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Manhole Detection using Image Processing on Google Street View imagery

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Abstract—Manholes are an essential part of the maintenance of both sewer lines and stormwater drains which are an integral part of rainwater management during monsoons. Open and broken manholes have been a cause of loss of life and injury for many years especially during rains when flooded roads cause low visibility. The positioning of said manholes according to other architecture such as metro stations, buildings and bridges shall endorse careful infrastructure management and help build efficient utility networks. The current methods used for keeping track of public utility networks lack technologies that can effectively eradicate human error while data management such as data-logging, database duplicity managers and de-seasonalization of manhole status data. Present methods involve heavy fieldwork to keep the map and status of manholes updated. Google street view images can be used to detect these manholes. This paper presents a method to detect manholes on a location basis. Its implementation can be supplemented with avoidance of the path of the manhole in times of emergencies and adversities. The areas explored in this paper are image pre-processing, detection methodology and correlation model. For pre-processing the images bilateral filtering, equalized histogram and Canny edge detection methods were used. After pre-processing the images, contour detection with convex hull method was deployed. For further detection, a method that uses pixel-wise iteration to eliminate undesirable contours was used. Finally, a regression model was created for finding a relation between the distance of manhole from the point of image capture and the area of the manhole in the image. This process can be further extrapolated for obtaining the GPS co-ordinates of the manhole.

Index Terms—Manhole Detection, Image Processing, Google Street View, Regression, Edge Detection, Histogram Normalization

I. Introduction

As a part of the extensive city planning and infrastructure alignment, a major chunk of work goes into streamlining the water lines and the flow of excess water for the sewage. The present model of working stormwater drains and sewage lines generate a huge network of manholes which in the recent past have become great causes of life hazards, especially in developing countries. The number of reported deaths in India in the year 2016 stood at 17278 and 19092 in the year 2017, a 10.5% increase year on year [1]. With the advent of private entities like Google LLC in the digital footprint space, locally updated high-resolution imagery is readily available. Underground utility networks need to be assessed while city planning and re-planning [2]. This has created an opportunity for extrapolation of that imagery for creating user-friendly applications for detecting and alerting users in times of emergencies. Furthermore, the record-keeping and mapping of utility spaces in cities across many countries has been done using inefficient methods and hence create inaccurate records and misinformation [3]. Finding information from these records has become a hassle. To ease this process, image processing techniques could be used to detect these manholes and enable state officials as well as the common man to be updated with the network of these sites [4]. This will help the officials to keep track of the utilities whereas for the common man, it would be a single information point for all the locations that need to be avoided in times of heavy rainfall or when drains overflow. The idea is aimed to reduce dependency on analog information stored in the form of paper records. Continuous mapping and infrastructure management based on the proposed solution paves a way for real-time condition assessment and resource administration [5].

Based on the current state of affairs in the resource allocation and management strata of utility network systems especially in metro cities, there is a need for a more technologically advanced and geographically scalable method to encapsulate geo-referencing of said manholes. The proposed methodology intends to create a database of manholes and provide updates on the same user information status available there.

Apart from bringing in new techniques to aid planning of manholes, the methodology also presents a great opportunity for utilization in other public sector undertakings for their betterment in terms of facility management [6]. Since the technologies make use of various image processing methods, which are yet to be exploited to their fullest potential by state facilities in many developing countries for resource management, the paper provides a model for adoption of more technically advanced methods for public resource administration.

This paper presents a methodology to create a database of the network of utility chambers and their location which can be accessed easily in the future. The images are acquired along with their co-ordinates from Google Street View Imagery.

Image processing techniques are then used to subtract extra information from the image, create a framework for outlining the detection of manholes and calculate the area. After the detection, the distance between the manhole and the point where the image is taken is calculated using the coordinates acquired. Then a regression model is created which is based on the distance and the area calculated, this is further used for predicting the position of the manhole based on the area. This paper aims to map existing manholes and store them in a database for capturing manholes and is not intended to be a real-time method.

II. METHODOLOGY

A. Functional Block Diagram

Fig. 1 describes the overall flow of the proposed methodology. The methodology was divided into three parts. First is pre-processing, which consists of preparing the field for taking input of images and do filtration of noise and unwanted detection. The second step is manhole detection. In this step, contours were drawn around likely candidates for being a manhole in the image, and then several methods were applied to eliminate contours to narrow down to one contour. The last step is creating a regression model to increase the accuracy of calculating the distance using GPS coordinates. The flowchart gives a visual understanding of some of the key decision points and design choices made in the methodology. Every block is a functional step and cannot be replaced without affecting the basic functional integrity of the method. This modular approach to the methodology allows for ease in planning future changes in functionality and flow to increase efficiency and integration with other supplementary methods.

B. Dataset

Three types of images are used to obtain the exact coordinates. The images and the coordinates are acquired through Google Street View. The first type of image is taken on the manhole to get its coordinates. The second type of image is taken at a distance of 1 meter from the manhole. The third type of image is taken at a distance of 2 meters from the manhole in the same direction as the first and the second type of image. The coordinates of these three types of images are stored separately for creating the regression model.

C. Pre-processing the Image

The images are processed to obtain clear contour detection with a high degree of accuracy. A combination of several techniques has been used to achieve this goal. For filtering,

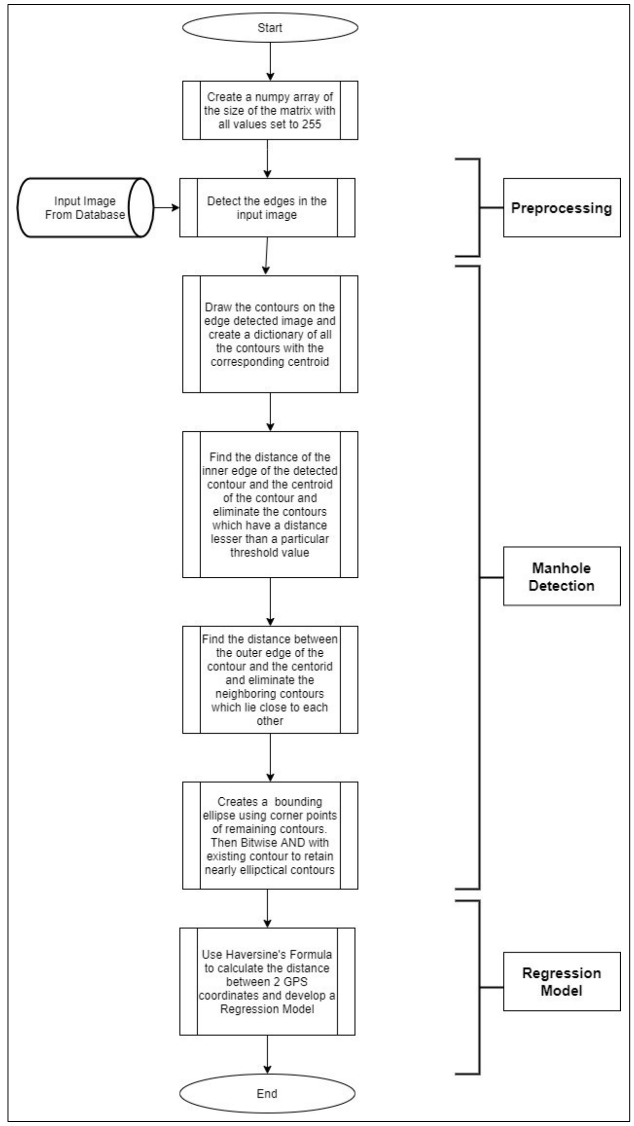

Fig. 1. Flowchart of the Proposed Methodology

several methods like average filtering method, mean filtering method and bilateral filtering method were used but ultimately, the bilateral filtering method was preferred over the other methods because this filter reduces the noise associated with the images while preserving the edges at the same time. This way sharper edges are obtained while performing the Canny edge detection which is described later [7].

The second step is the use of equalized histogram method. A histogram is a graphical representation of the total number of pixels varying intensity. For a non-equalized image, there are some intensity values around which maximum pixels are clustered. By normalizing this histogram the intensity values is spread equally across the image i.e. stretching the intensity range of the image. This improves the overall contrast of the image improving the contrast of the very low contrast regions closer to the average contrast value as done in [8]. Fig. 2(a) shows the original image, Fig. 2 (b) shows the normalized image obtained after histogram equalization, Fig. 2(c) shows the original histogram of the image and Fig. 2(d) shows the normalized histogram of the image.

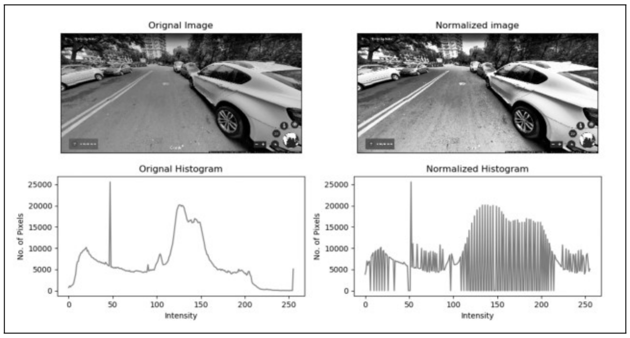

Fig. 2. a) Original Image b) Normalized Image c) Original Histogram d) Normalized Histogram.

This is followed by the use of canny edge detection [9] to detect edges of objects in the image. To make it easier to filter the edges, a final step where space in between the edges around extremely small objects detected are filled is applied so that they are not detected in further steps reducing the number of stray detection. Fig. 3 shows the output image obtained after applying all the above mentioned methods which are used to pre-process the image.

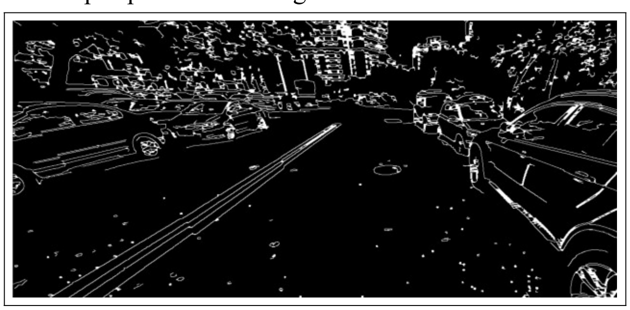

Fig. 3. Output obtained after pre-processing the image

III. Manhole Detection

Once the pre-processed images are obtained, the contours of the images are stored along with the centroid of each contour. To obtain smooth and continuous contours and prevent any false detection, convex hull algorithm [10] is used to detect these contours. The smallest convex polygon that can be formed by enclosing all given points is known as a convex hull. The algorithm works by dividing the given set of points into two halves, forming convex hulls and joining the uppermost and lowermost tangents of the two halves. The divide and conquer technique is used to break down the data set into a set of at least 5 points in each half and then working up to the final contour [11]. The distance between the centroid of the contour and the inner edge of the contour in four directions is computed by iterating over each pixel in these directions. Based on the distance calculated the smaller and the larger contours are eliminated and only the contours which are comparable to the size of the manhole remain in the image. Fig. 4 shows the output image obtained after elimination of the smaller contours using the above mentioned procedure.

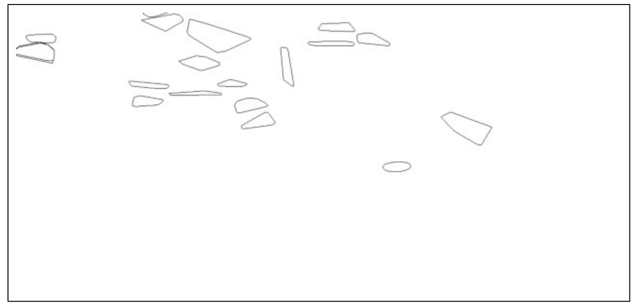

Fig. 4. Output obtained after elimination of smaller contours

Then, a similar procedure is used to eliminate all the contours which are very close to each other. The distance is now computed by iterating from the edge of the image until a neighboring white pixel of the contour is detected. This is done in all four directions. The contours which lie very close to each other are now eliminated as shown in Fig. 5.

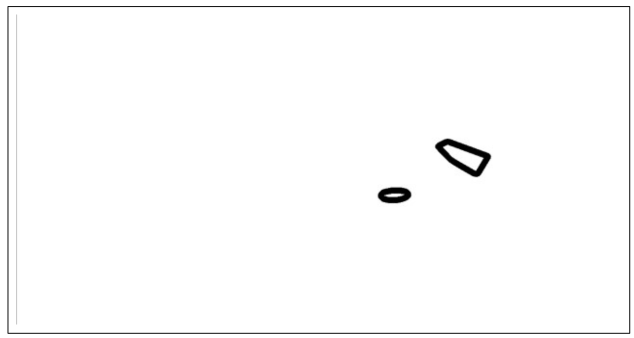

Fig. 5. Output obtained after elimination of neighboring contours

To eliminate the additional contours further, a bounding ellipse is drawn for each contour and a bit-wise AND operation is used with the previously obtained image. Since the shape of the manhole in the image is like an ellipse the other contours are now eliminated and only the contour of the manhole remains in the image. Fig. 6 shows the final output obtained after using bit-wise AND operation to obtain the isolated contour. Fig. 7 shown below

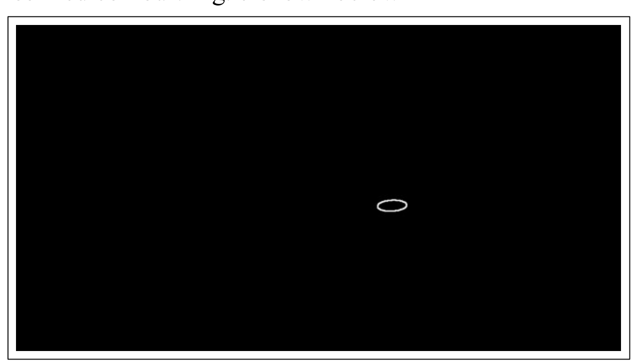

Fig. 6. Output isolated contour obtained

shows the final output showing the detected manhole in the original image.

Fig. 7. Output isolated contour obtained

Once the manholes are detected in the image, the areas of the manholes are computed. After computing the area, the distance between the manhole and the point from where the image was taken is computed. In the past Haversine formula has been used for finding location-based distance calculations. The same formula has been used for our research [12] [13]:

$$d = 2r\arcsin\sqrt{\sin^2\left(\frac{\phi_2-\phi_1}{2}\right) + \cos(\phi_2)\cos(\phi_1)\sin^2\left(\frac{\lambda_2-\lambda_1}{2}\right)} \quad (1)$$

Upon calculation of the positional coordinates, a regression model is used to map the area of the manhole against the distance. This model can be used further to calculate the distance based on the area of the manhole detected. Fig. 8 shows the regression.

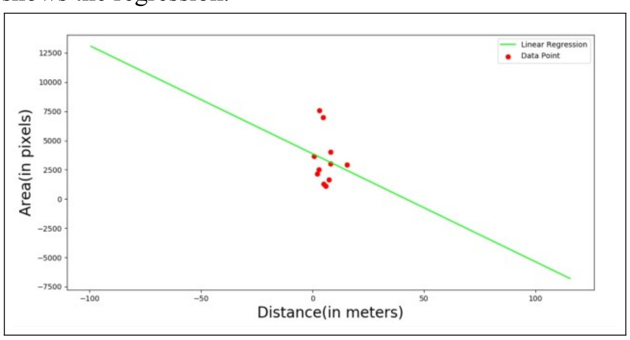

Fig. 8. Regression Model output

IV. Results

As a result of the application of above-mentioned techniques, a high rate of success has been witnessed while detecting the manholes.

In coherence with the detection mechanism, images were tested from 1 particular zone. The results obtained from the zone showcase that a fraction of images (3 in the case presented) were falsely detected due to the inability of the mechanism to segment the images based on their complex compositions. The images were selected based on different picture compositions that may be tackled if more diverse applications of this procedure are extrapolated. It allowed the mechanism to get exposed to different topographies and/or light compositions which commissioned a more comprehensive outlook about the mechanism's practical applications and future use. A success rate of 81% was observed while locating the precise location of manholes.

The results of the manhole detection for the said zone are indicated in the table(Table I) below.

TABLE I
Manhole Detection Results

Parameters	No. of Images
Total no. of Images	16
Detected Manholes	13
False Detection	3
Detected Manholes(%)	81%
False Detection(%)	19%

V. Conclusion

There were two main objectives for this paper. The first was to detect the manholes from street view imagery. The major difficulty faced was distinguishing these manholes from other objects which are present on the street and background of the image. The removal of stray contours detected especially due to the foliage was the most challenging aspect. The second objective was to a pinpoint the location of detected manholes on a map based on the GPS coordinates of the point from where the image was taken and the distance of that point from the manhole. Further work can be done to generate coordinates of detected manholes. This will be made possible by using the relation that can be generated between the distance from which the image of the manhole was taken and the area of the manhole as detected in the picture. By carrying out extensive testing a better correlation can be obtained. The database allocation mechanism will allow users to access information about pinpointing the location of said manholes which can be avoided during travel in times of adversities such as floods. This paper can be further built upon, to create user alert system and interface. Once the locations of manholes have been mapped, it can be stored on a database. User locations can be accessed via an app and when a user is in proximity, a warning can be sent to the phone or any wearable device.

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