algorithms can be applied to the problem;
- The feature engineering methods are used to find if additional features could improve the results of the machine learning algorithms.

The methodology is applied to a problem within an area of waste management, which is one of the biggest challenges imposed by the rapid growth of the urban population. For example, in Europe each person is expected to yearly produce six tones of waste of materials used in the daily life. An efficient strategy for facing the challenge of the waste management should address several directions including building a structured process for the waste disposal and maximising the recycling of the waste. When implementing these steps economical and environmental aspects should be taken into account. Waste transportation greatly affects both aspects and its optimisation can significantly increase the positive effects [2]. At the same time, there is a clear requirement that in order to keep recycling stations clean they should be emptied at a right time. It is non-trivial to fulfil this requirement in a scenario with several hundreds of recycling stations (each with several containers) that are spread over a large geographical area.

A Smart Waste Management system implementing elements of Internet of Things is an enabling technology addressing the challenges of the waste transportation optimisation. It will allow each recycling container reporting its filling level. The advanced functionality of such a system will enable predicting the expected emptying time of a recycling container, i.e., the time when the container's filling level will achieve a certain critical value. Filling level predictions will allow avoiding redundant transportation without violating the overfilling requirement. However, the quality of filling level predictions will determine the efficiency of a Smart Waste Management system. There are several technical challenges for achieving high quality predictions. Our analysis of an operating Smart Waste Management system revealed that one of these challenges is a problem of an accurate detection of a container being emptied using the measurements from a sensor mounted on top of a container. As it is demonstrated in Section II-B, the quality of filling level predictions depends on the correct detection of emptying. Inaccurate detections devalue filling level predictions; therefore, detection of container emptying is an integral step in obtaining qualitative predictions. Therefore, this article applies the proposed methodology to the problem of the emptying detection. Moreover, this study for the first time draws attention to the challenges and importance of the emptying detection for the functioning of Smart Waste Management systems.

ML refers to a significant function of Artificial Intelligent (AI) that allows a system the ability to learn and make the decision automatically without being explicitly instructed. Machine learning is a scientific study of some statistical models and algorithms [3]. Due to offering the most exceptional features in computing, the popularity of ML has reached the highest peak.

2. RELATED WORK

Worldwide, there is an enormous increase in the generation of waste per day. Approximately 1.9 billion tons of waste is generated annually, with a minimum of 35% that is not treated securely. As per the reports, the waste generated per person per day varies from 0.17 to 4.67 kilograms [9]. The overall waste is anticipated to exceed about 45 billion tons by 2055, which will be over double growth for the identical period. This section presents previous work related to our proposed model. Many great contributors had placed a significant trace in the field of Machine Learning on waste management.

Rutqvist, D., Kleyko, D., & Blomstedt, F. (2019), proposed a solution uses a Random Forest classifier on a set of features based on the filling level at different given time spans [4]. The authors investigated methods include the existing manually engineered model and its modification as well as conventional machines learning algorithms. The use of machine learning allows improving the classification accuracy and recall of the existing manually engineered model from 86.8% and 47.9% to 99.1% and 98.2%, respectively, when using the best performing solution. Finally, compared to the baseline existing manually engineered model, the best performing solution also improves the quality of forecasts for emptying time of recycling containers.

Sheng, T. J., et al., (2020) aims is to develop a smart waste management system using LoRa communication protocol and TensorFlow based deep learning model [5]. The existing recycle bin has also proved its ineffectiveness in the public as people do not recycle their waste properly. With the development of Internet of Things (IoT) and Artificial Intelligence (AI), the traditional waste management system can be replaced with smart sensors embedded into the system to perform real time monitoring and allow for better waste management. Object detection and waste classification is done in TensorFlow framework with pre-trained object detection model. This object detection model is trained with images of waste to generate a frozen inference graph used for object detection which is done through a camera connected to the Raspberry Pi 3 Model B+ as the main processing unit. LoRa communication protocol is used to transmit data about the location, real time and filling level of the bin. RFID module is embedded for the purpose of waste management personnel identification.

Rahman, M. W., et al., (2022), reflects a capable architecture of the Waste Management System based on deep learning and IoT. The proposed model renders an astute way to sort digestible and indigestible waste using a Convolutional Neural Network (CNN), a popular deep learning paradigm [6]. The scheme also introduces an Architectural Design of a smart trash bin that utilizes a Microcontroller with multiple sensors. The proposed method employs IoT and Bluetooth connectivity for data monitoring. IoT enables control of real-time data from anywhere while Bluetooth aids short-range data monitoring through an Android Application. To examine the efficacy of the developed model, the accuracy of waste label classification, sensors data estimation, and System Usability Scale (SUS) are enumerated and interpreted. The Classification Accuracy of the proposed architecture based on the CNN Model is 95.3125%, and the SUS score is 86%.

Varudandi, S., et al., (2021), proposed a solution for Waste Management. The main constituent of this system is a waste bin which will automatically segregate the waste by employing technologies such as Internet of Things and Machine Learning [7]. The bin is connected to the cloud to assist in systematic waste collection by tracking and uploading various data points for a particular bin. A group of these bins will help in efficient garbage collection and management starting from the origin of the waste itself. A daily generation of waste in tons requires an effective management technique. If not done suitably, virtually unlimited amounts of open spaces will be required to dump the waste. The proposed system will lend a hand to solve these waste management problems.

Chen, X. (2022), proposed automatic machine learning-based waste recycling framework (AMLWRF) to classify and separate materials in a mixed recycling application for improved separation of complicated waste [8]. The collection of waste is important in smart city service and smart technology has great potential for increasing garbage collection efficiency and quality all around the world. The major goal of this research is to examine Machine Learning Algorithm utilized in recycling systems. The IoT-powered devices may be installed in waste containers including recycling bins and it gives real-time data on garbage generating behavior. The proposed work compiles the most recent advances in recycling-related machine learning.

Khan, R., et al., (2021), finds the solution for rapid rise in inhabitants across the globe has led to the inadmissible management of waste in various countries, giving rise to various health issues and environmental pollution [10]. The waste-collecting trucks collect waste just once or twice in seven days. Due to improper waste collection practices, the waste in the dustbin is spread on the streets. The authors used Arduino UNO microcontroller, ultrasonic sensor, and moisture sensor, to prepare smart waste management system. A hardware prototype is also developed for the proposed framework. Thus, the presented solution for the efficient management of waste accomplishes the aim of establishing clean and pollution-free cities.

3. PROBLEM DEFINITION

The considered Smart Waste Management system was created to address the challenge of efficient waste transportation. The system aims at optimizing the waste management where a particular goal is to predict when a recycling container is going to be full [11].

The sensors used in the system are a customized hardware solution. The hardware is equipped with an ultrasonic range sensor, an accelerometer, and a GSM module. The ultrasonic sensor measures a filling level of a recycling container regularly throughout the day at a configurable interval. Because the sensor is retrofitted to the ceiling of its container the measured range is a distance from the ceiling to the current waste level. In order to get additional information for detecting potential emptying, the hardware is also equipped with an accelerometer [12]. The accelerometer continuously measures the acceleration of the corresponding container. If the acceleration exceeds a configurable threshold the sensor wakes the main processor with an interrupt. Then the processor measures how many interrupts it receives within a given time period. Thus, the accelerometer provides a vibration strength score. The obtained measurements are uploaded to a server using the GSM module. The processing of the sensory measurements for each recycling container is done on the server side. For example, the server transforms the distance to the waste level into the filling level in percentages. The server also collects the statistics and performs predictive analytics of the data received from the sensors. Finally, the server delivers the extracted information to a user interface. The work focuses on the topic of using sensor data to detect (i.e., binary classification) the emptying of a recycling container. In a realistic situation where most of the occurrences are not true emptying, a variety of data-driven strategies for tackling the problem are studied. This solution applies a Random Forest classifier to a set of characteristics depending on the level of filling at various time intervals. Finally, the best performing solution enhances the quality of forecasts for recycling container emptying time when compared to the baseline current manually created model.

4. SCOPE AND OBJECTIVES

The major objective of this project is to prepare a user-friendly input files panels that can handle large volumes of data to fulfill it. Smart waste management is a idea where we can control lots of problems which disturb the society in pollution and diseases and produce a lot more harmful effects to be faced. There will be validity checks, which will be applied to the data as soon as the input is given.

Prime objectives of design are as follows: Monitoring the waste management, Avoiding of human intervention in it, Reducing human time and effort to provide ease in each process of management.

The proposed system will focus on finding technical solutions to recycle the waste .The maintenance of sanity in the society and preventing pollution in our surroundings might result in well defined waste management .if not taken well care it may result in severe health complications to the inhabitants of the areas where garbage and environment conservation is not taken seriously.

5. STUDY OF EXISTING METHODOLOGY

The colossal increase in environmental pollution and degradation, resulting in ecological imbalance, is an eye-catching concern in the contemporary era [13]. Moreover, the proliferation in the development of smart cities across the globe necessitates the emergence of a robust smart waste management system for proper waste segregation based on its biodegradability. The current garbage collection management involves individuals who walk from in every household giving receipt to show payments was many for garbage collection service [15]. To get the service of the individuals or company, a resident or flat caretaker has to look for them and request for their service. The YOLOv3 algorithm has been utilized in the Darknet neural network framework to train a self-made dataset. The network has been trained for 6 object classes (namely: cardboard, glass, metal, paper, plastic and organic waste). Moreover, for comparative assessment, the detection task has also been performed using YOLOv3-tiny to validate the competence of the YOLOv3 algorithm. It will focus on the optimization of results, along with the prediction probability for other waste items in the real world.

Drawbacks of Existing Methodology

- Soil Contamination. Ideally, we would like our plastic, glass, metal and paper waste to end up at a recycling facility.
- Water Contamination.
- Extreme Weather Caused By Climate Change.
- Air Contamination.
- Harm towards Animal and Marine Life.
- Human Damage.

6. PROPOSED METHODOLOGY

The quality of filling level predictions will get to know the efficiency of a Smart Waste Management system. There are several major challenges for achieving high quality predictions. Our analysis of an operating Smart Waste Management system came for a conclusion that one of these challenges is a problem of a good and most likely detection of a container being emptied using the measurements from a sensor mounted on top of a container in our system that we implement [14].

With this system design specification, the general view and structure of the system as well as the components are shown and depicted. The various components described will be the main objective of the system making it completes to perform its purpose when it was being constructed and designed. In system design, the main concern is to come up with an appropriate design that will majorly help build a system of good quality and well accuracy.

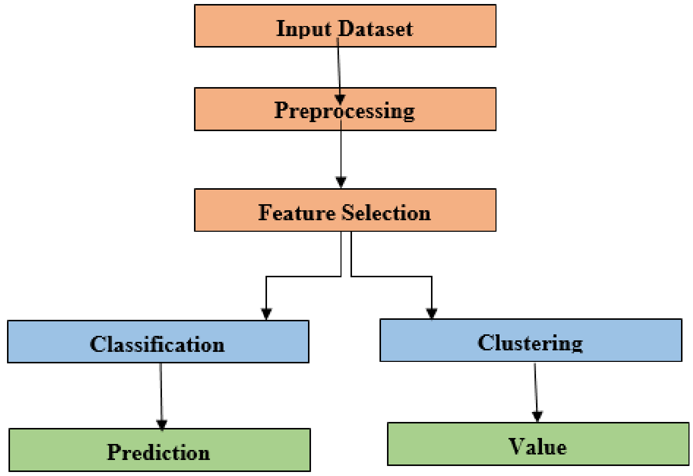

Figure: - Workflow of the Proposed Methodology

The purpose of the system design specification document is to bring clear clarity when developing the system; this will be possible through design of general system and expected flow of the system. Once the document brings a clear design structure, development will be easy and understandable.

A sensor that recognizes garbage approaching the lid of the smart bin lifts the lid so that it may be deposited on the first foldable flap below the lid because when trash is carried low enough to be detected. Rubbish may be deposited on the first inflatable flap of the receptacle, which manages all sorting for the consumer.

Phase 1: Data Pre-Processing

Data Preprocessing is an important step in machine learning and deep learning. Preprocessing is a series of data transformations to reduce the noise in the raw data. Preprocessing increases the sensitivity of analysis (SNR) and certifies the validity of the statistical model. In the proposed work, dealing with unbalanced datasets, oversampling and under sampling are helpful to balance the samples of two different classes. As the dataset is unbalance, we applied three sampling techniques on the dataset.

a) Random Over sampling.

b) Synthetic Minority Oversampling.

c) Adaptive synthetic sampling approach.

After applying sampling techniques accuracy and recall rates increased drastically.

Phase -2: - Feature Extraction & Selection

Feature extraction techniques are helpful in various image processing applications e.g. character recognition. As features define the behavior of an image, they show its place in terms of storage taken, efficiency in classification and obviously in time consumption also. A feature is a piece of information about the content of an image; typically about whether a certain region of the image has certain properties. Features may be specific structures in the image such as points, edges or objects.

Phase – 3: - Classification using Ensemble of Deep CNN

Deep learning models have achieved remarkable results in computer vision, so they become a new tendency in image recognition and classification. In this context appears our used Convolutional Neural Networks (CNN) algorithm. The CNN is divided into 4 steps which are Convolution, Non Linearity (ReLU), Pooling or Sub-Sampling and Classification (Fully Connected Layer). These operations are crucial to build a CNN system.

7. PERFORMANCE EVALUATION METRICS

To evaluate the proposed approach performance, several evaluation metrics described below [16].

1. **Sensitivity** –

Sensitivity measures the proportion of positives that are correctly identified. Sensitivity is the proportion of actual positives which are correctly identified as positives by the classifier.

2. **Specificity** –

Specificity relates to the test's ability to correctly reject healthy patients without a condition. Specificity of a test is the proportion of healthy patients known not to have the disease, who will test negative for it.

3. **Accuracy** –

Accuracy is the one metric for evaluation classification models. Informally, accuracy is the fraction of predictions our model got right. Formally, it is the ratio of number of correct predictions to the total number of input samples.

8. CONCLUSION

Using the Machine Learning model, this study illustrates how smart waste management may be done. This method ensures that waste is collected as soon as it reaches the maximum level. The authors intend to evolve a smart waste management system based on the perception of sustainable, integrated waste management. The closure of landfills could pose various potential hazards due to which public health may get affected. Open junkyards and the burning of undesirable wastes can lead to environmental pollution and many hazardous diseases. There should be a system that can effectively supervise the disposal and collection of waste and regulate the comprehensive growth of superfluous waste. The system proposed by us collects and efficiently treats the waste as compared to other models. It also saves fuel costs as well as time.

9. REFERENCES

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