Digital Image Processing for Evaluating Defect Level in Visual Quality Inspection

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Abstract

The traditional construction industry dilemma concerns the definition of an overall quality standard and acceptable level especially in aesthetic issue because some work items in visual inspection are difficult to measure the absolute defect quantity. These are limited by using human vision inspection. In current practice, the visual quality inspection is still relied on individual subjective judgment. It causes several problems such as multiple-standards and unreliability. Thus, this research paper presents an innovative visual inspection system that uses the digital image processing (DIP). It attempts to reduce the human subjective measure and enhance the reliability for evaluating the defect level. The digital image processing helps to interpret from image data to features of inspected object. It helps to solve the human vision limitation in unknown of absolute defect quantity. Moreover, this paper presents the allow representation of long-gathered knowledge, and its use to solve the decision problems.

Keywords: digital image processing, visual quality inspection, defect detection

1. Introduction

Due to the fact that a high quality is one of criteria influencing customer satisfaction with regard to the performance of construction projects beside cost and time. Therefore, quality is a key element of survival and success in a high competitive environment of construction business. The inspection is essential processes in quality control for protecting defection to assure that the quality of final products fulfilled specifications and customer requirements (Pesante-Santana ,1997).

The traditional construction industry dilemma concerns the definition of an overall quality standard and acceptable level. By its nature, quality evaluation in a construction work can be divided into two attributes that consist of measurable and subjective attributes. The measurable attributes are related to material types, construction techniques and functional requirements. These attributes including the standard, sampling and specification of construction works are defined in contract document. As these can be measured, they frequently use the mechanical instruments to enhance the sensory input for the human judgments. Instruments such as gages are used to determine thread sizes, gap thicknesses, angles between parts, hole depths, and weld features. Thus, the judgment on quality of work can be evaluated by comparing between measurement result and specification. In contrast, subjective attribute of work items are related to aesthetic issue especially in architectural works. The content in the contract document uncovers about this issue. Because inspectors use only visual inspection which is difficult to measure the absolute defect quantity, these are human vision limitation.

In current practice, the visual quality inspection is dependent on individual subjective judgment. The problems of confliction about the satisfaction of aesthetic level have arisen as a result of different customer perception. Moreover, several project participants who are involved in evaluating quality inspection have different experience. It has multiple-standards and unreliability on quality judgement. Therefore, the quality evaluation of subjective attribute needs the method to minimize these problems.

2. Previous related work

The construction industry illustrates many previous research works which are studied to overcome the limitations of subjective evaluation in visual quality inspection by human inspector (Georgopoulos et al., 1995; Lee, 2004; Lee et al., 2006). They developed an automatic procedure replacement by using computer vision and image processing technologies to automate the process. These attempts are to determine the defects of road infrastructure by using digital image processing. The result of the process can help to optimize infrastructure maintenance strategies in operation stage. The digital image processing (DIP) is a popular information technology in infrastructure field. Lee, Chang & Skibniewski (2006) studied the inspection of the deterioration of steel bridge coating. Georgopoulos, Loizos & Flouda (1995), and Lee (2004) proposed the information technology for inspecting the pavement crack. Therefore, the use of image processing can support human judgments in quantifying and evaluating construction defects.

Although previous researches aim to support human subjective judgments by using image processing to detect and quantify construction defects, few researches focus on evaluating the intensive defect level in subjective attribute of aesthetic issue during the construction stage. The acceptable level of defect about aesthetic issue in architectural work is difficult to judgment because it depends on each personal perception. These causes lead to confliction. Therefore, we envision challenge to evaluate the intensive defect levels about aesthetic issues using in each organization.

3. Research objectives

This research paper aims to present the conceptual framework of an innovative visual inspection system that uses the digital image processing (DIP). It attempts to reduce the human subjective measure and enhance the reliability for evaluating the defect level. The digital image processing helps to interpret from image data to features of inspected object. It helps to solve the human vision limitation in unknown of absolute defect quantity.

4. Principle of digital image processing

Digital Image processing means the computerized processes which help to enhance the quality of image into suitable form with objective such as reduce noise, contrast enhancement, image sharpening or high level process etc (Yodrayub, 2007). Interest in digital image processing methods stems from two principal application areas. These are the improvement of pictorial information for human interpretation and the processing of scene data for autonomous machine perception (Gonzalez and Woods, 1992). The digital image processing in computer vision can be grouped into three levels of computerized processes in the continuum (Gonzalez, Woods and et al., 2004).

(1) Low-level involves primitive operations such as image processing to reduce noise, contrast enhancement, and image sharpening. A low-level process is characterized by the fact that both its inputs and outputs are images.

(2) Mid-level involves tasks such as segmentation (partitioning an image into regions or objects), description of those objects to reduce them to a form suitable for computer processing, and classification (recognition) of individual objects. A mid-level process is characterized by the fact that inputs generally are images, but its outputs are attributes extracted from those images (e.g., edges, contours, and the identity of individual objects).

(3) High-level involves "making sense" of an ensemble of recognized objects, as in image analysis, and at the far end of the continuum, performing the cognitive functions normally associated with human vision.

This research applies all levels. Before image processing in high-level which uses algorithms of logical and mathematical model to analyze the defect feature of interesting object in image, the quality of image should be improved by pre-processing in low-and mid-levels for easier analysis. The algorithms in image processing are used to replace making sense and to overcome the subject judgment of human vision.

5. Conceptual framework of defect level evaluation system

The proposed conceptual framework is shown in Figure 1. It shows the whole methodology steps of defect level evaluation system that are sequentially linked together. The digital image processing is applied to quantify the defect value by analyzing image features of interesting object which humans solve unwittingly. Thus, the defect value is quantitative form which can compare with requirement standard. Knowledge management is applied to set own standard in visual quality inspection about aesthetic issue.

The system can be divided into seven modules which are spread in five main stages: (1) input stage (image acquisition module), (2) pre-processing stage (image quality enhancement and image scale adjustment module), (3) data analysis stage (image feature analysis module, defect value calculation module), (4) output stage (evaluation and translation module), and (5) capturing stage (knowledge base module). The case study of tiling inspection is chosen to present implementation of this concept. The detailed description of each stage is given as follows.

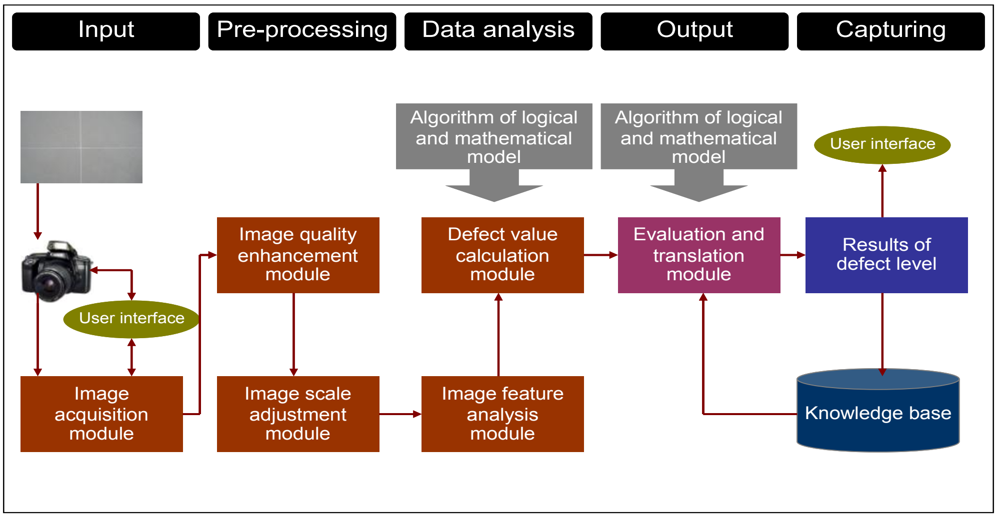


Figure 1: System architecture of defect level evaluation (modified from Laofor and Peansupap, 2009)

5.1 Input stage

The data flow starts from the data input stage that includes image acquisition module by connecting the digital camera with laptop pc. The image acquisition module captures and transfers image into computer for processing. The image contains the specific defect group for inspecting in each quality requirement. Under tiling inspection, the tile must be set in straight parallel lines. The distances between neighbouring tiles must be uniform. The neighbouring tiles have to be on the same level.

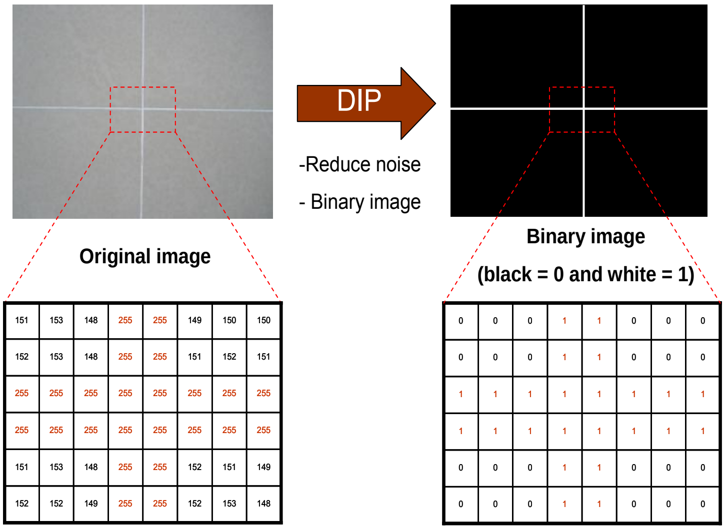
The glue has to be spread uniformly over the entire back of the tile. The tile must be pressed evenly against the floor (Navon, 2000). Our system does not intend to evaluate all quality requirements by using only image processing technique. But we focus on supporting visual quality evaluation in some quality requirements. Thus, the case study of tiling inspection can be inspected the straight parallel lines, uniform of distance between neighbouring tiles. The image acquisition must show the line, joint and level. The images should be taken in the same environment condition such as camera specification, pixels size (640x480), camera distance and others.

5.2 Pre-processing stage

The pre-processing stage aims to improve the quality of image into suitable form and easier analysis. It includes image quality enhancement module and image scale adjustment module.

- Image quality enhancement module

The image quality enhancement module uses the digital image processing to improve the quality of image for easier analysis. The case study of tiling inspection needs to reduce noise and convert colour image in Figure 2(a) to binary image (black and white) in Figure 2(b) by threshold techniques. The edge of tiles can be seen clearly for analysis in next module.



(a) (b)

Figure 2: Image quality enhancement

- Image scale adjustment module

The image scale adjustment module helps to adjust the scale ratio of image to the same unit with real object. Usually, the virtual image is pixel unit which is different from real object. Thus, it can not compare scale with requirement standard. The scale ratio (pixel per mm.) depends on photography conditions such as camera specification, camera distance and angle, and others.

5.3 Data analysis stage

The data analysis stage aims to interpret defect feature on image into quantity form that includes image feature analysis module and defect value calculation module.

- Image feature analysis module

The image feature analysis module uses the digital image processing to analyze image features in Figure 3 such as regions, edges, scale, interesting points and texture. This case study uses the difference of image pixels value between black (0) and white (1) for finding the coordinate of tile edges in both vertical line (V1,V2,..,Vm), horizontal line (H1,H2,..Hn). The slope (m) for finding angle of intersecting straight line in each point (PV1H1, PV1H2, PV2H1, PV2H2,.., PVmHn) can be calculated by using the linear regression equation. These are shown in Figure 4 after that it can be used to calculate the defect value in the next module.

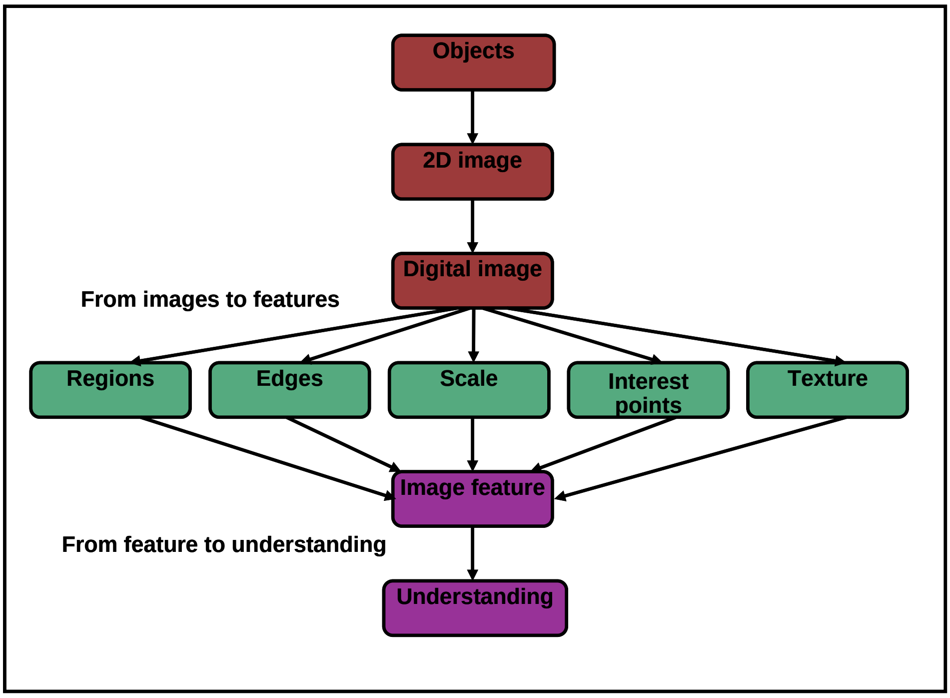


Figure 3: Digital image processing

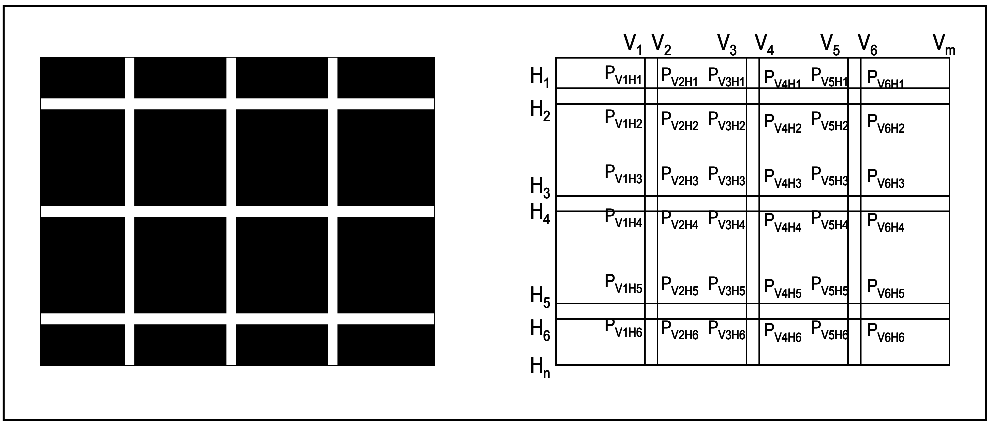


Figure 4: Image feature analysis

- Defect value calculation module

The defect value calculation module uses the algorithms of logical and mathematical model to quantify the defect value. It shows the intensive defect level from requirement standard. The case study of tiling inspection uses two algorithms to check the completion of tiling. First, the algorithm of distance inspection between neighbouring tiles (gap) must be uniform in Figure 5(a). Second, the algorithm of angle inspection of intersecting straight line must be right angle in Figure 5(b).

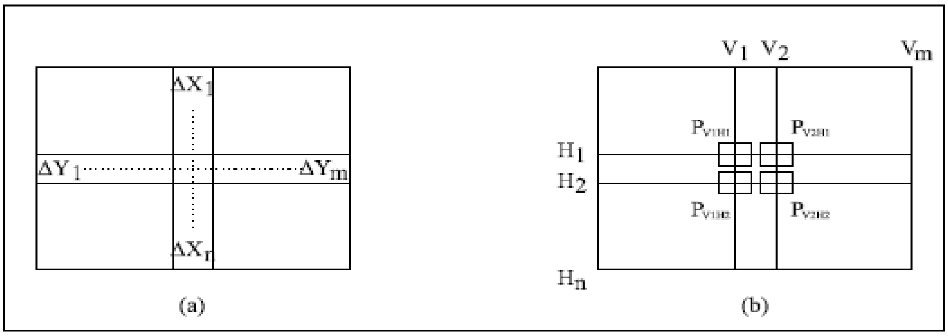


Figure 5: Algorithms of tiling inspection

5.4 Output stage

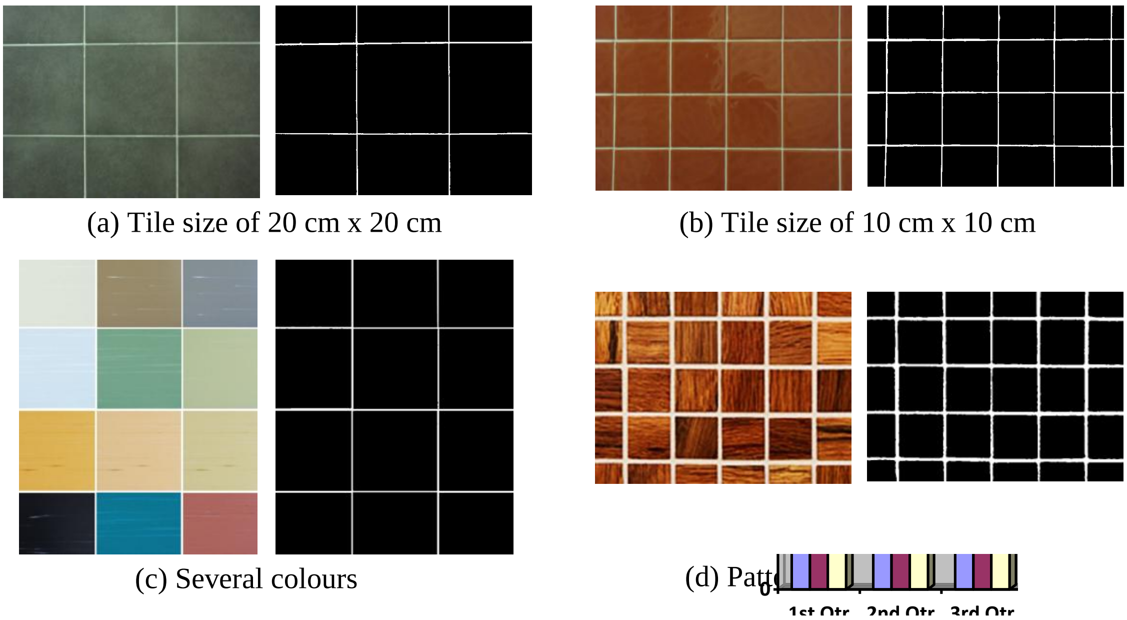
Output stage consists of evaluation and translation modules that can be translated into defect level by using the algorithm of logical and mathematical model. The algorithm is used to compare result of measurement from calculation with requirement standard from defect classification in knowledge base.

5.5 Capturing stage

In the capturing stage, the main purpose is to store defect value of quality criteria from representative images for developing quality standard. It is contained in the knowledge base module to support the evaluation and translation module. The representative images should be selected and classified by all project participants who involve in quality inspection process. This process helps the system by retrieving the inspectors' perception on quality standard and then can be used to capture the acceptable defect of work from project participants. Next, the representative images are evaluated by the defect value measurement. Thus, the criterion of defect level classification is developed to algorithm logical and mathematical model for evaluating the defect level of new image. This defect classification was stored as the knowledge base of representative quality standard. This acceptable defect in representative image can be used to compare with defect of the following works. The data flow of quality knowledge base is shown in Figure 1. This part can be used to create own standard in visual quality inspection about aesthetic issue for improving quality control continuously.

6. Results and discussion

This section aims to present results of testing and calculation of defect value from several tile cases. Due to the fact that tile manufacturing has several specifications such as material types, sizes, shapes, colours and patterns. Thus, our proposed system should cover these attributes. This research paper presents testing of different tile sizes, several colours and patterns of tile. From results of testing, our proposed system can be used to inspect in several tile sizes. However, the key problem is the converting of original image to binary image in several colours and patterns of tile which are shown in Figure 6.



(a) Tile size of 20 cm x 20 cm

(b) Tile size of 10 cm x 10 cm

(c) Several colours

(d) Patt

Figure 6: Tile cases

Each image has different threshold value for analyzing edge of gap line. The calculation results of defect value are shown in Table 1 and 2. The defect value from representative images can be set as criteria to evaluate the intensive and acceptable defect levels. These are used as a future quality standard of each construction project or organization.

Table 1: Results of distance inspection between neighbouring tiles (gap)

Lines	*Gaps*	*Defect value*	*Line*	*Gaps*	*Defect value*
(a) Tile size of 20 cm x 20 cm					
Vertical	*Ev1*	*0.480*	*Horizontal*	*Eh1*	*1.268*
	Ev2	*0.412*		*Eh2*	*0.648*
(b) Tile size of 10 cm x 10 cm					
Vertical	*Ev1*	*1.224*	*Horizontal*	*Eh1*	*2.256*
	Ev2	*0.505*		*Eh2*	*1.334*
	Ev3	*0.577*		*Eh3*	*1.275*
	Ev4	*0.483*			-
	Ev5	*0.892*			-
(c) Several colours					
Vertical	*Ev1*	*0.710*	*Horizontal*	*Eh1*	*0.763*
	Ev2	*1.205*		*Eh2*	*1.376*
		-		*Eh3*	*1.464*
(d) Pattern of tile					
Vertical	*Ev1*	*2.648*	*Horizontal*	*Eh1*	*4.344*
	Ev2	*2.619*		*Eh2*	*2.283*
	Ev3	*3.332*		*Eh3*	*2.134*
	Ev4	*2.909*		*Eh4*	*2.302*
	Ev5	*1.770*			-

Table 2: Results of angle inspection of intersecting straight line

Points	*Defect value*	*Points*	*Defect value*
(a) Tile size of 20 cm x 20 cm			
PV1H1	*0.178*	*PV2H1*	*0.115*
PV1H2	*0.075*	*PV2H2*	*0.012*
PV1H3	*0.156*	*PV2H3*	*0.219*
(b) Tile size of 10 cm x 10 cm			
PV1H1	*0.096*	*PV2H1*	*0.048*
PV1H2	*0.131*	*PV2H2*	*0.366*
PV1H3	*0.040*	*PV2H3*	*0.104*
(c) Several colours			
PV1H1	*0.032*	*PV2H1*	*0.037*
PV1H2	*0.120*	*PV2H2*	*0.124*
PV1H3	*0.115*	*PV2H3*	*0.120*
(d) Pattern of tile			
PV1H1	*0.044*	*PV2H1*	*0.182*
PV1H2	*0.003*	*PV2H2*	*0.141*
PV1H3	*0.081*	*PV2H3*	*0.035*

** These are just samples of all points on image.*

7. Verification

A preliminary verification of proposed method is necessary in order to estimate the accuracy of interpretation from developed program before these are used to create own standard in project or organization. The procedure of field verification included image acquisition, implementation of algorithms for binary image production and determination of defect value, and the comparative analysis of coincidence value between the visual rating by human inspector and developed program. Usually, the results of verification should have coincidence value in the range of 80-100%.

8. Conclusions

The current construction inspection process always encounters the confliction of acceptable defect level about the aesthetic issue in architectural work. This research paper aims to present the conceptual framework of the innovative visual quality inspection system that uses digital image processing. The system helps to enhance the reliability and overcome the limitation of human vision in an analysis of defect features and actual quantity calculation for identifying the evaluated criteria of each defect level. These are used to improve the standard of quality evaluation in each organization to ensure a quality standard corresponding with the customer requirement and reduce conflict between involved persons in evaluating defects of work. The case study of tiling inspection is chosen to present the implementation of this concept. Moreover, this paper presents the results of testing in several tile cases that there are different attributes such size, several colour and pattern of tile. However, the future work needs to test in other attributes of tile cases. In addition, we need to study and develop the algorithm in other case studies.

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