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RESEARCH ARTICLE

Adoption of artificial intelligence and the internet of things in dental biomedical waste management

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Abstract

The production of waste is an ongoing activity that must be managed efficiently to protect both the environment and the health of the general population. Therefore, proper management of waste from dental care is essential in protecting the environment's health, and it should become an inherent part of dental services. This study's primary objective was to use artificial intelligence in dental and biomedical waste management. The goal of this project was to develop an automated technique for categorizing dental trash to enhance the process of managing biological waste. In the proposed research, the support vector machine classifier has been regarded as the most effective method of classification for a dataset of Euclidean size. The most effective classifier used in the model is a support vector machine(with an accuracy of 96.5, 95.9% specificity, and 95.3% sensitivity) when classifying the different types of garbage. The categorization is accomplished through machine learning techniques to accurately separate waste into recycling categories, precisely four categories for dental biomedical waste. Based on the findings of these trials, this method has the potential to be used for garbage sorting and classification on different scales, which might aid in the scientific disposal of biological waste.

Keywords: Artificial intelligence, Biomedical waste management, Dental hospital, Internet things.

Introduction

The new notification released by the Ministry of Environment and Forests of the Government of India, states how each resident of an establishment that produces biomedical waste is required to comply with all regulations of the biomedical waste management (BMW) disposal process. That any sort of waste produced during the diagnosis, treatment, or immunization of humans or animals, or research pertaining to this information, or in the manufacturing and testing of biological or biomedical waste. This obligation is mentioned further in the text (Chen *et al.*, 2020). According to these criteria, a dentist is the person who occupies a clinic, is the one who creates biomedical waste and ought to be responsible for the clinic's general management. Inadequate and inappropriate waste management from oral health care could severely affect public health and considerably influence the environment. This is especially true when considering the growing number of dentists in urban places and the general public's rising understanding of dental treatment. It is possible that the overall waste from dental treatment that is created in metropolitan areas is not at all small. According to the most conservative estimates, a dental practice that usually operates probably generates between 0.5 and 1.0 kg of waste daily. A significant amount of garbage is likely produced by the approximately 4500 dentists who work in Mumbai and the surrounding area. Therefore, proper management of waste from dental care is essential in protecting the environment's health, and it should become an inherent part of dental services.

As a result of the presence of hazardous chemicals, toxic or infectious agents or medications, sharps, and the possibility that it is radioactive or genotoxic, the BMW poses

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a potential threat to individuals who come into contact with it. Lots of different groups, some of which are overlapping, might be at danger. Everyone from patients to dentists to those involved in trash treatment and disposal to the general public are all considered part of these groups (Ghods *et al*., 2023).

Infectious waste may contain pathogens that can enter the human body when the skin is broken, scratched, or punctured, when mucous membranes are breached, when the waste is inhaled, or when it is ingested. These wastes are now considered one of the major transmission modes of viruses across the world, and the most worrying part is that it has evidence showing that it may be the main cause of human immunodeficiency virus (HIV) transmission, in addition to hepatitis B and C, as well. Poor waste management is already a problem and the presence of resistant pathogens to both medicines and chemical disinfectants spells double trouble (Kordi *et al*., 2023).

It is high for many substances because of their toxicity, genotoxicity, tendency to cause fire, corrosion and explosions, reactivity, explosive power, or the fact that they are spread over shock. A fourth type of toxic, harmful, or caustic substance is a psychiatric agent whose presence alters behavior (e.g., alcohol or drugs of abuse). Crucially, they should be disinfected. Their volume of application is significantly enormous (Kordi *et al*., 2023) and these are corrosive, including reactive chemicals, leading to safety problems due to the potentially hazardous secondary products.

The exposure is mostly related to inhalation of dust or aerosols, skin absorption, or accidental ingestion of contaminated food with chemicals, cytotoxic drugs, and other waste (Kordi *et al*., 2023). It is genotoxic, causing possible DNA damage. These risks are often enough to harm people without any health insurance. According to the WHO: "Up to 43% of the global population - 2.6 billion people - were estimated to be exposed to household air pollution from solid fuels in 2016. The most vulnerable being women, children and the elderly" (Yunana *et al*., 2021). Healthcare waste, with special attention to anatomical waste, threatens the visual and health of urban residents (Kordi *et al*., 2023). It can also make the surroundings look like a low-quality environment because of how people throw their rubbish.

Sustainable transport is thus one of the aspects of sustainable development that seeks to redress the scales between social, environmental, and economic initiatives. Thus, it complies with multiple United Nations Sustainable Development Goals (SDGs) and corresponding goals for 2030. AI can be useful in sustainable transportation, specifically by increasing the efficiency of public transportation, road safety, congestion control and lowering environmental impacts. The goals include and are achieved by the use of AI techniques such as fuzzy logic, artificial neural networks, and optimization algorithms; Big data analysis; the implementation of IoT; and robotic process automation. This paper aims to determine the importance of sustainable transport, AI in various transport systems all over the world, the current state of sustainability, and future developments and trends in the field (Priya & K G, 2023).

Inappropriate waste management can have several unfavorable effects on the surrounding ecosystem. This may cause shifts in microbial ecology and resistance in microbes to many antimicrobial drugs. If the waste is allowed to build up, it poses a threat to public health for the following reasons: it rots, which makes it an ideal breeding ground for flies; it draws in rodents and other pests; any pathogens that may be present in the waste have the potential to be transferred to human food *via* flies and dust; there is the possibility that the waste will pollute the water and the soil; and refuse piles are unsightly and cause a nuisance due to offensive odors.

Methodology

Regarding image processing, the features are essential to the overall picture. Before acquiring any sample picture characteristics, several different methods, including binarization, thresholding, and normalization, amongst others, have been utilized. Then, methods for extracting functions have been presented to locate characteristics appropriate for recognizing and categorizing images. Character recognition is one of the many successful applications of feature extraction software in the image processing field. In the same way that features determine the behavior of an image, they also illustrate their place in terms of the amount of data stored, the effectiveness of categorization, and the processing time. The study would then investigate various kinds of extraction, features, and the context in which various extraction techniques are considered here. Following the preprocessing stage, the character identification procedure in this investigation extracts the featured information. The main goal of pattern recognition is to match each possible collection of input data with the appropriate set of output groups. The procedure of selecting features and classifying them can be broken down into two distinct parts.

Feature extraction is an important step in designing any good pattern recognition system. This phase is to determine what the relevant categories are used for. In this stage of the process, vectors are to be generated for the obtained features present in the alphabet. The input vector and the target output vector shall be read by the classifiers using this functional vector. By examining closer some of these traits, we can separate them more easily, which makes the differences clearer for the model to predict the trait. One of the potential techniques is by finding out the functions to get the important information out of the raw picture data.

Different levels of the above-discussed procedure have been distinguished in the categorization process by the usage of research instruments.

Dataset Collection

The data collection technique had to be carried out manually because there were no data sets about waste products that were readily present to the public. Several data enhancement techniques were used around every image about the representation of every group. These approaches included random image shearing, translation, and rotation. The given transformations to the images will be considered on various recycled substance configurations explicitly chosen for this purpose.

Data Preprocessing

It was necessary to preprocess the data to adapt it to the format the machine learning algorithms required because the data utilized for the given research consisted of photographs relating to trash. Each material photo used has a dimension of 512 by 384 pixels. Now, just to speed up the image analysis, we shrink the images to 10% of their original dimensions. The RGB values of the pixels in those images will be obtained; these can then be loaded in to extract features using the Read JPEG function available in the EB Image Package. The data would be divided like this in the training, 75% of the total data, and the validation, and 25% of the total data, which would be used to test the model if it was trained well or not.

Results

The effectiveness of the suggested approach is evaluated both with and without the use of preprocessing. For this study, one hundred different garbage photos were chosen for analysis ten times each. While there are only 20 photographs used in the testing phase, the evaluation section uses all 20 images from each round. There is a sensitivity of 92.39% and a specificity of 91.44%, which brings the overall accuracy to 93.83%. Figure 1 presents the findings as they have been compiled. The performance reached without picture preprocessing was less than that achieved with preprocessing. The accuracy was 88.93%, the sensitivity was 87.98%, and the specificity was 86.73%.

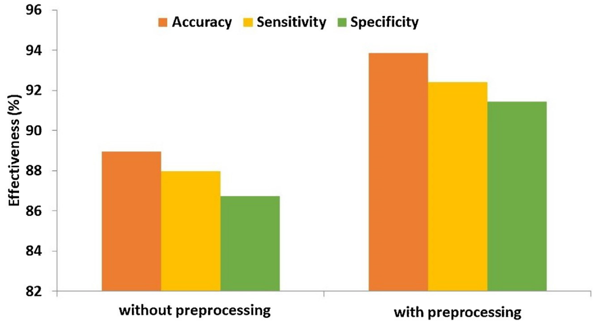

Figure 1: The efficiency of waste images of the preprocessing stage

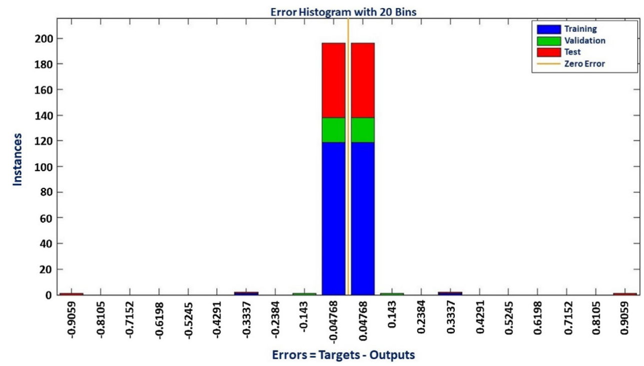

Figure 2: Error histogram having 20 bins

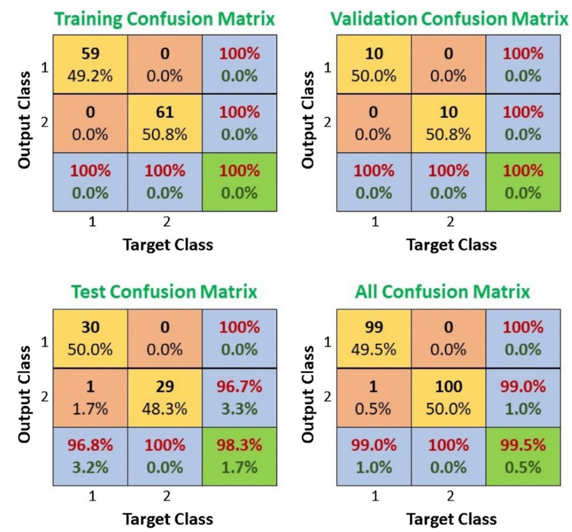

Figure 3: Confusion matrix for the support vector machine classifier, used for identifying the various types of garbage in an environment using binary classification

Before the peak, there is a negative variance after training (i.e., variance lower than human performance) for predicted/target values. Please look closely into Figure 2 for an error histogram with 20 bins and high resolution. This gives a summary of how well our logistic regression predictions did at predicting novels as not rubbish, newspapers as rubbish, everyday objects as rubbish, and then correctly predicted as rubbish. The confusion matrix used by the support vector machine classifier is shown in Figure 3. This provided further information on true/false positive/negative (TP, FP, FN and TN) count values and was weighted across all four waste type categories evaluated in this problem. The suggested machine learning (ML) classifier achieved a sensitivity level of 95.3%, specificity of 95.9%, and accuracy of 96.5%.

Discussion

Researchers explored and developed various waste management technologies based on the internet-of-things technology (Yunana *et al*., 2021) and (Maskeliūnas *et al*., 2019). According to (Folianto *et al*., 2015), using a primary device that specifies every category of waste bin, collects data, and transmits information *via* a wireless network helps minimize the amount of electricity used and maximizes the system's operational time. This is accomplished by the device's ability to acquire data. Nevertheless, the idea needs more specific and general process problems. Although the implementation has already begun (Pardini *et al*., 2019), it does not rely on anything besides the collecting of data; instead, the framework for the program is comprised of technology contributed by many different organizations.

On the other hand, several other methods emphasize implementing various waste disposal strategies to achieve peak performance. The authors (Bueno-Delgado *et al*., 2019) A plan will be developed to enhance the road network in neglected areas as well as a network to monitor and control waste disposal. Though an IoT-based system was considered, it was not accepted because the stack had to be explicit about how all bins were being managed and synchronized. The research is an alternate evaluation to determine smart bag authenticity and pick one customer in Philadelphia in the USA by means of the logistic regression method and via genetic algorithms. The research does not include any technology that can send data from the trash can to any other system. For instance, the maximizing algorithms for the optimum particle swarm methods, genetic algorithm, optimized colony, nearest neighbor, and IoT-based waste have been developed (Akhtar *et al*., 2017). These methods aim to remove as much of the waste as possible. In the study published by (Hannan *et al*., 2018), the researchers proposed a method for enabling an internet of things technology-controlled garbage network. This network consisted of a robotic-handed, self-supporting vehicle for gathering trash. However, the researchers should have used techniques to automate waste collecting. In the study (Jaid Jim *et al*., 2019), the device was run live in the field and coupled with the internet-of-things platform to construct a full waste management network (Figure 3). Instead of focusing on the design and optimization of GC systems, we suggested the design of an IoT infrastructure system, which included application integration, data processing, and management. In the study by (Popa *et al*., 2017), the researchers used Radio frequency identification technology to gather and communicate the data over a wireless network. Additionally, they devised a method for collecting food.

Most importantly, however, the limitations of this new technology have been challenged at a scale unrivaled by any global structure that has endured for as long: its intended purpose is the administration of an immense expanse. Ultimately, the researcher simply has to make the algorithmic nature of their findings nebulous, less able to adhere significantly to any one system or site. The article (Awe *et al*., 2017) points to the three types of waste, paper, recycling and trash disposal, as classifiers that are separated by their research - faster region-based convolutional neural networks. (Yang & Thung, 2016) to classify garbage into the six categories mentioned above presented convolutional neural network and support vector machine. The authors (Rad *et al*., 2017) have developed a method using Google Net Vision to map and classify rubbish in urban areas. According to the report's findings, the accuracy for identifying multiple types of garbage ranges from 63 to 77%. The researchers (Donovan, 2016) proposed employing Google's Tensor Flow in conjunction with video recording to recycle garbage immediately. This is not a theoretical outcome due to the research done thus far. The authors of (Mittal *et al*., 2016) devised a way to determine whether an image contains garbage by developing a solution.

They created an application for Android cell phones that deals with garbage. GarbNet is a service provided by CNN that analyzes images to determine where rubbish is located. Following optimization with GarbNet, we got an accuracy of 87.69%, with a specificity of 93.45%. The research also produced garbage in photographs. According to (Zheng *et al*., 2021), trash classification might be categorized as a specific issue. A new central database was built in this case, with 400 to 500 photos for each waste image class.

Conclusion

We take the perspective of a circular economy, where companies use recycled goods as a resource. The quality of the recycling obtained in these processes depends on the sorting and classification. That's why AI-based, fully automated solutions have been considered. Simulated experiments can determine the accuracy of the proposed model. The data is classified using machine learning methods and a decision-level fusion strategy. Or getting the recyclables into four piles like we have here. It consists of COVID-19 rubbish, plastics, glasses and other such kind of material. The suggested fusion method outperformed the single best performance feature technique substantially, according to the established study. A support vector machine (SVM) model correctly classified with 96.5% accuracy, 95.7% specificity and 95.3% sensitivity.

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Ethical Approval

Approved by Institutional Ethical Committee

Author's contribution

SM (Chen *et al*., 2020) and MD conceptualized the study. SM (Chen *et al*., 2020) conducted the study and collected the data. MD analyzed and interpreted the data. SM (Chen *et al*., 2020) and SM (Mahabob, 2021) did the literature review and drafted the manuscript. All three authors critically reviewed the final manuscript.

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