

A tentative toolbox for classification of frost damages on brick walls.

Detection of the degree of frost damage of brick walls by use of advanced image texture analysis (Angle Measure Technique (AMT)) and multivariate modeling

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Image analysis and processing

Introduction

Image processing and analysis has been more available to the research community with the introduction of digital cameras. Images of samples, constructions and so on are stored and processed both in documentation and research. Images used in documentation may easily be catalogued in database systems or in an easy available web application. Popular free web galleries like Menalto Gallery [14] and Coppermine [15] enables the combination of image documentary and database search for easy retrieval of images with common properties. These tools along with image analysis should be of great value and importance in building and construction research of historical immovables.

Image analysis is a powerful tool to model the connection between images of samples and features that the images describe. Features in our context include for example frost damage of bricks. Features are extracted from images using different techniques. Image analysis combined with imagery used in documentations gives the researcher at very strong toolkit to both arrange and structure huge amount of image data and do investigation of collections or single objects.

We will here describe a project written toolkit in Java as a possible application to be used to characterise frost damage of brick walls. Images has been recorded with a SLR digital camera and stored in a gallery database. The procedure described here is solely a guide to how to use the technique in a more serious and elaborate research.

Image analysis

Texture may be described as a visual pattern that is spatially repeated either deterministically or stochastically. The pattern may be completely deterministic like a chessboard, and completely random like a well-mixed salt and pepper. One may, however, exhibit intermediate degrees of randomness in the texture like tree bark, clouds, or sandstone. Texture in our context is described on a continuum from isotropic (having no particular orientation) to strongly anisotropic. Granite, for example, is isotropic, while a texture comprised of horizontal layers of sandstone or brick walls is anisotropic. Deterministic textures are anisotropic. A texture may exhibit different properties at different scales

AMT (Angle Measure Technique) will be used as a preprocessing algorithm to model the degree of frost damage from complex textured images of brick walls. AMT transforms an image from 2-D domain into a 1-D texture complexity domain, suitable for further multivariate data analysis [2, 12, 13]. AMT as a texture characterizing facility produces feature vectors (AMT-spectra) that may contain information of the hidden features in images.



AMT may be used in conjunction with other feature detecting techniques like features derived from Haralick gray level co occurrence matrix (GLCM) and images represented as the GLCM matrix [1]. The frost damage of bricks will be estimated from images of real brick walls by use of multivariate analysis. For a more elaborate description to image analysis techniques AMT, GLCM and multivariate modeling we refer to [1-7].

ImageJ Plugins.

The software toolkit is a plugin system for ImageJ [11]. It is a powerful toolkit to be used generally in image analysis. [8]. Angle Measure Technique (AMT) and Gray Level Concurrence Matrix (GLCM) plugins are well suited as tools to monitor the frost damage of brick walls. This toolkit system is a prototype system to be used in research and may be modified to the users needs. We will describe the use in an algorithmic way to show the flow of the analysis. It is important to point out that the image analysis described here is an explorative tool and requires a good knowledge to the techniques. The wall is divided into a number of regions (AOI) and a measure of frost damage is estimated as the percentage of frost damaged bricks. This technique requires methods for extraction of bricks as separate images (BLOBS). This technique is not described here. Recent work in this topic is described here [16] In our context these BLOBS are extracted by a partly manual technique. The technique should be applied in a more elaborate way in an automatic macro system not shown here. Multivariate analysis is performed in Matlab PLS toolbox [10]. In this context we only use the AMT plugin but the GLCM plugin gives remarkable fingerprints of frost damaged regions and may be a good monitor tool. The multivariate models are produced with Matlab and PLS toolbox [9, 10].

Algorithm

The algorithm proposed enables image analysis to automate the detection of frost damages in a typical brick wall.

- I. Retrieve image A of a brick wall sample from the gallery database of walls
- II. Divide the image A in a number of sub images as Area Of Interests (AOI) and segment each brick as a separate object.
- III. Do a manual assessment of the degree of damage of each brick (AOI). (1 is not damaged, 2 is damaged) only on the first A
- IV. Collect the AOIs into an image stack suitable for ImageJ with suitable labels for later identification.
- V. EITHER: Apply the AMT plugin resulting in feature vectors (AMT spectra). Parameters of the AMT plugin should be optimized.
- VI. OR: Apply the GLCM plugin resulting in feature images. Parameters should be optimized.
- VII. Do the multivariate analysis of AMT spectra and produce a multivariate calibration model based on crossvalidation [2,12]. Estimate the number of frost damaged brick AOIs. Save the model as a calibration model and use this as a prediction/classification model next time (on new A)
- VIII. Select a new image A from the wall and go to I. If finished proceed.
- IX. Frost damage index on images of the wall A gives the final result for the whole brick wall.

Example

Each brick in the wall A is segmented to single images. The images are mounted in a stack as input to the ImageJ plugins. Several techniques could be used for the segmentation process.

In this example we have used a manual technique to do the segmentation. Figure 1 shows the montage of the single bricks segmented from the wall. AMT is applied to the images and the % frost damage is estimated for one part of the wall (A). The bricks labeled b02 and b38 are shown as damaged and clean respectively.

AMT is applied to the images using circular unfolding [6,7]. Each AOI is unfolded to a vector of pixels and the applied to the AMT algorithm. AMT will characterize the scales in the unfolded image and the resulting AMT spectrum contains the characterizing scales of the image. The idea behind the use of AMT here is that the frost regions of the bricks will range in a typical scale of the unfolded pixel vector. The first 5000 pixels in the unfolded image are used to exclude the inner parts of the brick due to the fact that the frost damage only is visible on the outer parts of the bricks surface. AMT spectra in figure 2 show a clear discrimination between frost damages and clean bricks. In addition we observe the rough textured bricks as a separate group of spectra with much higher angle values.

A very informative plot based on the PLS model of AMT spectra is the latent vector score plot with single segmented bricks applied in the score positions. The frost damages are located near to each other. The results are shown in figure 3. We also observed the rough textured bricks as a separate class. The predictions of classes are shown in figure 4. Samples containing frost damages are green (*) and clean red (▽). The classes are technically coded as 0 and 1 and thus the predictions above or below 0.5 will be assigned to respective classes as rounded integers. As an alternative the use of Linear Discriminant Analysis (LDA) [12,13] applied on the latent factors scores will result in a better estimate of the % damage (94.1%). With the PLS and LDA applied to the AMT spectra we have a good estimate of the frost damage of the wall section A (29.4 %). By repeating the algorithm on a new wall section, it will be possible to characterize the whole brick wall status with respect to frost damage.

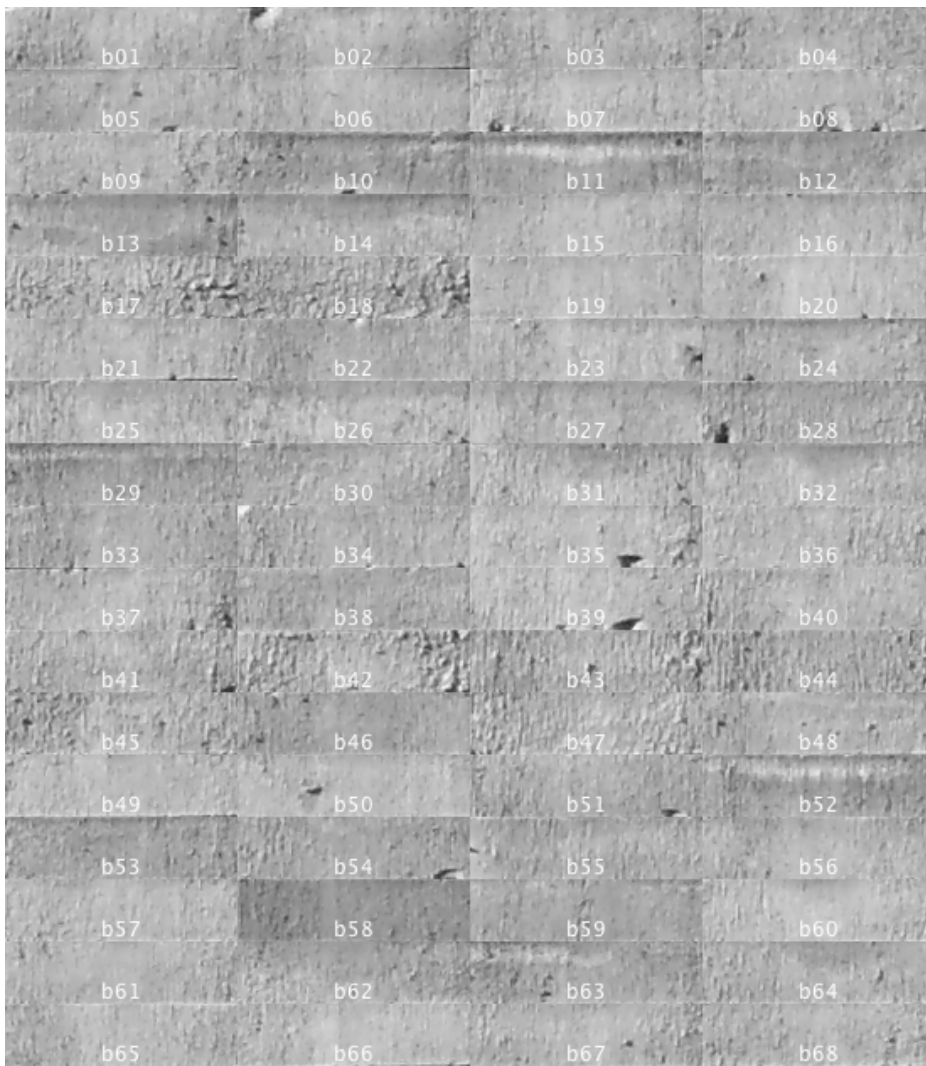


Figure 1. The segmented bricks are mounted as one image and labeled.

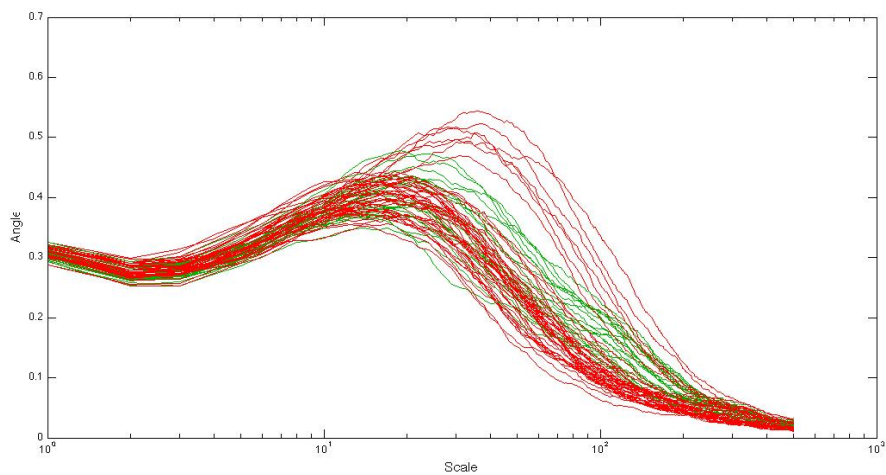


Figure 2: AMT spectra estimated from the segmented bricks. Frost damaged bricks (green) and clean bricks (red). Use of multivariate analysis is used to do a classification and frost damage estimate. In addition we observe the rough textured bricks as a separate group of spectra with much higher angle values.

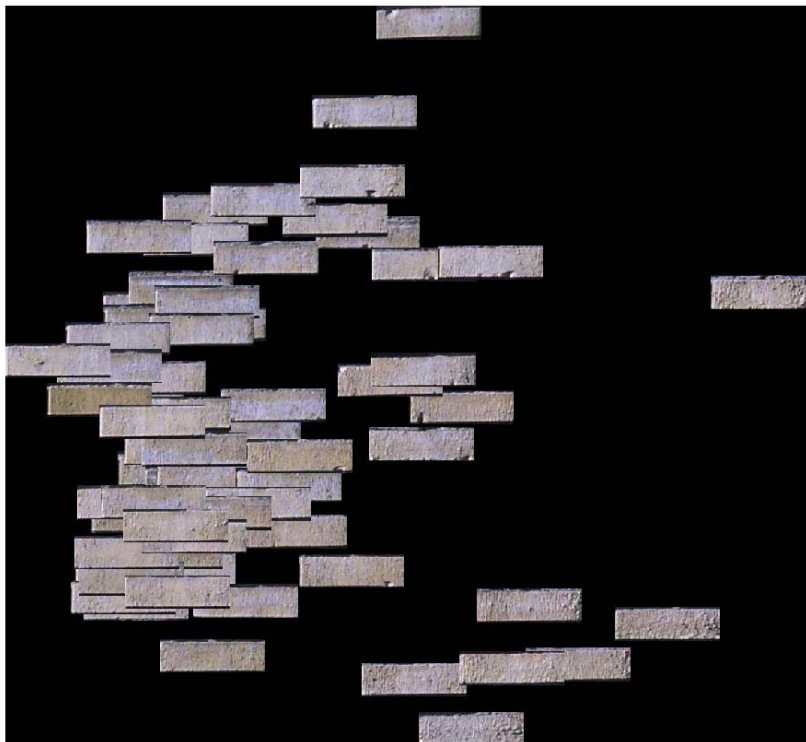
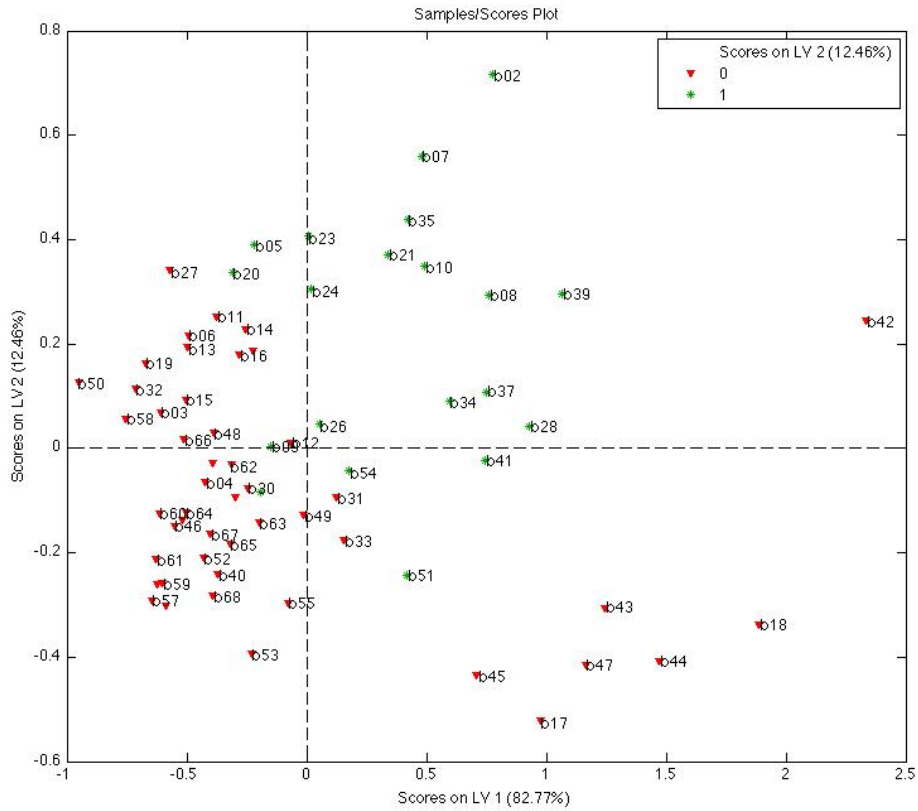


Figure 3 a, b. (a) Scores of LV 1 against LV 2. (b) The segmented bricks plotted in the LV 1 / LV2 coordinate system. The frost damages are located near to each other. Samples containing frost damages are green (*) and clean red (▽).

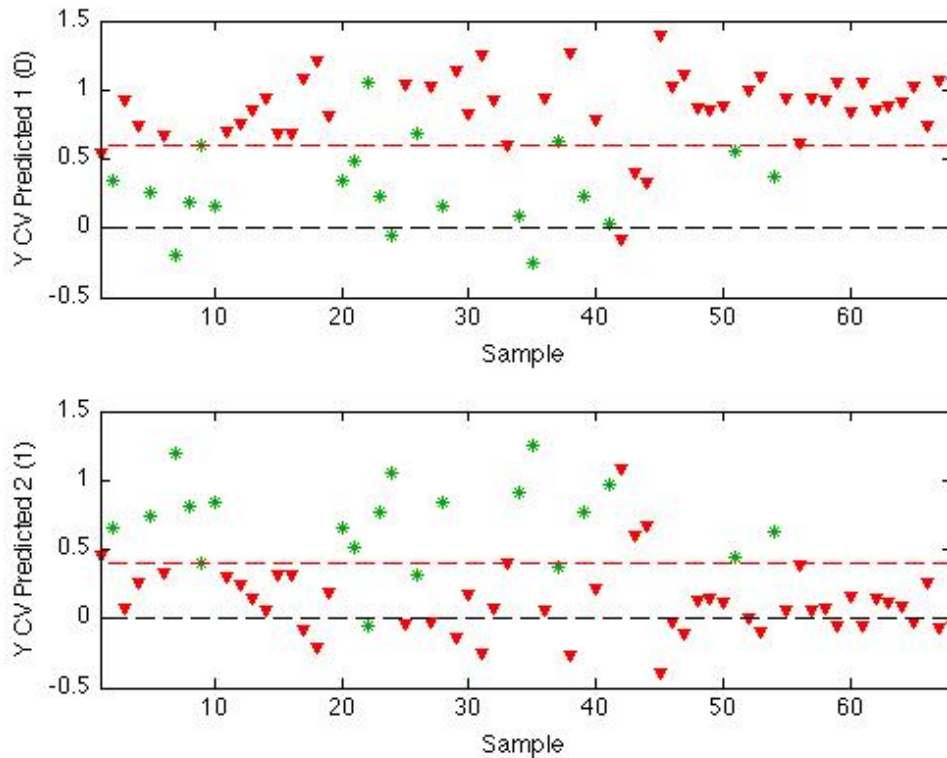


Figure 4. Predictions of the classes as a function of samples containing frost damages are labeled green (*) and clean are labeled red (▽).

Discussion

The proposed technique is based on a partly manual method. The manual assessments performed in step III will be used during a later prediction of frost damages. It should be verified in a later study that this technique is of real value to the research. The percent frost damage is possible to associate with a database of the brick wall and monitor the progress during coming years. The calibration model produced in step VII is produced in our example on a small number of images. A more robust model need more calibration samples. It is also of importance to implement more features to be decided, for example the texture surface of the bricks. In the score plot of figure 3 a, we observe the bricks with rough surface in the lower right area and along LV1 with the rough bricks to the right. There are no samples of this type with damages.

Figure 3 b shows the bricks that are damaged are located in the first quadrant. The bricks with a homogenous surface are located to the left, while bricks with a rough surface are located to the right. Plots like this are of great value as a tool to monitor single bricks and see how they compare to each other.

Conclusions

The proposed technique and the example is a powerful technique to monitor and characterize frost damages brick walls. The method should be automated in a more elaborate study and research.

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