DEVELOPMENT OF DIGITAL IMAGING TECHNIQUE FOR MAPPING CONCRETE CRACK

By

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This dissertation is submitted to

UNIVERSITI SAINS MALAYSIA

as partial fulfillment of requirements for the degree of

BACHELOR OF ENGINEERING (CIVIL ENGINEERING)

School of Civil Engineering
Universiti Sains Malaysia

May 2006

ACKNOWLEDGEMENTS

This research was necessarily a group effort, and I am grateful to the many people who helped pull it together. I would like to thank my advisor, Dr. Mohd Sanusi bin S Ahamad for his constant support and supervision throughout this project. I would also like to wish my thanks to Mr. Rashidi for their help and guidance in completion of this project. Not forgetting to thank all the staff and all the technicians of School of Civil Engineering. Last but not least a lot of thanks to all my friends for their helping me and cooperation throughout this project and make it a success.

ABSTRACT

The scope of the project covers the crack study on the concrete structure of building around Pekan Parit Buntar. This purpose of this study is to investigate a non-destructive technique (NDT) using digital imaging to measure and map the dimension of concrete wall crack at regular interval along it is length. This project also studies the possibility of using GIS technique in structural crack mapping and analysis. Crack could develop due to many reasons such as overloading, corrosion of reinforcement or alkali–aggregate reaction, excessive drying shrinkage and exposure to extreme temperatures. The damage can be impact the strength of the concrete. An understanding of the evolution of crack in concrete structure due to long term natural deformation is important in civil engineering field, while quantitative measurement can be difficult to make. However, non-destructive testing (NDT) has the ability to determine the strength and durability of critical construction without damaging them and the test can carried be out on – site. Those investigated structure members can be guaranteed to be perfect without any inspection or quality control. GIS based image processing used as NDT method to determine crack. The IDRISI GIS analytical software can carry out crack profile study determining the depth of cracks. The study has pursued that modeling can be developed for crack image study and development. GIS is ideal for engineering site investigation because it is very efficient and can display information according to user defined specifications.

ABSTRAK

Skop kajian bagi projek ini merangkumi struktur konkrit yang retak yang terdapat di sekitar Pekan Parit Buntar. Matlamat bagi kajian ini adalah untuk menyelidik teknik Ujian Tanpa Musnah, (NDT) dengan menggunakan imej digital untuk mengukur dan memetakan dimensi keretakan di atas dinding konkrit pada jarak yang sekata di sepanjang retak. Kajian ini juga untuk mengkaji kesesuaian penggunaan teknik GIS dalam kajian keretakan struktur. Keretakan boleh terjadi disebabkan beberapa sebab, antaranya adalah pembebanan berlebihan, hakisan terhadap tetulang atau tindak balas agregat-alkali, pengecutan pengeringan yang berlebihan dan terdedah kepada suhu yang melampau. Kerosakan-kerosakan tersebut boleh memberi kesan terhadap kekuatan konkrit. Pemahaman mengenai evolusi keretakan dalam struktur konkrit disebabkan oleh perubahan semula jadi dalam jangka masa yang panjang adalah penting bagi bidang kejuruteraan awam, manakala pengukuran kuantitatif adalah sukar untuk dilakukan. Walaubagaimanapun, Ujian Tanpa Musnah berkebolehan untuk menentukan kekuatan dan ketahanan pembinaan kritikal tanpa memusnahkan struktur konkrit dan ujian tersebut dapat dijalankan di tapak. Ujian yang dijalankan dijamin tidak akan memusnahkan tanpa pemeriksaan atau kawalan kualiti. IDRISI32 digunakan sebagai kaedah Ujian Tanpa Musnah dalam menentukan keretakan. Perisian dapat menghasilkan profil keretakan dan kedalaman retak. Kajian ini boleh membuktikan modeling GIS boleh membangunkan kemajuan imej keretakan. GIS adalah satu system yang sesuai untuk kajian pilihan tapak. Ini kerana ia adalah sangat efiksien dan boleh mempamirkan informasi mengikut spesifikasi pengguna.

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INTRODUCTION

1.1 Background Project

Crack in concrete is a normal phenomenon that often attack building structure. Crack is defined as a cleavage, crevice or something separation on the structure that can be seen by a human eye. Generally the damage started from the outer surface until infectious deep into inner surface that can caused impact to the strength and durability of the concrete. The study on crack measurement is usually using non – destructive testing (NDT). This method is adopted in this project as to ascertain that no deleterious effects will be made on the material or crack structure. Non – Destructive testing (NDT) is a very important aspect in safety and quality of structural inspection. NDT has the ability to determine the strength and durability of critical construction without damaging them and the test can carried out on – site. The data collection and the analysis of the crack image in this study utilized the combination of digital image capture with image processing and analysis technique in Geographic Information System (GIS). This is one of the newest technologies in helping to address development issues in crack problems. GIS has the capability to manage and critically analyses large data sets by displaying the information in a visual manner. It is can also interpret data by comparing different feature.

1.2 Problem Statement

If the structure was exposed to failure the workability of the concrete will be decrease. The damage can have an impact to the strength of the concrete. Normally failure defects and deterioration of concrete manifest themselves in the form crack. Non-destructive testing (NDT) was an effective technique to solve this problem. It is because the test does not damage the concrete structure while test being made on them self. This is one of the new technologies in studying the crack problem. The study represents the application of GIS in NDT to identify the depth of crack.

1.3 Objective of Study

The objective of this project is:

1. To investigate a non-destructive technique using digital imaging to measure and map the dimension of concrete wall crack at regular interval along it is length.
2. To investigate possibility of using feature extraction technique in GIS to interpolate and plot profile of crack in 3-dimension.

The scope of work in this study is comprised of two major tasks:-

1. Data capture of concrete wall cracks on building around Parit Buntar town area by means of high resolution digital camera.
2. Digital image processing of crack images using IDRISI GIS software to produce outline, depth and project of concrete crack.

A method of non-destructive technique is being applied by making references to rigorous literature study.

1.4 Benefit of the project

This case study will open the opportunity to civil engineers to apply GIS technology in structural building deformation. Non-Destructive Testing (NDT) is a common method in crack investigation but the application of digital imaging technique as the main source of the data capture is new. The use of GIS in the analytical crack analysis is considered as a good approach in term of cost saving time consumption. It will definitely optimize the work required in building deformation.

CHAPTER 2

LITERATURE STUDY

2.1 Introduction

In civil engineering, concrete structures of good quality should be durable. The elements of concrete structures detected by chemical reaction tend to be an expansion phenomenon, which leads to cracks. The concrete structures of inferior quality caused by cracks have influence on the structures' durability and strength. AAR (Alkali-Aggregate Reaction) found by Stanton (Dolar-Mantuani, 1983) produces cracks on concrete structures because of its chemical reactions. The cracks due to expansion pressure of AAR on concrete structure are adopted by contact mensuration in a traditional method. According to the "Crack-Scale", the traditional mensuration is operated by human to determine and locate the width and the position of crack. (L.C.CHEN, 2001) the sample lines with scaled width are taken to match the width along the track of cracks. However, thus kind of the time-consuming operation does not result consistently.

Nowadays mostly crack measurement is done using non – destructive testing. The method implemented in this testing is to ascertain no deleterious effects on the material or crack structure. The image analysis, method of non-destructive testing was used in this case study. Image analysis techniques allow the assessment of the characteristic of the crack network in concrete. (A.Shamshad et al., 2003) An image analysis technique is a process based on digital image processing (DIP). Digital image processing is a computer based technology by which scene is captured electronically in pixel form and then processed so that pictorial information about the scene can be extracted. (A.Shamshad et al., 2003) furthermore, to detect the crack in a image, an algorithm that look sharp changes in colour or grey level of neighboring pixels can be employed.

2.2 Crack Study

Concrete is a heterogeneous and multiphase material. It is durable and capable to endure for long duration time. If the structure was exposed to failure the workability of the concrete will be decrease. Normally failure defects and deterioration of concrete manifest themselves in the form crack. Crack is cleavage, crevice or something separation on the structure that we can watch and see by our self. The damage was starting from outer surface until infectious deep into inner surface that can be impact the strength of the concrete. Crack could develop due to many reasons such as overloading, corrosion of reinforcement or alkali–aggregate reaction, excessive drying shrinkage and exposure to extreme temperatures. (A.Shamshad et al., 2003) This problem should be solving before the crack become worst. There are so many ways to handle wall cracking. In this case study non – destructive testing is implemented to measure crack figure without doing harm to the inspected structure.

2.3 Types of crack

The concrete surfaces exposed to the outside atmosphere allow penetration of some of the materials contained in the atmosphere. The penetration of such materials may cause deterioration of the concrete and corrosion of the reinforcement bars. The damage is caused mainly by the penetration of carbon dioxide with water into the concrete and toward the reinforcement bars. Crack can be classified into four categories; there are hairline crack, normal crack, middle of wide crack and extreme width crack. The differences between those kinds of crack are shown in table below:

Classification	**Width**	**Feature**	**Description**
hairline crack	(0.05 – 0.1) mm	Could be seen when there is enough lighting	Would not cause erosion
normal crack	(0.1 – 0.3) mm	Easier be seen by naked eye	Would not cause extreme erosion
middle of wide crack	(0.2 - 1.0) mm	Both side of crack could be seen easily	The crack width can be accepted and control by reinforcement. Would cause erosion
extreme width crack	> 1.0 mm	Both side of crack could be seen easily compare to middle	Dangerous corrosion would cause

		of wide crack and the depth of crack can be measure	the depth of crack increase

Table 2.1: Cracking Classification (Sources: British Crown, 1992)

Figure 2.1(a): hairline crack

Figure 2.1(b): normal crack

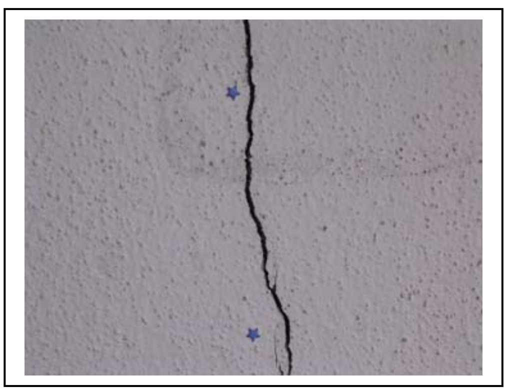


Figure 2.1 (c): middle of wide crack

Figure 2.1(d): extreme width crack

2.4 Non – Destructive Testing

Non – Destructive testing (NDT) is a very important role in safety and quality in any inspection. Mostly crack measurement is using non – destructive testing. This test does not impair the intended performance of the element or member under investigation. (British Standard 1881, 1986) NDT has the ability to determine the strength and durability of critical construction without damaging them and the test can carried out on – site. Those investigated structure member can be guaranteed to be perfect without any inspection or quality control, so that either sample must be extracted for testing or some sort of overall Non-Destructive Test (NDT) must be devised. The essential feature of NDT is that the test process itself produces no deleterious effects on the material or structure under test. (Gohodo Shuppan, 1986)

2.5 Method of NDT measurement

To investigate and measure crack figure, the inspection was checked and evaluated by NDT method. This is an appropriate method to implement because the cost of the testing is cheapest. There is several NDT technique usually used to concrete structure. From other research the familiar of NDT method that they were using are radar method by analysis of direct waves, ultrasonic surface wave method and image processing.

2.5.1 Radar method

Generally this method is used in reflection mode, where the reflections caused by changes in medium dielectric properties are recorded by the receiver (R). The most common application is the exploration of the signal reflected by the reinforcement (S2) to provide information on its depth. Another wave is the direct wave (S1), propagating along the air material interface in the subsurface with a velocity determined by the upper part of this subsurface. For commercially available coupled antennas, the transmitter and receiver are not dissociated, so the distance between them is always the same. Two antennas are therefore required to make measurements with various distances as for the Common Middle Point (CMP) or Wide Angle Reflection Refraction (WARR) techniques. A single antenna was used, so only the attenuation of the direct wave is analyzed. (Gilles Klysz et al, 2005)

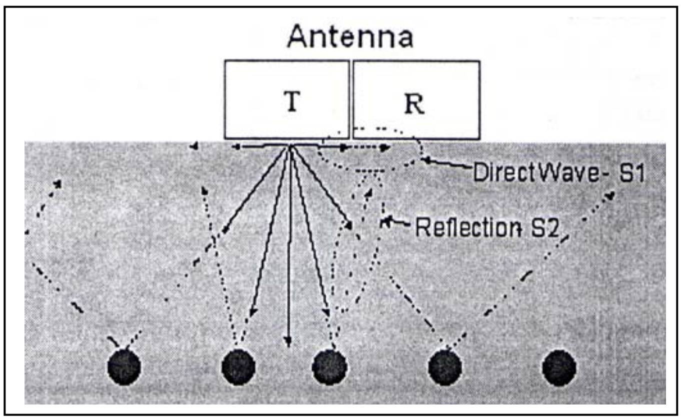


Figure 2.2: Propagation of electromagnetic waves in reinforced concrete (Gilles Klysz et al, 2005)

2.5.2 Ultrasonic Wave Surface Method

Concrete is a multi-phase material. Speed of sound in concrete depends on the relative concentration of its constituent materials, degree of compacting, moisture content, and the amount of discontinuities present. Sound attenuated by coarse granular structure (much acoustic scattering occurs). Testing is usually performed at kilohertz frequencies by the pulse through-transmission. (Ismail M. P. et al, 1996)

A surface wave may propagate along the free surface of a solid medium, within a depth around one wavelength. For frequency ranging from 250 kHz to 1 MHz, the wavelength is between 2 and 10 mm in concrete. High – frequency wave are thus appropriate for inspecting the near – to – surface degraded layer in concrete cover, where aggressive agents can penetrate. Its velocity is expected to decrease and its attenuation to increase with increasing porosity and micro cracking. (Gilles Klysz et al, 2005) Previous laboratory studies have demonstrated the ability of high frequency surface waves to detect thin distributed damage area in mortar (Ould Naffa et al, 2002)

The surface wave is well suited for on site inspection, as only a side access is required. In addition, it is dispersive in multi – layered media, i.e. its velocity depends on frequency. This remarkable property can be used to estimate the elastic property distribution as a function of depth (Matthews et al, 1996). Pulse velocity is usually measured from the time delay between two or more surface wave signal recorded at different distance from the source. By analyzing the spectral difference between those signals, in amplitude and phase, it is also possible to estimate attenuation and phase velocity. (Gilles Klysz et al, 2005)

2.6 Digital Image Processing of Cracks as part of NDT

The image processing is a system to converts the analog signal of the sensor into a digital data stream. Image processing is a unique in its combination of theory and implementation, which distinguishes it from more mathematical treatises on the subject. In addition the treatment of the basic image – processing techniques is sampling; filtering and data compression. An image can be processed as soon as information begins to be extracted from it. Image processing also involves the analysis and comprehension of images. Nevertheless, image analysis also known as scene analysis, seeks to extract the information contained in the various objects in a scene without placing any interpretation on them.

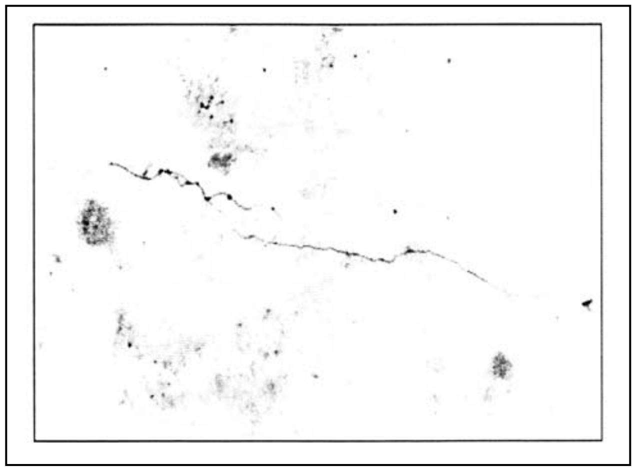


Figure 2.3: Image of a crack in a concrete structure (Paul M. Dare et al, 2003)

2.6.1 Reason behind Image Processing

In making the image more attractive, there may be a need to improve the image taken. There are many ways in which images can be processed, such as increasing contrast, improving the ability to make out certain details or contours, enhancing the clarity of certain zones or shapes, or reducing the noise or interferences which can have a variety of causes and make the information less useful. (Andre Marion, 1991) Enhancing the quality of image may also mean the search for an ideal image of the object if it has become degraded in a number of ways. An enhancement technique involved the use of such filtering, non – linear filtering and so on to produce smoothing, contour accentuation, enhancement and others. (Andre Marion, 1991) There is need to correct geometrical or photometric distortions introduced by a sensor, to reduced fluctuations caused by atmospheric turbulence from camera shake. An important aspect of image processing is the enormous amount of information which has to be handled when transmitting one or more images. It is helpful to find a way of reducing the quantity of information involved.

2.6.2 Image Restoration

In image processing restoration is compulsory in making the image more attractive. Image restoration can remove or minimizes some known degradations in an image. It can be seen as a special kind of image enhancement. The most common degradations have their origin in imperfections of the sensors or in transmission. This process uses polynomial equations to establish a rubber sheet transformation As if one of the grids were placed on rubber and warped to make it correspond to the other. A new grid is constructed and a set of polynomial is developing to describe the spatial mapping of data from the old grid into the new one. That is the actual process in this proceeding.

Figure 2.4: comparison between original image and restoration image (William K. Pratt, 1991)

The new grid is then filled with data values by resampling the old grid and estimating. The data value should be in the new value. Resampling options include a nearest neighbor option, which the new grid value is the same as that in the nearest cell in the old grid. Nearest Neighbor is a simplest strategy is to assign each corrected pixel, the value from the nearest uncorrected pixel. It has the advantages of simplicity and the ability to preserve original values in the altered scene, but it may create noticeable errors, which may be severe in linear features where the realignment of pixels is obvious.

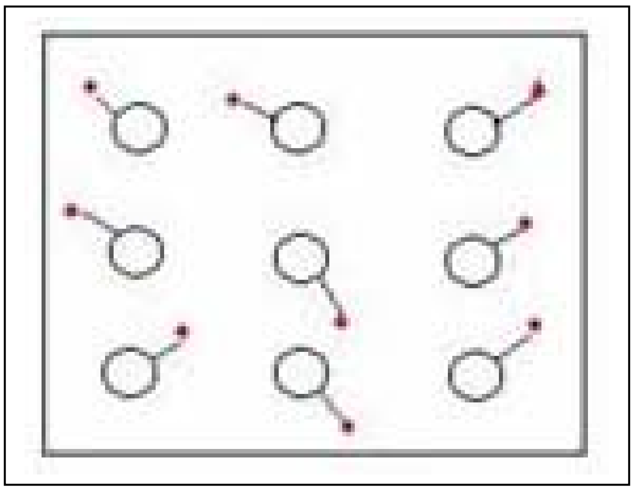


Figure 2.5: nearest neighbor

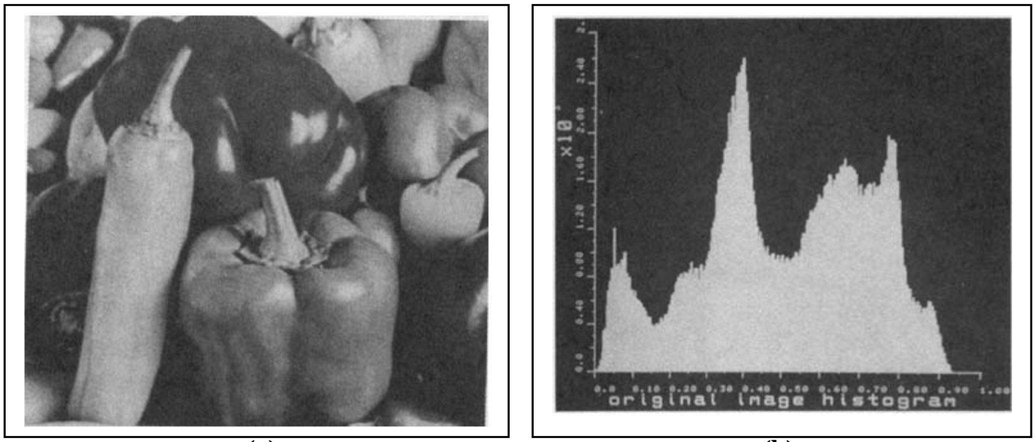
Resample is used for a variety of operations, including:-

1. Registering remotely sensed imagery to a grid referencing system
2. Registering maps with different reference systems over small areas (larger areas require a change in map projection) when one or both reference systems are not supported by the same projection
3. Undertaking minor changes in projection when one or both reference systems are not supported by the same projection.
4. Making non-integer changes in the resolution of an image.

2.6.3 Image Enhancement

Image enhancement processes consist of a collection of techniques that seek to improve the visual appearance of an image, or to convert the image to a form better suited analysis by a human or a machine. In an image enhancement system there is no conscious effort to improve the fidelity of a reproduced image with regard to some ideal form of the image, as it done in image restoration. (William K. Pratt, 1991)

Enhancement is a techniques which make use of such varied procedures as histogram modification, convolution, linear filtering , non-linear filtering etc; in other to produce smoothing, contour accentuation, enhancement and so on. (Andre Marion, 1991) Enhancing the quality of an image may also mean the search for an 'ideal' image of the object if it has become degraded in a number of ways. There is need to correct geometrical or photometric distortions introduced by a sensor, to reduced fluctuations caused by atmospheric turbulence from camera shake. (Andre Marion, 1991) Effective segmentation can be achieved in some classes of images by a recursive multilevel thresholding method. (Tomita, 1987) In the first stage of the process the image is threshold to separate brighter regions from darker regions by locating a minimum between luminance modes of the histogram. Then histograms are formed of each of the segmented parts. If these histograms are not unimodal, the parts are threshold again. The process continues until the histogram of a part becomes unimodal.



(a) **(b)**

Figure 2.6: (a) original image (b) image histogram (William K. Pratt, 1991)

Composite is apart of the enhancement techniques. Composite produces a colour composite image from three bands of byte binary imagery. 24 and 8 bits composites may be produced. The former is used by display and visual analysis. (IDRISI manual) The 256 Color Composite palettes contain composite colors from color index 0 through color index 215. Colors 216-255 include colors that may be useful for displaying features, such as roads, that are rasterized onto the color composite image. (IDRISI manual)

Original **Enhanced**

Figure2.6 (c): Edge enhanced compared to original

2.6.4 Image Classification

Image Classification has formed an important part of the fields of Remote Sensing, Image Analysis and Pattern Recognition. In some instances, the classification itself may form the object of the analysis. In others word Classification is to compressing image data by reducing the large range of Digital Number (DN) in several spectral bands to a few classes in a single image. Classification can reduces this large spectral space into relatively few regions and obviously results in loss of numerical information from the original image. There is no theoretical limit to the dimensionality used for the classification, though obviously the more bands involved, the more computationally intensive the process becomes. It is often wise to remove redundant bands before classification.

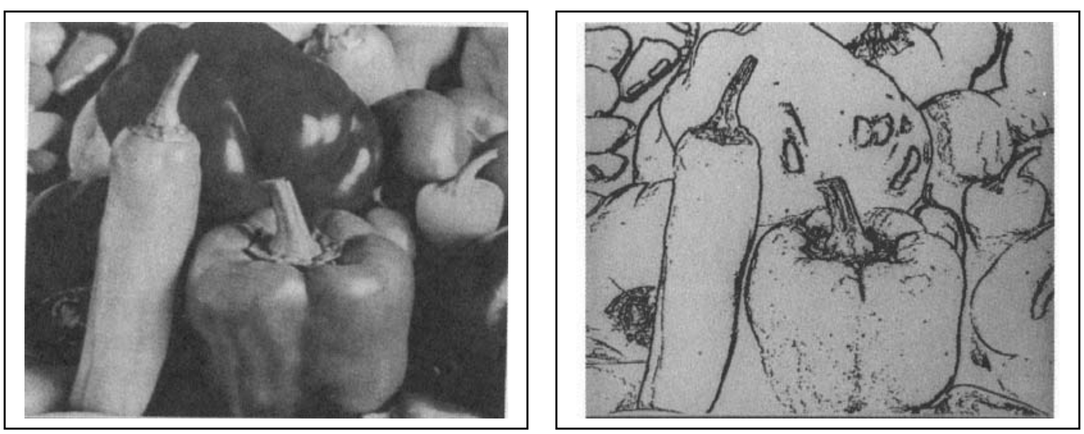
Classification can be comprise 4 steps, there are:

1. Pre-processing (e.g., atmospheric, correction, noise suppression, band rationing, Principal Component Analysis, etc.)
2. Training - selection of the particular features which best describe the pattern
3. Decision - choice of suitable method for comparing the image patterns with the target patterns.
4. Assessing the accuracy of the classification

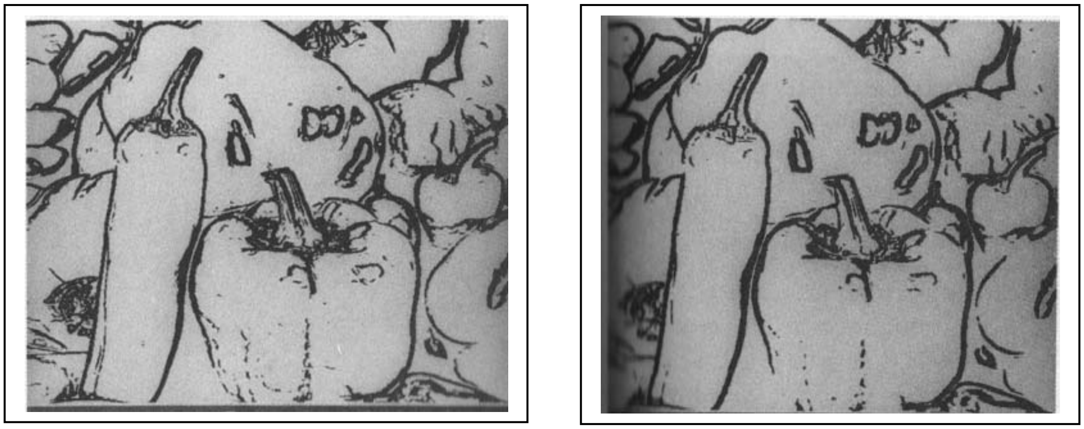
2.6.5 Transformation

Transformation can be done by different resampling methods where original pixels are resampled to match the geometric coordinates. Each resampling method employs a different strategy to estimate values at output grid for given known values for the input grid.

Texture is one of the sub topics in transformation process. Many portions of images of natural scenes are sharp edges over large areas. In these areas the scene can often be characterized as exhibiting a consistent structure analogous to the texture of cloth. (William K. Pratt, 1991) Texture includes four categories of analysis. The first uses variability in a 3 x 3, 5 x 5, or 7 x 7 pixel window to assess several different measures. The second estimates a fractal dimension within a 3 x 3 area. The third calculates the frequency of a specified input value within a 3 x 3 pixel window, or a 5 x 5 or 7 x 7 orthogonally-shaped pixel window. The fourth provides convolution filters to analyze edges in specific directions. While appropriate for many applications, these routines have been included to support the analysis and classification of remotely-sensed data. (IDRISI manual) The variables of texture according to each pixel are shown in figure below:



(a) **(b)**



(c) **(d)**

Figure 2.7: (a) original picture (b) 3x 3 pixels (c) 5x5 pixels (d) 7x 7 pixels (William K. Pratt, 1991)

2.6.6 Image Filtration

Filtering methods depends on their computational speed and their application when there already is enough bandwidth in the filtered estimate. For example, some sources of blur image, such as image motion, intrinsically have infinite bandwidth, so do not require an extrapolation from it. Filtering is a common and important operation and occurs at several points in the transmission chain (Fig 2.6.6 a). Once the image is in digital form, it may meet a variety of other filters in operations such as sampling-rate conversion and motion detection. (Don-Pearson, 1991) Recovery of the image from its samples taken place by means of an electro-optical low-pass post-sampling filter in cascade with the human eye, which itself low-pass filter (Pearson, 1975). If the whole processing-transmission system is designed correctly, the processed image should appear continuous in space and time, without visible defects. In practice, electro-optical filters are rather slow cut-off filters and most of the recovery filtering is done electronically or by the eye. (Don-Pearson, 1991)

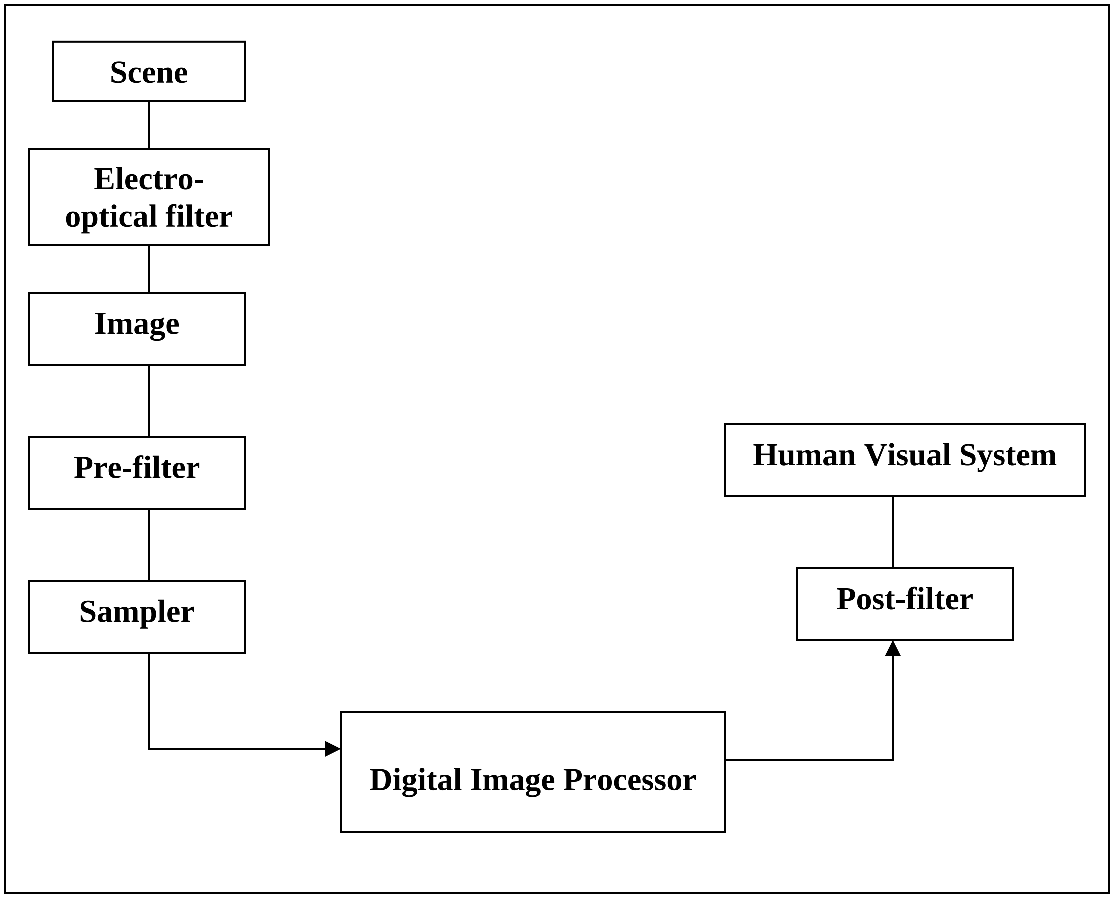


Figure 2.8: Filters (shaded) in the image processing chain (Don-Pearson, 1991)

2.7 GIS

Geographic Information System (GIS) is hard to define. It represents the integrations of many subject areas. A broadly accepted definition of GIS is the one provided by the National Centre of Geographic Information and Analysis: *A GIS is a system of hardware, software and procedure to facilitate the management, manipulation, analysis, modeling, representation and display of georeferenced data to solve complex problems regarding planning and management of resources.* (NCGIA, 1990)

GIS have emerged in the last decade as an essential tool for urban and resource planning and management. Their capacity to store, retrieve, analysis, model and map large areas with huge volume of spatial data has led to an extra ordinary proliferation of applications. GIS help interpreting data easier and different factors are comparable. GIS is ideal for site selection studies because it efficiently stores, analysis and can display information according to user defined specifications. GIS is capable of managing and critically analyzing large data sets with strong spatial components (Siddiqui et al., 1996) Benoit (1995) also emphasizes the importance of using GIS in facility sitting queries but notes that the output should be as decision support rather than a decision maker. Facility sitting is a complex process and incorporates social, political, economic and environmental concerns (Kone, 2000 and Bookout 1996)

GIS are now used for land planning, utilities management, transportation, ecosystem modeling, landscape assessment and planning; market analysis, visual impact analysis, facilities management, tax assessment, real estate analysis and many other applications.

2.8 IDRISI32

IDRISI32 is one of the software that represents GIS application. It consists of main interface program and 150 modules for data input, display and analysis of geographic data. Map that describes geographic data is incorporated in two basic forms of map layer, which is vector and raster image. Idrisi32 can support a variety format for value file and has a database management facility called database workshop.

GIS is presented in this research by two board categories of spatial model. These models are:

1. Vector data model
2. Raster data model

The vector model represents phenomena of objects as exactly and precisely as possible by storing of points, line (arc) and polygon (areas) in a continuous co-ordinate space (Ahamad M.S., 2003). The raster model represents phenomena as occupying the cells of a predefined, grid-shape tessellation (Jones, 1997).

2.8.1 Vector

Vector is a data structure used to store spatial data. Vector data is comprised of lines or arcs, defined by beginning and end points, which meet at needs. The locations of these nodes and the topological structure are usually stored explicitly. Features are defined by their boundaries only and curved lines are represented as a series of connecting arcs. Vector storage involves the storage of explicit topology, which rises overhead, however it only stores these points which define a feature and al space outside these features is 'non-existent'. A vector based GIS is defined by the vectorial representation of its geographic data. According with the characteristic of this data model, geographic objects are explicitly represented and within the spatial characteristic, the thematic aspects are associated.

There are different ways of organizing this double data base (spatial and thematic). Usually, vectorial systems are composed of these two components. The first one is manages spatial data and the second and manages thematic data. This is the named hybrid organization system, as it links a relational data base for the attributes with a topological one for the spatial data. A key element in those kinds of systems is the identifier of every object. This identifier is unique and different for each object and allows the system to connect both data bases.

2.8.2 Raster

Raster is a method for the storage, processing and display of spatial data. Each area is divided into rows and columns, which form a regular grid structure. Each cell must be rectangular in shape, but not necessarily square. Each cell within this matrix contains location co-ordinates within the ordering of the matrix, unlike vector structure which store topology explicitly. Area containing the same attribute value is recognized as much; however, raster structure cannot identify the boundaries of such areas as polygon.

Raster data is an abstraction of the real world where spatial data is expressed as a matrix of cells or pixels, with spatial position implicit in the ordering of the pixels. With the raster data model, spatial data is not continuous but divided into discrete units.

This makes raster data particularly suitable for certain types of spatial operation, for example overlay or area calculation. Raster structure may lead to increased storage in certain situations, since they store each cell in the matrix regardless of whether it is a feature or simply ‘empty’ space.

CHAPTER 3

METHODOLOGY

3.1 Introduction

A standard GIS heuristic methodological procedure has been implemented to fulfill the objective of this project. The research methodology of this study involved data collection process, data editing process and verification work, analysis and output presentation. The Appendix1 described the various steps of the methodology. The software used in this project is IDRISI-32 bit. It consists of main interface program and 150 modules for data input, display and analysis of geographic data.

3.2 Data capture

The study area covers several building wall in Parit Buntar town. Cracking images on the wall structure is the main focus in this study. The crack images are taken at different location to get the variation in results, the pictures are taken at three different building that has evidence of crack occurrences on them.

A digital camera 4.0 mega pixel (Canon Power Shot 3G) was used in this case study to get high quality digital images. To avoid a vertical distortion in the captured image, a tripod was used and was set up at a constant distant from the wall cracks. This is an important step in taking crack photos to avoid error of distortion from vertical plane during digitizing work in the IDRISI software (refer figure 3.1). During the data capture, random points on the crack were determined and depths of the crack at that point were measured. Measurement was made using thin plastic ruler and all depth are