Damage Index: Assessment of Mould Growth on Building Materials Using Digital Image Processing Technique

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Abstract

There is a growing concern over the adverse health effects of exposure to high concentration of mould spores in the indoor environments. Copious epidemolo-gical studies have shown a direct relationship between the exposure to indoor mould and several adverse health effects. The phenomenon of Sick building syndrome (SBS) and Building Related Illness (BRI) have also been attrib-uted to moulds exposure in the indoor environment. In spite of this growing concern, little have been reported on the development of an objective mould assessment particularly criteria for visual inspection of mould growth on building materials. The main premise of this study is that visual inspection related with mould damaged material can lead to objective ranking of the severity of damaged material, and reduce the subjective nature of mould dam-aged estimation by the use digital image processing (DIP) techniques.

A four stage technique procedure, invol-ving image preprocessing, Image segmentation and mould analysis and classification stage for the detection of mould growth is examined in this paper. Results obtained when this proposed algorithm was applied to acquired digital images collected from different infested building materials indicates the appropriateness of this method in enhan-cing the visual assessment and grading associated with mould growth on building materials.

Keywords: *Digital Image Processing, Mould, Assessment, Visual Inspection, Sick Building Syndrome (SBS) and Building Related Illness (BRI).*

I. INTRODUCTION

Fungi are ubiquitous; both in indoor and outdoor environments. Moulds fungi are microscopic in size and their spores travel through the air. Their growth and survival on surfaces is determined by the micro-environmental conditions of both the materials and the indoor space; such as the high humidity, temperature and particularly the water content of the material/substrate (water activity) [1]. They thrive on virtually all building materials and surfaces (both organic and inorganic) [6], [9], causing degradation of materials and components of buildings (Fig. 1).

There is a growing concern over the adverse effect of exposure to high concentration of moulds spores in the indoor environment; copious epidemological studies [12] have shown a direct relationship between the exposure to indoor mould and several adverse health effects such as asthma, wheezing, Rhino-sinusitis, Brain waves; the phenomenon of Sick building syndrome (SBS) and Building Related illness (BRI) have been attributed to mould exposure in the indoor environment [13]. The fungal growth on building material is thought to play a crucial role in the sick building syndrome [3], owing to the Mycotoxin produce when growing on building materials [5], [6], [9]. In USA the annual cost of asthma attributable to dampness and mould exposure in home is estimated to be $3.5 billion [12].

II. MOULD ASSESSMENT OVERVIEW

Assessments of fungal status of buildings usually involve questioning occupants of possible symptoms and adverse health effects, history of operation of the buildings, etc, visual inspection for evidence of contamination (by the inspector), collecting and analyzing samples (both air and materials). However, in case of visible mould growth on materials or building components, the air sampling may sometime be disregarded [2]; hence, visual inspection is often resorted to; to appraise the extent of the damage.

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(a) (b)

Fig. 1. Different types of Mould growth on buildings before Pre Processing stage (a) Visible Mould Growth (b) Less Visible Mould Growth

Evaluation of mould damage is complex in building and no criteria for evaluating such damage have been developed; consequently there is no criterion for evaluating the extent and severity of the damage [8].

The extent of the damage on building material is often categorized according to the extent /size (objective measure); as Mould growths ranges from small areas covering a few cm^2 to wide spread fungal infestation in heavily contaminated buildings, however the severity (subjective measure) of the damage often ranked between 1-5; class 1 representing minor damage, and class 5 representing severe damage [8].

Due to the subjective nature inherent in the assessment by visual inspection in evaluating the extent of the severity ; the premises of this study is that visual inspection related with mould damaged material can lead to objective ranking of the severity of damaged material , and reduce the subjective nature of mould damaged estimation, using digital image processing.

In applying digital image processing (DIP) for assessment of mould growth on building materials, a four stage technique is proposed in this paper, these are: Image Pre-Processing stage (IPPS), Image Segmentation Stage (ISS), Mould Infestation Analysis (MIA) and Mould Grading Stage (MGS). The quality of the image is enhanced to certain level in the ISS stage. In the second stage, enhanced image is segregated into two main classes. The third stage involves analyzing the geometric properties of the segmented image in order to get the details of the moulds in the image. The last stage which is called Mould Grading stage (MGS) involve using the information obtained in the MIA stage to categorise the level of severity of the building materials based on the acquired image.

III. MOULD INFESTATION DETECTION TECHNIQUE

In detecting the degree of mould infestation on building materials by the use of DIP techniques, a four-stage infestation technique namely Image Pre-processing stage (IPPS), Image Segmentation stage (ISS), Mould Infestation Analysis (MIA) stage and Mould Grading Stage (MGS) is presented in this section. The full block diagram is as shown in Fig. 2

Mould Infestation images on building materials is acquired by the use of Digital Camera (In this work, we use Panasonic DMC-FX12 Digital Camera, 7.0M Pixel Resolution) is made to undergo pre-processing stage for illumination equalization, Image scaling and noise filtering. The second stage, Image segmentation stage (as discussed in subsection 3.2), the output Image from the Pre-processing is clustered into two distinct classes, namely background information and Mould Features. The MIA stages (as discussed in subsection 3.3) detect mould and its associated properties.

The last stage, MGS is mainly concern with the grading of such an image. The details are as discussed below.

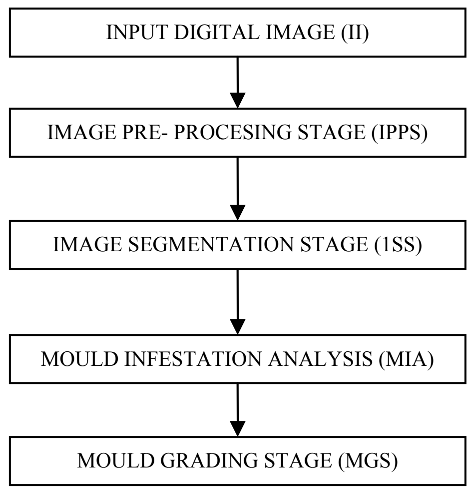


Fig. 2. Block diagram of the proposed method.

A. Image Pre-Processing Stage (IPPS)

This involves a five step processes, these are:

Step 1: The first stage in PPS stage is the color space conversion. The input image can be either a Red-Green- Blue (RGB) image is converted to grey scale image.

$$\begin{aligned} H &= \begin{cases} \theta, & for\ B \leq G \\ 360-\theta, & for\ B > G \end{cases} \\ S &= 1-\left\{ \frac{3}{R+G+B} \right\} min(R,G,B) \qquad (1) \\ I &= \frac{1}{3}(R+G+B). \end{aligned}$$

Where

$$\theta = cos^{-1}\left\{ \frac{[(R-G)+(R+B)]}{[(R-G)^2+(R-B)(G-B)]^{1/2}} \right\}$$

And

$$min\ (R, G, B),$$

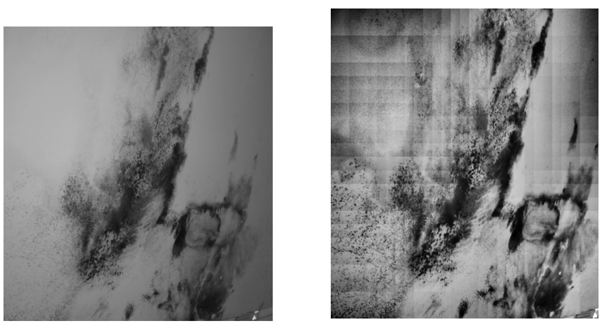
denotes the minimum of red, green and blue components of the input image [10].

Step 2: The Intensity matrix is extracted from the Hue Saturation-Intensity (HSI) obtained from step 1 above. The MATLAB syntax for this is as given in 2.

$$New\ Image = Old\ Image\ (:,:,3) \qquad (2)$$

Step 3: Image from step 2 above is fed to the edge padding section for edge padding effect.
Step 4: Image filtering on the image so as to reduce impulsive noise.
Step 5: Perform Global Local Adaptive (GLAPOW) on the image obtained in step 4 above.

Fig. 3 and Fig. 4 show two basic classification of mould growth based on visibility to human eyes before and after Pre-Processing stage. Further detail of all the steps involved in pre-processing can be found in [11].



(a) (b)

Fig. 3. (a) Visible Mould Growth before Pre Processing stage (b) Visible Mould Growth after Pre Processing stage

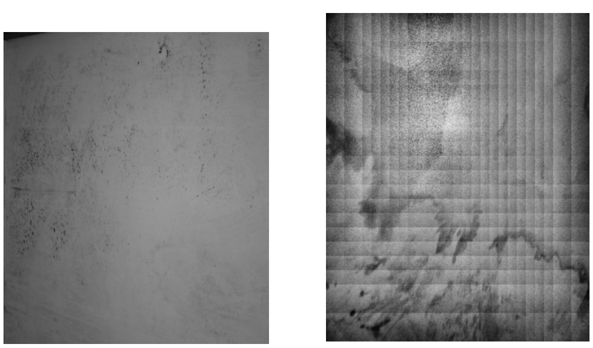
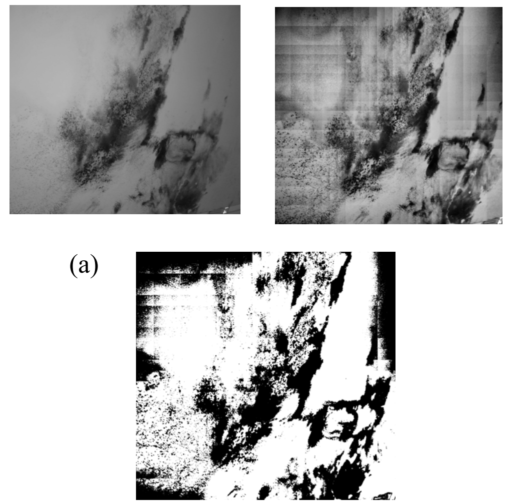


Fig. 4. (a) Less Visible Mould Growth before Pre Processing stage (b) Less Visible Mould Growth after Pre Processing stage

B. Image Segmentation Stage (ISS)

In Image segmentation stage (ISS), the objective is mainly to group image into regions with same properties or characteristics [10]. It plays an important role in image analysis system by facilitating the description of anatomical structures and other regions of interest.

ISS in this work is achieved by the use of k-means. K means method of segmentation with two non-overlapping classes was found to perform better than segmentation by simple thresholding. A typical segmented image is as shown in Fig. 5.



(b)

(a)

(c)

Fig. 5. (a) Visible Mould Growth before Preprocessing stage (b) Visible Mould Growth after Pre Processing stage (c) Segmented Image

C. Mould Growth Analysis (MGA) stage

In Mould Growth analysis stage, a set of geometric related criteria is applied to the segmented image. These are

Ratio of axis: The ratio of the minor to the major axis is determined for an infested area. This is mathematically expressed in (3) and the figure is as shown in Fig. 6

$$Ratio\ Test = \frac{Minor\ Axis\ filled\ by\ Mould}{Major\ Axis\ filled\ by\ Mould} \qquad (3)$$

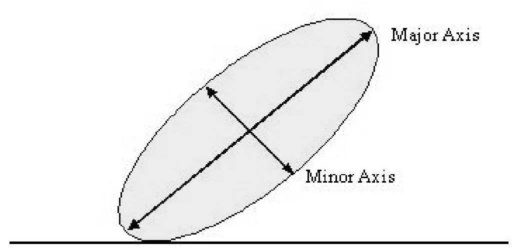


Fig. 6. Ratio Test.

Compactness Test: If a candidate mould region is enclosed in a rectangle, the ratio of the filled area to the total area is also used as a criterion. This is mathematically expressed in (4) and the figure showing this is as shown in Fig. 7.

$$\text{Ratio Test} = \frac{\text{Area filled by mould}}{\text{total area of the image}} \quad (4)$$

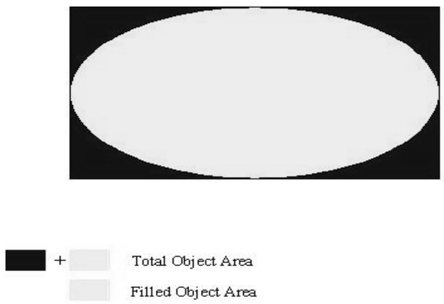


Fig. 7. Compactness Test.

D. Mould Grading Stage (MGS) stage

MGS involve the use of objective analysis of the output of the MGA stage. The two gradings in this research work are Compactness Test and Ratio Test. The grading for these two criteria are as given in Table. I.

Table I: Damage Index using Compact Test Ratio

Index	Description
0.00-0.249	Less severe
0.25-0.499	Moderately severe
0.50-0.749	Severe
0.75-1.000	Extremely severe

After evaluating the two criteria independently, Fig. 8 gives the final interpretation of the individual assessment. The interpretations of this Fig. 8 are:

A: This shows that both the compact test and Ratio test falls between the range of 0.00 – 0.499. Such a building is categorized as Less Severe Image
B: This shows that the compact test ratio falls between 0.50 – 1.00 and Ratio test falls within 0.00 – 0.499. Such a building is categorized as Moderately Severe.
C: This shows that the compact test ratio falls between 0.00 -0.499 and Ratio test falls within 0.50 – 1.00. Such a building is categorized as Severe.
D: This shows that the compact test ratio falls between 0.50 – 1.*0*0 and Ratio test falls within 0.50 -1.00. Such a building is categorized as Extremely Severe.

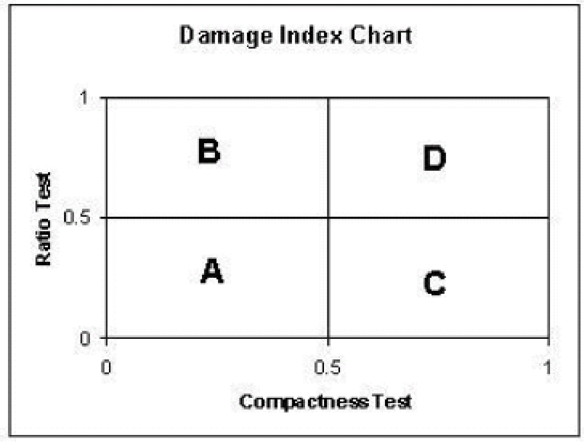


Fig. 8. Damage Index chart.

IV. Result obtained

Following the block diagram discussed in Section 3 and Fig. 2 respectively. In this paper, two of such images will be reported for discussion and analysis sake. From Fig. 9 and Fig. 10 looking at the Histogram of the input and output Images, we can observe that the use of this method greatly enhanced the image before segmenting and analysis. This out-put obtained here provides a means of visual inspect-ting the image before segmenting and analyzing such an image.

The output of MGS for the three images is a tabulated below:

TABLE II
Result of Damage Index for Mould Growth for 3 Images

Image number	Compact test	Ratio test	Interpretation
Image 1	0.3701	0.3506	Less severe
Image 2	0.3442	0.6281	Severe
Image 3	0.3795	0.5402	severe

V. Conclusion

The use of DIP is a novel technique in the objective analysis of Mould Growth on a Building. Aside from the fact that the Image obtained in this image will aid in visual inspection of the Building material, it also gives a precise value for the analysis and grading of this phenomenon, thereby providing a basis for objective evaluation and Rating of mould damaged building materials. A look at input Image 2 would have suggested that the mould growth on such a surface is of no significant but by applying this method it shows the enhanced version of the image thereby showing some of the mould details that are not easily visible to the human eye. In this paper we have suggested an objective Damage Index analysis by the application of Digital Image Processing technique and also provide a means of evaluating mould growth on a building material. There is an ongoing work in this area to introduce the use of intelligent system to this work and also to increase the criteria used for rating.

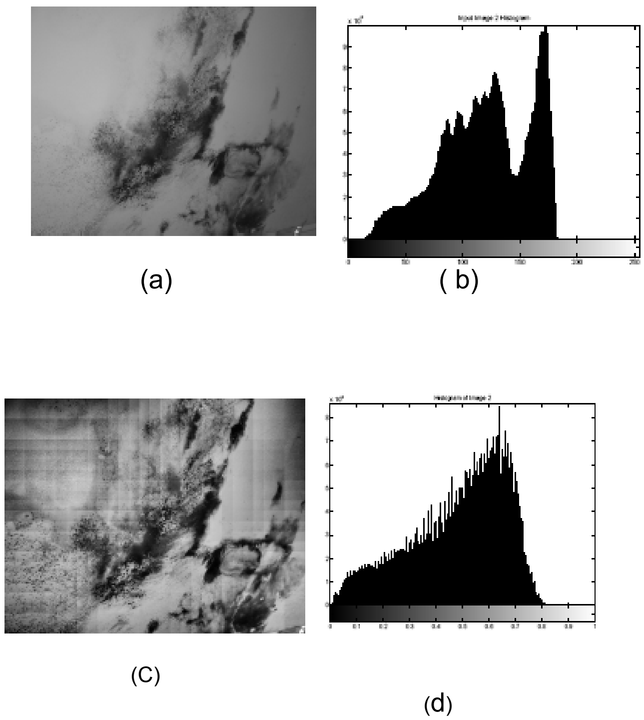


Fig. 9. (a) Visible Mould Growth before Pre Processing stage (b) Histogram Showing Intensity for Visible Mould Growth before Pre Processing stage(c) Visible Mould Growth after Pre Processing stage (d) Histogram Showing Intensity for Visible Mould Growth after Pre Processing stage

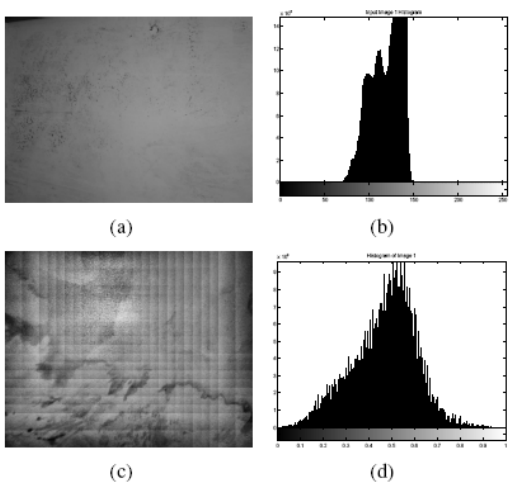


Fig. 10. (a)Less Visible Mould Growth before Pre Processing stage (b) Histogram Showing Intensity for Less Visible Mould Growth before Pre Processing stage(c)Less Visible Mould Growth after Pre Processing stage (d) Histogram Showing Intensity for Less Visible Mould Growth after Pre Processing stage

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