

INTELLIGENT CIVIC ISSUE DETECTION AND AUTOMATED COMPLAINT REPORTING USING COMPUTER VISION AND NLP

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Abstract— Poor and time consuming reporting is among the issues of urban infrastructure like potholes, rubbish and blockage of drains just to mention a few that have not been resolved. In the present paper, the application of AI-CIAD System is the automation of civic issue detection and reporting based on computer vision and natural language processing. Photos of problems with public infrastructure can be left by users via the React.js frontend and queries are handled by Python and FastAPI backend. After classifying a civic problem with the assistance of a deep learning model, a NLP module produces a structured complaint report with the description of issues and the geolocation API data depending on the photographs presented. The created reports are sent to the authorities to enable them react faster. The proposed solution will reduce the number of people hired, improve reporting and help to control smart cities because citizens are able to see infrastructure.

Keywords— AI, computer vision, natural language processing, deep learning, image classification, react.js, fastapi, geolocation APIs, automated complaint reporting, civic issue identification, smart city infrastructure, and urban infrastructure monitoring.

I. INTRODUCTION

The modern cities require to maintain their infrastructure because of aging road networks, environmental issues, and increase in traffic. Potholes are among the most frequent infrastructure challenges which cause damage to cars, accidents, rise in costs of vehicles servicing. Not only are the methods of physical examination and public complaints time consuming, but they are also slow and inefficient ways of detecting potholes. The latest developments in the computer vision and artificial intelligence have enabled automated

systems to recognize road defects using photos and video, and enhance infrastructure maintenance and surveillance. Such smart devices enable the authorities to identify the bad state of the roads and focus on the maintenance [1].

Different researches have suggested deep learning and machine learning to resolve the detection of potholes. Potholes in road photos are found using deep learning models such as CNNs and object recognition frameworks. Road defects can be automatically detected by analysing changes in texture, shape and depth of photos. To increase the accuracy of detection and real-time surveillance of the road infrastructure system, the concepts of hybrid computer vision- sensor have been studied [2].

Recent researches have improved civic issues reporting and communications besides automated identification. Algorithms can be smart enough to automatically identify complaint reports without human description of the problem through use of uploaded photos or videos. Problems that can be identified and analyzed by authorities can be detected and analyzed using the natural language processing and video-based analysis [3].

Deep learning models like CNN-based and YOLO are used to improve pothole detection systems. Smart transportation and municipal applications can utilize these models since they are capable of processing big amounts of data and identifying the degradation of roads in real-time. The advanced object recognition structures allow monitoring transportation infrastructure and detect potholes accurately and classify the problems on the road [4].

Neural network models may be used by computer vision-based detection systems to determine the size and severity of potholes. The system can identify and approximate the size and depth of the potholes with CNN-based structures and Faster R-CNN. These technologies stimulate the active maintenance of the infrastructure as they assist the officials in allocating funds

and in ensuring the prioritization of the repairing the infrastructure in the first place [5].

It is thanks to these developments that the application of computer vision-based AI-CIAD is suggested in this paper. The proposed system will facilitate the users to post on-line regarding potholes. Deep learning algorithms involve the analysis of photos in accordance with the relevant information and provide reports on complaints. The method will help to minimize manual workforce, enhance problem identification, and improved control over the urban infrastructure.

II. LITERATURE SURVEY

Image Analysis through Computer Vision and Learning to identify potholes, Dhiman and Kelle, 2019.

The system of pothole detection by means of machine learning and image processing was proposed by Dhiman and Kellett as a computer vision-based system. Their system identifies the potholes automatically in the form of gathering visual information on the road surface in terms of taking photos. Image analysis using learning was observed to be more practical in detection accuracy compared with manual inspection in the study. The technology is not applicable to automatize the reporting process or to communicate with municipal structures of complaints but is rather focused on detection.

The researchers in Dhiman and Kellett (2021) applied deep learning and computer vision to detect potholes and the level of potholes.

Deep learning was incorporated by Dhiman and Klette to detect and evaluate the severity of potholes. They apply road pictures and convolutional neural networks to categorize potholes in terms of their size and depth. The suggested solution enhances infrastructure repair planning and identification. It does not have automated reporting and it also needs large labeled datasets.

In asphalt pavement, Koch and Brilakis (2011) found the images of potholes as a result of image processing.

One of the first image-processing based automated potholes detectors invented by Koch and Brilakis. The method is an analysis of edges and texture of pavement images to find potholes in the pavement. The technique shows that it is possible to detect road damage via the use of computer vision. Nonetheless, it is not as powerful as newer deep learning techniques, and is sensitive to illumination.

Zhang et al. (2016) detected road cracks with the help of deep convolutional neural networks.

Zhang et al. developed a road fracture detector that is grounded on deep learning based on convolutional neural networks. More complicated visual features are automatically identified to properly identify the fractures. However, in the study, they found out that deep learning is more effective compared to image processing in identifying infrastructure damages. The research mostly focuses on crack detection, and not automated reporting systems or pothole detection.

Fan et al., 2021. Segregating Inequality Maps of the 3D Reconstruction of the Surface of the Road and Potholes.

The potholes were identified by Fan and associates using 3D road surface reconstruction. They make use of the disparity map segmentation and stereo eye to view defects on the road surface. The equipment enhances the inspection of the road conditions as the depth and shape of the potholes are well determined. The technology might not be extensively used due to the fact that it needs special hardware and a powerful processing unit.

Intelligent pothole detection: A Deep Learning-based Dilated Convolution, Ahmed, 2021.

In order to detect potholes on the road in images, Ahmed suggested a deep learning algorithm to help in the dilated convolution networks. The model is able to maximize the receptive field in order to enhance feature extraction without increasing computational expenses. Pothole detection is enhanced by different road conditions as it is experimentally determined. Automated reporting is not the primary issue to the system, but accuracy detection.

Road Surface Anomaly Detection Near-Real-Time Road Surface Monitoring, Sattar et al., 2021.

In order to observe the road conditions, Sattar and others designed near real time road surface anomaly detecting system. Their method applies machine learning to detect potholes and cracks in road pictures. The machine constantly patrols the roads and identifies the issues with a very high speed. The proposed solution does not have an automated generating complaints feature and a user-based reporting interface.

Pereira et al. (2018) established a deep learning approach of detecting potholes on the road.

Pereira and other authors proposed the pothole detection methodology using the convolutional neural network. In their approach the images of the road captured by the camera are automatically read to determine the potholes. The findings indicate how deep learning systems can be used to identify road damage. It entails large training data and cannot be implemented to the systems of civic concerns.

Yik et al., 2021: Pothole Detection in real time using Deep Learning.

Yik et al. developed a system of real-time pothole detection, which is a deep-learning-based system. Its system detects potholes sooner and more precisely, by real-time road picture analysis. Deep learning can be applied in real-time monitoring of traffic in the study. The technology is detection based and does not automatically process complaints and report issues.

Kim and Ryu (2014) studied and analysed the techniques of detecting potholes.

Kim and Ryu have studied sensor and computer vision and vibration pothole detection systems. They contrast advantages and disadvantages of road infrastructure surveillance detecting system. The study shows that the automated means of detection increase the effectiveness of repairing roads. It is not a novel paradigm that the article offers, but mainly it explores the current detection techniques.

III. METHODOLOGY

In the suggested system, the systematic routines are capable of identifying issues with the civic infrastructure automatically and generating complaints reports. It is possible to publish the photos of civil problems, i.e. potholes, rubbish and drainage obstacles, through a React.js interface. The python and FastAPI backend server scale and normalize the data sent in form of images and location. The image is used to determine civic concerns through a deep learning computer vision model. A Natural Language Processing (NLP) module generates a formal complaint report with the type and location of the problem following a geolocation APIs recognizing the problem. The ready report is addressed to the concerned municipal body to increase the speed of civic issues reporting and response.

A. Proposed Undertaking:

Potholes and other road infrastructure problems are detected by the proposed AI-CIAD system using picture analysis. Photos of the road condition are uploaded by citizens

via a web interface and processed on the backend server, which contains computer vision models. By examining visual patterns in supplied photographs, the AI detection module finds potholes and other surface imperfections. The approach will help the authorities to understand the nature and the extent of the damage on the road by identifying the area covered and categorizing the defect.

In addition to identification of issues, the system also automates reporting of complaints by developing organized reports that include information about the nature and point of issues. The reports are forwarded to the concerned administrative department and stored in the system database. Centralization of the data control, the automatic generation of the complaints and the opportunity to identify with the help of the artificial intelligence reduce the number of human reports and checks of the complaints and make the monitoring of the civic issues easier. This would enhance the smart city and infrastructure management.

B. System Architecture:

The architecture is the proposed AI-CIAD system that comprises of user interface, the backend server, the AI detection module and the database management system. The architecture begins with the user portal where people can post their pothole photos using a web interface. Upon verification of the request, the server provides the photos to the AI analysis part. Computer vision and deep learning use the AI module to obtain significant visual patterns of the surface and identify defects in infrastructure.

Once the problem is identified, the system systematizes and analyzes data. When the backend holds location information, the complaint is sent to the administrative interface and ticket management system so that the authorities can investigate, monitor and resolve problems that have been reported. It combines work verification, ward mapping, and prediction services, which should relay complaints to the appropriate department and make sure that they are resolved. The photos, discoveries, and reports on complaints submitted are stored in one database and are monitored and analyzed effectively to automate the handling of the problems with the urban infrastructure.

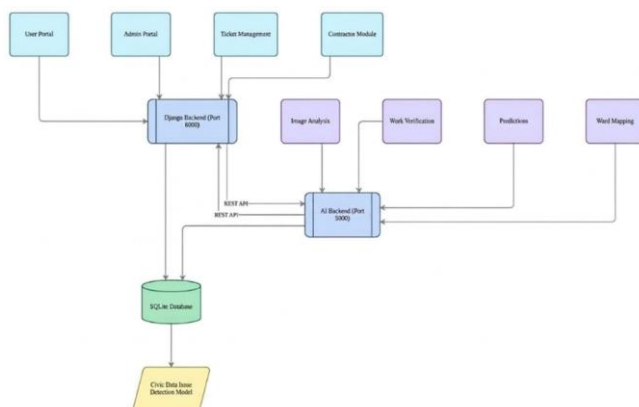


Fig.1. Architecture

IV. IMPLEMENTATION

A. MODULES:

a) User Interface Module:

People will be able to share the photos of the damaged roads and potholes with the help of this functionality. One can easily make complaints and take and post photos in the system to process..

b) Image Processing Module:

This module is employed to resize, normalize and remove noise of uploaded pictures. The model of AI detection takes images and improves the accuracy of detection.

c) AI Detection Module:

This session uses computer vision algorithms that are based on deep learning to analyze road photographs and detect infrastructure defects. It compiles significant visual features of the image and classifies identified items in order to find potholes.

d) Complaint Generation Module:

This module will automatically format a complaint report and have it created upon the identification of a civic issue. The report is provided with categories of the issue and image evidence to assist the authorities in responding.

e) Ticket Management Module:

Lifecycles of complaints are handled by this module. The database stores solutions of problems, assigns tickets to corresponding authorities and documents facts of complaints.

f) Admin Management Module:

Administrators are able to monitor the situation, verify complaints and report about the state of repair with the assistance of this module. The unresolved complaints are available and authorities can easily take action on the dashboard in response to the municipal issues.

B. ALGORITHMS:

1. Convolutional Neural Network (CNN) Algorithm

Civic concerns are automatically detected and classified from uploaded photographs using the CNN algorithm. CNN processes images with several convolution layers, and pooling layers to get edges, textures, and patterns. The features facilitate the algorithm in categorizing civic issues like potholes, garbage, and drainage blockages. CNN enhances the detection of infrastructure problems and minimizes the use of hands.

$$TF = \frac{\text{Number of times term } t \text{ appears in document } d}{\text{Total number of terms in document } d}$$

2. Natural Language Processing (NLP) Algorithm

The NLP is employed to generate report on complaints in structured form on the basis of municipal issues automatically. After the AI model recognizes the nature and point of the problem, the NLP module produces a formal complaint text or report to the municipal authorities. The automation substitutes manual descriptions of complaints.

$$IDF(t, D) = \log\left(\frac{N}{DF(t)}\right)$$

- N = Total number of documents
- $DF(t)$ = Number of documents containing term t

3. Transfer Learning (ResNet / MobileNet)

Transfer Learning is a deep learning that improves a network based on ResNet or MobileNet pre-training. The technique uses information from big picture datasets to civic issue identification instead of training the model from scratch. This method reduces the time spent on training and improves the accuracy of the model even with a small dataset.

$$TF-IDF(t,d) = TF(t,d) \times \log\left(\frac{N}{DF(t)}\right)$$

$$V_{\text{sentence}} = \frac{1}{N} \sum_{i=1}^N \text{Embedding}(\text{token})$$

3. About Dataset

These images of the road surface testify to the issues of the common infrastructure, potholes, and fractured sections of the road. Public road condition data, online resources, and images from experimental testing were among the image sources. In order to train the supervised deep learning models, the images in the dataset are labeled according to the kind of road defect. The data set contains normal and defective road images to make the computer differentiate between damaged and healthy roads.

Image scaling, normalization and noise reduction were also applied to the dataset prior to the training of the models to improve the accuracy of the detection. In order to evaluate the AI detection model, it was split into a training set and a test set. The system learned to identify the visual characteristics of potholes through the training data and its ability to predict and classify road defects was confirmed through the testing data. This data is used by the proposed system to detect potholes and automate reporting of municipal problems.

V. EXPERIMENTAL RESULTS

The suggested AI-based civic problem detection system was experimented on the surface photographs of the roads where potholes and other anomalies exist. A large quantity of road images was experimented with the trained deep learning model to determine the accuracy of pothole detection. The system detected potholes and was able to mark them during testing using bounding boxes and confidence scores. Based on the outcomes of the experiment, the model can distinguish between normal and damaged road surfaces, and they can be autonomously applied to determine the problems with municipal infrastructure. The results prove that the suggested approach can help the authorities to find the issues on a road very fast and improve the quality of infrastructure.

The technology can identify potholes on numerous road conditions and perspectives as the testing screenshots reveal. Once the visual data of the given image is received by the object recognition model, potholes are demonstrated by bounding boxes. These results on detection suggest that the suggested system is capable of predicting and deciphering actual road images in a precise manner. The AI-based detection, the development of complaints automatically, and mapping of locations make the process of civic issue reporting and smart city infrastructure management more efficient.

Accuracy: Find out real gains and losses to evaluate test dependability. Mathematics comes next.

$$\text{Accuracy} = \frac{(TN + TP)}{T}$$

Precision: Precision is a measure of positive instances or accuracy of classification. To compute accuracy, the following is computed:

$$\text{Precision} = \frac{TP}{(TP + FP)}$$

Recall: The ability of a model to predict all the situations of the machine learning category is measured by the

proportionality of the correct prediction observations (among all the positives).

$$\text{Recall} = \frac{TP}{(FN + TP)}$$

F1-Score: A good machine learning model is represented by high F1 score. The accuracy of the model is boosted by precision and recall. The relative number of times a model correctly forecasts a set of data is referred to as accuracy.

$$F1 = 2 \cdot \frac{(\text{Recall} \cdot \text{Precision})}{(\text{Recall} + \text{Precision})}$$

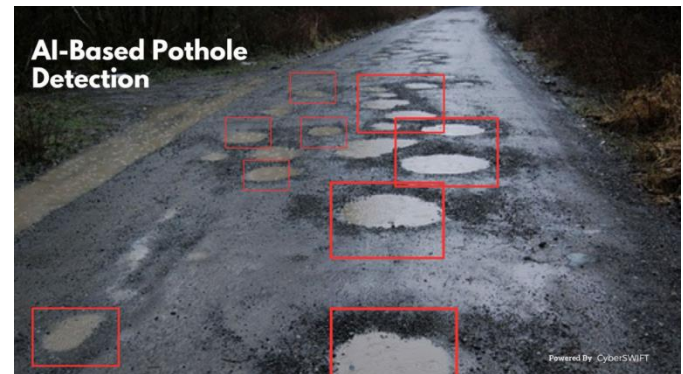


Fig 2 AI-based pothole detection output

Fig. 2 shows that the deep learning model identifies potholes after an analysis of the road image with the assistance of bounding boxes. The system will have the capability to automatically identify defects on the road and civic matters reported by automatically identifying damaged road surfaces.

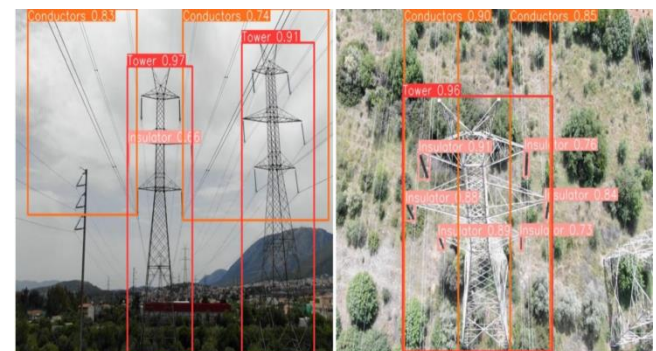


Fig 3: the object detection results for power transmission infrastructure

The AI model detects towers, conductors, and insulators with confidence ratings in the findings of power transmission infrastructure object detection. The bounding boxes show that adverse conditions can be detected with the help of deep learning algorithms to identify various infrastructure components.

VI. CONCLUSION

The Automated Reporting System based on Artificial Intelligence-Driven Civic Issue Detection System is a good tool to report on the issues in the municipal infrastructure. The system promotes communication between the government and citizens by alleviating human efforts and implementing computer visions, natural language processing, and internet utilization.

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