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# FPGA Based Intelligent Potholes Detection System

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**ABSTRACT:** The objective of this project is to develop a low cost vision-based driver assistance system over FPGA, to provide a solution of detection and avoidance of potholes in the path of a vehicle on road. We propose a conceptual framework where a centralized system detects and assists the driver to avoid potholes on roads. The system also identifies the potholes which are to be repaired immediately. The project will use an FPGA model to deploy image processing algorithms efficiently so that the output can be achieved in real time.Pothole avoidance may be considered similar to other obstacle avoidance except that the potholes are depressions rather than extrusions from a surface. A vision approach was used since the potholes were different visually from the background surface. The basic idea of this system is to detect the pothole at a distance from which driver is driving the vehicle, to alert the driver if pothole is arriving in the way to reduce the speed of the vehicle or take another path as well as to alert the local road development authorities for immediate repairing.The detailed description of the system based on image processing developed to process and analyze the dataset captured using the camera that gives high efficiency and accuracy compared to the conventional methods of pothole detection.

**KEYWORDS**: Pothole; Image Segmentation; Edge Detection; FPGA

## I. INTRODUCTION

Municipalities around the world spend millions of dollars to maintain and repair their roadways damaged due to potholes. A pothole refers to a shallow pit on a road's surface, caused by activities like erosion, weather, traffic and some other factors. These anomalies when accumulated in the transportation system, constitutes to major problems. While driving in the night just the headlights might not suffice in assisting the driver to detect the presence of the pothole. Many other unexpected hurdles on road apart from potholes may cause severe consequences. Abysmal road conditions cause wastage of precious fuel, wear and tear of the tyre and damage to the vehicle. These problems, even though they appear to be less significant at an individual level, constitute to major problems when taken in cumulative, collective and large scale manner. The problems constituted by these potholes result in low fuel economy, accidents, traffic coagulations etc, which have an adverse impact on the economy of a country and day to day life of citizens.

All these reasons demand that it is important to collect information of such bad road conditions and through a series of processing and analyzing the obtained information, appropriate conclusions are derived which in turn, warn the driver. It can be proved that the traffic system can be bettered to a greater extent when these problems are checked and taken care of. Detecting and hence avoiding potholes may reduce the fuel consumption, wear-tear and maintenance cost of a vehicle. Also, avoiding potholes increases road safety and indirectly decreases the total travel time in some cases.

Here we propose a novel conceptual framework where the detection, avoidance and maintenance of potholes are taken care of to a great possible extent. In the information gathering phase, a vehicle with a camera mounted on its front end travels along the road, thereby capturing images of the road. Henceforth in the analyzing phase, this data will be processed by an algorithm to detect potholes along the path travelled earlier by the vehicle. It is this algorithm which will determine the reliability of the pothole detection by the system in place. It makes use of equipment already present on the vehicle, like GPS. The data is collected from many vehicles, aggregated and analyzed at a central location and the assessment results are displayed interactively to facilitate road maintenance operations.

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Our system accounts for a better, faster and reliable method in detection, avoidance and maintenance of potholes. Thus this architecture based on FPGA model to deploy image processing algorithms efficiently, when employed brings about a radical change in existing roadways transportation system.

## II. RELATED WORK

There are several vehicular sensing methods for pothole detection. Some of these use accelerometers or lasers for data acquisition. This section contains a short review ofpothole detection and avoidance algorithms implemented.Some techniques use image processing for the detection.The said application is utilizing image-processing and pattern recognition methods designed and modified to the needs andconstraints of road analysis.The study proposes that the autonomous vehicle system is a demanding application for our daily life. The vehiclerequires on-road vehicle detection algorithms. Given thesequence of images, the algorithms need to find on-road potholes in real time. The authors propose detection of potholes on the road from stream of video frames.The technique here is an edge detection technique for extraction of pothole areas on the road.In this paper, we discuss a solution for detection and avoidance of simulatedpotholes in the path of a vehicle operating in anunstructured environment.The author presents a robust and real time approach to detect and avoid potholes in urban streets and other roads based on generating a topview of the road.

## III. PROPOSED SYSTEM

The serve of automobile accident statistics in the world accounts that, despite the declining number of fatalities, the number of accidents readily increasing resulting in serious injuries or even death. The one of the major cause of traffic accidents is “Improper Driving” due to driver’s inattention and fatigue. Also the other major contribution to these mishaps on roads is the increasing rate of defects on these roads. These defects are a result of the increasing amount of traffic and the climatic conditions, both of which can not be changed.

Fig : Example defects cracking, pop-outs, wear and polishing and potholes

There are various types of defects possible on the roads some of them can be stated as :

- Cracking : Areas where the road surface has been split apart, classified as longitudinal transverse and crocodile or combination cracking.
- Pop-outs : Areas where pressure from blow has forced the surface of the road to be raised.
- Wear and Polishing : Areas of smooth black tar occurring on asphalt surfaces.
- Potholes : Areas where there is an absence of asphalt or a hole. Potholes usually emerge from areas where there has been severe cracking.

From the above different types of defects, the one of particular interest and the problem at hand are the potholes. Early detection of cracks in road surfaces, allows maintenance to be performed before cracks develop into more serious problems, such as potholes and pop-outs.

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Here we propose a novel approach where a centralized system detects and assists the driver to avoid potholes on roads. Our system accounts for a better, faster and reliable method in detection, avoidance and maintenance of potholes based on image processing developed to process and analyze the dataset that gives high efficiency and accuracy compared to the conventional methods of pothole detection.

## IV. METHODOLOGY AND IMPLEMENTATION

### 4.1 *Block Diagram of the System :*

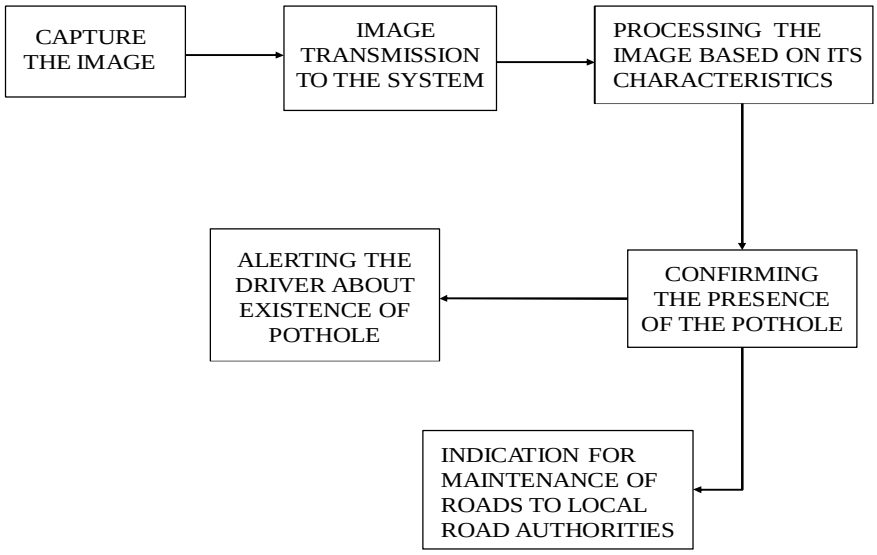


Fig.: Functional Block Diagram of The FPGA Based Intelligent Potholes Detection System

### 4.2 *Approaches for Pothole Detection using Image Segmentation*

Image segmentation is the process of partitioning/subdividing a digital image into multiple segments or sets of pixels regions also known as super pixels. The image segmentation is based on measurements taken from the image and might be gray level, color texture, depth or motion. The result of image segmentation is a set of segments that collectively cover the entire image.

The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. All the pixels in a region is similar with respect to some characteristic or computed property, such as color, intensity, or texture. With respect to some characteristics adjacent regions are differ. Image segmentation is typically used to locate objects and boundaries like lines, curves, etc. in images.

Edge detection is one of the frequently used technique in digital image processing. Edge detection produces something like a line drawing of an image which highlights the intensity changes. In general, the boundaries of objects tend to produce sudden changes in the image intensity. For example different objects are usually different colors and hues and this causes an image intensity to change as we move from one object to another. In addition, different surfaces of an object receive different amount of light, which again produces intensity changes. Hence the intensity information that we extract from the image will tend to indicate object boundaries, but not always. The edges identified by edge

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detection are often disconnected. To segment an object from an image however, one needs closed region boundaries. The desired edges are the boundaries between such objects.

Sobel, Prewitt and Canny Edge Detection are the various edge detection techniques which have been implemented on the captured dataset.

Algorithm used for the Pothole Detection using Segmentation is as follows:

STEP 1: Convert captured images of both plain road and pothole from a color image to GREY image as eye is more sensitive to luminance components and processing of image becomes faster.

STEP 2: Noise removal filters are used to remove unwanted disturbance i.e. low frequency components and to preserve high frequency components, which is the edge of the pothole image.
Filter is a device or process that removes some unwanted component or feature from a signal. Filtering means removing some frequencies and not others in order to suppress interfering signals and reduce background noise.

STEP 3: Next step is to detect an edge. Sobel edge detection technique, Prewitt Edge Detection as well as Canny Edge Detection is used since noise is completely removed from these techniques.

**A.Sobel Method**: The Sobel operator performs a 2-D spatial gradient measurement on an image and so emphasizes regions of high spatial frequency that correspond to edges. Typically it is used to find the approximate absolute gradient magnitude at each point in an input grayscale image. In theory at least, the operator consists of a pair of 3x3 convolution kernels as shown in Figure. One kernel is simply the other rotated by 90o. The convolution masks of the Sobel detector are given below.

| | | |
|---|---|---|
| -1 | 0 | +1 |
| -2 | 0 | +2 |
| -1 | 0 | +1 |

Gx

| | | |
|---|---|---|
| +1 | +2 | +1 |
| 0 | 0 | 0 |
| -1 | -2 | -1 |

Gy

Fig. : Sobel Mask

**B. Prewitt Method:** The prewitt edge detector is an appropriate way to estimate the magnitude and orientation of an edge. Although differential gradient edge detection needs a rather time consuming calculation to estimate the orientation from the magnitudes in the x and y-directions, the compass edge detection obtains the orientation directly from the kernel with the maximumresponse. The prewitt operator is limited to 8 possible orientations, however experience shows that most direct orientation estimates are not much more accurate. This gradient based edge detector is estimated in the 3x3 neighbourhood for eight directions. All the eight convolution masks are calculated. One convolution mask is then selected, namely that with the largest module.

| | | |
|---|---|---|
| -1 | 0 | +1 |
| -1 | 0 | +1 |
| -1 | 0 | +1 |

Gx

| | | |
|---|---|---|
| +1 | +1 | +1 |
| 0 | 0 | 0 |
| -1 | -1 | -1 |

Gy

Fig. : Prewitt Mask

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**C. Canny Method:** It is a method to find edges by isolating noise from the image without affecting the features of the edges in the image and then applying the tendency to find the edges and the critical value for threshold. Here thresh is a two element vector in which the first element is the low threshold, and the second element is the high threshold.

### *4.3 Parametric Approaches for Pothole Validation*

After detecting the edges of the potholes, now comparison of plain road image with the captured image is done to validate the presence of a pothole. For that the following are the Parametric Approaches have to be taken:

- The first parametric approach is Pixel Information Calculation
- Second approach is calculating 1st order moment
- Next approach is calculating 2nd order moment

Figure below specifies the image of plain road which is the reference image and the image of the pothole road.

a. b.

Fig : a) Plain Road and b) Pothole Road

*Pixel Information Calculation:* The number of pixels having specific grey level in the plain road image in the dataset and the captured image of the road is calculated. Based on the predefined threshold value, the presence of a pothole is determined.

*1st Order Moment:* In this method, the 1st order moment of the plain road image and the 1st order moment of the image of the road in consideration are calculated. If the 1st order moment value of the road image in consideration is lesser than the predefined threshold value, then image on the road is a pothole image and driver is given an alert message to reduce speed of vehicle.

*2nd Order Moment:* In this method, the 2nd order moment of the plain road image and the 2nd order moment of the image of the road in consideration are calculated. If the 2nd order moment value of the road image in consideration is greater than the predefined threshold value, then image on the road is a pothole image and driver is given an alert message to reduce speed of vehicle.

### *4.4 Field Programmable Gate Arrays*

Field Programmable Gate Arrays (FPGAs) represent reconfigurable computing technology, which is in some ways ideally suited for video processing. Reconfigurable computers are processors which can be programmed with a design, and then reprogrammed (or reconfigured) with virtually limitless designs as the designer's needs change. FPGAs generally consist of a system of logic blocks (usually look up tables and flip-flops) and some amount of Random Access Memory (RAM), all wired together using a vast array of interconnects. All of the logic in an FPGA can be rewired, or reconfigured, with a different design as often as the designer likes. This type of architecture allows a large

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variety of logic designs dependent on the processor's resources), which can be interchanged for a new design as soon as the device can be reprogrammed.

Today, FPGAs can be developed to implement parallel design methodology, which is not possible in dedicated DSP designs. ASIC design methods can be used for FPGAdesign, allowing the designer to implement designs at gate level. However, usuallyengineers use a hardware language such as VHDL or Verilog, which allows for a designmethodology similar to software design. This software view of hardware design allowsfor a lower overall support cost and design abstraction.

The goal of this project is for real-time (30 frames per second) processing of grayscale image data, a goal in which an FPGA system using parallel algorithms should have little difficultly achieving.

## V. EXPECTED RESULT

The various edge detection techniques used such as Sobel, Prewitt and Canny Edge Detection techniques, Canny Edge Detection technique should be used for pre-processing as it should prove to be the most efficient noise removal technique. Considering the results obtained after the analysis, it will be concluded that 1st Order Moment Calculation and 2nd Order Calculation are two parametric approaches that give the best efficiency for validation of the pothole from the considered samples of Plain Road Images as well as Pothole Road Images.

FPGA Based Intelligent Potholes Detection System should give a clear indication of number of potholes on the road and gives a clear indication for maintenance of roads to the local road development authorities. This system will also alert the driver to reduce the speed of vehicle if there is a pothole on the road. Intelligent Pothole Detection System via GPS technology can upload the area where the pothole is intense so that other drivers can be alerted before they come across such roads. The FPGA Based Intelligent Potholes Detection System directly or indirectly saves the life of many human beings.

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