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Automated Detection of Robust Morphology Regions to Quantify Corrosion Damage & Identify its Type

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Abstract

This paper examines a novel approach of corrosion damage diagnosis and restoration based on image processing for quantitative and qualitative evaluation of degradation effects on stone surfaces. This methodology can be applied in situ in association with a variety of non-destructive monitoring schemes, and on images acquired from several imaging modalities, capturing from micro- to macro-scale characteristics. Corrosion regions morphology and extent is a key aspect in the quantification of corrosion and its identification. The efficacy of various cleaning interventions as well as the characteristics and the identification of corrosion are approached through parametric and non parametric statistical significance tests. Once corroded areas have been accurately detected, they are subsequently processed in order to extract some robust features indicating structural aspects of decay. The extracted features are selected to form a multivariate feature space which in turn is clustered through unsupervised clustering techniques to obtain the different types of corrosion

Introduction

The degradation phenomena encountered on stonework form an aspect of high importance nowadays. Several investigations were carried out with the aim of studying the factors, extent and phenomenology of stone decay [1]. In a polluted environment, the most frequently observed decay phenomena on stone surfaces are the formation of black crusts. Thus the necessity of developing robust techniques of estimating the characteristics of corrosion is a prerequisite for determining accurate reconstruction strategies.

The main objective of this work [1] [2] is the development of computer-vision schemes for non-destructive estimation of the extent and the type of corrosion though an analytic study of the substrate structural integrity. The methodology is tested across a large collection of images depicting corrosion damage of various phenomenologies which have been illustrated in terms of different monitoring modalities capturing from micro- to macro-scale characteristics. Further to evaluating the method accuracy in extracting corrosion topology and extent we also aim at quantizing the severity of degradation and the efficacy of cleaning interventions in terms of accurate statistical metrics based on multivariate tests of statistical significance.

Materials & Methods

In order to address the effective shape detection of decay spots, we tested a category of local morphological operators in combination with sensitive blob detectors to approach the exact topology of decay regions on the surface matrix. A Morphological fusion algorithm [2] was finally proposed to expand the areas detected by the local region growing approach up to the size derived by the morphological operators thus guaranteeing better segmentation results. A further contribution of this work is finally that it attains to establish associations between the type of corrosion and the shape of the decayed regions obtained through our automated multivariate statistical testing framework [3]. Affine invariant shape features where extracted via considering the boundary cross-sections and evaluating the statistical norms on the cross-sections length distribution Furthermore, we have also developed an automated framework for clustering the degradation type according to shape, colour and size features. For the formation of corrosion feature clusters we have employed the unsupervised clustering (un-supervised refers to the algorithm's ability to define the number of clusters without any prior knowledge regarding their shape, spatial distributions in the feature space etc) algorithm DBSCAN [3] based on forming clusters of arbitrary shape according to their proximity in the N-dimension feature space.

Results

Our automated framework is tested through wide image datasets depicting representative decay effects. The directionality of corroded areas is studied through evaluating the standard deviation on the distribution of corroded areas orientations. Larger values of standard deviation reflect corroded areas encountered at arbitrary orientations with respect to the surface axes. On the other hand, low values of standard deviation represent corroded regions directed at specific orientations. Compactness, eccentricity and higher order boundary moments were also studied in association with the severity of degradation and the type of corrosion. Summarizing the results derived by series of experiments, it was assessed that the decay patterns detected on more severely corroded surfaces tend to be more compact than decay regions remaining after the cleaning interventions or decay regions encountered on rain-washed surfaces. Thus, decay areas detected on untreated surfaces tend to form patterns of circle-like shape while the shape of decay regions detected on treated surfaces deviate significantly from circle. The tendency of decayed particles to attain a spherical shape can be adequately explained-on account of the second thermodynamic law.

Conclusions

The contribution of this research work stems from its ability to be applied in-situ without involving any intervention destructive to the material. Moreover, the detection strategy considers structural aspects of the stone surface in order to adapt the algorithmic parameters to the dynamically varying stone structure. Thus, the detection techniques are sufficiently sensitive to the local variations caused to the systematic variations caused by decay areas presence while suppressing random variations caused by the background stone structure. This in turn means that the basic characteristic of the detection strategies is that they decouple the detection of useful information from the background activity by performing local analysis of feature distributions. The extracted decay features form a multi-dimensional feature space which is subsequently clustered via the aid of an unsupervised clustering algorithm [3].

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