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Automatic Pavement Crack Detection Algorithm

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Abstract— Pavement crack detection and evaluation is a vital component in highway maintenance and management. It is difficult to detect cracks effectively and accurately through ideal detecting algorithm. This paper improves the pavement crack image processing algorithm from the angle of grey level transformation, median filter and image intensification according to the characteristics of the pavement crack image. Utilizing this model, this study implements an automatic crack classification and quantification method for defect image segmentation and image edge detection, results show that the proposed detection method can effectively remove the isolated noise point, smooth the edge and improve the segmentation accuracy.

I. INTRODUCTION

Traditionally, road surface evaluation and maintenance is based on the inspection staff's judgment and experience. The inspection personnel walks or drives slowly through asphalt and concrete pavements observing surface defects and degradation to make recommendations for immediate and long term maintenance. The manual inspection procedure is not only cumbersome, time consuming and expensive but is also susceptible to human error and inefficiency. With safety of the personnel and passengers in mind, this functional and important process of inspection can be significantly improved using a formalized imaging system that will ease the effort required to inventory road surfaces like highways and runways through periodic evaluations and subsequent surface distress management.

One of the major distresses on pavements is cracking. Cracking may appear in many shapes and the extent and type of cracking is an important distress parameter when doing maintenance planning. One of the major reasons for crack detection is that once the pavement has cracking water can precipitate through the pavement down to unbound layers. Unbound layers with high moisture content is weak and during winter and the high water content may lead to extensive frost heave problems, resulting in accelerated cracking. Cracks in the asphalt pavement are also the initiation to potholes and similar surface damages.

Crack detection is traditionally made through visual inspections. On larger road networks automated and mobile methods have been used for several years to get a better and faster coverage, objective data and improved traffic safety. The automated systems for crack data collection often consist of two main parts 1/a light source and 2/a camera system. The type of camera and light system can vary but the majority of the systems rely on collection of road surface images. However, the analysis of the crack data is still to a large part done by individual persons and thus it results in a subjective and less repeatable analysis. This paper describes the experience from Ramboll RST doing both automated data collection and automated analysis on larger road networks. The experiences are drawn from more than 100 000 km of

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survey in multiple countries and analysis using the PAVUE and AIES systems.

The paper will describe the experience from a system that enables data analysis at the same speed the survey is carried out. The analysis is totally objective and free from human intervention. The paper will point out the benefit from using different analysis settings for different pavement types, where the switch between various pavements is done from texture measurements using laser sensor. The paper will also discuss the importance from quality in the collected surface images and to what extent an automated analysis could be used.

The key to successful road surface evaluation lies in identifying different types of distress and linking them to the cause. Recognizing the defects and also understanding their cause based on their appearance helps rate pavement conditions and select cost effective repair measures. As a first step towards automation, high speed digital imaging sensors deployed on mobile vehicles have been successfully demonstrated in combination with image processing algorithms for crack detection. Such video based vision systems have two major drawbacks. They do not provide sufficient depth information and also have ambient illumination requirements. The depth information is of particular significance in surface evaluation because the rating scheme for the road surfaces is not just dependent on the length and width of the cracks alone as is the case with pavement distress applications but also on the depth. Crack depths in the order of a few millimeters require high precision distance measurements. Hence, the design requirements for a comprehensive visual data collection system should address accuracy and precision in three dimensions of measurement, speed of acquisition, time required for post processing, ease of visualization and evaluation. Our system integrates visual range and color data with position and orientation information through hardware measurements and provides better accuracy for fast digitization of large scale road surfaces at almost equal acquisition and processing time. We are able to generate accurate geo-referenced 3D models that are compensated for sensor motion caused by the changing physical environment. The multi-sensor integrated 3D models improve automatic crack detection and classification. Furthermore, accurate archives of such 3D models of road surfaces over time can be used for statistical wear and tear analysis.

NON-DESTRUCTIVE TESTING FOR CRACK DETECTION (NDT)

Non-destructive testing (NDT) methods are techniques used to obtain information about the properties or internal condition of an object without damaging the object. Non-destructive testing is a descriptive term used for the examination of materials and components in such way that allows materials to be examined without changing or destroying their usefulness. NDT is a quality assurance management tool which can give impressive results when used correctly. It requires an understanding of the various methods available, their capabilities and limitations, knowledge of the relevant standards and specifications for performing the tests. NDT techniques can be used to monitor the integrity of the item or structure throughout its design life.

The greatest disadvantage of the conventional methods of testing concrete lies in the fact that in-situ strength of the concrete can not be obtained without damaging the actual structure. Also the test specimens are destroyed, once the test is performed and subsequent testing of the same specimens is not possible. Thus the effect of prolonged curing, weathering action and other time dependent characteristics can not be correctly calculated. No matter how well a concrete mix is designed, there are variations in mixing conditions, amount of compaction or curing conditions at site which cause the variations in the final product. The variability between the batches of concrete of the same mix proportion is assessed by testing test specimens under load in the laboratory. Such tests enable the variability of constituents of the mix to be controlled, but they can not take into account the differences of compaction and actual curing conditions between the test specimens and the corresponding concrete in a structure. It is these differences, which are difficult to assess by conventional strength tests, Also, conventional method of testing is not sufficient to predict the performance of the structures under adverse conditions e.g. exposure to liquid, gas, and chemicals radiation, explosion, fire, extreme cold or hot weather, marine and chemical environment. All such severe exposure conditions may induce deterioration in concrete and impair the integrity, strength and stability of the structure. Thus, conventional strength test does not give idea about the durability and performance of the actual concrete in the structure. This gave the impetus to the development of non-destructive methods for testing structural concrete in-situ.

Thus, NDT methods are extremely valuable in assessing the condition of structures, such as bridges, buildings, elevated service reservoirs and highways etc. The principal objectives of the non-destructive testing of concrete in situ is to assess one or more of the following properties of structural road concrete as below

- In situation strength properties
- Durability
- Density
- Moisture content
- Elastic properties
- Extent of visible cracks
- Thickness of structural members having only one face exposed
- Position and condition of steel reinforcement
- Road concrete cover over the reinforcement.
- Reliable assessment of the integrity or detection of defects of road concrete members even when they are accessible only from a single surface.

The standard life of R.C.C. frame structure is considered to be in the range of 50-60 years approximately depending upon the use and the importance of the structure. But it has been observed that many of the buildings completing just 50% of their life in coastal areas found to be in distressed condition and this needs the evaluation of the strength of the building so that appropriate remedial action can be taken to improve performance of the building depending upon the extent of deterioration of the structure.

Structure may also get damaged due to fire, earthquake, explosion, etc. there could be loss of strength and reduction in area of cross section due to fire depending on intensity of fire ,temperature, duration of fire and size of the structural member. Stability of such member becomes critical. It is imperative to measure residual strength and assess stability by NDT means.

Related work towards road surface distress survey, especially on airport runways and army maintained highways dates back to early 1980's. The pavement management system (PMS) idea was proposed by the U.S Army and has since then undergone metamorphosis keeping pace with improving imaging technology. However, transportation departments met with limited real-time success using digital imaging techniques towards automatic crack detection and filling , until the late nineties. Non-visual sensors and several improvements on image-based methods were proposed during this period. We summarize these methods in Figure 1 and discuss the advantages and disadvantages of the different types of sensing methodologies. Analog films have been completely replaced by digital cameras. Among digital systems, video cameras are preferred to line scan methods for the ease of use without special illumination requirements, though line scan methods offer very high resolution data. Range sensors that directly give depth measurements have limited field of view while profilometers and acoustic sensors though inexpensive can only provide low resolution and a low dynamic range.

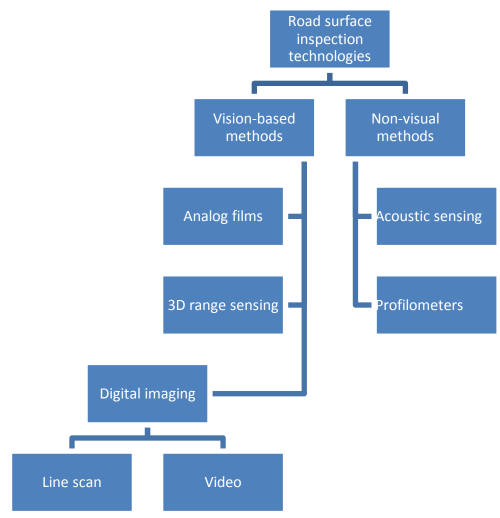

Fig. 1. Summary of technologies demonstrated for road surface inspection.

In 1987, Mendelsohn listed several of these methods including acoustic sensors and profilometers and suggested that the imaging modality was a promising approach. At that time, the processing and image acquisition speeds challenged the feasibility of a fast and efficient inspection system. Several surveys were conducted to make an assessment of the feasibility of incorporating image acquisition and processing methods for both development and implementation of automated road surface inspection [7, 8]. The conclusions of the survey encouraged by improving hardware and processing equipment have led to most of the commercial video-based systems available today that basically consist of an array of high speed imaging sensors supported with illumination equipment. The video data from such systems though promises to be sufficient for distress detection [9], requires spatial information for crack filling after detection and maintenance. A potential solution AMPIS [10] was proposed that combined GPS information with video to create GIS-like databases of road surfaces. AMPIS claims improved road network identification, pavement inspection for better maintenance and data management over the base framework of PMS.

Taking a robotic approach, Hass et al. [11] proposed a system to overcome the shortcomings of the video-based system to make depth measurements by incorporating a laser range sensor. Hass et al. concluded that combining laser range data and video image data can provide overall better accuracy and speed of crack detection although due to the time consuming aspect of laser range sensing in 1992, they demonstrated range imaging for crack verification after the detection using the video based system. Several 3D approaches have been demonstrated since then. Laurent et al. propose a synchronized laser scanning mechanism to capture high precision 3D range and texture profiles. Bursanescu and Blais [12] reiterate a 3D optical sensor as the answer to high resolution and high accuracy acquisition and redesign a Biris sensor to meet the specific requirements of the pavement inspection application. They demonstrate six such sensors mounted on a mobile platform acquiring data at normal highway speeds.

In summary of the related work, we tabulate different other systems in the literature that have combined different methodologies in Table 1. We list the systems, their

accuracies, processing speeds and the modalities included to

better understand how each one of these modalities contributes towards better and efficient pavement inspection.

The main goal of pavement inspection is being able to identify crack patterns, rut depths and the roughness of the cracks. Current data collection methods still necessitate integration of several heterogeneous technologies. We further identify the scope for improvements in system design targeting the time of acquisition and processing and list the important characteristics of a real-time deployable system. An ideal road data collection system must operate in real time

System/ Group	Modalities used	Resolution of imagery	Special notes
Komatsu	Video, Line scan	4 mega pixel image.	Collects data in the night with argon lights at 10 km/hr.
WiseCrax	Dual video cameras	Detects 3mm wide cracks	Can collect data at 80 km/hr.
GPSVan	Stereo and analog camera, GPS , INS	Built for large scale imaging	Acquires geo-spatial data for urban planning.
National Optics	3D range	< 0.5 mm in width and depth	Novel synchronized laser scanning approach proposed.
NRC (Canada)	3D range	3mm wide,4mm deep cracks	An array of Biris 3D sensor used.
AMPIS	Video, GPS	0.3 mega pixels	Limited field of view.
RoadCrack	Array of CCD	1mm crack width.	Can collect 400 km of data in one day at highway speeds.

gathering and post processing speeds. The duration required for data analysis should not overwhelm the time required for acquisition. A single pass data collection should be sufficient for cost-effective distress identification and localization, the critical aspect being the accuracy and robustness of the system and its extendibility to arbitrary terrain. With all these system requirements in mind we now present our prototype system in the following section.

SCHMIDT'S REBOUND HAMMER TEST

The rebound hammer method could be used for :

- Assessing the compressive strength of road concrete with the help of suitable co-relations between rebound index and compressive strength
- Assessing the uniformity of the road concrete
- Assessing the quality of road concrete in relation to the standard requirements
- Assessing the quality of one element of road concrete in relation to another.(1)

Principle of test: The test is based on the principle that the rebound of an elastic mass depends on the hardness of the surface upon which it impinges. When the plunger of the rebound hammer pressed against the surface of the road concrete, the spring controlled mass rebounds and the extent of such rebound depend upon the surface hardness of road concrete. The surface hardness and therefore the rebound is taken to be relation to the compressive strength of road concrete. The rebound is read off along a graduated scale and is designated as the rebound number or rebound index.

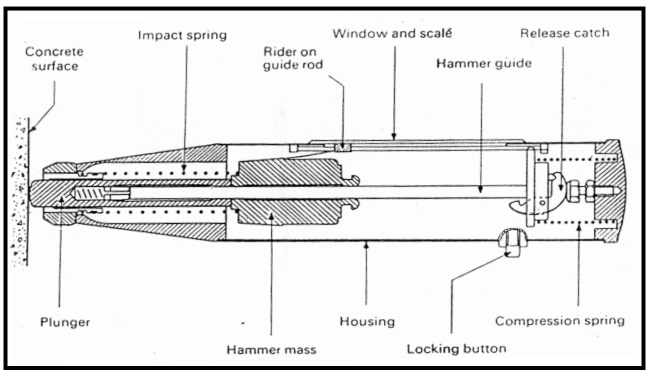

Fig.2 : Basic Features of Rebound Hammer

a. Working of rebound hammer:

A schematic cut way view of schmidt rebound hammer is shown in fig. 1. The hammer weight about 1.8 kg., is suitable for use both in a laboratory and in the field. When the plunger of rebound hammer is pressed against the surface of road concrete, a spring controlled mass rebounds and the extent of such rebound depends upon the surface hardness of road concrete.The rebound distance is measured on a graduated scale and is designated as rebound number. Basically, the rebound distance depends on the value of kinetic energy in the hammer, prior to impact with the shoulder of the plunger and how much of that energy is absorbed during impact. The energy absorbed by the road concrete depends on the stress-strain relationship of road concrete. Thus, a low strength low stiffness road concrete will absorb more energy than high strength road concrete and will give a lower rebound number.

Method of testing (operation)

1. To prepare the instrument for a test, release the plunger from its locked position by pushing the plunger against the road concrete and slowly moving the body away from the road concrete. This causes the plunger to extend from the body and the latch engages the hammer mass to the plunger rod.
2. Hold the plunger perpendicular to the road concrete surface and slowly push the body towards the test object. (The surface must be smooth, clean and dry and should preferably be formed, but if trowelled surfaced are unavoidable, they should be rubbed smooth with the carborundum stone usually provided with the equipment. Loose material can be ground off, but areas which are rough from poor compaction, grout loss, spalling or tooling must be avoided, since the results will be unreliable).
3. As the body is pushed, the main spring connecting the hammer mass to the body is stretched. When the body is pushed to the limit, the latch is automatically released and the energy stored in the spring propels the hammer mass towards the plunger tip. The mass impacts the shoulder of the plunger rod and rebounds.
4. During rebound, the slide indicator travels with the hammer mass and records the rebound distance. A button on the side of the body is pushed to lock the plunger in the retracted position and the rebound number is read from the scale.

The test can be conducted horizontally, vertically upward or downward or at any intermediate angle. Due to different effects of gravity on the rebound as the test angle is changed, the rebound number will be different for the same road concrete. This will require separate calibration or correction charts, given by the manufacturer of the hammer.

Correlation procedure: Each hammer is provided with correlation curves developed by the manufacturer using standard cube specimens. However, the use of these curves is not recommended because material and testing conditions may not be similar to those in effect when the calibration of the instrument was performed. A typical correlation procedure is given as below:

1. Prepare a number of 150 mm cube specimens covering the strength range to be encountered on the job site. Use the same cement and aggregates as are to be used on the job. Cure the cubes under standard moist curing room conditions.
2. After capping, place the cubes in a compression testing machine under an initial load of

approximately 15% of the ultimate load to restrain the specimen. Ensure that cubes are in saturated surface dry conditions.

3. Make 5 hammer rebound readings on each of four moulded faces without testing the same spot twice and minimum 20 mm gap from edges.
4. Average the readings and call this the rebound number for the cube under test.
5. Repeat this procedure for all the cubes.
6. Test the cubes to failure in compression and plot the rebound numbers against the compressive strength on a graph.
7. Fit a curve or a line by the method of least squares.

It is important to note that some of the curves deviate considerably from the curves supplied with the hammer.

Limitations: Although the rebound hammer provides a quick inexpensive means of checking the uniformity of road concrete, it has serious limitations and these must be understood clearly for interpretation of test results.

NON-DESTRUCTIVE TESTING OF ROAD CONCRETE BY ULTRASONIC PULSE VELOCITY METHOD

The ultrasonic pulse velocity method is used for non-destructive testing of plain, reinforced and press tressed road concrete whether it is precast or cast in-situ

Objects: The main objects of the ultrasonic pulse velocity method are to establish

- The Homogeneity of the Road concrete
- The Presence of Cracks, Voids and other Imperfections
- Changes in the Structure of the Road concrete Caused by the Exposure Condition, Corrosion, Wear etc. which may occur with time,
- The Quality of the Road concrete in Relation to the Specified Standard Requirements.
- The Quality of One Element of Road concrete in Relation to the Another.
- The Values of the Dynamic Elastic Modulus of the Road concrete.

This is one of the most commonly used method in which the ultrasonic pulses generated by electro-acoustical transducer are transmitted through the road concrete. In solids, the particles can oscillate along the direction of sound propagation as longitudinal waves or the oscillations can be perpendicular to the direction of sound waves as transverse waves. When the pulse is induced into the road concrete from a transducer, it undergoes multiple reflections at the boundaries of the different material phases within the road concrete. A complex system of stress waves is developed which includes longitudinal (Compressional), shear (Transverse) and surface (Rayleigh) waves. This transducers convert electrical signals into mechanical vibrations (transmit mode) and mechanical vibration into electrical signals (receive mode). The travel time is measured with an accuracy of +/- 0.1 microseconds. Transducers with natural frequencies between 20 kHz and 200 kHz are available, but 50 kHz to 100 kHz transducers are common.

The receiving transducer detects the onset of the longitudinal waves which is the fastest wave. Because the velocity of the pulses is almost independent of the geometry of the material through which they pass and depends only on its elastic property. Under certain specified conditions, the velocity and strength of road concrete are directly related. The common factor is the density of road concrete; a change in the density results in a change in a pulse velocity, likewise for a same mix with change in density, the strength of road concrete changes. Thus lowering of the density caused by increase in water-cement ratio decreases both the compressive strength of road concrete as well as the velocity of a pulse transmitted through it.

Pulse Velocity method is a convenient technique for investigating structural road concrete. The underlying principle of assessing the quality of road concrete is that comparative higher velocities are obtained when the quality of road concrete in terms of density, homogeneity and uniformity is good. In case poorer quality of road concrete, lower velocities are obtained. If there is a crack, void or flaw inside the road concrete which comes in the way of transmission of the pulses, the pulse strength is attenuated and it passes around the discontinuity, thereby making path length longer. Consequently, lower velocities are obtained. The actual pulse velocity obtained depends primarily upon the material and the mix proportion of the road concrete. Density and modulus of elasticity of aggregate also significantly affect the pulse velocity.

Transducers: Piezoelectric and magnetostrictive types of transducers are available in the range of 20 kHz to 150 kHz of natural frequency. Generally, high frequency transducers are preferable for short path length and low frequency transducers for long path lengths. Transducers with a frequency of 50 to 60 kHz are useful for most all-round applications.

There are three possible ways of measuring pulse velocity through road concrete :

a. Direct Transmission (Cross Probing) through Road concrete:

In this method transducers are held on opposite face of the road concrete specimen under test as shown in fig. The method is most commonly used and is to be preferred to the other two methods because this results in maximum sensitivity and provides a well defined path length.

b. Semi-direct Transmission through Road concrete :

Sometimes one of the face of the road concrete specimen under test is not accessible, in that case we have to apply semi-direct method as shown in fig. In this method, the sensitivity will be smaller than cross probing and the path length is not clearly defined.

Indirect Transmission (Surface Probing) through Road concrete :

This method of pulse transmission is used when only one face of road concrete is accessible. Surface probing is the least satisfactory of the three methods because the pulse velocity measurements indicate the quality of road concrete only near the surface and do not give information about deeper layers of road concrete. The weaker road concrete that may be below a strong surface can not be detected. Also in this method path length is less well defined. Surface probing in general gives lower pulse velocity than in the case of cross probing and depending on number of parameters. Table 2 : Velocity Criteria For Road concrete Quality Grading

As per Table 2 of IS 13311 (Part 1) : 1992

Sr. No.	Pulse Velocity by Cross Probing (km/sec)	Road concrete Quality Grading
1.	Above 4.5	Excellent
2.	3.5 to 4.5	Good
3.	3.0 to 3.5	Medium
4.	Below 3.0	Doubtful

Note : In case of doubtful quality of road concrete, it may be necessary to carry out further tests.

Combined methods: There are different non-destructive testing methods which can be broadly classified as those which measure the overall quality of the road concrete, dynamic or vibration methods like resonance frequency and ultrasonic pulse velocity tests and those which involve measurement of parameters like surface hardness, rebound, penetration, pull-out strength etc. are believed to be indirectly related to the compressive strength of road concrete. In addition, radiographic, radiometric, nuclear, magnetic and electrical methods are also available. Since such non-destructive tests are at best indirect methods of monitoring the particulars, characteristics of road concrete. The measurements are influenced by materials, road concrete mix proportions and environmental factors. When the data of the materials and mix proportions used in the construction are not available, as is often the case. In view of the limitation of the methods for the predicting the strength of road concrete in the structure, IS 13311 (Part 1) : 1992 Code has suggested to use combined method of ultrasonic pulse velocity and rebound hammer methods to alleviate the errors arising out of influence of materials, road concrete mix proportions and environmental parameters on the respective measurement.

The use of more than one methods are capable of providing useful information and statically improved accuracy for estimation of in situ strength of road concrete.

Combination of ultrasonic pulse velocity method and Schmidt rebound hammer may result much better estimation of strength of road concrete because the influence of certain factors in the composition of the road concrete and its curing are minimized.

DETECTION OF CORROSION BY HALF-CELL POTENTIOMETER

Steel shares about 40 to 70% of the load in RCC. During last few decades it has been observed that, corrosion of reinforcement in severe in structures near seashore and in the vicinity of chemical industries. A lot of attention is needed for detecting this deterioration and protecting it with proper treatment. Thus due importance shall be given for measuring the size of bar and the amount of corrosion.

PROFOMETER / REBAR LOCATOR AND BAR SIZER

Principle and Procedure: The reinforcement bar is detected by magnetising it and inducing a circulating "eddy current" in it. After the end of the pulse, the eddy current dies away, creating a weaker magnetic field as an echo of the initial pulse. The strength of the induced filed is measured by a search head as it dies away and this signal is processed to give the depth measurement. The eddy current echo is determined by the depth of the bar, the size of bar and the orientation of the bar. This detection of location of reinforcement is required as a pre process for core cutting.

Profometer is a portable battery operated magnetic device that can measure the depth of reinforcement cover in road concrete and detect the position of reinforcement bars, Fig-. The basic principle in this method is that the presence of steel affects the field of electromagnet. Fig- shows a typical circuitry diagram to locate rebars and cover includes the probe unit and display unit.

In the typical Proformeter, the probe unit consists of a high permeable U-shaped magnetic core on which two coils are mounted. An alternating current is passed through one of these coils and the current induced in the other coil is measured. The induced current depends upon the mutual inductance of the coils and upon the nearness of the steel reinforcement.

Profometer is available in three models namely Model 'S', Model 'S+', and Model 'SCANLOG'. Model 'S' is standard equipment and is used for locating rebars, measuring road concrete cover, storing and evaluation of data. It displays location of rebar and road concrete cover on a LCD monitor with x/y meter scale and values obtained can be printed and down load to PC also.

Model 'S+' is similar but this software can print cyber scan data without PC. Model 'SCANLOG' is similar to S+ but it also includes integrated software for grey-scale display of road concrete cover and can give direct print out without PC. Using any of above model rebars can be scanned over a defined area by connecting the mobile probe first and following procedure is as follows :

a) Select defined area from 'Basic Steps' with scan area option
b) Set bar diameter of first layer
c) Select option 'Scanning Bar' from menu.
d) Press 'start' to locate the rebars over selected area.
e) The starting position of a mobile probe can be defined with the cursor and the cursor is moved with arrow keys to locate the rebars. The cursor position is then transferred to the measuring area.

In similar way, other rebars in first layer is marked

The rebars in second layer is also marked by moving probe in other direction as shown in Fig. Cover is also simultaneously measured.Store the diagram showing the position of rebars in first and second layer and road concrete cover. Cyber scan print out can be obtained on a printer.

In the similar manner diameter of bar can also be determined. A typical arrangement for measurement of bar diameter by using diameter prob. There are various factors, which affect the Profometer results. These factors are: arrangement of reinforcement, variation in the iron content of cement and use of aggregate with magnetic properties, metal ties also affects the magnetic field. These factors should be considered in interpretation of observations obtained from this instrument.

CORROSION MAPPING

Reinforcement in road concrete will not corrode if the protective iron oxide film formed by the high alkaline condition of the road concrete pore fluid with a pH around 13 is maintained. This film gets destroyed by chlorides or by carbonation, if moisture and oxygen are present, resulting in corrosion. In the corrosion process anodic and cathodic areas are formed on the reinforcement, causing dissolution of the steel and the formation of expansive corrosion products at the anode.

HALF-CELL POTENTIOMETER

Principle and Procedure: The instrument measures the potential and the electrical resistance between the reinforcement and the surface to evaluate the corrosion activity as well as the actual condition of the cover layer during testing. The electrical activity of the steel reinforcement and the road concrete leads them to be considered as one half of weak battery cell with the steel acting as one electrode and the road concrete as the electrolyte. The name half-cell surveying derives from the fact that the one half of the battery cell is considered to be the steel reinforcing bar and the surrounding road concrete. The electrical potential of a point on the surface of steel reinforcing bar can be measured comparing its potential with that of copper – copper sulphate reference

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electrode on the surface. Practically this achieved by connecting a wire from one terminal of a voltmeter to the reinforcement and another wire to the copper sulphate reference electrode. Then readings taken are at grid of 1 x 1 m.

The risk of corrosion is evaluated by means of the potential gradient obtained, the higher the gradient, the higher risk of corrosion. The test results can be interpreted based on the following table.

Table 3 : Half Cell Potential Corresponding to Percentage Chance of Corrosion Activity(21)

Half-cell potential (mv) relative to Cu-Cu sulphate Ref. Electrode	% chance of corrosion activity
Less than -200	10%
Between -200 to -350	50% (uncertain)
Above -350	90%

Significance and Use: This method may be used to indicate the corrosion activity associated with steel embedded in road concrete. This method can be applied to members regardless of their size or the depth of road concrete cover. This method can be used at the any time during the life of road concrete member.

Reliability and Limitation: The test does not corrosion rate or whether corrosion activity ahs already started, but it indicates the probability of the corrosion activity depending upon the actual surrounding conditions. if this method used in combination with resistivity measurement, the accuracy is higher. If the road concrete surface has dried to the extent that it is dielectric, then pre wetting of road concrete is essential.

RESISTIVITY METER (RESI)

One of the major problems facing an engineer today is deterioration of road concrete member by corrosion of rebars. So it is prime concern to determine the state of corrosion in the bars. For this several commercial equipments are available, one of these commercial equipments available is Resistivity Meter (RESI). It is portable equipment and can be easily operated.

RESI consists of a display unit and resistivity probe as shown in Fig. Display unit consists of memory of 7200 values and power is supplied to the unit with the help of batteries. Resistivity probe is available with integrated electronics for the measurements by four-point method. In this method resistivity probe is connected with the display unit to obtain brief display. All the functions are tested and checked before starting the measurement process. After checking, unit probe is placed on the area to be measured. Measurement can be done with grid to represent the resistivity value for a large area. The grid of suitable size is marked on the surface and measurements are taken. There are various factors which affect the observations such as moisture content, carbonation and chloride contents, temperature, connection between probe and road concrete.

For taking reliable measurements good contact between the foam pad of the resistivity probe and the road concrete surface is essential. Though resistivity meter is used to monitor corrosion but if this technique is used with half-cell potential measurements, it will give more accurate results and corroded zone can be monitored more efficiently.

PAVEMENT CRACK DETECTION ALGORITHM:

Highway pavement is damaged due to repeated rolling compaction by vehicles so that structural layers are unable to bear the load and various cracks are caused such as fractures, massive cracks, transverse cracks and longitudinal cracks. Crack is the early performance of most pavement crack diseases; so crack is an important index to evaluate the quality of highways. In case cracked roads are not repaired timely, the damage will become increasingly serious on rainy and snowy days and under the action of vehicle load, which can greatly affect the running speed and safety of vehicles. Thus, highway maintenance is of great importance. Presently, manual measurement and analysis are the main methods adopted in our country to detect pavement damages, which can no longer meet the increasingly higher requirements for highway pavement detection [1]. Prior to 1990s, highway administrations adopted unreasonable pavement maintenance schemes for short of systematic data collection and evaluation, scientific maintenance decision management, limited experience and inadequate quantitative evaluation to pavement damages and damage degree, resulting in deterioration of pavement quality and increase of use cost. In order to improve the quality of pavement management and maintenance, we must extract useful information from the pavement crack image and make a detailed description. Based on characteristics of the shape, highway pavement cracks can be divided into regular cracks and irregular cracks; the former contains longitudinal cracks and transverse cracks ,and the latter contains massive cracks, fractures and net shaped cracks. Longitudinal cracks, transverse cracks, fractures, net-shaped cracks and massive cracks are commonly seen in most highway pavement diseases which not only appear earlier but also become increasingly serious.

. IMAGE PROCESSING

Highway defect recognition mainly consists of image preprocessing, image segmentation, image feature extraction, image edge detection and image recognition shown in the figure.

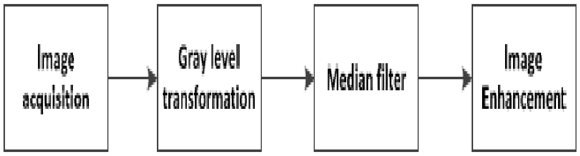


Fig.3.Specific processes of data mining model

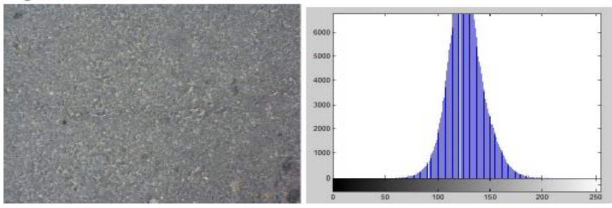
The image quality will be worsened in the process of formation, transmission and record due to imperfect imaging system, transmission media and recording equipment, resulting in degraded image, poor visual effect and difficulty in computer processing. Since the image quality is worsened by such factors as imaging system, imaging environment and imaging features, it is hard to show the characteristics by a displayed mathematical expression.

Gray level transformation

Suppose the highway image I(x,y) consists of background of inhomogeneous gray level (illumination) Ib(x,y), pavement crack disease In(x,y) and noise caused by stone and pitch, namely

$$I(x,y) = I_b(x,y) + I_n(x,y) + I_c(x,y)$$

Thus, the inhomogeneous gray level can be corrected through finding out the background signal and segmenting the background from the original image. Based on the analysis above, the key is to extract the background image. It is difficult to acquire a flawless background in practical application; if any, the location distance in the timer shaft is large and the illumination distribution is uneven.



F ig.4. Gray level transformation and its histogram

Image de-noising

Median filter is a kind of nonlinear processing technique which can restrict noises and is easy to use without need forstatistical characteristics of the image during actual computation. It is based on an image characteristic; that is, noise often appears as an isolated point corresponding to a few pixel numbers; while the image is made of small blocks with many pixel numbers and a large area. Although median filter method can eliminate isolated noise points in the image, it damages and fuzzes up edges and details when noise is restricted. So a gradient inverse weighted method is proposed in this model. The gray level in an area changes less than that between areas in a discrete image and the gradient absolute value on the edge of an area is larger than that between areas. In case the reciprocal of the gradient absolute value between the center pixel and the adjacent points is defined as the weighted value of adjacent points in an nxn window, the weighted value of those inside the area is the maximum; while the weighted value of those near the edge and outside the area is the minimum. Then, the image can be smoothed, and edges and details will not be fuzzed up through averaging the weighted neighborhood partially. In order to control the gray value of the smoothed pixel within the gray unit of the original image, a normalized gradient reciprocal is taken as the weighting coefficient; the implementation algorithm is specific below:

Suppose the gray value of point (x,y) is f(x,y)□n=3; the gradient reciprocal in 3X3 neighborhood is defined as below:

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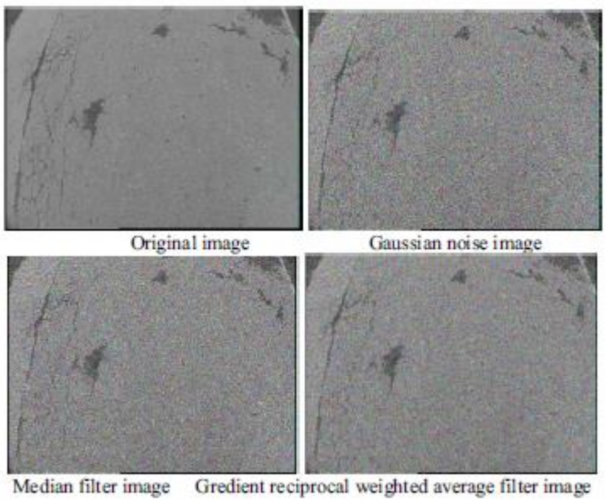
$$g(x,y,i,j) = \frac{1}{\left|f(x+i,y+j) - f(x,y)\right|}$$



F ig.5.

Image of median filter and gradient reciprocal weighted average filter

Image intensification

Histogram is the foundation for various spatial domain processing techniques which can be applied to image intensification effectively. Modeling processing of grey level histogram refers to transforming the gray level by the specified gray level distribution; it is applicable to poor contrast and over brightness or over darkness of image, and gray level concentration on the bright and dark side. Histogram equalization is a kind of effective method; in other words, the gray value of the transformed image is distributed evenly and the overall contrast ratio of the image has been improved. It can be described by a mathematical formula as below:

$$g(x,y) = INT\left(\frac{v(u) - v_{\min}}{1 - v_{\min}}(L-1)\right)$$

In the formula, g(x,y) is the gray value of the transformed image, u is the gray level of the original image, v is the frequency of gray level distribution, Vmin is the minimum value of the gray level distribution frequency, and INT is the round number.

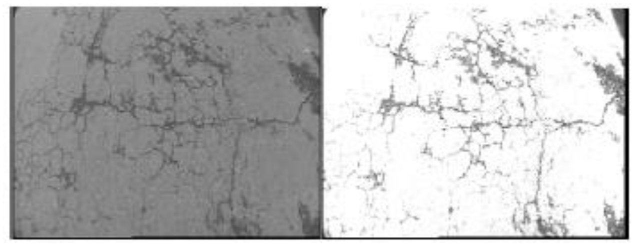


Fig.6.The original image and image enhancement result

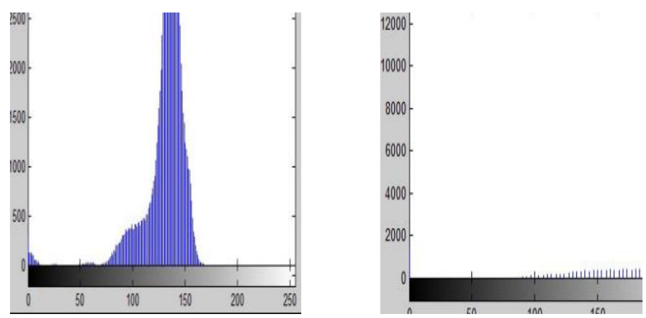


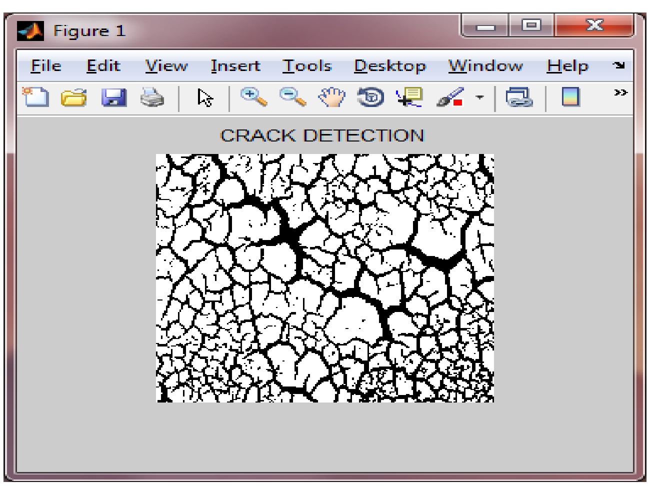
Fig.7. The original image histogram The image after enhancement histogram

The histogram of the equalized crack image shows that the dynamic range is enlarged, while the "single peak" of the equalized histogram shows unclear features because the edges are exposed unevenly during imaging and the intensified image looks "fuzzy".

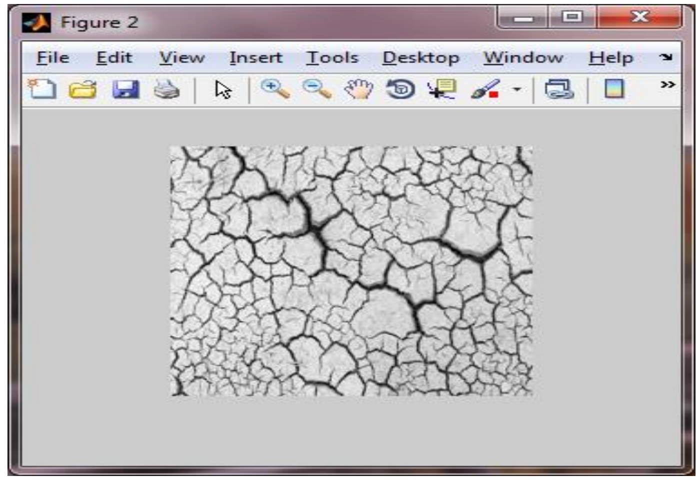
Edge detection

Image edge is quite useful for image recognition and computer analysis. Edge detection can outline the object clearly for the observer; and edge is an important feature in image recognition rich in internal information. Essentially, partial image features will not be shown in the edge continuously but mark the end of an area and the start of another. Actually, edge detection aims to extract the boundary between the object and the background of the mage through an algorithm in case that the edge is defined as the border of a boundary area whose gray level changes rapidly. Changes of the gray level can be shown by the distribution gradient; so the edge detection operator can be acquired through partial image differentiation technique.

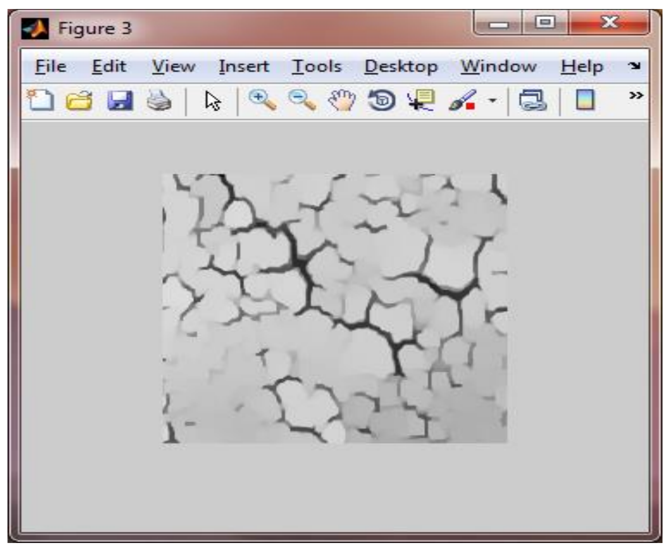
EXPERIMENT RESULTS



(A) Crack Detection



(B) Edge Detection



(C) SMOOTHENING

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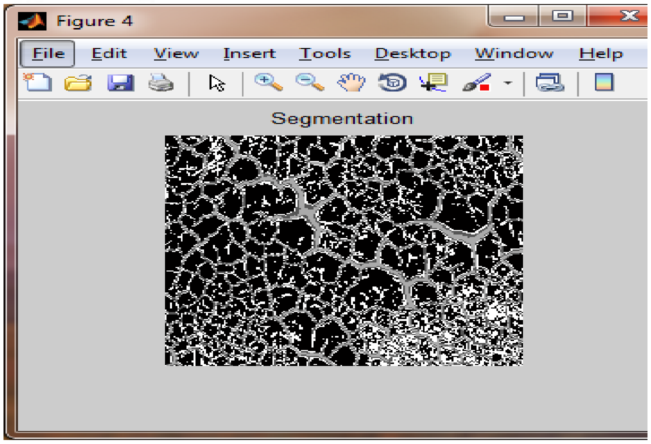
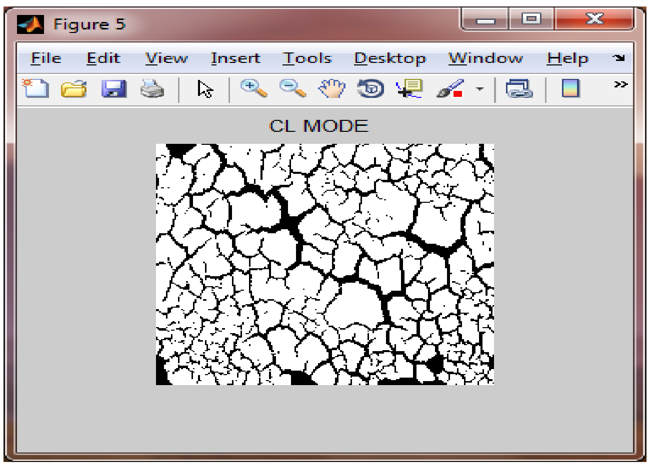


(D) Segmentation



(E) CL MODE

The experiment results shows the A-G output figure of various steps to produce the optimal solution for finding the detection by using novel algorithm identify. The results shows the effectiveness of proposed algorithm and this is obtained by running the images using MATLAB platform.

CONCLUSION

The proposed method is independent of data acquisition techniques and is adaptable to different crack detection algorithms with minor modification. Currently, we are applying the proposed method to realize balancing selection between processing effect and process complexity, this paper segments the defective image through edge detection and threshold segmentation now that it is hard and ineffective to process the crack image through current researches and algorithms. It has demonstrated a strong capability in experimental tests and is promising for transforming sensing data and crack detection results into useful decision support information. Improvements in the crack detection algorithms can also contribute to a more accurate automatic crack evaluation.

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