Manhole cover monitoring system over IOT

Wesam moneer Rasheed
Asia Pacific University of Technology and Innovation

Raed Abdulla
Asia Pacific University of Technology and Innovation

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Wesam Moneer Rasheed
School of Engineering
Asia Pacific University of Technology & Innovation (APU)
Kuala Lumpur, Malaysia
TP046026@mail.apu.edu.my

Raed Abdulla
School of Engineering
Asia Pacific University of Technology & Innovation (APU)
Kuala Lumpur, Malaysia
raed@staffemail.apu.edu.my

Low Yee San
School of Engineering
Asia Pacific University of Technology & Innovation (APU)
Kuala Lumpur, Malaysia
yee.san@staffemail.apu.edu.my

***Abstract*— Manhole recognition and monitoring is one of the essential needs for modern society, particularly smart city plan. The idea of this project roots in fact that missing or stolen manholes results in various road accidents and it shrinks the quality of city. The major challenge in this research is to investigate a method in recognition of manholes and further investigation on the condition of manhole on road. The report can be simultaneously updated in IOT platform which can be further used with other applications such as WAZE or Google MAP. This method uses Naïve Bayes classifier to train dataset and detect as well as recognize the missing manhole on road. This project has three main components including 1) Recognize manhole on road, 2) Detect missing manhole, and 3) Update the coordinates to IOT platform. The software used for image processing was MATLAB. The coordinates were obtained via Arduino Mega and SIM808 GSM modem to updates the missing manhole covers coordinates on BLYNK IOT. The result obtained from the accuracy of the Naïve Bayes classifier indicates that the system can perfectly detect the missing manhole with total accuracy of 85%. The True Negative Rate (TNR), Positive Predictive Value (PPV) and False Discovery Rate (FDR) were found to be 80%, 90%, and 10%, respectively. The data shows that the system results in 100% accuracy in detection for speed of below 20 KMPH. The result indicates that the camera can varied from 30 to 42 degrees while obtaining best result without any misdetection. The rate of recognition for the system with 30 fps is found to be 71.58% by dividing the total time for processing a frame over the total frame time duration). The Latency test in obtaining the coordinates indicates that the proposed system takes 4.724 seconds in average to obtain the coordinates from GSM modem.**

***Keywords*— *Manhole cover, microcontroller, google map, smart city application, arduino, Internet of Things*.**

I. INTRODUCTION

Every From a couple of years, the failure of Manhole Cover (MC) is gaining more importance than ever. Failure of MC can have severe impacts on economy, security and safety of a region. Traditional methods of control measures cannot fill the void that has been created from a number of incidents in city areas. Therefore, there is a need of full automated monitoring systems and it has now become the part of smart cities development [1].

In most of the smart city applications, Internet of Things (IoT) devices are being employed for automatic monitoring systems [2-5]. Monitoring of manhole cover is gaining more importance in IoT applications. Issues relating to manhole cover affects the security, safety and economy of a society. A number of challenges rise, as there are just 30% MC monitoring systems based on automatic structures, which need to be extended from circuit design point of view [6].

Development of smart cities and implementation of automated manhole covers has gained much importance in previous years. A number of incidents occur regarding the safety and security of people due to the issues of manhole cover (MC). Uncovered holes pose a great challenge to citizens and can cause safety hazards to underground structures. To prevent accidents from manhole-cover an intelligent manhole cover management system has been introduced as a basic platform in smart cities [7].

Developing cities usually do not focus on opened manhole covers and are not monitored properly. These manholes can be a great threat to lives and assets in a number of ways. Manholes can be filled with some toxic and hazardous materials and underground structures can get affected from these materials. Systems need to be developed to monitor the lids of manhole covers to avoid accidents. Developments are made to replace traditional and manual methods with IoT based automated monitoring systems [8].

The issue of poorly managed and stolen gas well covers is becoming an alarming situation in different countries. The existing manhole cover systems are found to be covering single monitoring parameters, have immature technology and contain inefficient analysis capabilities to find and eradicate issues regarding manhole covers and security. The traditional methods of manhole cover protection and monitoring cannot cope with the challenges of increasing population and underground infrastructures, therefore, there is a need to develop more automatic systems of monitoring [9].

To detect the issues regarding manholes, a system with Global Positioning system (GPS) has been developed based on ultrasonic sensors and accelerometers to detect manholes accurately. For monitoring of the road, the sensor-based system detects the vehicles and provides data to cloud system continuously. This system helps drivers to avoid manhole on the road and provide them with alarming alerts. The sensor-based system also provides useful data to Highway Maintenance Department in a smart city. This proposed method employs accelerometer and ultrasonic sensors. The data obtained from sensors is processed and analysed through Honey Bee optimization algorithms. This system can also provide information of any accident occurred on the road to save other vehicles from its effects. A survey report showed that in India, nearly 50% of the roads are damaged because of manholes and can cause dangerous impacts on humans and vehicles. The sensor-based systems are seen to be more fast and liable modes of manhole detection [10].

Another method of manhole detection is Light Detection and Ranging (LiDAR) which works on infrared rays for detection. A 2D and 3D LiDAR system can be developed based on camera detection to detect manholes. This system is connected to a computer imaging program to detect manholes. Detecting systems can get affected by harmful electromagnetic waves, so in this case, the LiDAR system can be employed for detection. LiDAR system is a laser scanning technique and requires less cost and maintenance. A computing system is employed based on Raspberry Pi module for detection of manholes. Image-based detection technique is developed which can perform a number of tasks like controlling the images and noise filtration while detection manholes [11].

Another innovative smart technology for detecting manholes is image processing by using a camera and it can directly be inserted into cars and other vehicles. A number of image processing modes can be employed based on python Language from Open CV library and can be installed on cars and vehicles to detect manholes ahead on the road. One mode of image processing technique is the use of smartphone accelerometer. An automatic report or data can be generated by detecting a manhole in this technique by employing a Web server. The proposed system can find out the specific location of a manhole on the road and provides its information to the server, where it is processed and then sends the report to the user or vehicle driver. An LED light signal is indicated in this system on the location of manhole to given an alert to the driver on road [12].

Most of the reviewed studies have proposed their system in detection and monitoring existence of pothole on the road [11] and [13] while other studies have proposed a monitoring system based on the pre-known location manhole on the road [7-9]. Therefore, there is gap in this field of research in finding or detecting the manholes in the first place. The recognition of manhole on the road requires sophisticated system which can be attached to cars and bikes on the road to report automatically a missing manhole on road. Detection of manhole and differentiation of manhole from potholes is the key challenge to overcome in this study. Finding manhole on road can also drive other features of the proposed system where the manhole's lid is missing or the manhole's lid is not properly placed which can prevent many accidents and vehicle damage that is the major concern in smart cities.

Most of proposed systems requires a pre-phase step where government shall equip all the manholes with certain systems proposed in studies of [1]. Therefore, the proposed systems are expensive in implementation. The major challenge in reduction of this cost is to introduce a portable system that can scan manholes on the road and report missing or stolen lids.

The sensor-based detecting systems are usually developed for short range detection, up to 50 cm and with less accuracy for detection of pothole and manhole. In the study of [14]; and [15] a sensor-based system was proposed to detect and report the presence of pothole on roads to cars and vehicles. This system is less reliable in terms of safety of the driver and carrier. Sensor-based systems are weak in technology of detection and are not capable to detect the whole surface of the road. An ultrasonic sensor can detect the distance of a carrier from the pothole on road in the range of 2cm to 400cm. The sensor is placed at 30 degrees which can provide 50% coverage of the area or a half portion of 400 cm3. This system is not suitable for a single lane with 3 meters of width.

Laser-based system also contain a number of issues regarding the speed of vehicle and error in estimation of width and depth of pothole or opening of a manhole. Study of [11] and [13] , have tested this system with a speed of 2KMPH for pothole detection, which is not applicable speed for a vehicle to run on the road with this speed. Error rate is higher in results due to which the laser-based system is not liable. If the detection system run with a speed more than 2KMPH, the error rate increases in pothole detection. So, the system becomes irresponsive on the speeds more than 2KMPH and becomes unstable. A number of techniques have been proposed based on vision systems to detect pothole by employing 2D images and videos [16]. Other researchers proposed a process of asphalt surface imaging technique [17]. This method proposed the use of segmentation of region based on histogram and spot filters. This process established an advanced process to convert images into videos.

Therefore, the main objectives of this research is to develop a manhole detection and monitoring system based on computer vision and image processing techniques in MATLAB environment and to integrate the proposed system with IOT interface.

II. PROPOSED SYSTEM METHODOLOGY

This research uses a camera (Logitech C170) to captures frames from road surface. The camera is directly connected to PC running MATLAB R2020a software. The frames are further processed (by applying Naïve Bayes machine learning algorithm) to detect and recognize missing manhole.

In order to retrieve the GPR3S location of missing manhole, SIM808 GSM modem is used. The GSM modem is powered by a 12v battery. In order to stabilize the voltage, a step down converter is used which can regulate the voltage at 9v DC for the SIM808. The external battery is used in this system due to the high power required by SIM808 in communicating with IOT platform. Arduino Mega is connected to SIM808 GSM module. In order for SIM808 to communicate with Arduino Mega, both boards must have same ground. The Rx and Tx pins of SIM808 GSM modem is connected to serial 1 (pins 18 and 19, respectively) of Arduino Mega.

The communication between Arduino Mega and PC (Computer vision block) is using a serial cable. This communication is designed to be unidirectional from MATLAB to Arduino Mega only.

In the proposed system, there have been TWO (2) main blocks which include;

1) Recognition of manhole through computer-vision approach: the camera is utilized in this technique which can capture 30 frames per second and these frames are then processed to detect the absence of manhole. A Naïve Bayes classifier is employed to prepare and filter the frames obtained. MATLAB software is used to flag-up the absence of manhole.

2) Localizing the missing manhole: The location of manhole shall be updated on MAP. This feature of system can be further used by various GPS navigation software app such as Google Map and WAZE to show the missing manhole on road to prevent accident. The localization requires system to get the coordinates of the missing manhole via the GSM/GPRS module and update the location on Map on IOT platform.

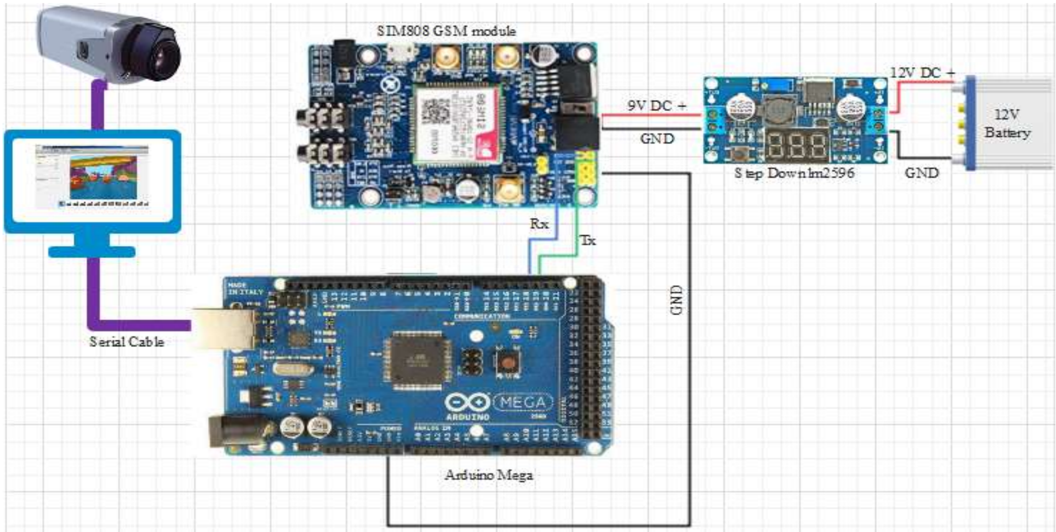

Fig. 1. Circuit diagram of the proposed system

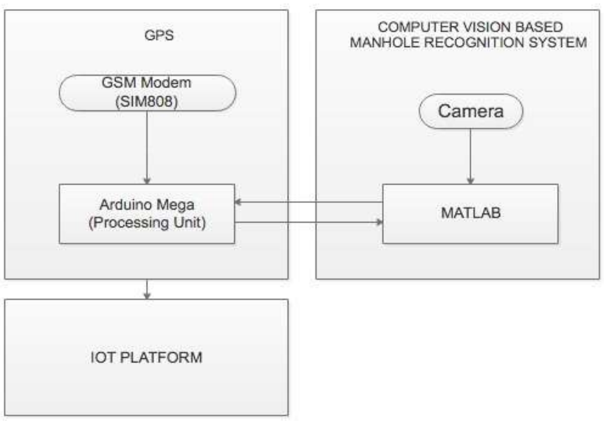

Fig. 2. Manhole cover monitoring and recognition system block

For manhole detection through computer vision system, the camera need to be placed on the center of a car. The camera shall be placed at about 30 degrees with respect to the surface of road on the car.

Naïve Bayes classifier and HOG feature extraction: In the discussed system, the main machine learning concept is based on feature extraction of HOG and Naïve Bayes classifier. This classifier provides more speed in recognition process as through bicycles the detection of pot-holes could be dismissed by acceleration. In the given system, camera is set to generate 30 frames per second and total of 17 frames are processed per second.

The undergoing project was supervised through computer-vision system and processed through sensor techniques by attaining various samples from road. A manhole can develop a blob region of 1/8 of the whole frame size.

Bilateral filtering to smooth asphalt: The recognition speed could be lower on enhancing the filtration layers and the asphalt noise can also be reduced through proper filtration. Therefore, a bilateral filter was employed to smooth the road. A certain section of the road is cropped through bilateral filter on a far sight of the camera where asphalt particles are small to smooth the rest of the road with a same color. It is said to be a smoothing bilalteral filteration by L*a*b color space. In case of a small cropped image, processing time can be enhanced through bilateral filtration process. Better smoothness can also be attained from a small sized image.

Video Processing (Real-time recognition of manholes): To detect manholes with a continuous process, frames need to be processed within less processing time with installed cameras on cars or roads.

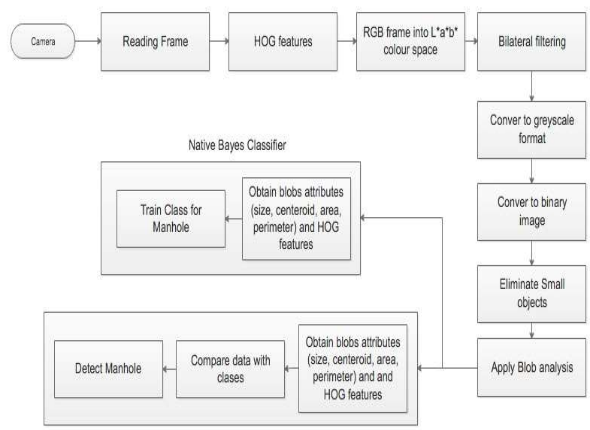

Fig. 3. Block diagram of the computer vision system for Manhole recognition.

The MATLAB interface provides user to communicate with Arduino by defining the COM port. The upper panel is the wireless network system where user can add the COM port and press on “connect To Arduino” button. If the connection is successful, a green tick sign will appear on the yellow axis right next to the communication port. The device will automatically assign the port number for the camera to system by default.

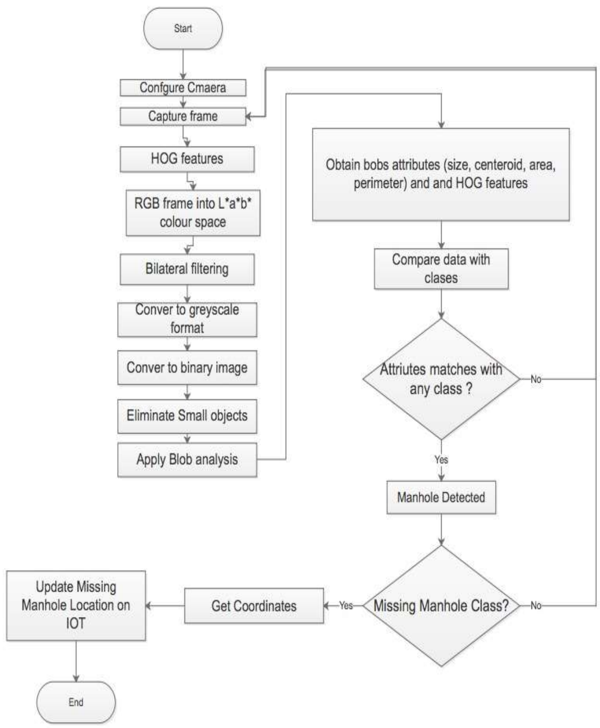

Fig. 4. Manhole recognition system flowchart based on computer vision

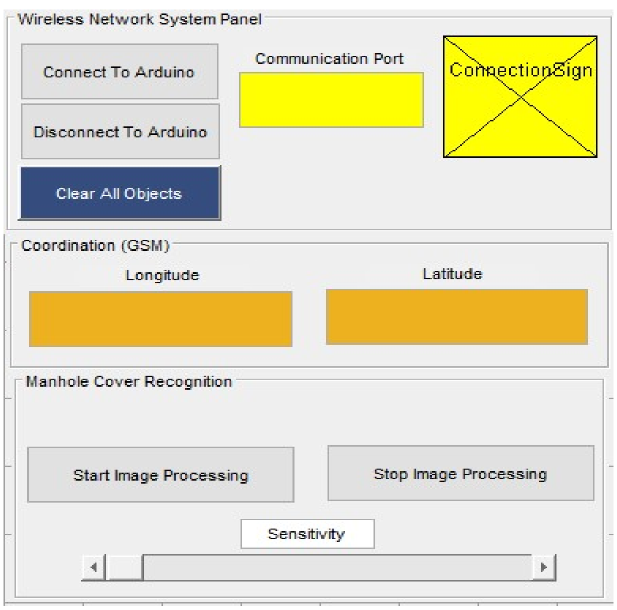

Fig. 5. Control panel of system

III. TESTING AND RESULTS

A) *Accuracy of pothole detection with computer vision technique*

The test indicates the efficiency and accuracy of the proposed method in recognition of missing manhole cover. This test will considers that a car with speed of 20 KMPH is moving on road to detect missing manhole covers. The speed of the car was both controlled with the odometer of vehicle and WAZE application. In this test, a sedan car is used. This test considers 20 samples. In each sample, manhole covers exists. In some samples, the manhole cover is lid off for the sake of testing in this project. The duration of this test will be 10 second per samples. The evaluation of the classifier will be based on following:

- True Negative detection: If the entire test (sample) has not mistaken in detection while there is manhole cover. The value of 1 will be appear in the table if this error happens.
- False Negative detection: Manhole Cover was missing and it was ignored by program.
- False positive detection: Program flagged missing manhole cover while the manhole cover was on its place.
- True Positive detection: Manhole cover was missing and it was perfectly detected by the program.

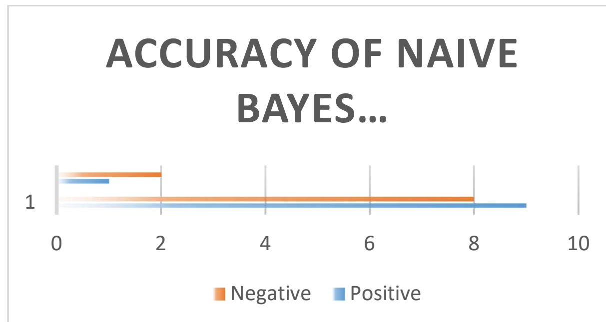

Fig. 6. Naïve Bayes classifier Performance (True = 1 & False = 0)

The result obtained from the accuracy of the Naïve Bayes classifier indicates that the system can perfectly detect the missing manhole with total accuracy of 85%. The True Negative Rate (TNR), Positive Predictive Value (PPV) and False Discovery Rate (FDR) were found to be 80%, 90%, and 10%, respectively.

B) *Misdetection with respect to Car speed*

This test is designed to test the accuracy of proposed system with respect to speed of car. In this test, the car's speed increases from 5 to 8, 10, 15, 20, and 30 KMPH. There will be 5 sample per each speed. In each sample, the accuracy of detection of manhole cover as well as the accuracy of system in recognizing missing manhole cover will be observed and the data will be collected.

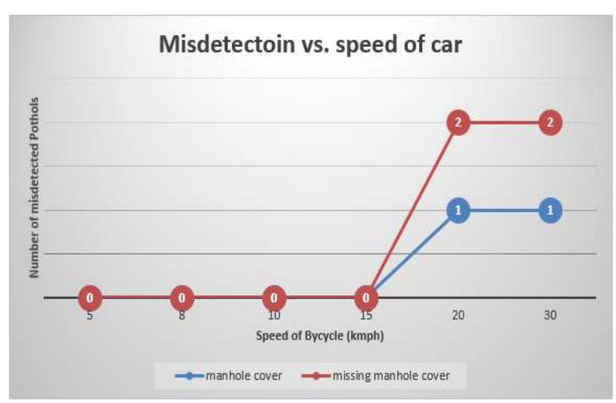

Fig. 7. Misdetection of system versus the speed of car

The speed of the car was both controlled with the odometer of vehicle and WAZE application. In this test, a sedan car is used. Speed of the car increases from 5 to 8, 10, 15, 20, and 30 KMPH. The image processing is activated on MATLAB. In this test, the coordinates and IOT update is neglected. In each observation, the result of system in detecting a manhole and missing manhole will be logged on excel file.

The data shows that the system results in 100% accuracy in detection for speed of below 20 KMPH. However, the number of misdetection for manhole cover was raised to 1 for both speed of 25 and 30 KMPH which drops the accuracy of system to 80%. The number of misdetection for missing manhole cover was also raised to 1 for both speed of 25 and 30 KMPH which drops the accuracy of system to 80%.

C) Coverage distance of manhole cover detection

This test will show what angle is perfect for camera to face the road surface. The higher angle will have very poor concentration on road and the manholes in far distance will be likely detected (in which it is highly depending on the perfect distance of which the manhole cover is detected in this system). The best angle must cover 80% of pixels by road surface. However, if the angle of camera is lowered down a lot, the distance of detected manhole will be very close to car which may result in misdetection as well. The initial angle of camera will be 30 degrees and the angle of camera will be increased up to 46 degrees. This system will take a sample for each angle. The initial angle of camera will be 30 degrees and the angle of camera will be increased up to 46 degrees. The system's performance will be evaluated based on:

- Misdetection: System missed a manhole on road or it wrongly detected a manhole on road while it was not exist.
- Total True detected manhole: The missing manhole cover was detected correctly.

TABLE I. MANHOLE COVER DETECTION COVERAGE DISTANCE

Sample	Angle of camera	Distance	misdetection	True Detection
1	30	5	0	1
2	32	5.4	0	1
3	34	5.9	0	1
4	36	6.3	0	1
5	38	6.8	0	1
6	40	7.2	0	1
7	42	7.6	0	1
8	44	8.3	1	0
9	46	9.1	1	0

The result indicates that the camera can varied from 30 to 42 degrees while obtaining best result without any misdetection. This can result in detection of manhole in distance of 5 to 7.6 meters away from car. However, increasing the angle to 44 and 46 onwards results in misdetection mainly due to ignoring the manhole cover. This is due to the very poor concentration on road as only 10% of pixel is associated to the road.

IV. CONCLUSION

A remote sensing method is proposed to detect manhole and recognize missing manhole on road. This method uses Naïve Bayes classifier to train dataset and detect as well as recognize the missing manhole on road. This research has three main components including 1) Recognize manhole on road, 2) Detect missing manhole, and 3) Update the coordinates to IOT platform.

The machine learning concept used in this system is based on Naïve Bayes Classifier and HOG feature extraction. The main reason to select this classifier is to speed up the process of recognition as manholes can be dismissed by acceleration of the car. In this method, total of 17 frames are processed per second while the camera is set to resolution of with 30 frames per second. This project was based on supervision as the criteria of a possible manhole cover was practically computed and processed with various samples from road. Usually a manhole cover will create a blob region that is 1/8 of the size of whole frame. Therefore, small potholes have been ignored in this system to increase the processing time.

The result indicates that the camera can varied from 30 to 42 degrees while obtaining best result without any misdetection. This can result in detection of manhole in distance of 5 to 7.6 meters away from car. However, increasing the angle to 44 and 46 onwards results in misdetection mainly due to ignoring the manhole cover.

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