DIGITAL IMAGE PROCESSING OF WEATHERED STONE FOR DETERMINING THE OPTIMUM CLEANING LEVEL OF STONEWORK

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ABSTRACT

In this study, the authors introduced a new image component sampling technique that can be used to evaluate level of cleaning of weathered masonry stone for historic buildings. The proposed technique is based on the Standard Pattern (SP). The images taken from different stages of cleaning are used to setup the SP and empirical model to predict the level of cleaning against the duration of cleaning. With the model and SP, Pollution Density Index (PDI) from the image of a building can be evaluated. An optimum cleaning duration can be calculated for each area base on PDI distribution on the surface of the building. The proposed method has been proved to be effective and easy to implement. It can be applied to different way of cleaning.

INTRODUCTION

Image processing is widely used in all kind of building conservation activities [1-3]. In this study, the authors introduced a new image component sampling methodology that can be used to evaluate level of cleaning of weathered masonry stone for historic buildings. The suggested technique is based on the image component analysis of the stone surface in a controlled testing environment for setting up Standard Pattern (SP). The images taken from different stages of cleaning are used to setup the SP and the image analysis results are employed to propose the empirical model to predict the level of cleaning against the duration of cleaning. With the model and SP, one can also predict the Pollution Density Index (PDI) from the image of a building by comparing each area of the image with the SP and then evaluate the PDI with the proposed model. With this PDI distribution on the surface of the building, an optimum cleaning duration can be calculated for each area. To evaluate the PDI distribution on a complicated building surface, the surface will be discretised into small planar areas for evaluation. In this study, the image processing is carried out on Adobe CS3 software package. The proposed method has been proved to be effective and easy to implement. It can be applied to different way of cleaning.

EQUIPMENT

To test the proposed method, recycle glass granulate was used to weathered sand stone samples as a trial test as the sand stone is one of the most commonly used materials for masonry building in Scotland and recycle glass is one the most environmental friendly materials. The test equipment used in this test includes an air compressor, enclosed cleaning chamber (Figure 1).

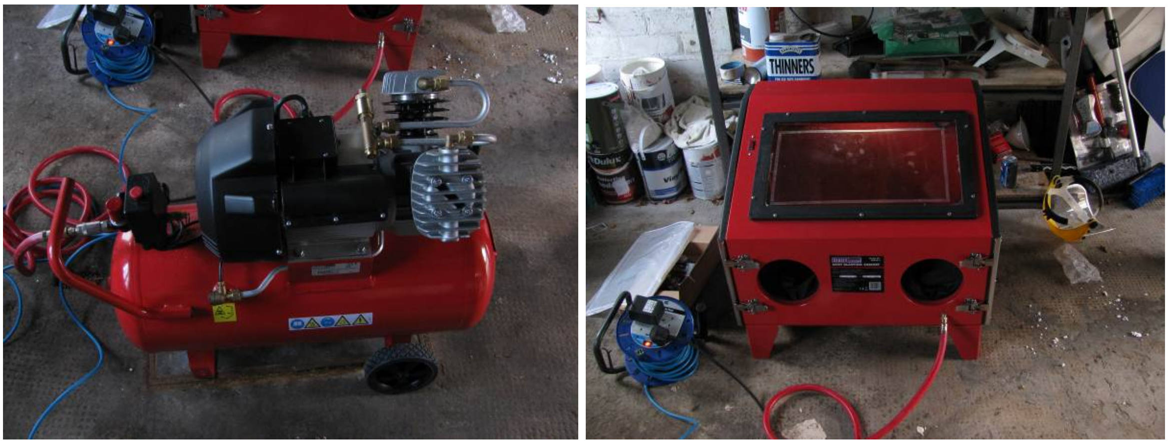

Figure 1: Air compressor and enclosed cleaning chamber

In order to photo the stone surface in a control environment, a wooden frame is design to make sure each photo was taken in same distance and same configuration. To keep the illumination of the sample surface in same condition, two LED flood illuminators are mount on top of the frame (Figure 2). The frame was kept in a dark environment when take the photos of samples at different stages of cleaning. The camera used in this test is Canon PowerShot 100s.

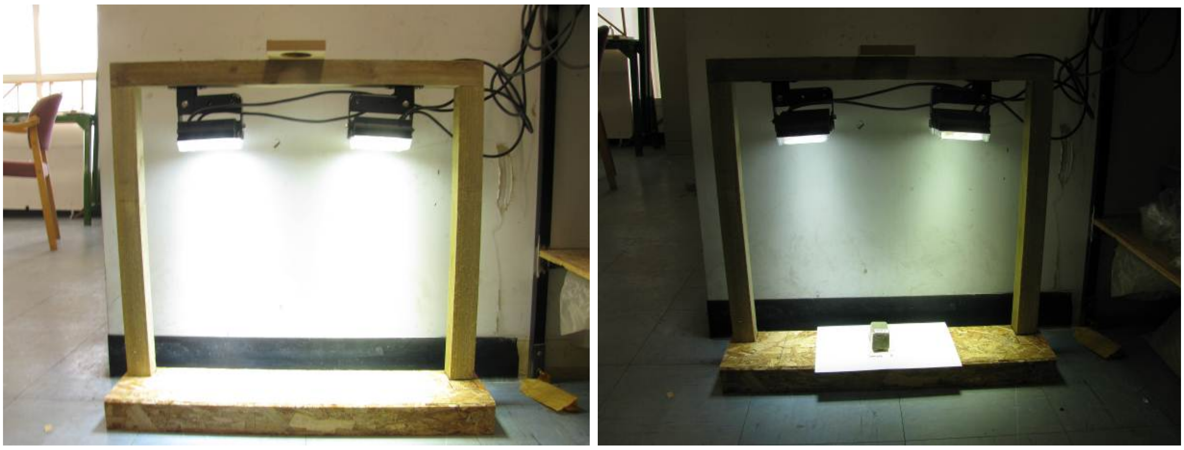

Figure 2: Frame for photo shooting

CALIBRATION

The calibration is the important step to provide the basic index for the new surface and polluted surface. In order to obtain a fresh surface, the sample stone is cut into the stone for 1-2cm to obtain a fresh surface, and the photo of this new surface is then photo and analysed to obtain the index for a new surface. The polluted external surface is also photo and analysed to obtain the index for the untreated surface. Both photos are taken under the frame mentioned above. A comparison of two photos is given in Figure 3. A screen shot of the data analysis with Adobe CS3 is also shown in Figure 4.

(a) Polluted (b) fresh

Figure 3: Polluted and fresh surfaces of sandstone

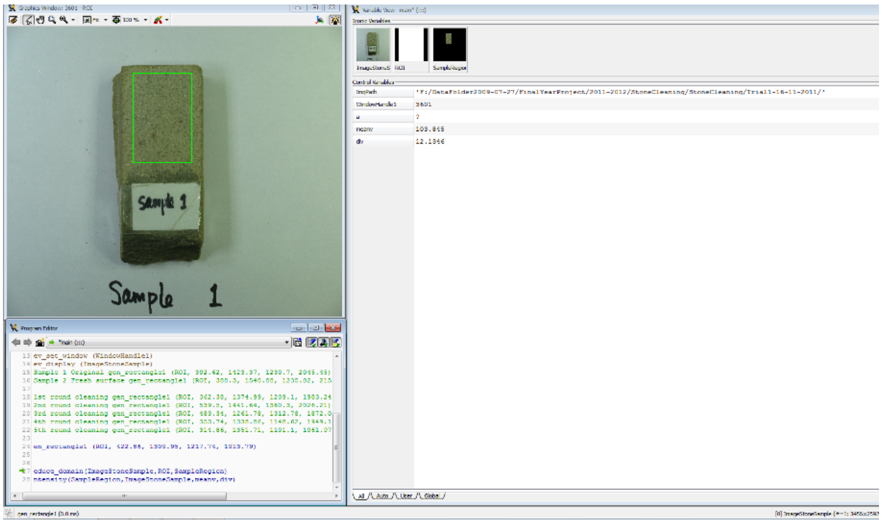

Figure 4: Screen shot of data analysis

TEST PROCEDURE

After calibration, the sample stones are put in the enclosed chamber to clean for a fix time in turn and then will be taken out to take the photos of the surface at different cleaning stage. After analysis the surface images, a level of cleaning can then be plot out against the time/stage of cleaning. The test result of sample 1 is shown in Table 1. The normalised cleanness value of the untreated surface is called the Pollution Density Index (PDI). The curve indicating different level of cleaning at each cleaning steps is shown in Figure 5. All the values tested are taken from 1000 sample points for each image. The cleanness of different stages C_i are calculated from the following formula

$$C_i = GV_f / GV_i$$

Where

GV_f is the grey value of fresh surface;

GV_i is the grey value of surface of corresponding round of cleaning

Table 1: Test result of sample 1

	Mean of Gray Scale	Std Div	Cleanness*
Dirty surface	62.47	10.43	1.68
1 round cleaning	79.99	14.07	1.31
2 round cleaning	87.19	13.38	1.20
3 round cleaning	93.70	12.62	1.12
4 round cleaning	98.25	12.38	1.07
5 round cleaning	103.85	12.13	1.01
Fresh surface	104.96	11.03	1.00

*Cleanness =Gray sale of (cleaned surface/fresh surface)

A typical normalised cleanness value in a 5-round cleaning test is show in Figure 5. A value of 1 indicated a fresh surface. From this curve, it can be seen that first and second round the cleaning is the most effective two steps. The later stages are less effective and will cause more abrasive damage to the surface.

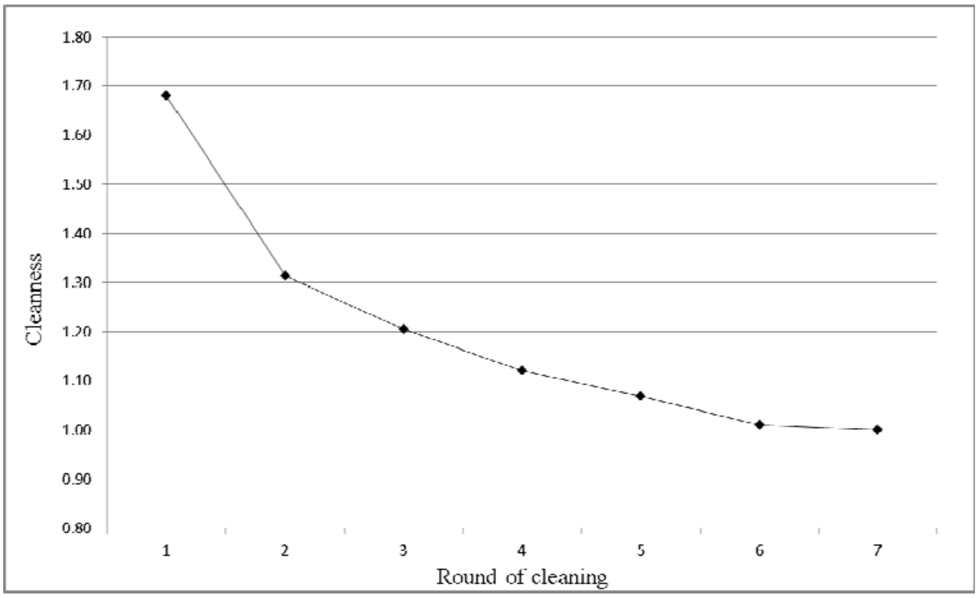

Figure 5: Levels of cleaning for Sample 1 at different cleaning stages

Same test procedure is repeated for 10 samples. Test result is shown in Figure 7. From the 10 sets of datum, a preliminary model to predict the level of cleanness after each round of cleaning is proposed as following:

$$y = \max(1.6236x^{-0.262}, 1.0)$$

where x is the number of round cleaned, y is the cleanness of the surface. Since the normalised cleanness of a fresh surface is 1.0, so in no case the value of the cleanness level of the cleaning surface should drop below 1.0. A set of images for sample 5 at different stages (Standard Pattern, SP) are shown in Figure 6. D indicates the surface before treatment. F indicates flesh surface and R1-5 indicates the treated surface after 1^{st} -5^{th} round of cleaning.

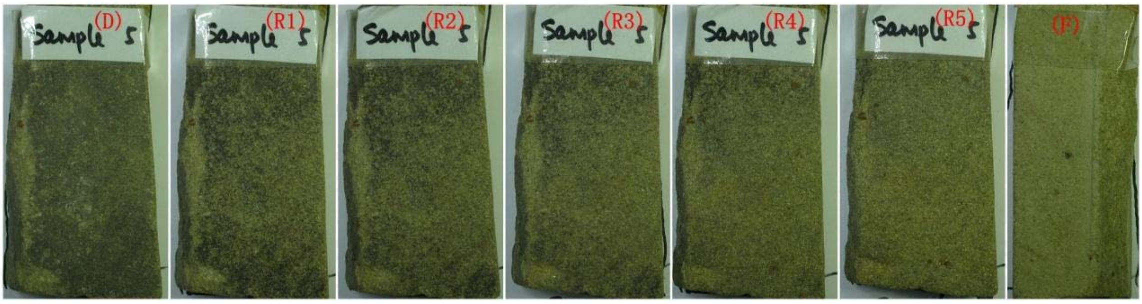

Figure 6: Images of sample 5 at different cleaning stages

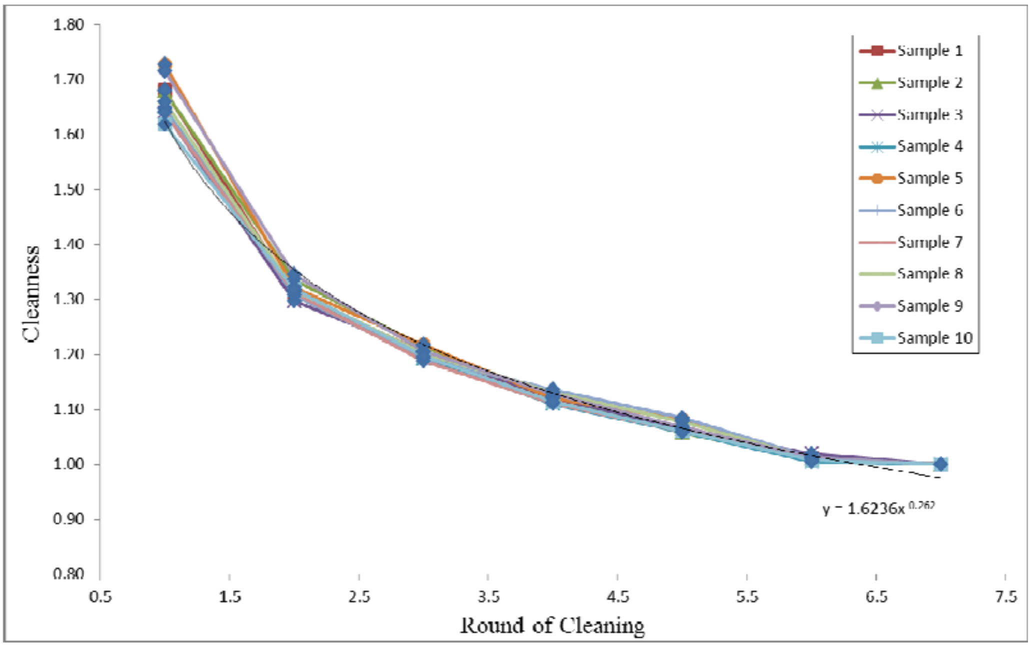

Figure 7: Sample 1-10 test result and empirical model of cleaning

With this empirical equation, the estimation of the cleaning duration and cost of a building surface can be predicted quantitatively. Thus, an optimum cleaning plan for a surface of the building can be followed up accordingly.

CONCLUSION

In this paper, the authors introduced a new image component sampling technique that can be used to evaluate level of cleaning of weathered masonry stone for historic buildings. The proposed technique is based on the Standard Pattern (SP). The images taken from different stages of cleaning are used to setup the SP and an empirical model to predict the level of cleaning is proposed based on the power function. With the proposed model and SP, Pollution Density Index (PDI) can be evaluated from a digital photo of a building. An optimum cleaning duration can be calculated for each area base on PDI distribution on the surface of the building. The proposed method has been proved to be effective and easy to implement. It can be applied to different way of cleaning.

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