STRUCTURAL HEALTH MONITORING USING MACHINE LEARNING

A PROJECT REPORT

Submitted by

P. AKASH	814720106005
A. ANAS	814720106006
K. HARISOMAN	814720106031

in partial fulfillment of the award of the degree

of

BACHELOR OF ENGINEERING IN

ELECTRONICS AND COMMUNICATION ENGINEERING

SRM TRP ENGINEERING COLLEGE, TIRUCHIRAPPALLI

ANNA UNIVERSITY: CHENNAI 600 025

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BONAFIDE CERTIFICATE

Certified that this project report "**STRUCTURAL HEALTH MONITORING USING MACHINE LEARNING**" is the bonafide work of "**P.AKASH (814720106005), A.ANAS (814720106006), K.HARISOMAN (814720106031)**" who carried out the project work under my supervision.

Signature	**Signature**
Dr.B.RAMASUBRAMANIAN	**Mr.G.PARAMESWARAN**
PROFESSOR	**SUPERVISOR**
HEAD OF THE DEPARTMENT	**ASSISTANT PROFESSOR**
Department of Electronics & Communication Engineering	Department of Electronics & Communication Engineering
SRM TRP ENGINEERING COLLEGE	SRM TRP ENGINEERING COLLEGE
Tiruchirapalli-621 105	Tiruchirapalli-621 105

Submitted to the project viva-voce examination held on ____________________

INTERNAL EXAMINER **EXTERNAL EXAMINER**

ANNA UNIVERSITY: CHENNAI 600 025

DECLARATION

We hereby declare that the work entitle "**STRUCTURAL HEALTH MONITORING USING MACHINE LEARNING**" is submitted in partial fulfillment for the degree in B.E, Anna University of Chennai, is a record of our own work carried out by us during the academic year 2023-2024 under the supervision and guidance of **Mr .G.PARAMESWARAN** , Assistant Professor, Department of Electronics and Communication Engineering, SRM TRP Engineering College, Trichy-621 105. The extended sources of information are derived from the existing literature and have be enindicated through the dissertation at the appropriate places. The matter embodied in this work is original and has not been submitted for the award of any other degree or diploma, either in this or any other University.

Signature of candidates(s)

P. AKASH	814720106005
A. ANAS	814720106006
K. HARISOMAN	814720106031

I certify that the declaration made above by the candidates is true

Signature of the guide,

Mr.G.PARAMESWARAN

Assistant Professor/ECE

ACKNOWLEDGEMENT

It is a great opportunity to express our sincere thanks to all the people who have contributed to the successful completion of our project work through their support, encouragement, and guidance.

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We are sincerely grateful to **Dr. B. GANESH BABU,** Principal of SRM TRP Engineering College for his valuable support and encouragement in carrying out our project.

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We express our gratitude to our Project Coordinator **Dr.B.RAMASUBRAMANIYAN,** Department of Electronics and Communication Engineering, for his generous help and continuous encouragement to bring out this project work.

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ABSTRACT

We are witnessing a notable work on advancing Building Damage Detection (BDD) through the application of deep learning methodologies. In the aftermath of natural disasters or incidents, prompt and accurate identification of structural damage is crucial for effective response and recovery. Leveraging the capabilities of deep neural networks, specifically convolutional neural networks (CNNs), our proposed model aims to autonomously detect and classify building damage from diverse data sources, including high-resolution satellite imagery and on-site photographs .The deep learning model is trained on extensive datasets, enabling it to learn intricate patterns and features associated with various degrees of structural damage. Through this learning process, the system becomes adapt at distinguishing between undamaged structures, minor damage, and severe structural compromise. The utilization of CNNs facilitates spatial hierarchies of features extraction, enhancing the model's ability to capture nuanced information in complex images .The proposed BDD system offers a scalable and adaptable solution, capable of handling different types of disasters and imaging conditions. By automating the detection process, it significantly expedites the assessment of building damage, allowing for swift and informed decision-making in disaster response scenarios. This research contributes to the advancement of automated tools for building damage assessment, ultimately supporting more efficient and effective disaster management strategies.

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CHAPTER 1

1. INTRODUCTION

1.1 IMAGE PROCESSING

An image is an array, or a matrix, of square pixels (picture elements) arranged in columns and rows. In a gray scale image each picture element has an assigned intensity that ranges from 0 to 255. A grey scale image is what people normally call a black and white image, but the name emphasizes that such an image will also include many shades of grey. There are two general groups of 'images': vector graphics (or line art) and bitmaps (pixel-based or 'images'). Some of the most common file formats are:

GIF — an 8-bit (256 colour), non-destructively compressed bitmap format. Mostly used for web. Has several sub-standards one of which is the animated GIF.

JPEG — a very efficient (i.e. much information per byte) destructively compressed 24 bit (16 million colours) bitmap format. Widely used, especially for web and Internet (bandwidth-limited).

TIFF — the standard 24 bit publication bitmap format.

Compresses nondestructively with, for instance, Lempel-Ziv-Welch (LZW) compression.

PS — Postscript, a standard vector format. Has numerous sub-standards and can be difficult to transport across platforms and operating systems.

PSD – a dedicated Photoshop format that keeps all the information in an image including all the layers.

1.1.1 Colours:

For science communication, the two main colour spaces are RGB and CMYK.

1.1.1.1 RGB:

The RGB colour model relates very closely to the way we perceive colour with the r, g and b receptors in our retinas. RGB uses additive colour mixing and is the basic colour model used in television or any other medium that projects colour with light. It is the basic colour model used in computers and for web graphics, but it cannot be used for print production. The secondary colours of RGB – cyan, magenta, and yellow – are formed by mixing two of the primary colours (red, green or blue) and excluding the third colour. Red and green combine to make yellow, green and blue to make cyan, and blue and red form magenta. The combination of red, green, and blue in full intensity makes white. In Photoshop using the "screen" mode for the different layers in an image will make the intensities mix together according to the additive colour mixing model. This is analogous to stacking slide images on top of each other and shining light through them.

1.1.1.2CMYK:

The 4-colour CMYK model used in printing lays down overlapping layers of varying percentages of transparent cyan (C), magenta (M) and yellow (Y) inks. In addition a layer of black (K) ink can be added. The CMYK model uses the subtractive colour model.

1.1.1.3 Gamut:

The range, or gamut, of human colour perception is quite large. The two colour spaces discussed here span only a fraction of the colours we can see.

Furthermore the two spaces do not have the same gamut, meaning that converting from one colour space to the other may cause problems for colours in the outer regions of the gamuts.

1.1.2 Fundamental steps in image processing:

1. Image acquisition: to acquire a digital image

2. Image preprocessing: to improve the image in ways that increases the chances for success of the other processes.

3. Image segmentation: to partitions an input image into its constituent parts or objects.

4. Image representation: to convert the input data to a form suitable for computer processing.

5. Image description: to extract features that result in some quantitative information of interest or features that are basic for differentiating one class of objects from another.

6. Image recognition: to assign a label to an object based on the information provided by its descriptors.

7. Image interpretation: to assign meaning to an ensemble of recognized objects.

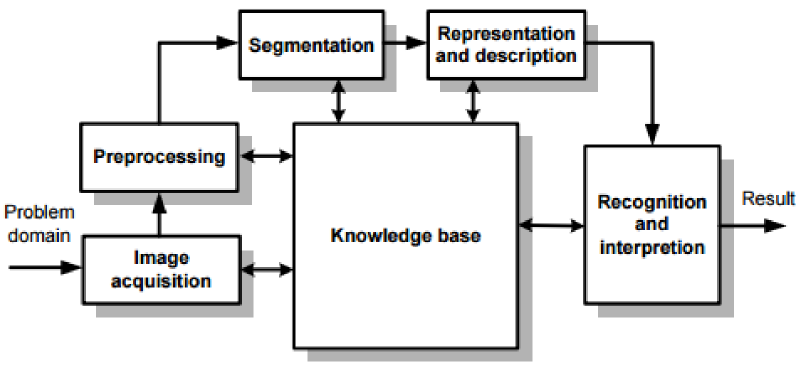


Figure 1.1 Blocks on image Processing

1.1.3 Purpose of Image processing

The purpose of Image processing has 5 types,

- Visualization - Observe the objects that are not visible.
- Image sharpening and restoration - To create a better image.
- Image retrieval - Seek for the image of interest.
- Measurement of pattern – Measures various objects in an image.
- Image Recognition – Distinguish the objects in an image.

1.1.4 Applications of Image processing

- Remote sensing
- Medical imaging
- Forensic Studies Textiles
- Material science
- Military
- Film industry
- Document Processing

1.2 TYPES OF IMAGE PROCESSING:

The two types of Image Processing are

- Analog image processing
- Digital image processing

1.2.1 Analog image processing

Analog or visual techniques of image processing can be used for the hard copies like printouts and photographs. Image analysts use various fundamentals of interpretation while using these visual techniques. The image processing is not just confined to area that has to be studied but on knowledge of analyst. Association is another important tool in image processing through visual techniques. So analysts apply a combination of personal knowledge and collateral data to image processing.

1.2.2 Digital image Processing

Digital image processing is the use of computer algorithms to perform image processing on digital images. As a subcategory or field of digital signal processing, digital image processing has many advantages over analog image processing. It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and signal distortion during processing. Since images are defined over two dimensions (perhaps more) digital image processing may be modeled in the form of multidimensional systems.

Many of the techniques of digital image processing, or digital picture processing as it often was called, were developed in the 1960. The cost of processing was fairly high, however, with the computing equipment of that era. That changed in the 1970s, when digital image processing proliferated as cheaper computers and dedicated hardware became available. Images then could be processed in real time, for some dedicated problems such as television standards conversion. As general-purpose computers became faster, they started to take over the role of dedicated hardware for all but the most specialized and computer-intensive operations.

With the fast computers and signal processors available in the 2000s, digital image processing has become the most common form of image processing and generally, is used because it is not only the most versatile method, but also the cheapest.

Digital Processing techniques help in manipulation of the digital images by using computers. As raw data from imaging sensors from satellite platform contains deficiencies. To get over such flaws and to get originality of information, it has to undergo various phases of processing. The three general phases that all types of data have to undergo while using digital technique are Pre- processing, enhancement and display, information extraction.

1.3 IMAGE PROCESSING TECHNIQUES:

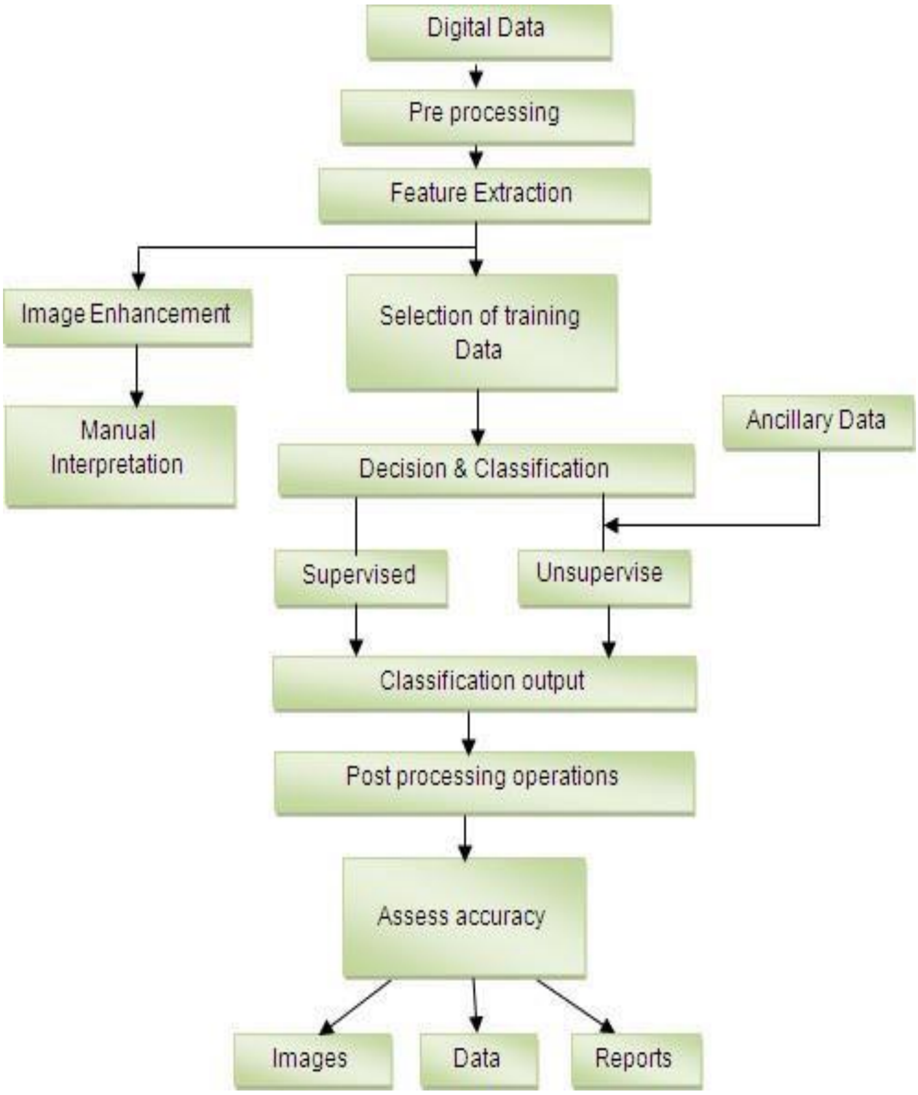


Figure 1.2 Block diagram of digital image processing

1.4 WIRELESS SENSOR NETWORK

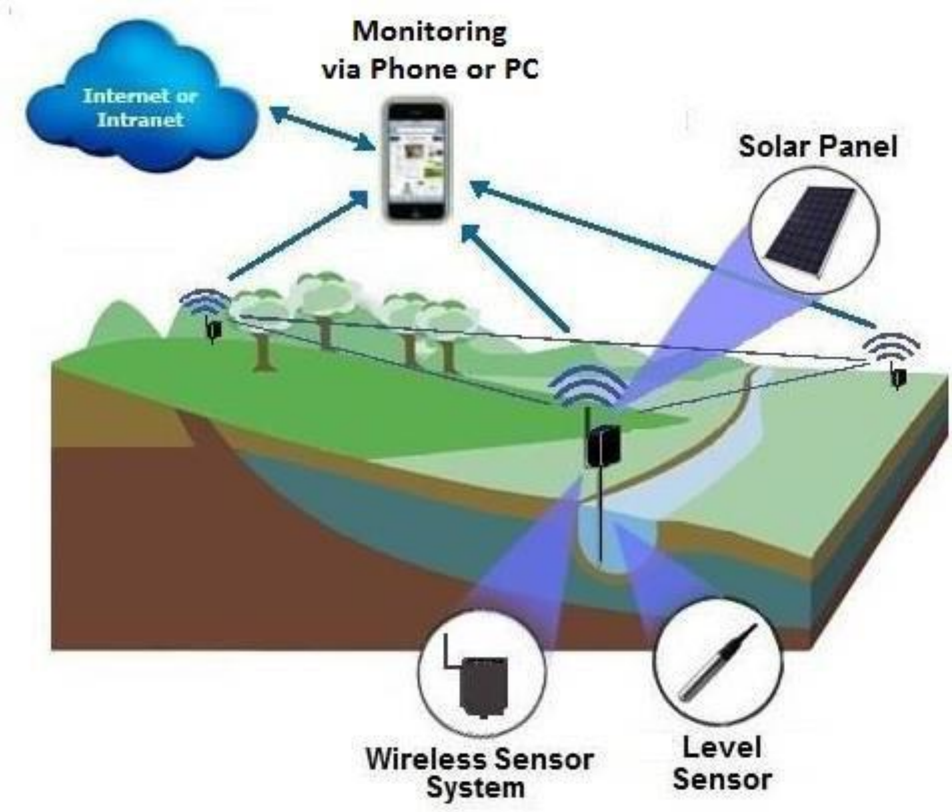


Fig1.3 Wireless Sensor Network

A wireless sensor network (WSN) is a wireless network consisting of spatially distributed autonomous devices using sensors to monitor physical or environmental conditions. A WSN system incorporates a gateway that provides wireless connectivity back to the wired world and distributed nodes (see Figure 1). The wireless protocol you select depends on your application requirements. Some of the available standards include 2.4 GHz radios based on either IEEE 802.15.4 or IEEE 802.11 (Wi-Fi) standards or proprietary radios, which are usually 900 MHz.

Wireless sensor network (WSN) refers to a group of spatially dispersed and dedicated sensors for monitoring and recording the physical conditions of the environment and organizing the collected data at a central location. WSNs measure environmental conditions like temperature, sound, pollution levels, humidity, wind, and so on.

These are similar to wireless ad hoc networks in the sense that they rely on wireless connectivity and spontaneous formation of networks so that sensor data can be transported wirelessly. WSNs are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring, and so on.

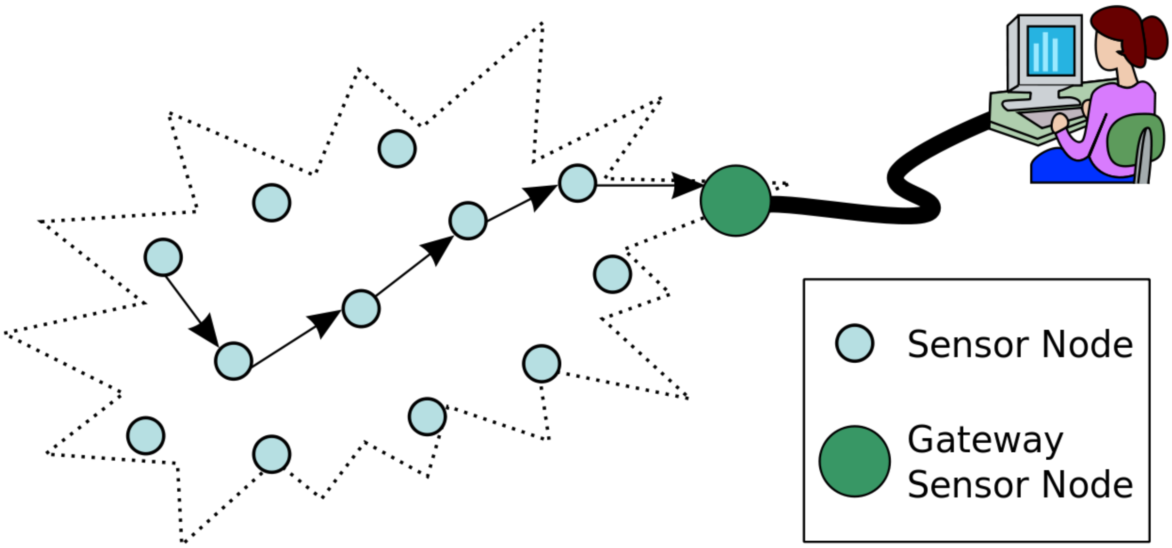


Figure 1.3.1 Typical multi-hop wireless sensor network architecture

The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust, although functioning "motes" of genuine microscopic dimensions have yet to be created. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding.

1.5 WSN IN INDUSTRIAL MONITORING

1.5.1 Machine health monitoring

Wireless sensor networks have been developed for machinery condition-based maintenance (CBM) as they offer significant cost savings and enable new functionality. Wireless sensors can be placed in locations difficult or impossible to reach with a wired system, such as rotating machinery and untethered vehicles.

1.5.2 Data center monitoring

Due to the high density of servers racks in a data center, often cabling and IP addresses are an issue. To overcome that problem more and more racks are fitted out with wireless temperature sensors to monitor the intake and outtake temperatures of racks. As ASHRAE recommends up to 6 temperature sensors per rack, meshed wireless temperature technology gives an advantage compared to traditional cabled sensors.

1.5.3 Data logging

Wireless sensor networks are also used for the collection of data for monitoring of environmental information, this can be as simple as the monitoring of the temperature in a fridge to the level of water in overflow tanks in nuclear power plants. The statistical information can then be used to show how systems have been working. The advantage of WSNs over conventional loggers is the "live" data feed that is possible.

1.5.4 Water/waste water monitoring

Monitoring the quality and level of water includes many activities such as checking the quality of underground or surface water and ensuring a country’s water infrastructure for the benefit of both human and animal. It may be used to protect the wastage of water.

1.5.5 Structural health monitoring

Wireless sensor networks can be used to monitor the condition of civil infrastructure and related geo-physical processes close to real time, and over long periods through data logging, using appropriately interfaced sensors.

1.5.6 Wine production

Wireless sensor networks are used to monitor wine production, both in the field and the cellar.

1.6 STRUCTURAL HEALTH MONITORING

Structural health monitoring (SHM) refers to the process of implementing a damage detection and characterization strategy for engineering structures. Here damage is defined as changes to the material and/or geometric properties of a structural system, including changes to the boundary conditions and system connectivity, which adversely affect the system's performance.

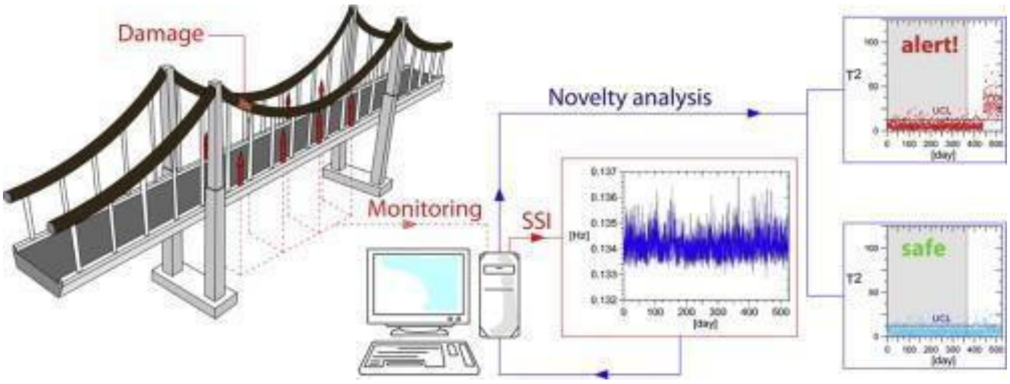


Figure 1.4 Structural Health Monitoring

The SHM process involves the observation of a system over time using periodically sampled dynamic response measurements from an array of sensors, the extraction of damage-sensitive features from these measurements, and the statistical analysis of these features to determine the current state of system health. For long term SHM, the output of this process is periodically updated information regarding the ability of the structure to perform its intended function in light of the inevitable aging and degradation resulting from operational environments. After extreme events, such as earthquakes or blast loading, SHM is used for rapid condition screening and aims to provide, in near real time, reliable information regarding the integrity of the structure. Infrastructure inspection plays a key role in public safety in regards to both long-term damage accumulation and post extreme event scenarios. As part of the rapid developments in data-driven technologies that are transforming many fields in engineering and science, machine learning and computer vision techniques are increasingly capable of reliably diagnosing and classifying patterns in image data, which has clear applications in inspection contexts.

1.7 STATISTICAL PATTERN RECOGNITION

The SHM problem can be addressed in the context of a statistical pattern recognition paradigm. This paradigm can be broken down into four parts:

- Operational Evaluation,
- Data Acquisition and Cleansing,
- Feature Extraction and Data Compression, and
- Statistical Model Development for Feature Discrimination.

When one attempts to apply this paradigm to data from real world structures, it quickly becomes apparent that the ability to cleanse, compress, normalize and fuse data to account for operational and environmental variability is a key implementation issue when addressing Parts 2-4 of this paradigm. These processes can be implemented through hardware or software and, in general, some combination of these two approaches will be used.

1.7.1 Health Assessment of Engineered Structures of Bridges, Buildings and Other Related Infrastructures

Commonly known as Structural Health Assessment (SHA) or SHM, this concept is widely applied to various forms of infrastructures, especially as countries all over the world enter into an even greater period of construction of various infrastructures ranging from bridges to skyscrapers. Especially so when damages to structures are concerned, it is important to note that there are stages of increasing difficulty that require the knowledge of previous stages, namely:

- Detecting the existence of the damage on the structure
- Locating the damage
- Identifying the types of damage

- Quantifying the severity of the damage

It is necessary to employ signal processing and statistical classification to convert sensor data on the infrastructural health status into damage info for assessment.

1.7.2 OPERATIONAL EVALUATION

Operational evaluation attempts to answer four questions regarding the implementation of a damage identification capability:

- What are the life-safety and/or economic justification for performing the SHM?
- How is damage defined for the system being investigated and, for multiple damage possibilities, which cases are of the most concern?
- What are the conditions, both operational and environmental, under which the system to be monitored functions?
- What are the limitations on acquiring data in the operational environment?

Operational evaluation begins to set the limitations on what will be monitored and how the monitoring will be accomplished. This evaluation starts to tailor the damage identification process to features that are unique to the system being monitored and tries to take advantage of unique features of the damage that is to be detected.

1.7.3 DATA ACQUISITION, NORMALIZATION AND CLEANSING

The data acquisition portion of the SHM process involves selecting the excitation methods, the sensor types, number and locations, and the data acquisition/storage/transmittal hardware. Again, this process will be application specific. Economic considerations will play a major role in making these decisions. The intervals at which data should be collected is another consideration that must be addressed.

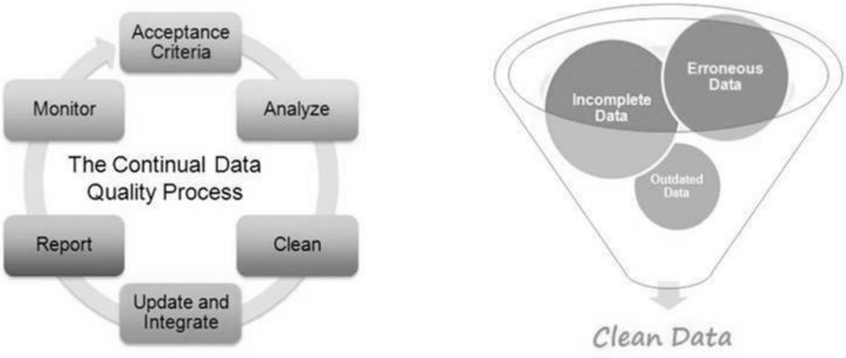


Figure 1.5 Data Quality Process

Because data can be measured under varying conditions, the ability to normalize the data becomes very important to the damage identification process. As it applies to SHM, data normalization is the process of separating changes in sensor reading caused by damage from those caused by varying operational and environmental conditions. One of the most common procedures is to normalize the measured responses by the measured inputs. When environmental or operational variability is an issue, the need can arise to normalize the data in some temporal fashion to facilitate the comparison of data measured at similar times of an environmental or operational cycle. Sources of variability in the data acquisition process and with the system being monitored need to be identified and minimized to the extent possible. In general, not all sources of variability can be eliminated. Therefore, it is necessary to make the appropriate measurements such that these sources can be statistically quantified. Variability can arise from changing environmental and test conditions, changes in the data reduction process, and unit- to-unit inconsistencies.

Data cleansing is the process of selectively choosing data to pass on to or reject from the feature selection process. The data cleansing process is usually based on knowledge gained by individuals directly involved with the data acquisition. As an example, an inspection of the test setup may reveal that a sensor was loosely mounted and, hence, based on the judgment of the individuals performing the measurement, this set of data or the data from that particular sensor may be selectively deleted from the feature selection process. Signal processing techniques such as filtering and re-sampling can also be thought of as data cleansing procedures.

Finally, the data acquisition, normalization, and cleansing portion of SHM process should not be static. Insight gained from the feature selection process and the statistical model development process will provide information regarding changes that can improve the data acquisition process.

1.7.4 STATISTICAL MODEL DEVELOPMENT

The portion of the SHM process that has received the least attention in the technical literature is the development of statistical models for discrimination between features from the undamaged and damaged structures. Statistical model development is concerned with the implementation of the algorithms that operate on the extracted features to quantify the damage state of the structure. The algorithms used in statistical model development usually fall into three categories. When data are available from both the undamaged and damaged structure, the statistical pattern recognition algorithms fall into the general classification referred to as supervised learning.

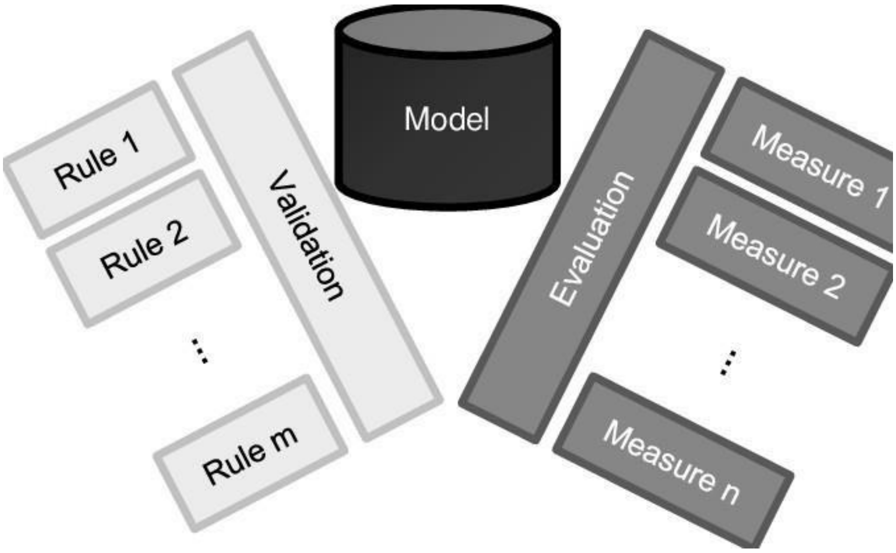


Figure 1.6 Statistical Model Development

Group classification and regression analysis are categories of supervised learning algorithms. Unsupervised learning refers to algorithms that are applied to data not containing examples from the damaged structure. Outlier or novelty detection is the primary class of algorithms applied in unsupervised learning applications. All of the algorithms analyze statistical distributions of the measured or derived features to enhance the damage identification process.

1.8 SHM COMPONENTS

SHM System's elements include:

- Structure
- Sensors
- Data acquisition systems
- Data transfer and storage mechanism
- Data management
- Data interpretation and diagnosis:
    - System Identification

- Structural model update
- Structural condition assessment
- Prediction of remaining service life

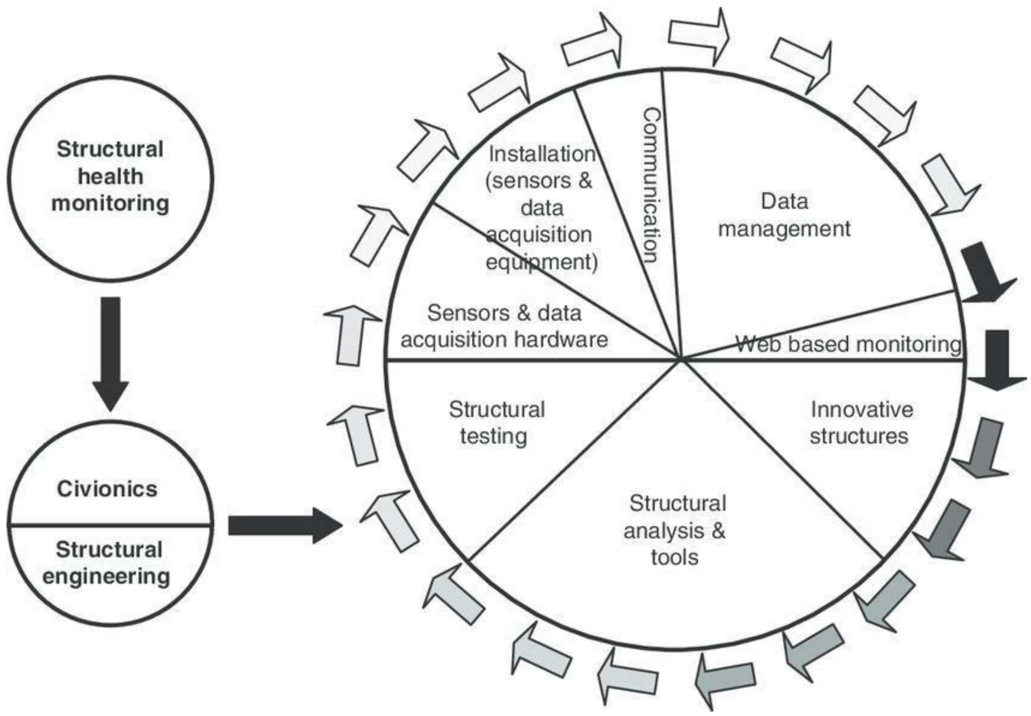


Figure 1.7 Monitoring Structural Changes

An example of this technology is embedding sensors in structures like bridges and aircraft. These sensors provide real time monitoring of various structural changes like stress and strain. In the case of civil engineering structures, the data provided by the sensors is usually transmitted to a remote data acquisition centres. With the aid of modern technology, real time control of structures (Active Structural Control) based on the information of sensors is possible.

As the rapid developments of the wireless telecommunication and the embedded technology, the sensor technology gets more and more innovative, and the wireless sensor network (WSN) with characteristics of small volume, low power consumption, and convenient application has emerged. The realization of WSN based on embedded system has become a hot topic in recent years. ZigBee technology, one of the most popular technologies in the field of WSN, gradually becomes a dispensable part of people's life. Due to its flexible characteristics, ZigBee technology is widely applied in lots of fields, such as automatic control and remote data acquisition. This project demonstrates the safety monitoring system based on the ZigBee WSN technology for supervising the state of large outdoor advertising board.

CHAPTER 2

2. LITERATURE SURVEY

2.1 TITLE: A High Resolution UAV Semantic Segmentation Dataset for Natural Disaster Damage Assessment.

AUTHOR: Chowdhury T And Murphy R

YEAR: 2023

DESCRIPTION: Recent advancements in computer vision and deep learning techniques have facilitated notable progress in scene understanding, thereby assisting rescue teams in achieving precise damage assessment. In this paper, we present RescueNet, a meticulously curated high-resolution post-disaster dataset that includes detailed classification and semantic segmentation annotations. This dataset aims to facilitate comprehensive scene understanding in the aftermath of natural disasters. RescueNet comprises post-disaster images collected after Hurricane Michael, obtained using Unmanned Aerial Vehicles (UAVs) from multiple impacted regions. The uniqueness of RescueNet lies in its provision of high-resolution post-disaster imagery, accompanied by comprehensive annotations for each image. Unlike existing datasets that offer annotations limited to specific scene elements such as buildings, RescueNet provides pixel- level annotations for all classes, including buildings, roads, pools, trees, and more. Furthermore, we evaluate the utility of the dataset by implementing state- of-the-art segmentation models on RescueNet, demonstrating its value in enhancing existing methodologies for natural disaster damage assessment.

2.2 TITLE: Structural Damage Detection Technique of Secondary Building Components using Piezoelectric Sensor

AUTHOR: Shibata D and Yoshino Y

YEAR:2023

DESCRIPTION: The demand for the Sensors of various types have been practically applied in the industry to satisfy this need. Among the sensors, piezoelectric sensors are an extremely promising technology by virtue of their cost advantages and durability. Although they have been used in aerospace and civil engineering, their application for building engineering remains limited. Remarkably, recent catastrophic seismic events have further rein-forced the necessity of rapid damage detection and quick judgment about the safe use of facilities. Faced with these circumstances, this study was conducted to assess the applicability of piezoelectric sensors to evaluate building components. Specifically, this study emphasizes structural damage caused by earthquakes. After first applying to cyclic loading tests to composite beam component specimens and steel frame subassemblies with a folded roof plate, the prospective damage posi-tions were also found using finite element analysis. Crack propagation and buckling locations were predicted adequately. The piezoelectric sensors provided output when the concrete slab showed tensile cracks, or when the folded roof plate experienced local buckling. Furthermore, damage expansion and progression were detected multiple times during loading tests. Results showed that the piezoelectric sensors can detect structural damage of building components, demonstrating their potential for use in inexpensive and stable monitoring systems.

2.3 TITLE: A Systematic Review of Structural Health Monitoring Systems to Strengthen Post-Earthquake Assessment Procedures. AUTHOR: Lopez Castro

YEAR:2022

DESCRIPTION: Structural health monitoring (SHM) is vital to ensuring the integrity of people and structures during earthquakes, especially considering the catastrophic consequences that could be registered in countries within the Pacific ring of fire, such as Ecuador. This work reviews the technologies, architectures, data processing techniques, damage identification techniques, and challenges in state-of-the-art results with SHM system applications. These studies use several data processing techniques such as the wavelet transform, the fast Fourier transform, the Kalman filter, and different technologies such as the Internet of Things (IoT) and machine learning. The results of this review highlight the effectiveness of systems aiming to be cost-effective and wireless, where sensors based on microelectromechanical systems (MEMS) are standard. However, despite the advancement of technology, these face challenges such as optimization of energy resources, computational resources, and complying with the characteristic of real-time processing.

2.4 TITLE: Monitoring and Assessment of Indoor Environmental Conditions in Educational Building Using Building Information Modelling Methodology.

AUTHOR: Aguilar AJ

YEAR:2022

DESCRIPTION: Managing indoor environmental quality (IEQ) is a challenge in educational buildings in the wake of the COVID-19 pandemic. Adequate indoor air quality is essential to ensure that indoor spaces are safe for students and teachers. In fact, poor IEQ can affect academic performance and student comfort. This study proposes a framework for integrating occupants' feedback into the building information modelling (BIM) methodology to assess indoor environmental conditions (thermal, acoustic and lighting) and the individual airborne virus transmission risk during teaching activities. The information contained in the parametric 3D BIM model and the algorithmic environment of Dynamo were used to develop the framework. The IEQ evaluation is based on sensor monitoring and a daily schedule, so the results show real problems of occupants' dissatisfaction. The output of the framework shows in which range the indoor environmental variables were (optimal, acceptable and unacceptable) and the probability of infection during each lecture class (whether or not 1% is exceeded). A case study was proposed to illustrate its application and validate it. The outcomes provide key information to support the decision-making process for managing IEQ and controlling individual airborne virus transmission risks. Long-term application could provide data that support the management of ventilation strategies and protocol redesign.

2.5 TITLE: Developing a Green Building Assessment Tool for Ethiopia. AUTHOR: Anshebo MA

YEAR:2022

DESCRIPTION: Keeping roads in a good condition is vital to safe driving and is an important task of both state and local transportation maintenance departments. One important component of this task is to monitor the degradation of road conditions, which is labor intensive and requires domain expertise. Recently, computer vision and machine learning techniques have been successfully applied to automate road surface survey. In this work, we focus on detecting cracks on the pavement surface, because they represent the most prevalent type of road damage and exhibit strong texture cues. A large number of recent literatures in crack detection and characterization of pavement surface distresses clearly demonstrates an increasing interest in this research area. Automatic detection of pavement cracks is an important task in transportation maintenance for driving safety assurance. However, it remains a challenging task due to the intensity inhomogeneity of cracks and complexity of the background, e.g., the low contrast with surrounding pavement and possible shadows with similar intensity. Inspired by recent success in applying deep learning to computer vision and medical problems, a deep- learning based method for crack detection is proposed in this paper. A supervised deep convolutional neural network is trained to classify each image patch in the collected images

CHAPTER 3

SYSTEM

ANALYSIS

3.1 EXISTING SYSTEM

Automatic crack detection is a very challenging image classification task with the goal of accurately marking crack areas. To improve the continuity of crack detection, researchers have attempted to detect cracks by introducing minimal path selection (MPS) , minimal spanning trees (MSTs), and crack fundamental elements (CFEs). ƒThese methods can partially eliminate noise and improve crack detection continuity. However, only the low-level features can be roughly obtained, some complex high-level crack features may not be presented, and utilized correctly. A randomly structured forest-based method is presented to detect cracks automatically. ƒis method can effectively suppress noise by manually selecting crack features and learning internal structures. Although it improves the recognition speed and accuracy but does not perform well when dealing with complex pavement crack situations. ƒTherefore, traditional machine learning methods simulate cracks by manually setting color or texture features. In these methods, the features cover only some specific real-world situations. The set of crack features is simplified and idealized, which cannot achieve the robust detection requirements for pavement diseases. To process a large volume of concrete structure image data regarding cracks, the machine learning-based classification approach has recently received significant attention. The support vector machine (SVM) was applied to detect “crack” and “no-crack” conditions from concrete image data through extracting handcrafted manual features. The feature extraction process acts as a vital bridge between the raw image and rich feature vectors regarding cracks, which are used for classification

3.1.1 DISADVANTAGES

- Accuracy is less
- Provide high number of false positive rate
- Complexity is high

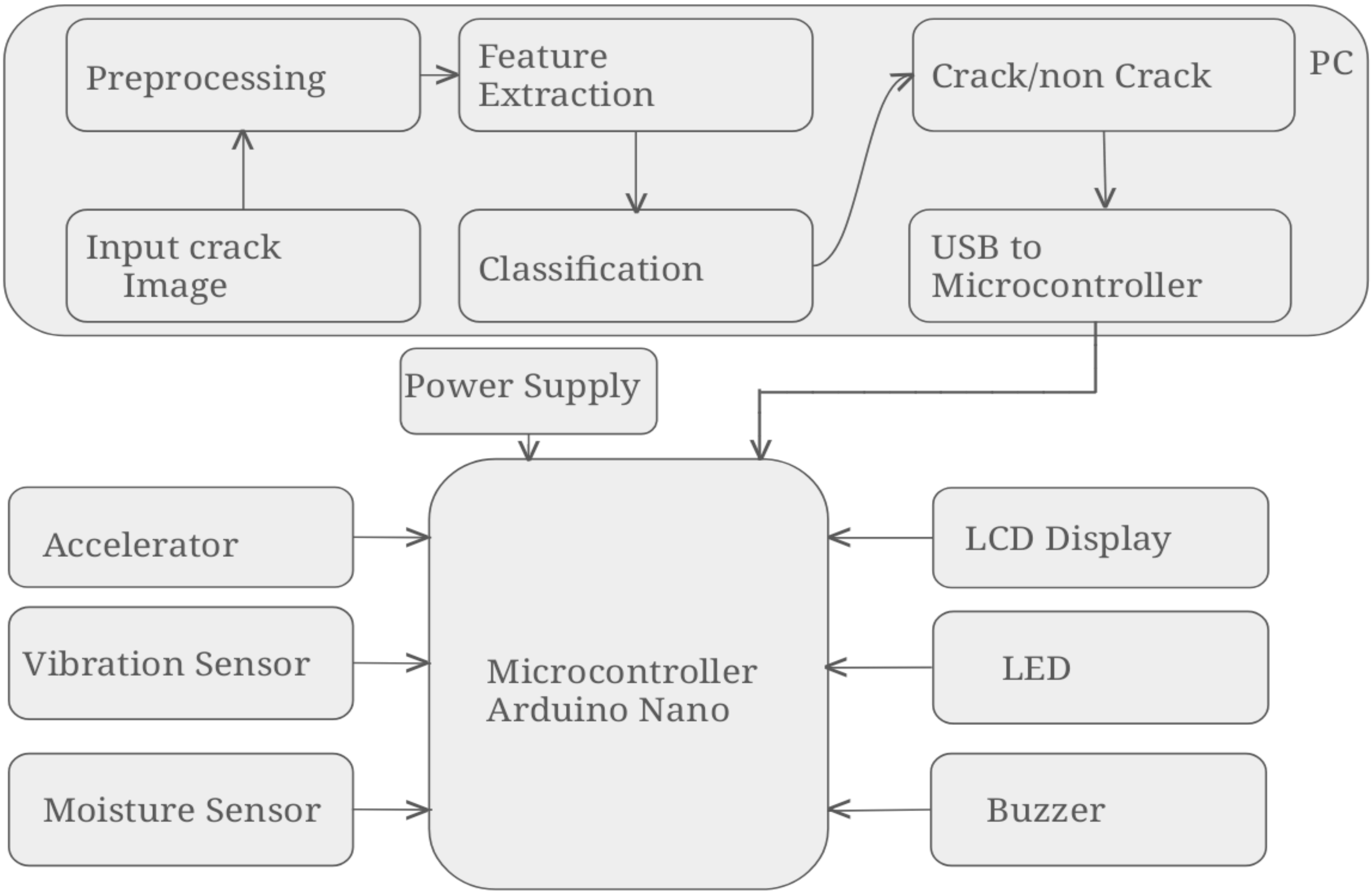
3.2 PROPOSED SYSTEM

In building monitoring concrete floor inspection, generating a crack map enables assessing important information about the surface health. In addition, detecting cracks early minimizes maintenance-renovation efforts and costs. Currently, crack detection is mainly performed by human experts. It is a tiring, time consuming, costly and above all subjective task. An improvement is to use scanning vision systems and possible basic image processing algorithms highlighting at least some cracks. In this case, experts just have to visualize the image sequences. However, it is still suggestive. In order to overcome these problems, many efforts are currently done to automatize the inspection. Cracks generally present radiometric and geometric features such as darker than the background and elongated. These are the reasons why scanning vision systems based on a monochrome camera; image processing and recognition are natural tools for this task. These tools are used in this work. However, it is still a current challenge to detect automatically (and fast) a wide variety of cracks in a wide variety of concrete floors. In proposed system we can implement the framework to segment the images to identify the crack with improved accuracy rate. It may be possible to classify cracked and non-cracked images directly from the original images by using Artificial Neural Network (ANN). However, the method using only ANN without image processing will require more computation time, since the training images have so many information. Thus it is required to include the image processing before applying ANN step in order to develop an effective process. It is required to distinguish cracks from normal concrete surface automatically to reduce the effort of the human inspectors. In this project, ANN are adopted to replace the human intelligence, that is to say, to replace the human classification though visual inspection. The proposed algorithm, the multi-layer ANN is basically used and back propagation algorithm is used for training the NN.

3.2.1 ADVANTAGES

- Improved accuracy rate
- Less number of false positive rate
- Complexity is less
- Handle large number of image pixels

BLOCK DIAGRAM



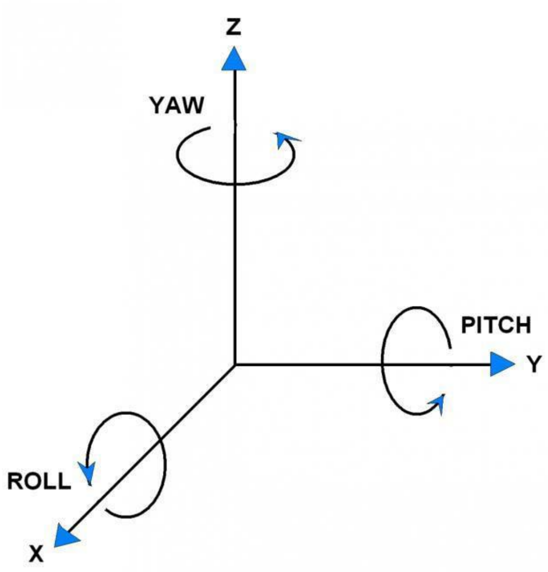
3.3 WORKING EXPLANATION

Concrete is always prone to cracking during the construction and service period due to its natural weakness in tension. Cracking is one of the leading causes of erosion and deformation, and finally, the collapse of concrete structures. Cracks are also a source of moisture and material infiltration and are very dangerous for vibrating structures. Fortunately, it is possible to prevent many financial losses and casualties by early detection of cracks and to prevent their growth and development. The damage of road surface reduces its service life. In order to improve road maintenance and management efficiency, detection and recognition of pavement are studied based on video images in this project. Firstly, we collect a large number of road surface images of 3 different conditions including transverse crack, longitudinal crack and turtle crack separately to construct road surface conditions library. Secondly, deal the road damaged image with gray, gray transform and contrast enhancement. Then, use binarization method to deal with crack image and projection to identify crack category. Finally, develop the pavement crack recognition software based on Matlab.

3.4 WIRELESS SENSOR NODE DESIGN

3.4.1 Selection of Sensor Module

Sensor module is used to get the tilt angle. In this project, an inclinometer based on a MEMS accelerometer was adopted for the SHM. The MEMS accelerometer responds to gravity sensitively. Thus, a MEMS accelerometer sensor in a stationary state measures both the static acceleration and the acceleration due to gravity. In this case, a certain angle is generated between the static acceleration and the acceleration due to gravity. This angle corresponds to the slope of the sensor or the so-called tilt. The ADXL335 sensor, which is a MEMS three-axis accelerometer, is selected as motion processing unit, and its functional blocks are showed in Fig.



It contains an embedded a 3-axis MEMS accelerometer, and a Digital Motion Processor (DMP) hardware accelerator engine that is capable of processing complex 3-axis sensor fusion algorithms. The ADXL335 sensor features three 8-bit analog-to-digital converters (ADCs) for digitizing the outputs and 8-bit ADCs for digitizing the accelerometer outputs.

The sensor data fusion algorithms, which used to get the tilt angle, consist of one-order complementation algorithm, Kalman filtering algorithm, and quaternion algorithm, etc. Considering the computing time and processing efficiency of nodes, the combination of quaternion algorithm with the DMP of ADXL335 can not only obtain tilt angle data quickly and easily, but also meet the precision requirement. The tilt angle can be expressed as: roll, rotate angle around the X axis; pitch, rotate angle around the Y axis; yaw, rotation angle around the Z axis. The spatial arbitrary posture of the current equipment can be expressed accurately by these three angles.

3.4.2 The Structure of Wireless Sensor Node

Sensor data acquisition node is the basic element of wireless data acquisition network, namely ZigBee sensor end device. A lot of nodes that distribute in different parts of the equipment under test can accomplish the function of multi point data acquisition. Here, the structure of sensor data acquisition node is designed by integrating sensor module, MCU, wireless transceiver module, and power supply module, etc

3.5 DEVELOPMENT OF WSN

ZigBee wireless control transceiver module is responsible for sensor data read and pre-processing, and also has wireless networking capabilities. As a result, the data package is carried forward according to the protocol provisions of the ZigBee wireless network. Z-Stack is a complete ZigBee protocol stack and application development solution that is distributed by TI Corporation and conforms to the ZigBee Alliance standard. In this protocol stack, Z-Stack helps developers to achieve most of the ZigBee protocol content. Therefore, for the application development based on ZigBee protocol stack, the researchers do not need to repeatedly develop ZigBee protocol when designing huge data communication management system, and just develop the application framework provided by Z-Stack. By calling the application interface function provided by Z-Stack and modifying the device configuration information, the implementation of the wireless network node with custom function is completed.

3.6 MONITORING CENTER DESIGN

The monitoring platform adopts the PC-based microprocessor as the master control unit. Hardware setup comprises ZigBee board, power circuit, interface circuit, UART interface circuit, coordinator module, and IO module, etc.

Each sensor node sends the collected data to the coordinator module by wireless network mode. Then the data communication is realized between the coordinator and the PC by using UART interface.

3.7 PROPOSED ALGORITHM FLOW

3.7.1 PREDICTIVE ANALYTIC ALGORITHMS

For safety monitoring of the outdoor advertising board, the monitoring

data

are huge with strong continuity and difficulty in function representations. Time series analysis provides an effective method for the analysis of dynamic data. It is a branch of statistics and widely used in trend prediction. By time series analysis, we build models to describe the states of the outdoor advertising board and extract information from the dynamic data, as well as construct feature vectors for the discrimination

In this project, exponential smoothing model was used to describe the development trend of the monitoring data. The double exponential smoothing of sequence (Y) is defined by the recursive form.

A reasonable smoothing constant α should be chosen based on an appropriate evaluation criterion. The method is to calculate the smoothing sequences corresponding to the plurality of smoothing constants α first, and then calculate the mean square error (MSE) or the average absolute error (MAD). The smoothing constant corresponds to the minimum of MSE or MAD and its predicted value is the most reasonable.

CHAPTER 4

SYSTEM REQUIREMENTS

HARDWARE REQUIREMENTS

- Processor : Dual core processor 2.6.0 GHZ
- RAM : 1GB
- Hard disk : 160 GB
- Compact Disk : 650 Mb
- Keyboard : Standard keyboard
- Monitor : 15 inch color monitor

SOFTWARE REQUIREMENTS

- Operating System : Windows OS
- Front End : MATLAB
- Application : WINDOWS APPLICATION

4.1 Hardware specification

4.1.1 Power Supplies

A power supply (sometimes known as a power supply unit or PSU) is a device or system that supplies electrical or other types of energy to an output load or group of loads. The term is most commonly applied to electrical energy supplies, less often to mechanical ones, and rarely to others.

This circuit is a small +5V power supply, which is useful when experimenting with digital electronics. Small inexpensive wall transformers with variable output voltage are available from any electronics shop and supermarket. Those transformers are easily available, but usually their voltage regulation is very poor, which makes then not very usable for digital circuit experimenter unless a better regulation can be achieved in some way. The following circuit is the answer to the problem.

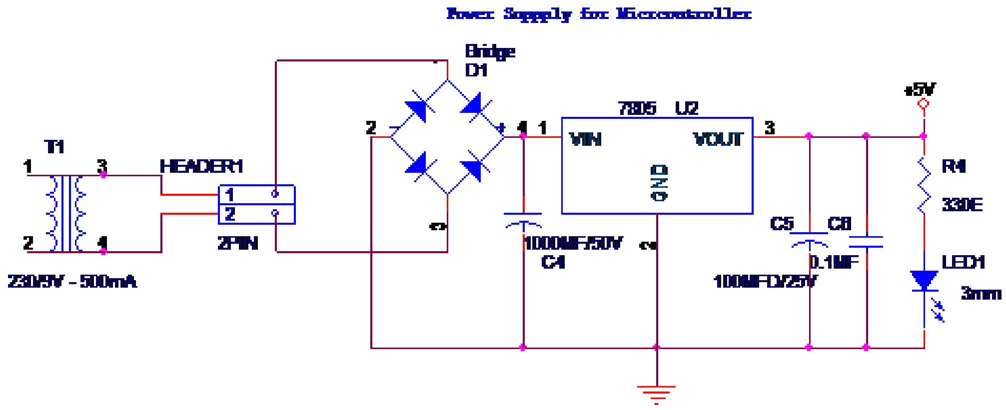


Figure 4.1 Block diagram of power supply

4.1.2 Transformer

A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled wires. A changing current in the first circuit (the primary) creates a changing magnetic field; in turn, this magnetic field induces a changing voltage in the second circuit (the secondary). By adding a load to the secondary circuit, one can make current flow in the transformer, thus transferring energy from one circuit to the other. The secondary induced voltage V_S is scaled from the primary V_P by a factor ideally equal to the ratio of the number of turns of wire in their respective windings:

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

By appropriate selection of the numbers of turns, a transformer thus allows an alternating voltage to be stepped up — by making N_S more than N_P or stepped down, by making it less.

A key application of transformers is to reduce the current before transmitting electrical energy over long distances through wires. Most wires have resistance and so dissipate electrical energy at a rate proportional to the square of the current through the wire. By transforming electrical power to a high-voltage, and therefore low-current form for transmission and back again afterwards, transformers enable the economic transmission of power over long distances. Consequently, transformers have shaped the electricity supply industry, permitting generation to be located remotely from points of demand. All but a fraction of the world's electrical power has passed through a series of transformers by the time it reaches the consumer.

Transformers are some of the most efficient electrical 'machines', with some large units able to transfer 99.75% of their input power to their output. Transformers come in a range of sizes from a thumbnail-sized coupling transformer hidden inside a stage microphone to huge gigavolt-ampere-rated units used to interconnect portions of national power grids. All operate with the same basic principles, though a variety of designs exist to perform specialized roles throughout home and industry.

The transformer is based on two principles: first, that an electric current can produce a magnetic field (electromagnetism) and, second, that a changing magnetic field within a coil of wire induces a voltage across the ends of the coil (electromagnetic induction). By changing the current in the primary coil, one changes the strength of its magnetic field; since the secondary coil is wrapped around the same magnetic field, a voltage is induced across the secondary.

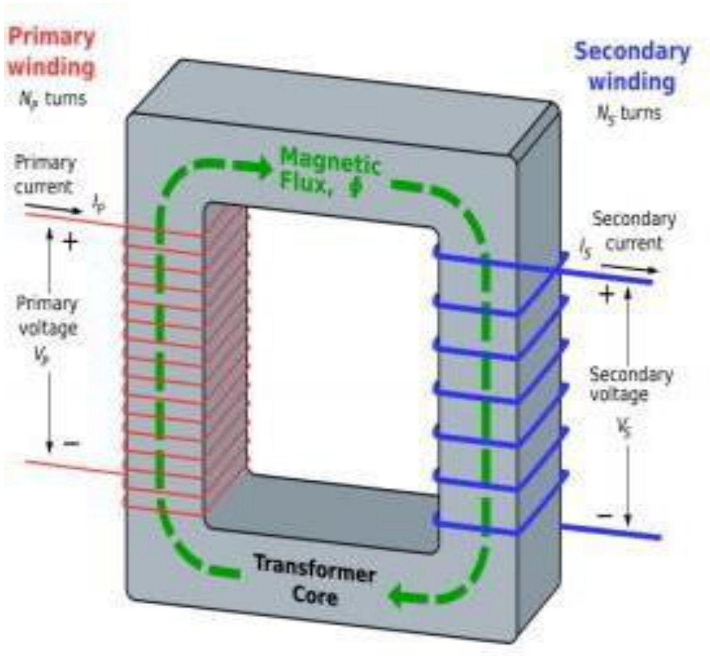


Figure 4.2 An ideal step-down transformer

A simplified an ideal step-down transformer design is shown in the above figure. A current passing through the primary coil creates a magnetic field. The primary and secondary coils are wrapped around a core of very high magnetic permeability, such as iron; this ensures that most of the magnetic field lines produced by the primary current are within the iron and pass through the secondary coil as well as the primary coil.

4.1.3 Rectifier

A rectifier is an electrical device that converts alternating current (AC), which periodically reverses direction, to direct current (DC), which flows in only one direction. The process is known as rectification. Rectifiers are used as components of power supplies and as detectors of radio signals. Mainly there are three types of rectifier i.e. half wave rectifier, full wave rectifier and Bridge Rectifier.

4.1.3 Half-wave rectifier

In half-wave rectification of a single-phase supply, either the positive or negative half of the AC wave is passed, while the other half is blocked. Because only one half of the input waveform reaches the output, mean voltage is lower. Half-wave rectification requires a single diode in a single-phase supply, or three in a three-phase supply. Rectifiers yield a unidirectional but pulsating direct current; half-wave rectifiers produce far more ripple than full-wave rectifiers, and much more filtering is needed to eliminate harmonics of the AC frequency from the output.

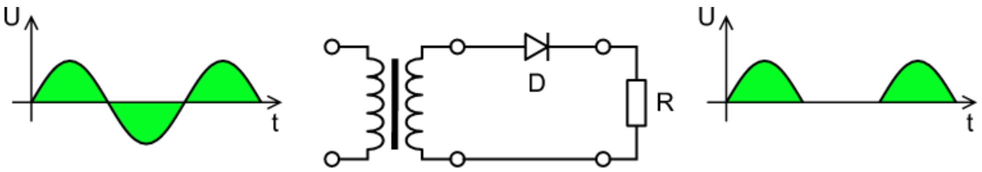


Figure 4.4 Half Wave Rectifier

4.1.4 Full-wave rectifier

A full-wave rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output. Full-wave rectification converts both polarities of the input waveform to pulsating DC (direct current), and yields a higher average output voltage. Two diodes and a center tapped transformer are needed.

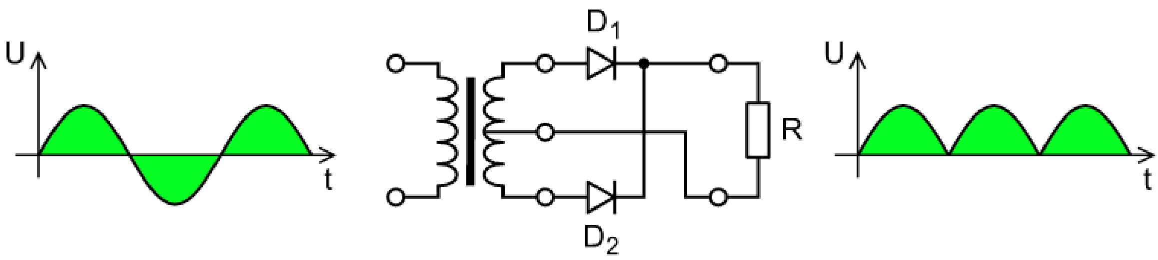


Figure 4.5 Full-Wave Rectifier

4.1.5 Bridge Rectifier

A diode bridge is an arrangement of four (or more) diodes in a bridge circuit configuration that provides the same polarity of output for either polarity of input. When used in its most common application, for conversion of an alternating current (AC) input into a direct current (DC) output, it is known as a bridge rectifier. A bridge rectifier provides full-wave rectification from a two-wire AC input, resulting in lower cost and weight as compared to a rectifier with a 3-wire input from a transformer with a center-tapped secondary winding. The essential feature of a diode bridge is that the polarity of the output is the same regardless of the polarity at the input.

4.1.6 Basic operation

According to the conventional model of current flow, current is defined to be positive when it flows through electrical conductors from the positive to the negative pole. In actuality, free electrons in a conductor nearly always flow from the negative to the positive pole. In the vast majority of applications, however, the actual direction of current flow is irrelevant. Therefore, in the discussion below the conventional model is retained.

In the diagrams below, when the input connected to the left corner of the diamond is positive, and the input connected to the right corner is negative, current flows from the upper supply terminal to the right along the red (positive) path to the output, and returns to the lower supply terminal via the blue (negative) path.

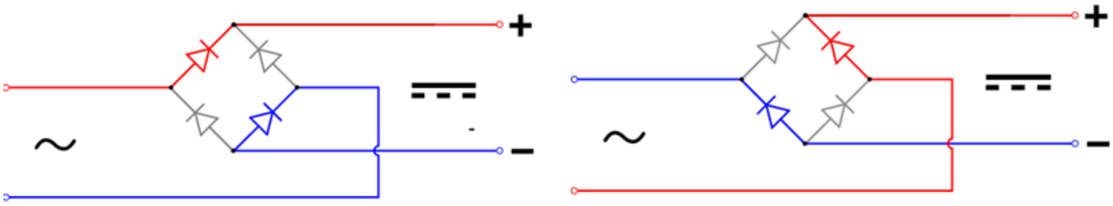


Figure 4.6 Operation of bridge rectifier

When the input connected to the left corner is negative, and the input connected to the right corner is positive, current flows from the lower supply terminal to the right along the red (positive) path to the output, and returns to the upper supply terminal via the blue (negative) path.

In each case, the upper right output remains positive and lower right output negative. Since this is true whether the input is AC or DC, this circuit not only produces a DC output from an AC input, it can also provide what is sometimes called "reverse polarity protection". That is, it permits normal functioning of DC-powered equipment when batteries have been installed backwards, or when the leads (wires) from a DC power source have been reversed, and protects the equipment from potential damage caused by reverse polarity.

4.1.7 IC Voltage Regulators

Voltage regulators comprise a class of widely used ICs. Regulator IC units contain the circuitry for reference source, comparator amplifier, control device, and overload protection all in a single IC. Although the internal construction of the IC is somewhat different from that described for discrete voltage regulator circuits, the external operation is much the same. IC units provide regulation of either a fixed positive voltage, a fixed negative voltage, or an adjustable set voltage. A power supply can be built using a transformer connected to the ac supply line to step the ac voltage to desired amplitude, then rectifying that ac voltage, filtering with a capacitor and RC filter, if desired, and finally regulating the dc voltage using an IC regulator. The regulators can be selected for operation with load currents from hundreds of milliamperes to tens of amperes, corresponding to power ratings from milliwatts to tens of watts.

Three-Terminal Voltage Regulators

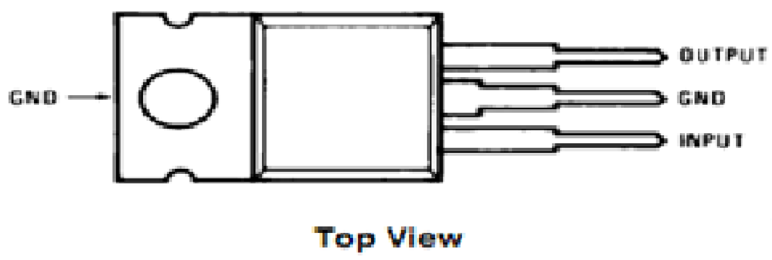


Figure 4.7 Three-Terminal Voltage Regulators

Figure shows the basic connection of a three-terminal voltage regulator IC to a load. The fixed voltage regulator has an unregulated dc input voltage, V_i, applied to one input terminal, a regulated output dc voltage, V_o, from a second terminal, with the third terminal connected to ground. For a selected regulator, IC device specifications list a voltage range over which the input voltage can vary to maintain a regulated output voltage over a range of load current. The specifications also list the amount of output voltage change resulting from a change in load current (load regulation) or in input voltage (line regulation). The series 78 regulators provide fixed regulated voltages from 5 to 24 V. Figure shows how one such IC, a 7805, is connected to provide voltage regulation with output from this unit of +5V dc. An unregulated input voltage V is filtered by capacitor C1 and connected to the IC's IN terminal. The IC's OUT terminal provides a regulated + 12V which is filtered by capacitor C2 (mostly for any high-frequency noise). The third IC terminal is connected to ground (GND). While the input voltage may vary over some permissible voltage range, and the output load may vary over some acceptable range, the output voltage remains constant within specified voltage variation limits. These limitations are spelled out in the manufacturer's specification sheets. There are two types of voltage regulator they are 78xx series and 79xx series.

78xx series

There are common configurations for 78xx ICs, including 7805 (5 V), 7806 (6 V), 7808 (8 V), 7809 (9 V), 7810 (10 V), 7812 (12 V), 7815 (15 V), 7818 (18 V), and 7824 (24 V) versions. The 7805 is the most common, as its regulated 5-volt supply provides a convenient power source for most TTL components.

Less common are lower-power versions such as the LM78Mxx series (500 mA) and LM78Lxx series (100 mA) from National Semiconductor. Some devices provide slightly different voltages than usual, such as the LM78L62 (6.2 volts) and LM78L82 (8.2 volts) as well as the STMicroelectronics L78L33ACZ (3.3 volts).

79xx series

The 79xx devices have a similar "part number" to "voltage output" scheme, but their outputs are negative voltage, for example 7905 is -5 V and 7912 is -12 V. The 7912 has been a popular component in ATX power supplies, and 7905 was popular component in ATX before -5 V was removed from the ATX specification.

Positive Voltage Regulators in 7800 series

IC Part	**Output Voltage (V)**	**Vi (V)**
7805	+5	7.3
7806	+6	8.3
7808	+8	10.5
7810	+10	12.5
7812	+12	13.6
7815	+15	17.7
7818	+18	21.0
7824	+24	27.1

Table 4.1Positive Voltage Regulators in 7800 series

4.8 ACCELEROMETER

This Accelerometer module is based on the popular ADXL335 three-axis analog accelerometer IC, which reads off the X, Y and Z acceleration as analog voltages. By measuring the amount of acceleration due to gravity, an accelerometer can figure out the angle it is tilted at with respect to the earth. By sensing the amount of dynamic acceleration, the accelerometer can find out how fast and in what direction the device is moving. Using these two properties, you can make all sorts of cool projects, from musical instruments (imagine playing and having the tilt connected to the distortion level or the pitch-bend) to a velocity monitor on your car (or your children's car). The accelerometer is very easy interface to an Arduino Micro-controller using 3 analog input pins, and can be used with most other micro controllers, such as the PIC or AVR.

The ADXL335 can measure at least +/- 3G in the X, Y and Z axis. It is perfect for high-resolution static acceleration measurements such as tilt-sensing, as well as for moderate dynamic accelerations from motion, shock or vibration.

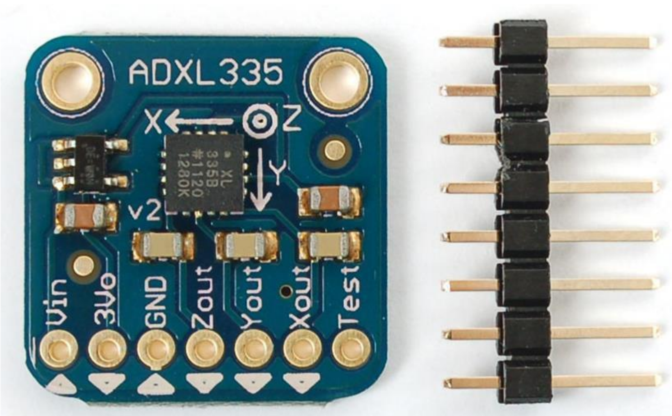


Figure 4.8 ADXL335

or most accelerometers, the basic connections required for operation are power and the communication lines. Accelerometers with an analog interface show accelerations through varying voltage levels. These values generally fluctuate between ground and the supply voltage level. An ADC on a microcontroller can then be used to read this value. These are generally less expensive than digital accelerometers.

ADXL335 is 3 axis accelerometer with on board voltage regulator IC and signal conditioned Analog voltage output. The module is made up of ADXL335 from Analog Devices. The product measures acceleration with a minimum full-scale range of ±3 g. It can measure the static acceleration of gravity in tilt-sensing applications, as well as dynamic acceleration resulting from motion, shock, or vibration.

The user selects the bandwidth of the accelerometer using the CX, CY, and CZ capacitors at the XOUT, YOUT, and ZOUT pins. Bandwidths can be selected to suit the application, with a range of 0.5 Hz to 1600 Hz for the X and Y axis, and a range of 0.5 Hz to 550 Hz for the Z axis.This is the latest in a long, proven line of analog sensors – the holy grail of accelerometers. Accelerometers are generally low-power devices. The required current typically falls in the micro (µ) or milli-amp range The ADXL335 is a triple axis accelerometer with extremely low noise and power consumption – only 320uA! The sensor has a full sensing range of +/-3g. There is an on-board voltage regulation, which enable you to power the board with 3V to 6V DC. Board comes fully assembled and tested with external components installed. The included 0.1uF capacitors set the bandwidth of each axis to 50Hz.

4.8.1 Features:

- 3V-6V DC Supply Voltage
- Onboard LDO Voltage regulator
- Can be interface with 3V3 or 5V Microcontroller.
- All necessary Components are populated.
- Ultra Low Power: 40uA in measurement mode, 0.1uA in standby@ 2.5V
- Tap/Double Tap Detection
- Free-Fall Detection

A three axis accelerometer detects linear accelerations in three perpendicular directions. If it helps, picture a ball inside a box with pressure sensitive walls. As you shake the box around, the ball presses against different walls, which tellsj you the direction of acceleration. If the accelerometer is not moving, the ball will still push against the walls simply due to gravity. By comparing the readings on the x, y and z axis, you can work out the orientation of a stationary object.

4.9 SENSORS FOR VIBRATION MEASUREMENT

Sensors for vibration are sensors that operate according to different mechanical or optical principles to detect vibrations of an observed system.

The measurement of vibrations can be done using various types of sensors. Although there are no direct vibration sensors, vibrations can be measured indirectly, deducing values from classic mechanical or optical quantities. These sensors differ in some features. Among other things they can be divided based on active and passive behaviour, there are sensors that measure relative and others absolute. Other distinctive features are frequency range, signal dynamics and the quality of the measurement data. The following sensors shown here were first structured in a contacting and a non-contacting group and within these in the sub items path, velocity and acceleration measurement.

Figure 4.9 Buzzer

This sensor buffers a piezoelectric transducer. As the transducer is displaced from the mechanical neutral axis, bending creates strain within the piezoelectric element and generates voltages.

4.9.1 Specifications:

The Vibration Sensor Detector is designed for the security practice When Vibration Sensor Alarm recognizes movement or vibration, it sends a signal to either control panel Developed a new type of omni-directional high sensitivity Security Vibration Detector with omni-directional detection

- Sensitivity: Height adjustable
- Consistency and Interchangeability: Good
- Reliability and Interference: Accurate triggering strong anti-interference
- Automatic Reset: Automatic reset is strong
- Signal Post-processing: Simple
- Output Signal: Switch signal
- No External Vibration Analysis of Plates: Product design vibration analysis of the internal amplifier circuit
- Detection Direction: Omni-directional

- Signal Output: Switch signals
- Output Pulse Width: The vibration signal amplitude is proportional to
- Operating Voltage: 12VDC (red V + shield V-)
- Sensitivity: Greater than or equal 0.2g
- Frequency Range: 0.5HZ ~ 20HZ
- Operating Temperature Range: -10 ? ~ 50

Figure 4.10 Vibration Sensor

4.10 LCD (LIQUID CRYSTAL DISPLAY)

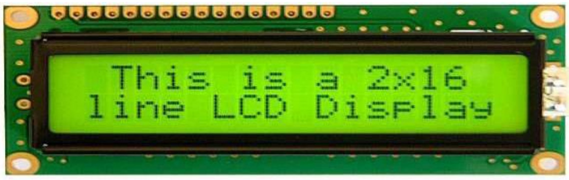


Figure 4.11 LCD Display

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits.

A 16x2 LCD means it can display 16 characters per line and there are 2 such lines. In this LCD each character is displayed in 5x7 pixel matrix. This LCD has two registers, namely, Command and Data. The command register stores the command instructions given to the LCD, The data register stores the data to be displayed on the LCD

The data is the ASCII value of the character to be displayed on the LCD.Liquid crystal displays are used for display of numeric and alphanumeric character in dot matrix and segmental displays. The two liquid crystal materials which are commonly used in display technology are nematic and cholesteric whose schematic arrangement of molecules is shown in fig. The most popular liquid crystal structure is the Nematic Liquid Crystal (NLC). In this all the molecules align themselves approximately parallel to a unique axis (director), while retaining the complete translational freedom. The liquid is normally transparent, but if subjected to a strong electric field, The removal of the applied electric field allows the crystal structure to regain its original form and the materials become transparent.

Based on the construction, LCD's are classified into two types. They are,

- Dynamic scattering type

- Field Effect Type.

4.10.1 Dynamic scattering type

The construction of the dynamic scattering liquid crystal cell is shown in the fig. The display consists of two glass plates, each coated with tin oxide ($SnO2$) on the inside with transparent electrodes separated by a liquid crystal layer,5µA to 50 µA thick. The oxide coating on the front sheet is etched to produce a single or multi- segment pattern of characters, with each segment properly insulated from each other. A weak electric field applied to liquid crystal tends to align molecule in the direction of the field. As soon as the voltage exceeds certain threshold value, the domain structure collapses and the appearance is changed. As the voltage grows further, the flow becomes turbulent and the substance turns optically homogenous. In this disordered state, the liquid crystal scatters light.

Thus, when the liquid is not activated, it is transparent. When the liquid is activated, the molecular turbulence causes light to be scattered in all directions and the cell appears bright. This phenomenon is called dynamic scattering

4.10.2 Field effect type

The construction of the field effect LCD display is similar to that of the dynamic scattering type, with the expectation that two thin polarizing optical filters are placed at the inside of each glass sheet.

The LCD material is of twisted nematic type which twists the light (change in direction of polarization) passing through the cell when the latter is not energized. This allows light to pass through the optical filters and the cell appears bright. When the cell is energized, no twisting of light takes place and the cell appears dull.

Liquid crystal cells are of two types (i) transitive type (ii) reflective type. In the transitive type cell both glass sheets are transparent so that the light from the rear source is scattered in the forward direction when the cell is activated. The reflecting type cell has a reflecting surface on one side of the glass sheet. The incident light on the front surface of the cell is dynamically scattered by an activated cell. Both types of cells appear quite bright when activated even under ambient light conditions.

Liquid crystals consume small amount of energy, in a seven segment display the current drawn is about 25 µA for dynamic scattering cells and 300 µA .

for field effect cells LCD's require ac voltage supply. A typical voltage supply to dynamic scattering LCD's are normally used for seven-segmental displays.

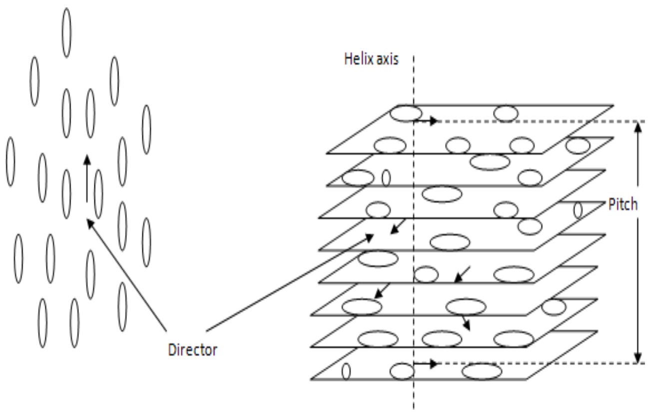


Figure 4.12 Schematic arrangement in liquid crystal

4.10.3 Features of LCD

- Operating voltage range is 3-20V ac.
- It has a slow decay time. Response time is 50 to 200 ms.
- Viewing angle is 100 degree.
- Invisible in darkness. Requires external illumination.
- Life time is limited to 50,000 hours due to chemical graduation.

4.10.4 Advantages of LCD

- The voltage required is small.
- They have low power consumption. A seven segment display requires about 140 W (20 W per segment).

CHAPTER 5

5 .SOFTWARE DESCRIPTION

5.1 MATLAB

MATLAB is a programming language developed by MathWorks. It started out as a matrix programming language where linear algebra programming was simple. It can be run both nder interactive sessions and as a batch job. MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment and fourth-generation programming language. A proprietary programming language developed by Math Works, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems. Mathematics is the basic building block of science and engineering, and MATLAB makes it easy to handle many of the computations involved. You should not think of MATLAB as another complication programming language, but as a powerful calculator that gives you fingertip access to exploring interesting problems in science, engineering, and mathematics. And this access is available by using only a small number of commands and functions because MATLAB's basic data element is a matrix (or an array). This is a crucial feature of MATLAB

— it was designed to group large amounts of data in arrays and to perform mathematical operations on this data as individual arrays rather than as groups of data. This makes it very easy to apply complicated operations to the data, and it makes it very difficult to do it wrong. In high-level computer languages you would usually have to work on each piece of data separately and use loops to cycle over all the pieces. In MATLAB this can frequently do complicated “things” in one, or a few, statements (and no loops). In addition, in a high-level language many mathematical operations require the use of sophisticated software packages, which you have to find and, much worse, to understand since the interfaces to these packages are frequently quite complicated and the documentation must be read and mastered.

5.1.1 FEATURES OF MATLAB

- It is a high-level language for numerical computation, visualization and application development.

- It also provides an interactive environment for iterative exploration, design and problem solving.

- It provides built-in graphics for visualizing data and tools for creating custom plots.

- MATLAB's programming interface gives development tools for improving code quality, maintainability, and maximizing performance.

- It provides tools for building applications with custom graphical interfaces.

- It provides functions for integrating MATLAB based algorithms with external applications and languages such as C, Java, .NET and Microsoft Excel

5.1.2 USES OF MATLAB

- It is a high-level language for numerical computation, visualization and application development.

- It provides built-in graphics for visualizing data and tools for creating custom plots.

- MATLAB's programming interface gives development tools for improving code quality, maintainability, and maximizing performance.

- It provides tools for building applications with custom graphical interfaces.

- It provides functions for integrating MATLAB based algorithms with external applications and languages such as C, Java, .NET and Microsoft

Excel.

5.2 MATLAB files

MATLAB allows writing two kinds of program files:

Scripts - script files are program files with .m extension. In these files, you write series of commands, which you want to execute together.

Functions - functions files are also program files with .m extension. Functions can accept inputs and return outputs. Internal variables are local to the function.

You can use the MATLAB editor or any other text editor to create your .m files.

CHAPTER 6

6. IMPLEMENTATION

6.1 MODULES

- IMAGE ACQUISITION
- PREPROCESSING
- CONTRAST ENHANCEMENT
- BINARIZATION
- SEGMENTATION

6.2 MODULES

DESCRIPTION IMAGE

ACQUISITION

Image-based systems have several benefits for monitoring the crack propagation in different structural material. Initially, when these systems were used to measurement of cracks, more attention was paid to features of objects and repeatability. Also, the use of remote sensing techniques allows the measurement of cracks without the need for access to the validated elements, and also provides stable image storage for each observation in any period. These systems are helpful for those who are involved in the design of structures or those who are responsible for maintaining the infrastructure systems when analyzing the relationship between loading and damage locations. In this module, we can input the image with any type and any size.

6.3 PREPROCESSING

Pre-processing is a common name for operations with images at the lowest level of abstraction both input and output are intensity images. These iconic images are of the same kind as the original data captured by the sensor, with an intensity image usually represented by a matrix of image function values (brightnesses). Image pre-processing methods are classified into four categories according to the size of the pixel neighborhood that is used for the calculation of new pixel brightness. The aim of pre-processing is an improvement of the image data that suppresses unwilling distortions or enhances some image features important for further processing, although geometric transformations of images (e.g. rotation, scaling, translation) are classified among pre-processing methods here since similar techniques are used. The user has to select the required lung frame image for further processing. In this module convert the RGB image into gray scale image. The colors of leaves are always green shades and the variety of changes in atmosphere cause the color feature having low reliability. Therefore, to recognize various plants using their leaves, the obtained leaf image in RGB format will be converted to gray scale before pre-processing. The formula used for converting the RGB pixel value to its grey scale counterpart is given in Equation.

$$Gray = 0.2989 * R + 0.5870 * G + 0.1140 * B$$

where R, G, B correspond to the color of the pixel, respectively.

6.4 CONTRAST ENHANCEMENT

In this module, we can implement contrast enhancement to improve the contrast pixels. Linear contrast enhancement, also referred to as a contrast stretching, linearly expands the original digital values of the remotely sensed data into a new distribution. By expanding the original input values of the image, the total range of sensitivity of the display device can be utilized. Linear contrast enhancement also makes subtle variations within the data more obvious. These types of enhancements are best applied to remotely sensed images with Gaussian or near-Gaussian histograms, meaning, all the brightness values fall within a narrow range of the histogram and only one mode is apparent.

6.5 BINARIZATION

Image binarization is the process of taking a gray scale image and converting it to black-and-white, essentially reducing the information contained within the image from 256 shades of gray to 2: black and white, a binary image. This is sometimes known as image thresholding, although thresholding may produce images with more than 2 levels of gray. The process of binarization works by finding a threshold value in the histogram – a value that effectively divides the histogram into two parts, each representing one of two objects (or the object and the background). In this context it is known as global thresholding. Based on this step, binary image is created.

6.6 SEGMENTATION

ANN has significant application in crack detection. The purpose of ANN is to generate a network system with little errors but also yield good result from the testing data set. In this module implement artificial neural network algorithm to classify image as normal or cracked. The neural network itself isn't an algorithm, but rather a framework for many different machine learning algorithms to work together and process complex data inputs. Such systems "learn" to perform tasks by considering examples, generally without being programmed with any task- specific rules. An ANN is based on a collection of connected units or nodes called artificial neurons, which loosely model the neurons in a biological brain. Each connection, like the synapses in a biological brain, can transmit a signal from one artificial neuron to another. An artificial neuron that receives a signal can process it and then signal additional artificial neurons connected to it. In common

ANN implementations, the signal at a connection between artificial neurons are a real number, and the output of each artificial neuron is computed by some non-linear function of the sum of its inputs. The weight increases or decreases the strength of the signal at a connection. Artificial neurons may have a threshold such that the signal is only sent if the aggregate signal crosses that threshold.

Step 1: Randomly initialize the weights and biases.

Step 2: feed the training sample.

Step 3: Propagate the inputs forward; compute the net input and output of each unit in the hidden and output layers.

Step 4: back propagate the error to the hidden layer.

Step 5: update weights and biases to reflect the propagated errors.

Training and learning functions are mathematical procedures used to automatically adjust the network's weights and biases.

Step 6: terminating condition

Based on these steps leaves and fruits are classified with disease names with improved accuracy rate.

SIGNIFICANCE OF PROPOSED METHOD TOWARDS SUSTAINABLE

FUTURE

6.7 SUSTAINABLE DEVELOPMENT GOALS:

Sustainable development is a concept and method that aims to balance economic growth, social progress, and environmental protection in a way that serves the demands of the current generation without jeopardizing future generations' ability to satisfy their own needs. To create a more sustainable and resilient future entails merging economic development, social fairness, and environmental stewardship

6.8 SIGNIFICANCE CONTRIBUTION TOWARDS SDG:

Goal 1: Industry, Innovation, and Infrastructure - SHM contributes to the development of resilient infrastructure through continuous monitoring and maintenance, ensuring safety and sustainability.

Goal 2: Sustainable Cities and Communities - SHM enhances the safety and longevity of buildings, bridges, and other infrastructure, fostering sustainable urban development.

Goal 3: Climate Action - By detecting and addressing structural weaknesses early, SHM helps mitigate the impact of natural disasters, reducing carbon emissions associated with rebuilding efforts.

Goal 4: Partnerships for the Goals - Collaboration between governments, industries, and research institutions is crucial for advancing SHM technologies and implementing effective monitoring systems globally.

Goal 5: Affordable and Clean Energy - SHM can help optimize the operation and maintenance of energy infrastructure such as wind turbines and solar panels, increasing their efficiency and lifespan, thus contributing to the availability of affordable and clean energy.

Goal 6: Clean Water and Sanitation - SHM technologies can monitor the integrity of water infrastructure such as dams, pipelines, and reservoirs, ensuring the safe and efficient delivery of clean water and sanitation services.

Goal 7: Decent Work and Economic Growth - By reducing the need for costly and disruptive manual inspections and enabling predictive maintenance, SHM supports economic growth and creates opportunities for skilled employment in the field of infrastructure monitoring and maintenance.

Goal 8: Life on Land - SHM helps in the conservation and sustainable management of terrestrial ecosystems by monitoring the impact of infrastructure development on wildlife habitats and natural landscapes, thus promoting biodiversity and ecosystem resilience.

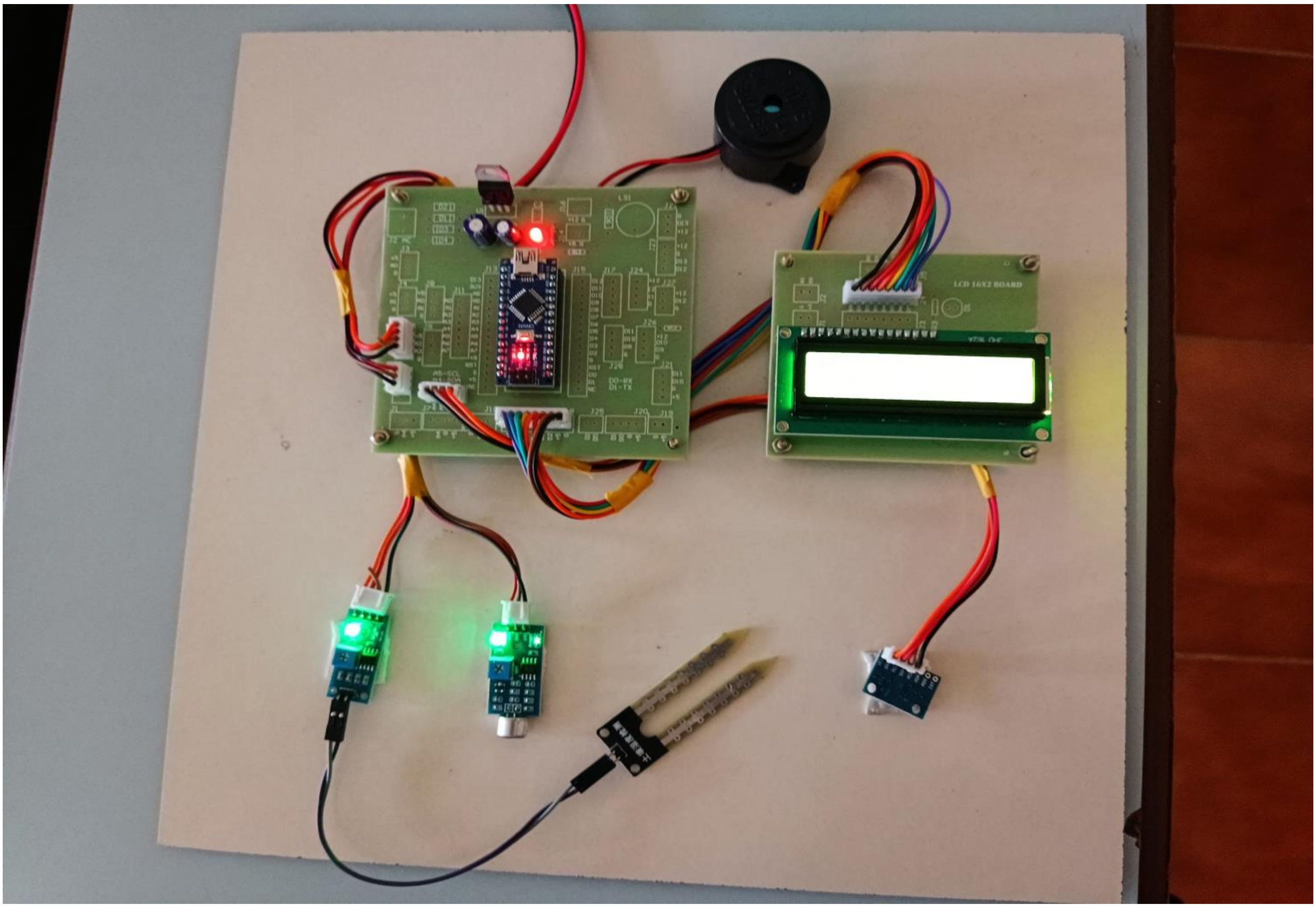
Goal 9: Quality Education - SHM technologies provide opportunities for education and capacity building in engineering, technology, and data analysis, empowering communities to effectively monitor and maintain their infrastructure for long-term sustainability.

Goal 10: Peace, Justice, and Strong Institutions - Reliable infrastructure is essential for fostering stability and resilience in communities, and SHM contributes to the development of strong and resilient institutions by ensuring the safety and integrity of critical infrastructure assets.

CHAPTER 7

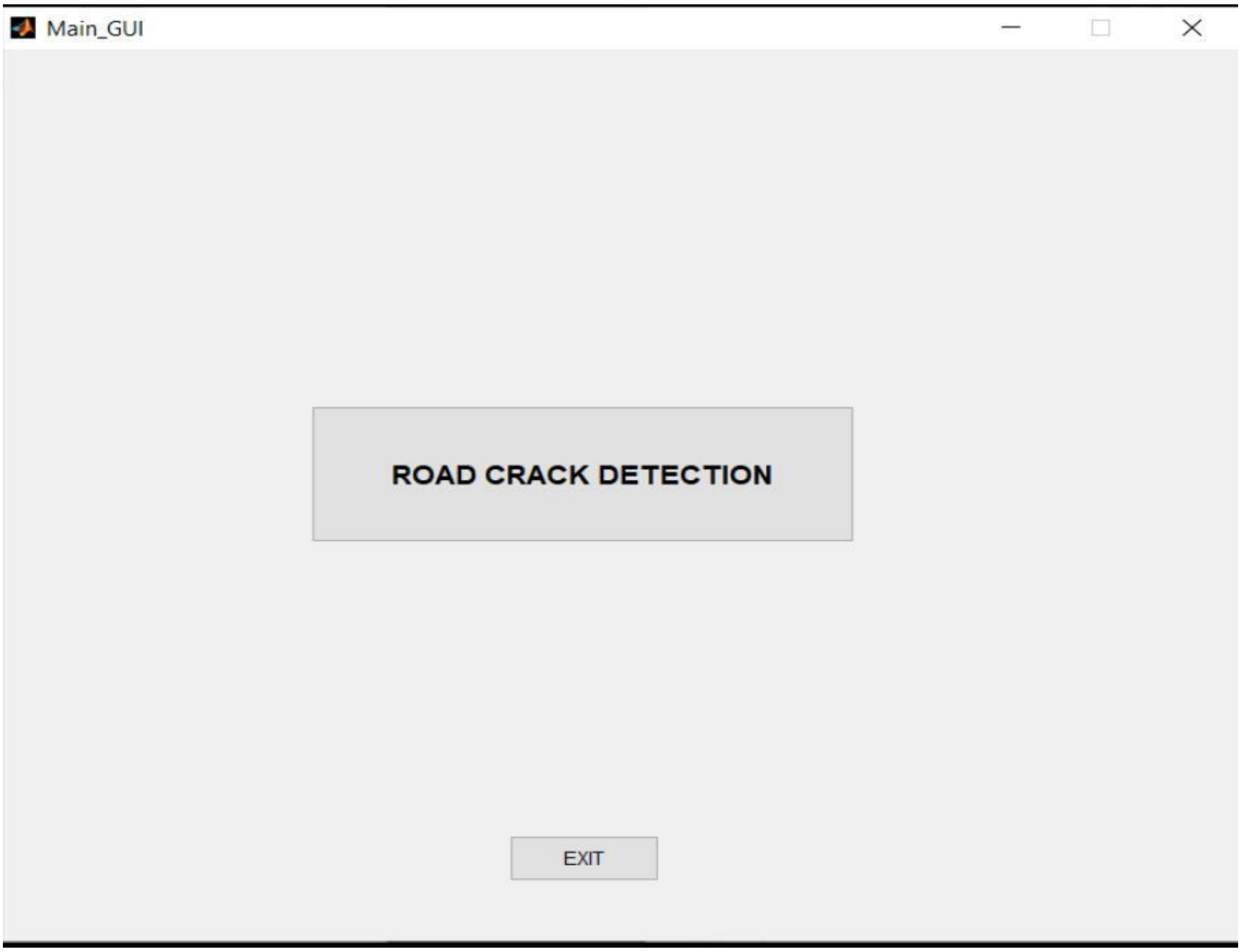
7.RESULTS AND DISCUSSIONS

EXPERIMENTAL SETUP:

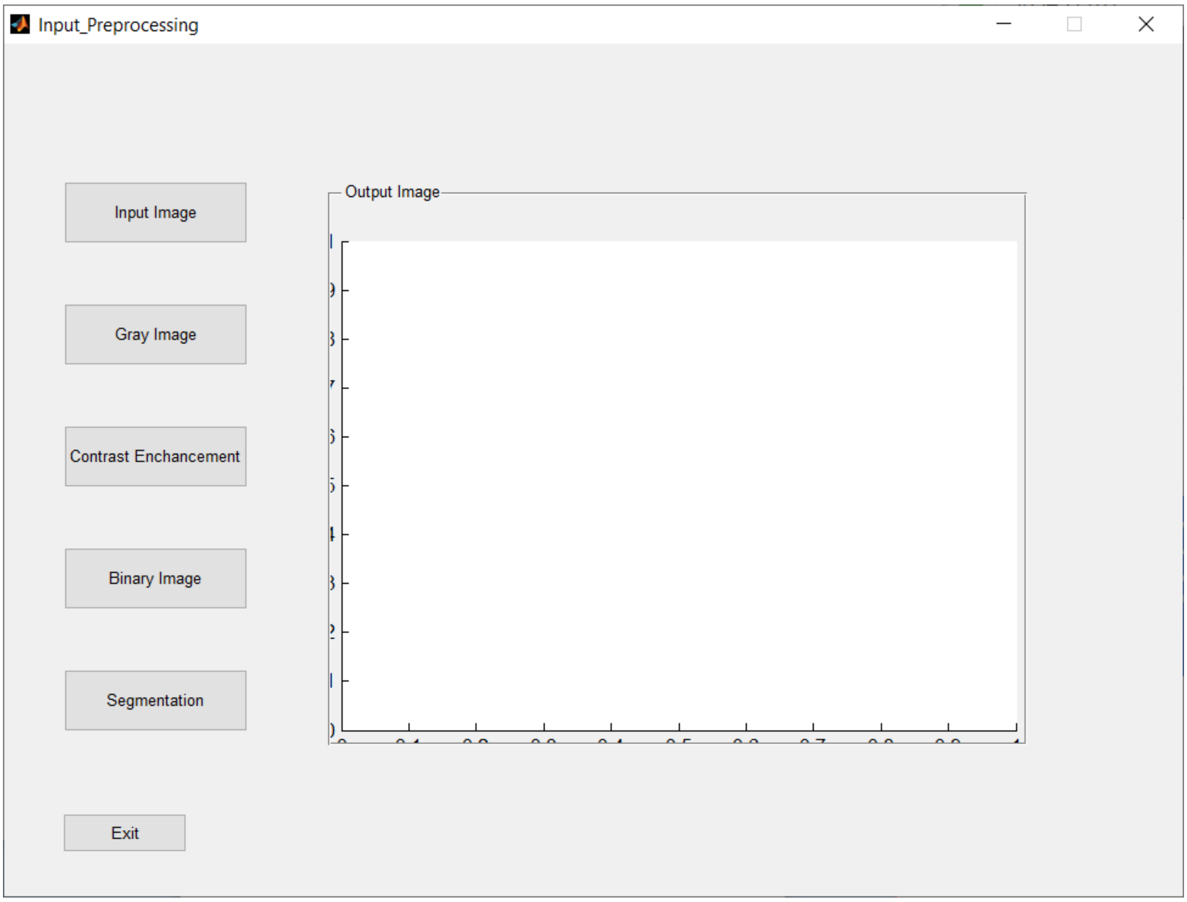


7.1 Experimental Setup

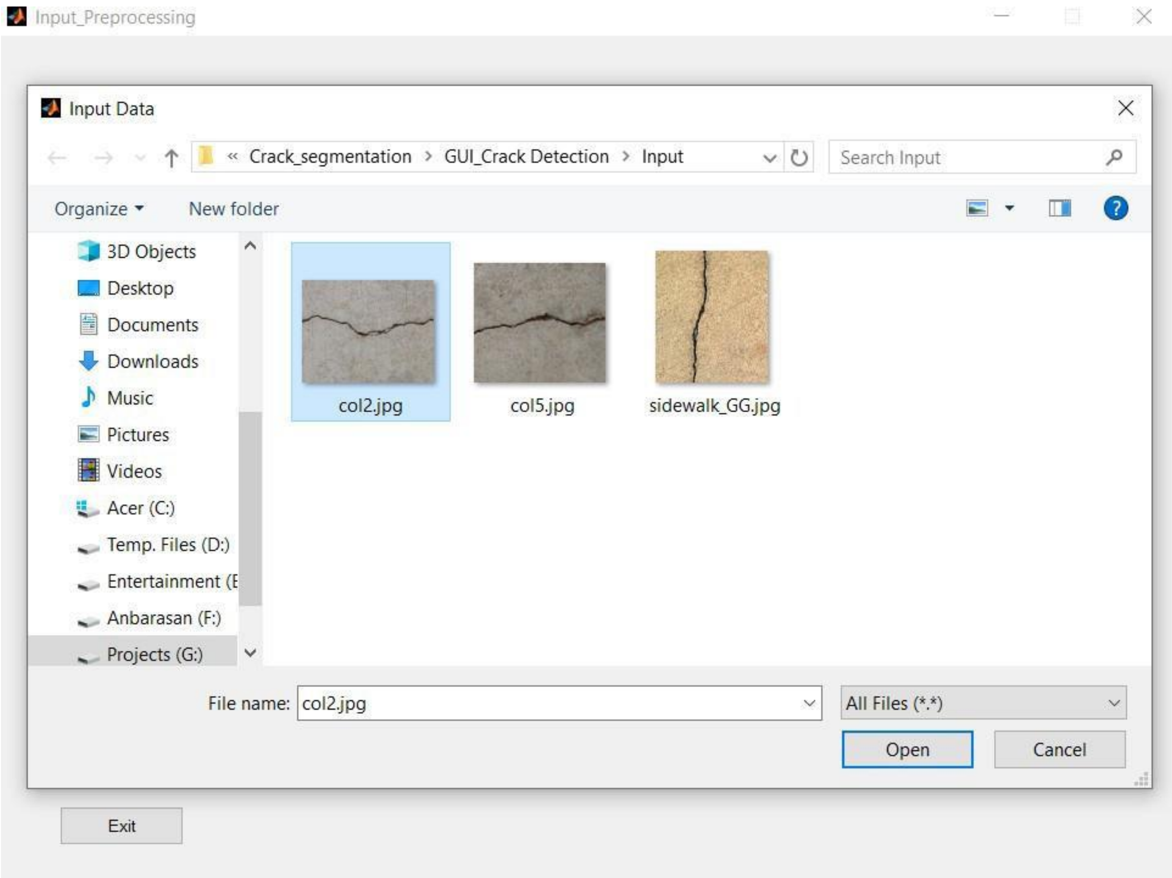
7.1 HOME PAGE



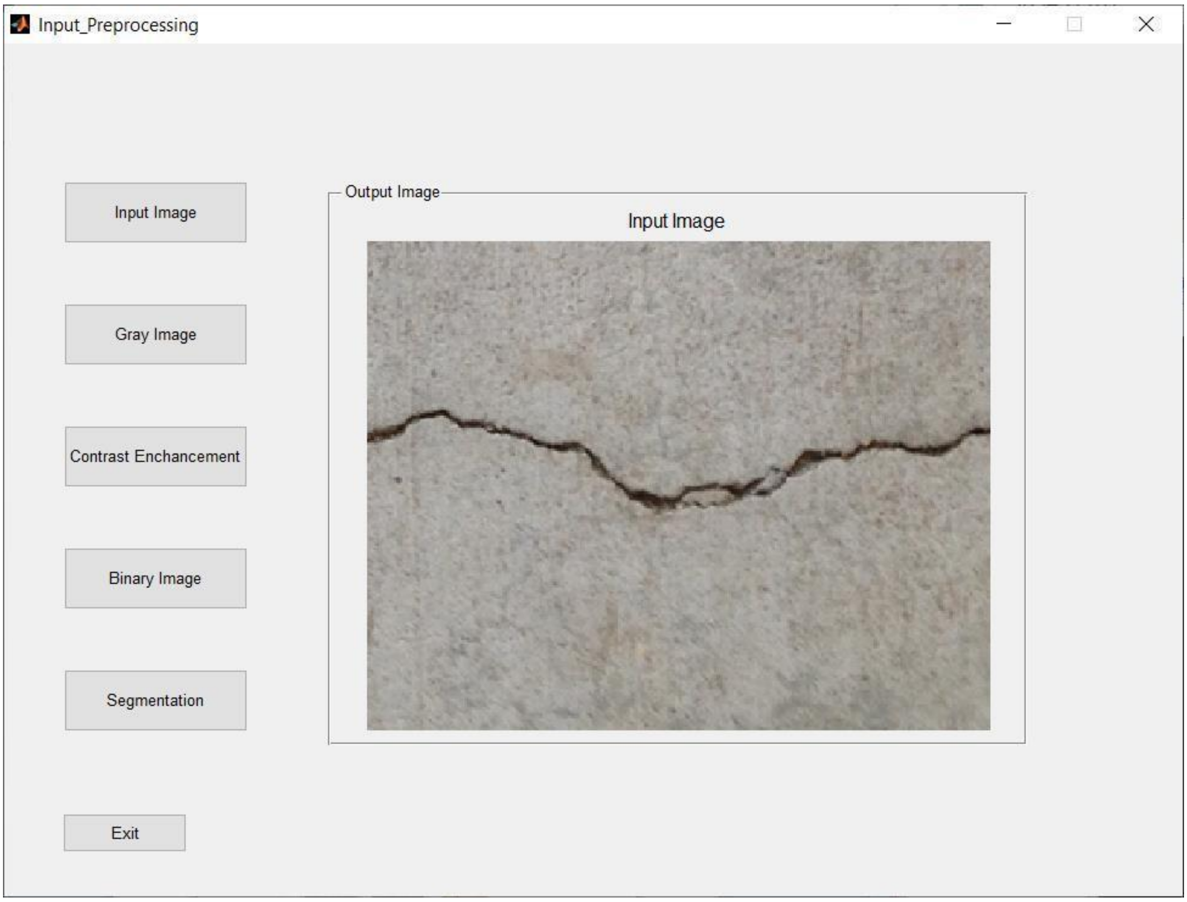
7.2 INPUT IMAGE



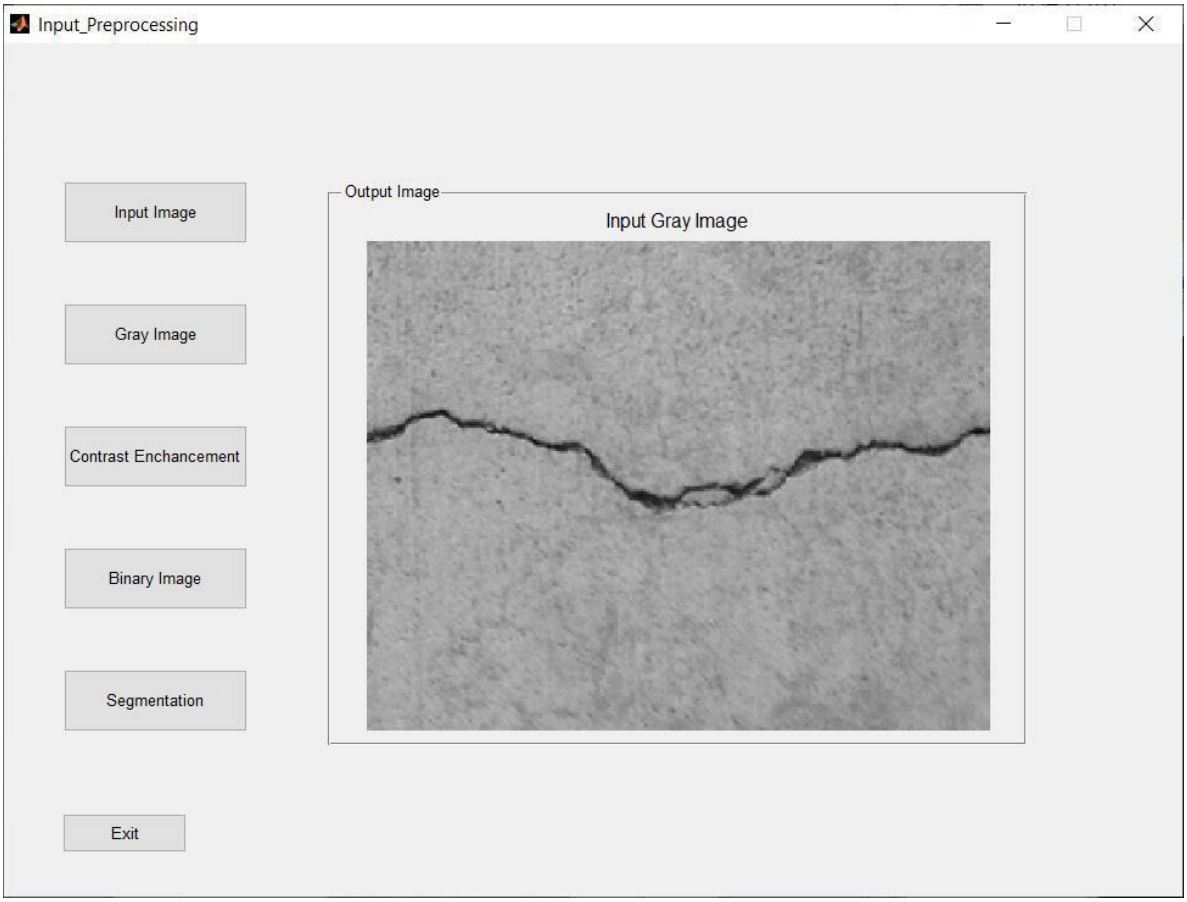
7.3 SELECT IMAGE



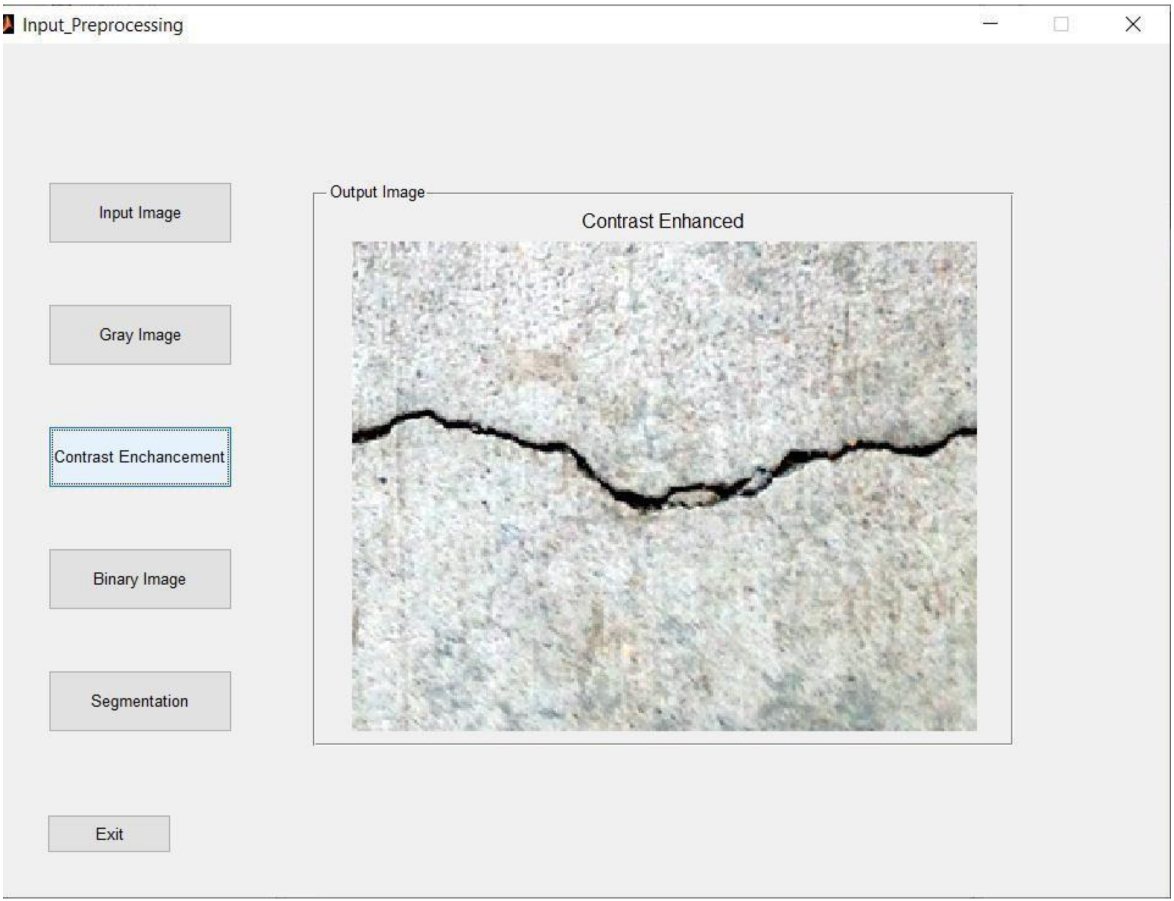
7.4 IMAGE IN HOME PAGE



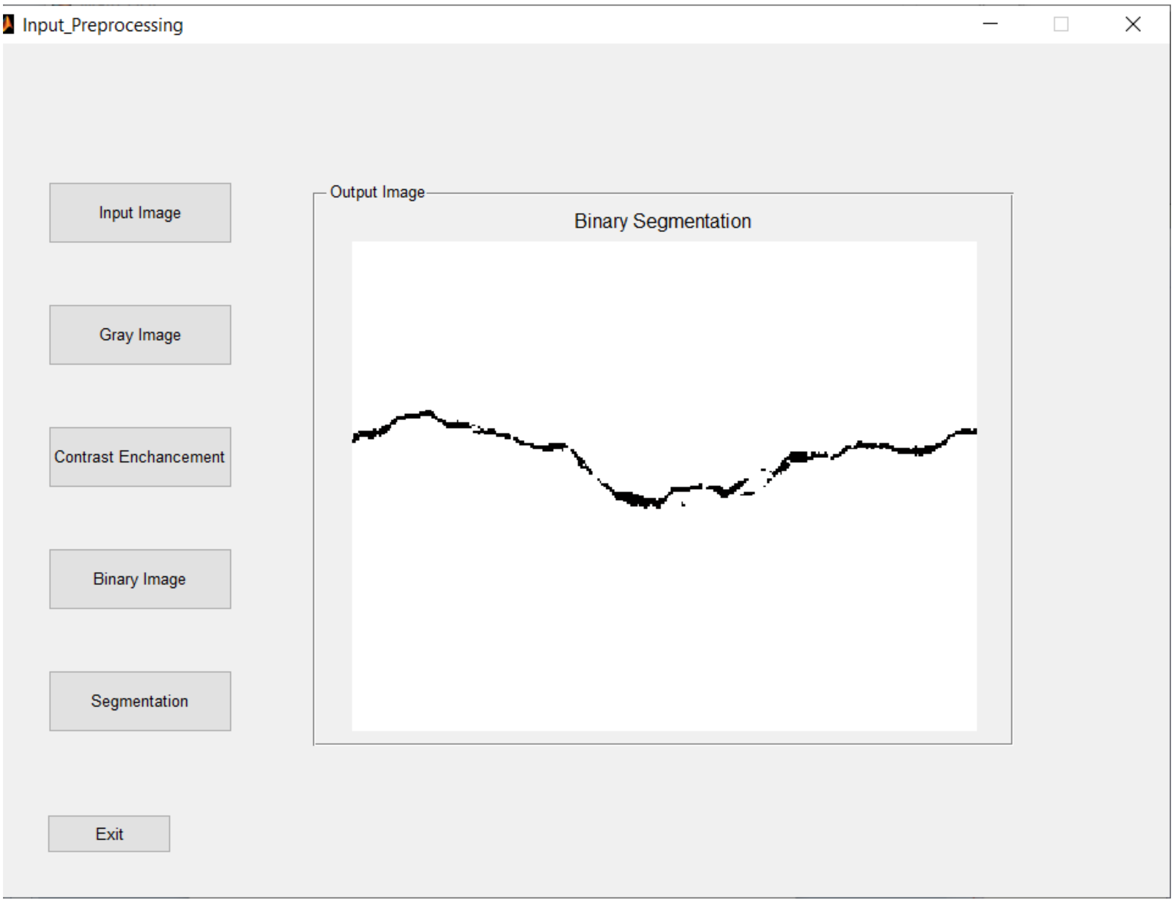
7.5 PREPROCESSING – GRAY SCALE CONVERSION



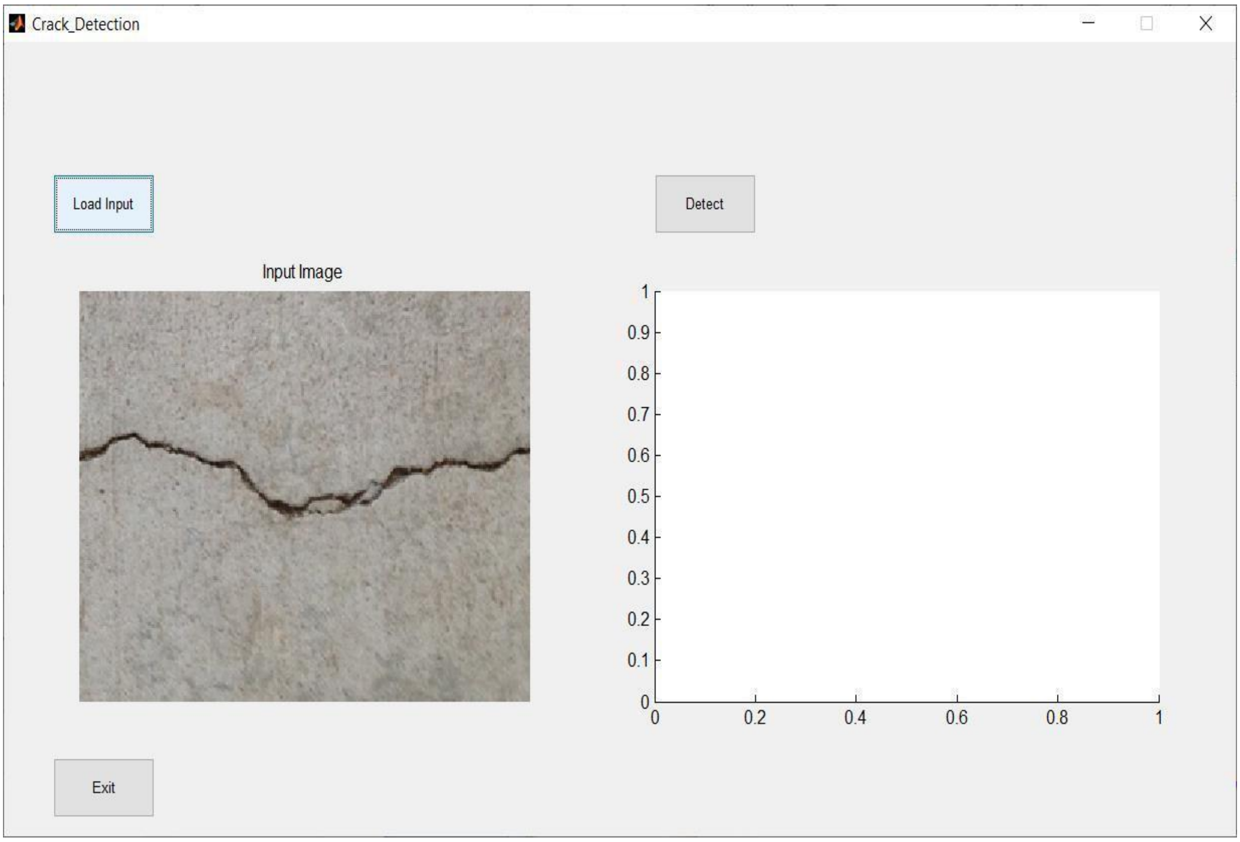
7.6 CONTRAST ENHANCEMENT



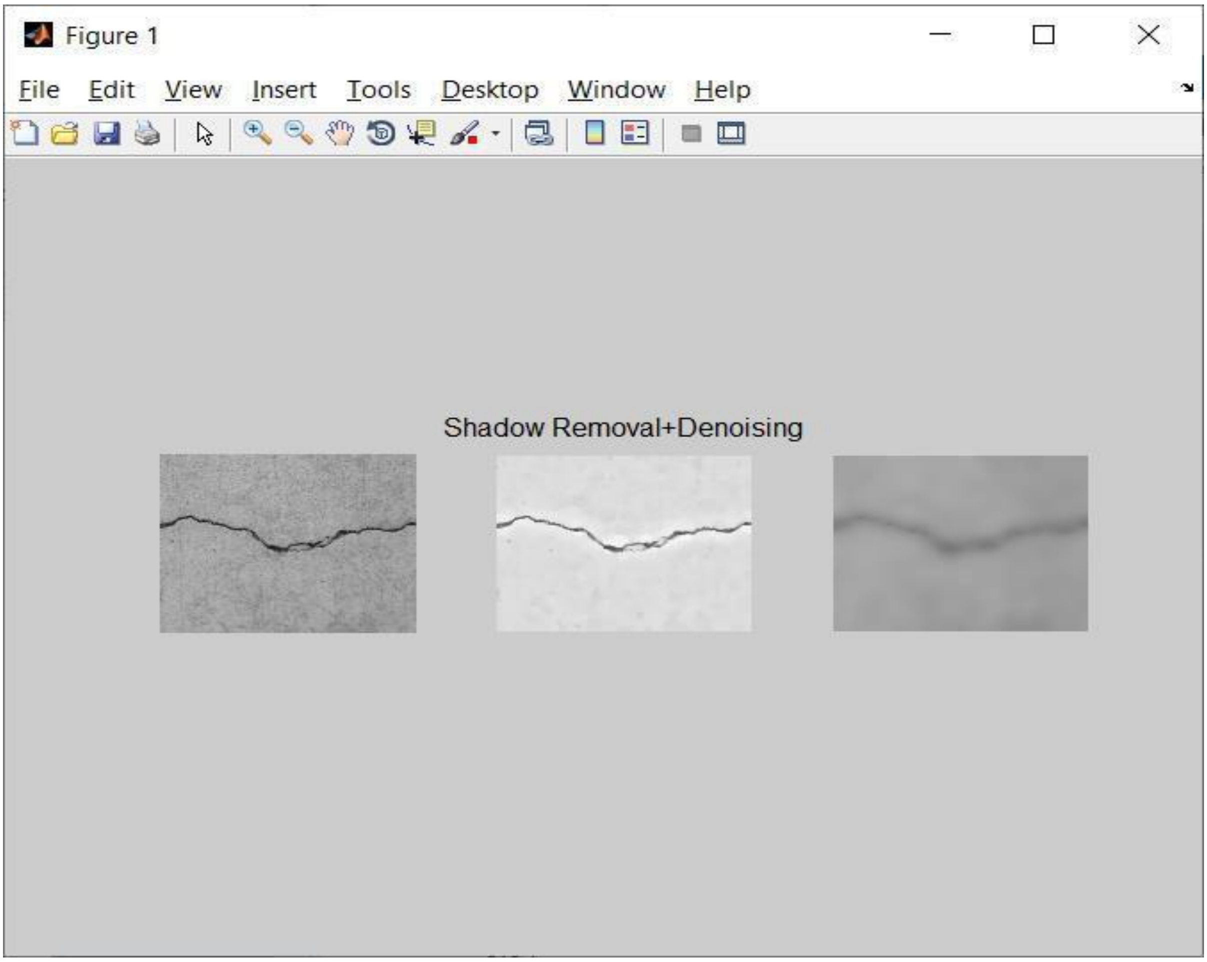
7.7 BINARY SEGMENTATION



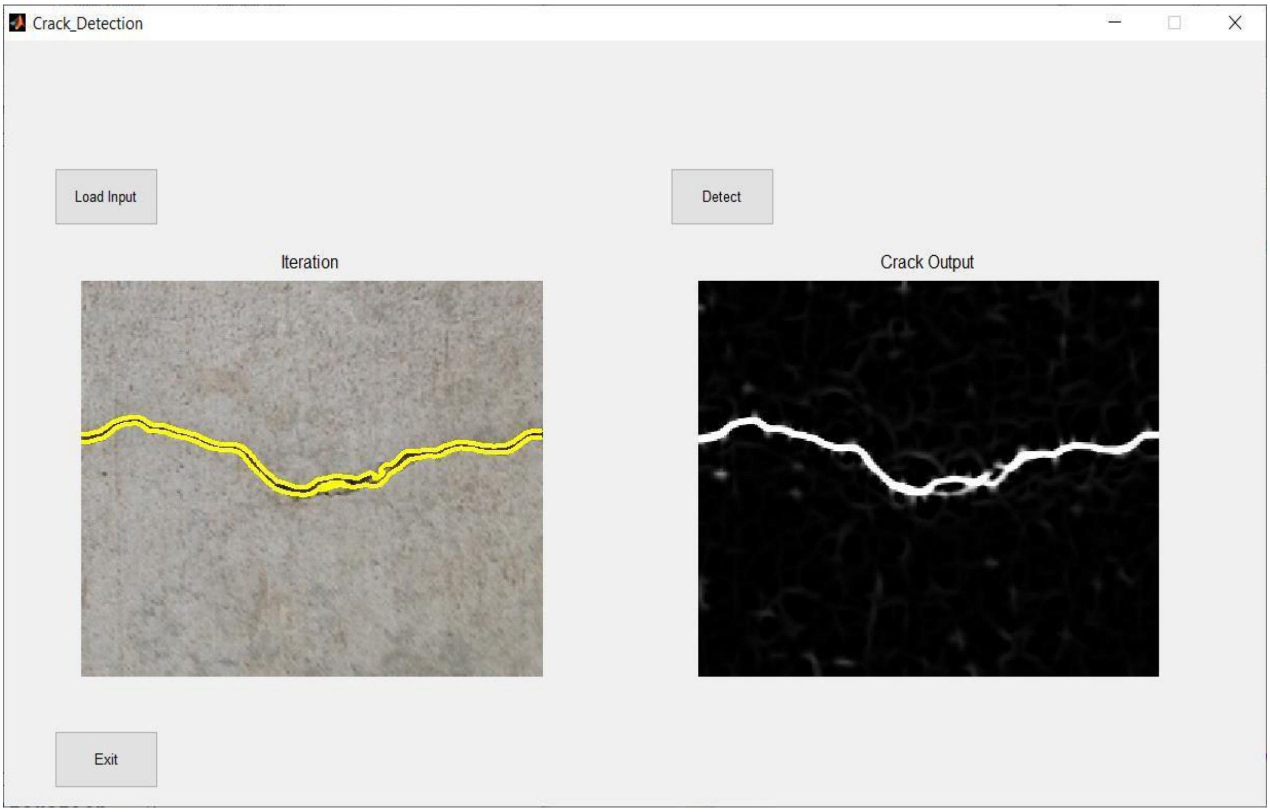
7.8 CRACK DETECTION



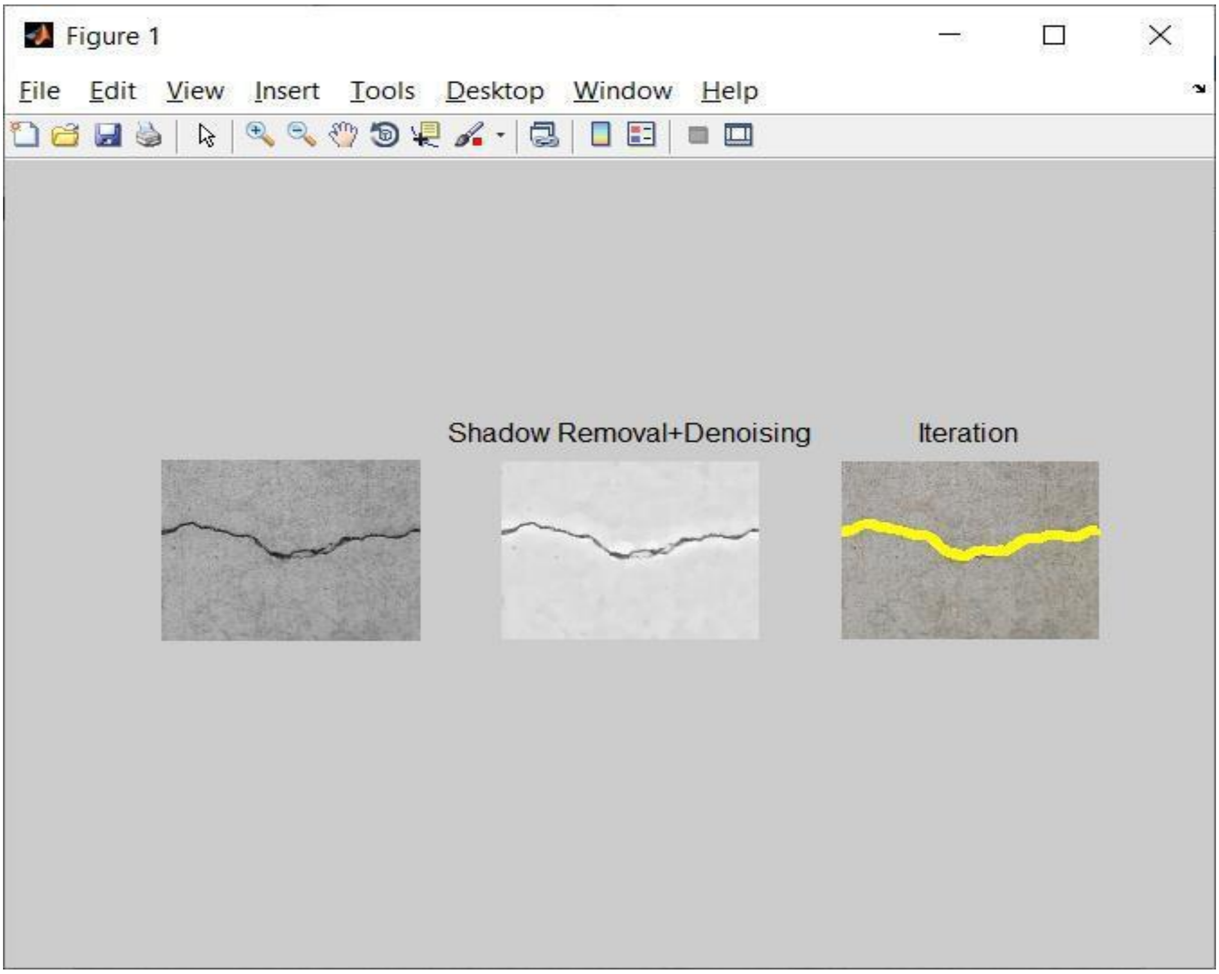
7.9 SHADOW REMOVAL AND DENOISING



7.10 CRACK IDENTIFICATION

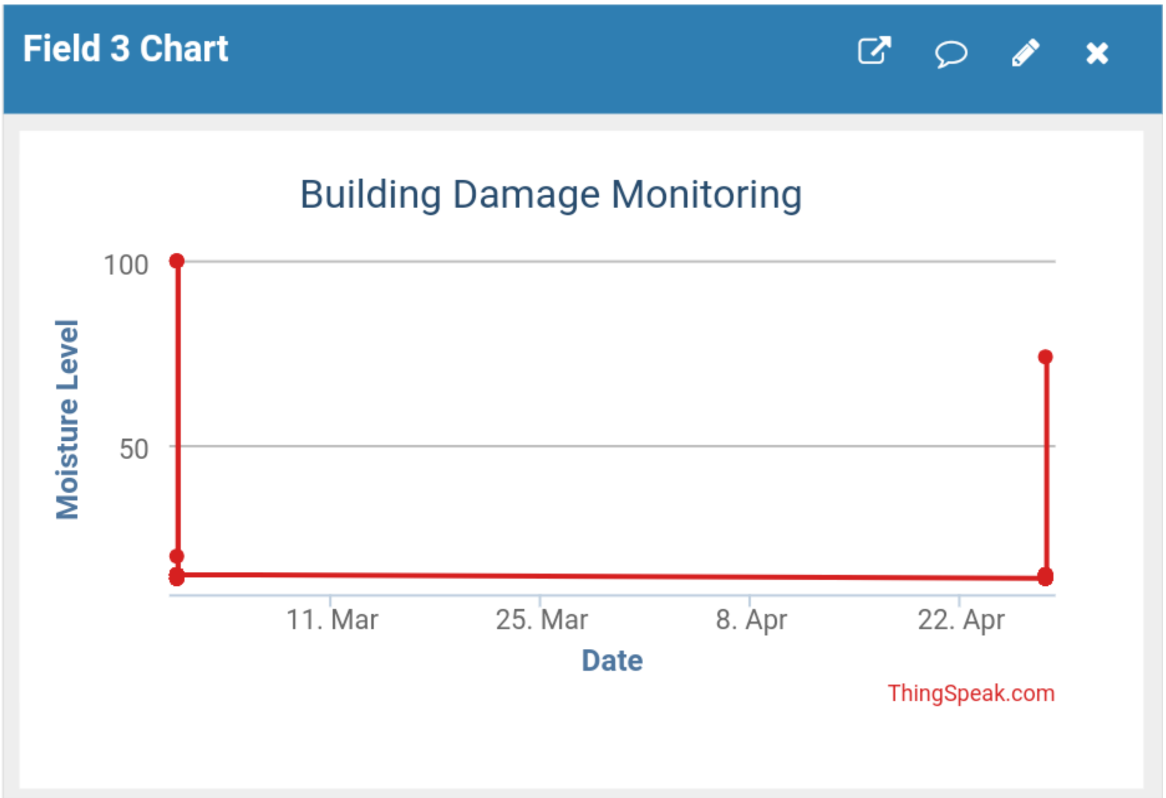


7.11 ITERATION OUTPUT

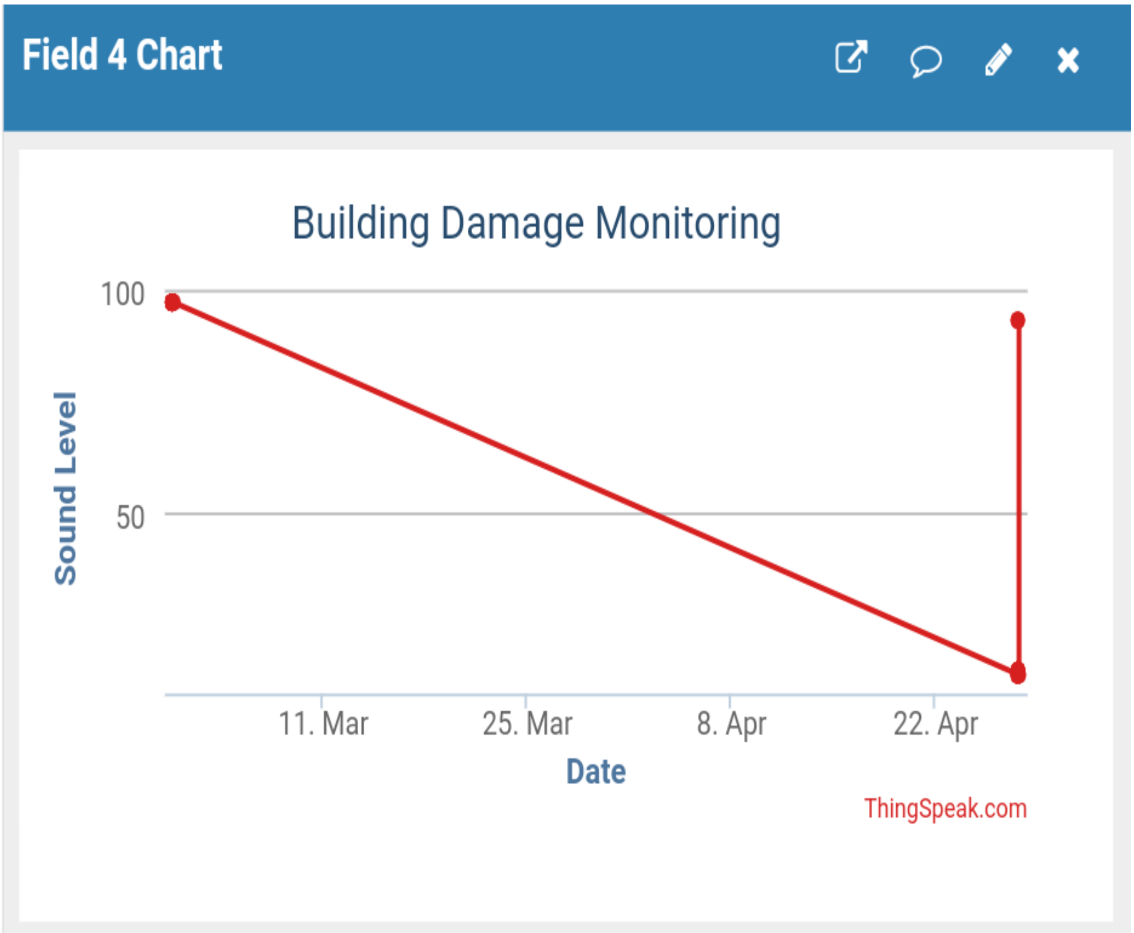


7.12 FINAL OUTPUT

Moisture Level :

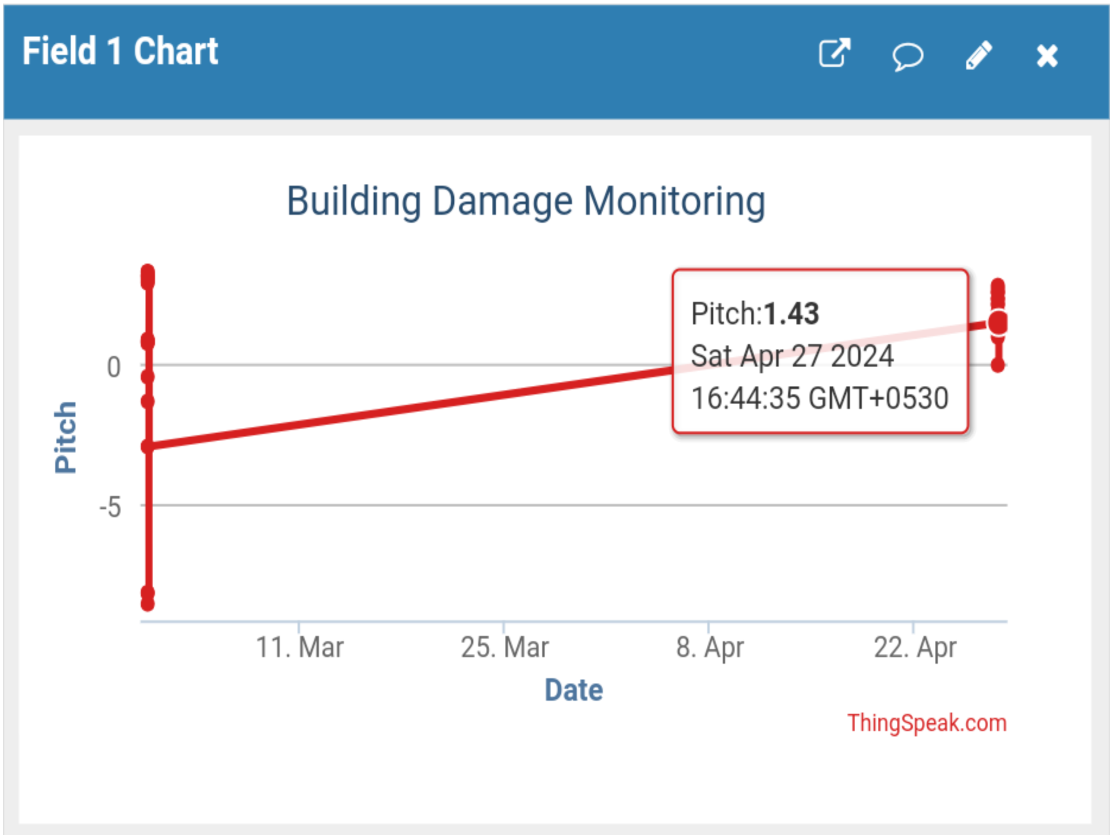


Sound Level :



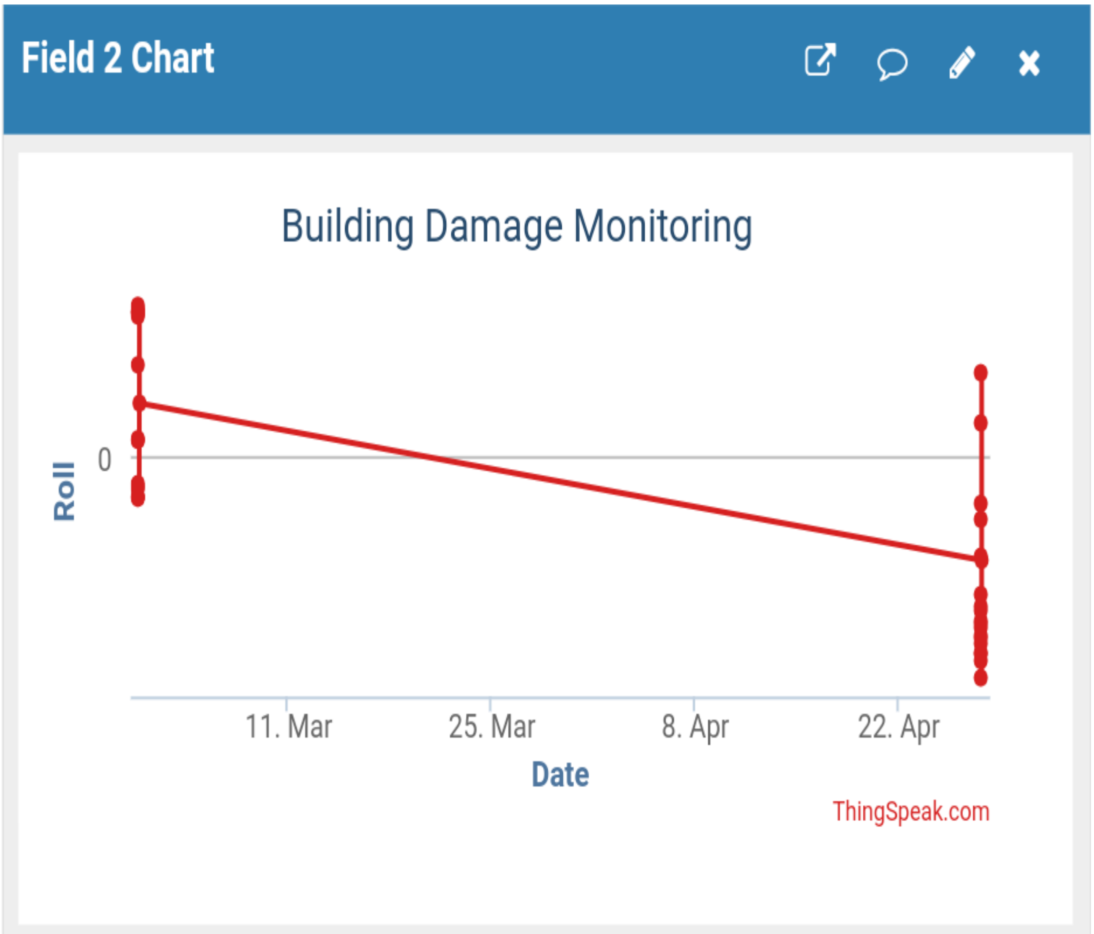
Field 4 Chart
Building Damage Monitoring
100
50
Sound Level
11. Mar
25. Mar
8. Apr
22. Apr
Date
ThingSpeak.com

PITCH :



Field 1 Chart
Building Damage Monitoring
Pitch:1.43
Sat Apr 27 2024
16:44:35 GMT+0530
0
-5
Pitch
11. Mar
25. Mar
8. Apr
22. Apr
Date
ThingSpeak.com

ROLL :



Field 2 Chart
Building Damage Monitoring
Roll
0
11. Mar
25. Mar
8. Apr
22. Apr
Date
ThingSpeak.com

CONCLUSION

In order to evaluate the safety of a concrete structure, a method to detect cracks from camera image was proposed. First, it was possible to visualize the concrete crack easily through the image processing techniques such as improved preprocessing, contrast enhancement, binarization and segmentation method. Second, the existence of cracks in many images could be automatically identified using the trained ANN. The proposed algorithm was verified with the real concrete surface image of a bridge and the result shows high accuracy in image classification. However, the test had the limitation that it was performed at the similar environmental conditions such as similar weather, existence of fog, hue of the concrete surface, the shape of structures. It means that construction environment is very diverse and the proposed algorithm needs to be evaluated in various fields of application. The algorithm also needs to be improved for the better accuracy. In addition, the various optimization methods can be applied to determine optimal parameters required in the image processing. It is important in the visualization of crack and the acquisition of the exact crack information.

In future, we can extend the framework to implement various algorithms to improve the accuracy in crack detection and also extended with embedded framework.

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SOURCE CODE

APPENDIX :

```
% Reading the image
clc
clear all
close all

% Addpath
addpath(genpath('Utilities'));
TestPath = 'TestData';
if ~exist(TestPath, 'dir')
    mkdir(TestPath)
end

% Standard Input
[InrgbImg,grayinImg,imagename, pathname] =
StdIP.readImg2D(0.4);
figure;imshow(InrgbImg);title('Input Image')
% Image adjust
Istrech = imadjust(InrgbImg,stretchlim(InrgbImg));
figure,imshow(Istrech)
title('Contrast stretched image')
figure;imshow(grayinImg);title('Gray Scale')

Igray_s = rgb2gray(Istrech);
% Image segmentation by thresholding
level = 0.08;
Ithres = im2bw(Igray_s,level); figure,imshow(Ith)
```

```
title('Binary Segmentation')
Numberofwhitepixels= int2str(nnz(Ithres));

I = InrgbImg;
inputSize = size(I);
targetSize = [80 90];

rect = randomWindow2d(inputSize,targetSize);
% rect = randomCropWindow2d(inputSize,targetSize);
rectXYWH = [rect.XLimits(1) rect.YLimits(1) ...
    diff(rect.XLimits)+1 diff(rect.YLimits)+1];


annotatedI =
insertShape(I,"rectangle",rectXYWH,"LineWidth",3);
figure; imshow(annotatedI)

% Shadow + Clutter removal
deshadow_obj = DeShadow(grayinImg);
deshadow_param.n_iter_shadow    = 500;
deshadow_param.n_iter_reconst   = 500;
deshadow_param.error            = 0.01;
deshadow_param.cnvg_cnt         = 15;
deshadow_param.interval         = 50;
deshadow_param.smooth_trm       = 0.8;
%-- parameters to tune
deshadow_param.sigma            = 5;
deshadow_param.power            = 2.4;
```

```
m);
deshadow_param.shadow          =
sh3; smoothImg =
deshadow_obj.reconstructImage(deshadow_param);
smoothImg = smoothImg./max(smoothImg(:));

% Segmentation with Vessel Enhancement
% enhImg = VesselEnhanceFrangi(smoothImg,2:4,2);
%-- static function of TuFF
param_Variable.vessel_type          = 'dark';
param_Variable.Img                  = smoothImg;
param_Variable.detector_orientation = -90:15:90;
param_Variable.predictor_orientation = -30:10:30;
param_Variable.scale                = [2];
param_Variable.offset_factor        = 0.6;      %-- d =
offset_factor*sigma

enhImg = TuFF.vesselEnhanceLDE(param_Variable);
%-- enhance vessels with LDE
figure;imshow(enhImg);title('Crack Output');

Numberofwhitepixels1= int2str(nnz(enhImg));

% Segmentation with Initialization
% phi0   = TuFF.initRegionManual(inImg, 'ellipse',200);
%-- Static function of TuFF
phi0 = TuFF.initRegionOtsu(enhImg,0.6,200);
figure;imshow(phi0>0);title('CNN Iteration');
```

```
param_Tuff.phi0        = phi0;
param_Tuff.enhI        =
enhImg; param_Tuff.max_iter
                          = 400;
param_Tuff.error       = 0.5;
param_Tuff.cnvg_cnt    = 10;
param_Tuff.interval    = 25;
param_Tuff.disp_Img    =
InrgbImg; param_Tuff.magnify
                        = 200;
param_Tuff.col         = 'y';
%-- parameters to tune
param_Tuff.dt          = 0.8;
param_Tuff.pull_back   = 0.1; % 1/0:do(not)use
deflation; essential for nice shape
param_Tuff.p           = 2;   % exponent in
1/1+()^p param_Tuff.smooth_trm  = 1.2;
param_Tuff.edge_trm    = 0.7;
param_Tuff.attr_trm    = 0.0;
param_Tuff.edge_range  = 7;
param_Tuff.attr_range  = 7;

TuFF_obj = TuFF(smoothImg); %-- object for TuFF
class
% phi = TuFF_obj.runFastEATuFF2D(param_Tuff);
phi = TuFF_obj.runEATuFF2D(param_Tuff);

% Diplay segmentation results
im1 = InrgbImg;
im2 = phi>0;
```

```
se_cl = strel('disk',2);
se_op = strel('disk',1);
```

im2 = imclose(im2,se_cl);

StdIP.imageOverlay(im1,im2,200,[1 1 0]); %--- yellow =
[1,1,0]
% Delete the objects
delete(deshadow_obj);
delete(TuFF_obj);

labeled_Image = bwlabel(enhImg, 8);
% Get all the properties
OB_Measurements = regionprops(labeled_Image,
grayinImg, 'all');
numberOf_OB = size(OB_Measurements, 1);

textFontSize = 1;
labelShiftX = -1;

% Print header line in the command window.

fprintf(1,'Particular #   Mean   Intensity
                                C.Area Diameter\n');
% Loop over all object printing their measurements to the
command window.

k = 1; % Loop through all pixels.
  % Find the mean of each pixel.
  % directly into regionprops.
  thisOBPixels = OB_Measurements.PixelIdxList; % Get
list of pixels in current object.

```
  meanGL = mean(grayinImg(thisOBPixels)); % Find
mean intensity (in original image!)
  meanGL2008a = OB_Measurements.MeanIntensity;


  OB_Area = OB_Measurements.Area;    % Get area.
OB_Perimeter = OB_Measurements.Perimeter;    % Get
perimeter.
  OB_Centroid = OB_Measurements.Centroid;    % Get
centroid one at a time
  OB_ECD = sqrt(4 * OB_Area / pi);          %
Compute ECD - Equivalent Circular Diameter.
  fprintf(1,'#%2d %15.1f %13.1f %11.1f %9.1f % 8.1f \n
', k, meanGL, OB_Area, OB_Perimeter, OB_ECD);
  % Put the "particular number" labels on the
"boundaries" grayscale image.
  text(OB_Centroid(1) + labelShiftX, OB_Centroid(1),
num2str(1), 'FontSize', textFontSize, 'FontWeight',
'Bold');
% end
fprintf('\n');

addpath(genpath('./rnn_d'));
% Load Pre-Trained Data
load('RCNNData.mat');

% Create the RNN-Net network.
imageSize = [256 256 1];
numClasses = 2;
[lgraph] = rnn_Layers(imageSize, numClasses);
```

```
% Set training options.
options = trainingOptions('sgdm',
    ... 'InitialLearnRate',1e-3, ...
    'MaxEpochs',20, ...
    'MiniBatchSize', 4, ...
    'VerboseFrequency', 10,
    ... 'Verbose',false, ...
    'Plots','training-progress');

% figure,imshow(bw_result);title('Segmentated Output');
% figure;
% imshowpair(bw_result,I,'blend'); title('Final Output');
% Options = trainingOptions('Plots', 'training-progress');

% TestImg
TestImg = imageDatastore(TestPath,...
        'LabelSource',...
        'foldernames',...
        'IncludeSubfolders',true);

% Load pretrained network
net = rnn_dnet();
lgraph = layerGraph(net);


% Inspect the first layer
net.Layers(1);
% Inspect the last layer
net.Layers(end);
% Number of class names for ImageNet classification
```

```
numel(net.Layers(end).ClassNames);

% Number of categories
numClasses = 2;
% New Learnable Layer
newLearnableLayer = fullyConnectedLayer(numClasses,
...
        'Name','new_fc', ...
        'WeightLearnRateFactor',10, ...
        'BiasLearnRateFactor',10);

% Replacing the last layers with new layers
lgraph =
replaceLayer(lgraph,'fc1000',newLearnableLayer);
newsoftmaxLayer =
softmaxLayer('Name','new_softmax');
lgraph =
replaceLayer(lgraph,'fc1000_softmax',newsoftmaxLayer)
;
newClassLayer =
classificationLayer('Name','new_classoutput');
lgraph =
replaceLayer(lgraph,'ClassificationLayer_fc1000',newCla
ssLayer);

% Create augmentedImageDatastore from training and
test sets to resize
% images in imds to the size required by the network.
imageSize = net.Layers(1).InputSize;
```

```
validationTestSet =
augmentedImageDatastore(imageSize, TestImg,
'ColorPreprocessing', 'gray2rgb');

% Get the network weights for the second convolutional
layer
w1 = net.Layers(2).Weights;

% Scale and resize the weights for visualization
w1 = mat2gray(w1);
w1 = imresize(w1,5);


% Display a montage of network weights. There are 96
individual sets of
% weights in the first layer.
figure
montage(w1)
title('First convolutional layer weights');
featureLayer = 'fc1000';

% Extract test features using the CNN
testFeatures = activations(net, validationTestSet,
featureLayer, ...
    'MiniBatchSize', 32, 'OutputAs', 'columns');

% Preprocessing Technique
imdsTrain.ReadFcn =
@(filename)preprocess_Xray(filename);
imdsTest.ReadFcn@(filename)preprocess
```

```
% Training Options, we choose a small mini-batch size
due to limited images
options = trainingOptions('adam',...
    'MaxEpochs',30,'MiniBatchSize',8,...
    'Shuffle','every-epoch', ...
    'InitialLearnRate',1e-4, ...
    'Verbose',false, ...
    'Plots','training-
    progress');

% Data Augumentation
augmenter = imageDataAugmenter( ...
    'RandRotation',[-5
    5],'RandXReflection',1,...
    'RandYReflection',1,'RandXShear',[-0.05
0.05],'RandYShear',[-0.05 0.05]);

% Pass CNN image features to trained classifier
predictedLabels1 = predict(preTrainedData, testFeatures,
'ObservationsIn', 'columns');

[XTrain,YTrain] = digitTrain4DArrayData;

idx = randperm(size(XTrain,4),1000);
XValidation = XTrain(:,:,:,idx);
XTrain(:,:,:,idx) = [];
YValidation = YTrain(idx);
YTrain(idx) = [];
[ imageInputLayer([28 28 1])
```

```
    convolution2dLayer(3,8,'Padding','same')
    batchNormalizationLayer
    reluLayer

    maxPooling2dLayer(2,'Stride',2)

    convolution2dLayer(3,16,'Padding','same')
    batchNormalizationLayer
    reluLayer

    maxPooling2dLayer(2,'Stride',2)

    convolution2dLayer(3,32,'Padding','same')
    batchNormalizationLayer
    reluLayer

    fullyConnectedLayer(10)
    softmaxLayer
    classificationLayer];

options = trainingOptions('sgdm', ...
    'MaxEpochs',8, ...
    'ValidationData',{XValidation,YValidation}, ...
    'ValidationFrequency',30, ...
    'Verbose',false, ...
    'Plots','training-
    progress');
   net11 = trainNetwork(XTrain,YTrain,layers,options);
```

```
testImage = readimage(TestImg,1);
ds = augmentedImageDatastore(imageSize, testImage,
'ColorPreprocessing', 'gray2rgb');
% Extract image features using the CNN
imageFeatures = activations(net, ds, featureLayer,
'OutputAs', 'columns');
% Make a prediction using the classifier
commandwindow;
predictedLabel2 = predict(preTrainedData,
imageFeatures, 'ObservationsIn', 'columns');

disp('S_Area: ')
disp(OB_Perimeter)




disp(data);


disp(' ');
disp(['Predicted Label: ', predictedLabel2]);


if isequal (predictedLabel2, 'crack')
   msgbox('Classification Output: Building Crack
Detected...')


   if (OB_Perimeter >= 500)
   data = 'High';
   msgbox('Crack Severity Level: HIGH')
else
```

```
    data = 'LOW';
    msgbox('Crack Severity Level: LOW')
    end

elseif isequal (predictedLabel2, 'non-crack')
    msgbox('Classification Output: NON CRACK')
else
    msgbox('Classification Output: Abnormal')


end
```

PUBLICATION

1.PARAMESHWARAN G, AKASH P, ANAS A, HARISOMAN K, **"STRUCTURAL HEALTH MONITORING USING MACHINE LEARNING",** INTERNATIONAL CONFERENCE ON INFORMATION TECHNOLOGIES (ICRDET 2024), ORGANIZED BY DHAANISH AHMED INSTITUTE OF TECHNOLOGY, TAMILNADU, INDIA.

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