

The Printed Patterns Investigation for the Purposes of Deformation Analysis Performed by Digital Image Correlation System

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Abstract In this contribution an analysis of printed random patterns used for the evaluation of displacement fields and strain fields by the use of low-speed digital image correlation system is described. For the analysis three patterns with speckles of different shapes and sizes and variously distributed grey values as well were choices. As a quality assessment criteria of the reached results a percentage of non-correlated regions, mean or maximal value of the approximated error radius of the investigated object contour points coordinates were chosen. All these parameters were examined by the evaluation performed by the using of different calibration files and subsequently by the different values of facet size.

Keywords: digital image correlation, random pattern, displacement fields, strain fields

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1. Introduction

Digital image correlation is a modern optical method served for the displacement analysis and deformation analysis as well. Its basic principle is based on a comparison of digital images captured during the investigated objects loading [1,2].

The comparison is performed on small picture elements called facets. To ensure the comparison of the corresponding image points it is necessary to accomplish an appropriate contrast of these points. It is possible to reach the needed points contrast by the creation of a random black and white pattern on the object surface. The most common techniques of the random pattern creation are [3]:

- manual spraying of the speckles with maximal size of some mm by the use of black spray colors,
- manual spraying of the speckles with the size from 250 μm to several mm by the use of a paintbrush wetted to a black color,
- manual painting of the speckles with the size from 0.25 mm to several mm by an unerasable marker,
- light dusting of the speckles with the size of ca. 50 μm and more by the use of a spraygun,
- printing of the speckles on a vinyl foil with the size from 0.25 mm to several mm,
- light dusting of unfiltered Xerox toner powder on a damp white surface for the speckles with the size from ca. 30 μm to 50 μm ,

- light dusting of filtered Xerox toner powder on a damp white surface for the speckles with the size of ca. 15 μm ,
- chemical etching of the metal materials with the obtained speckles size from 1 μm to 200 μm .

The use of the first three techniques [4,5,6] is relatively arduous and the created pattern does not need to achieve the homogeneity, what can cause some trouble by the image correlation. Although the chemical etching of the metal materials and the dusting of Xerox toner powder should ensure the creation of fine pattern with sufficient homogeneity, it does not need to be available for everyone. For that reason we decided to analyze some pattern printed on a vinyl foil [7], which can be applicable nearly on each samples surface. For the purposes of small or macroscopic objects investigation the possibility of a speckle size alternation, able by the use of printed patterns, becomes a big advantage. The experiment was done by a low-speed digital image correlation system Q-400 Dantec Dynamics.

2. The Analysis and the Quality Assessment of the Chosen Printed Random Patterns

The algorithm of Dantec Dynamics correlation systems, working on pseudo-affine coordinates transformation from the first image to the second one, checks the intensity of the image points and transforms the identical facets positions into 3D coordinates. The quality of corresponding facets mating is dependent on the facet size.

In general the correlation error is growing with the decreasing of the facet size. The minimal facet size is limited by the size (each facet has to contain black and white color) and contrast of the speckles. Potential pattern imperfections can affect the correlation process insofar, that some object parts do not be correlated or they be correlated with errors. By the measurements with high requirements for the results accuracy it is necessary to pay attention to the random pattern creation.

2.1. Random Patterns and Their Analysis

By the experimental assessment of the contrasty pattern quality three different stochastic patterns printed on the vinyl foil were compared. These patterns were simply created by the use of CorelDraw functions. The speckle size was chosen for purpose of surface investigation with the size of ca. 10x10 cm. Due to the analysis performed by the same light conditions the patterns were bonded on one flat specimen (Figure 1).



Figure 1. Configuration of the 3-D correlation system with investigated patterns bonded on a flat specimen

As the appraising indicators subsequent quantities were considered:

- mean value of approximated error radius of the specimen contour points coordinates,
- maximal value of approximated error radius of the specimen contour points coordinates,
- percentage of non-correlated regions.

Typical facet sizes used for evaluation are in the range from 15x15 to 30x30 px. We examined the indicators mentioned above depending on the alterant facet size. Minimal facet size 9x9 px was limited by the speckle size and as the maximal facet was set the value 53x53 px. Each pattern was evaluated independently, however by the same correlation parameters settings (see Table 1) corresponding to the evaluation with high accuracy.

Table 1. Correlation parameters setting

Correlation parameters:	
Facet size:	9-53
Grey value interpolation:	Bicubic spline (normal)
Outlier tolerance:	Low
Correlation accuracy:	0.1 pixel
Correlation residuum:	20 grey values
3D reconstruction residuum:	0.2 pixel

In the first step the influence of different calibration targets used for the cameras calibration on the approximation of error radius of the specimen contour

points coordinates was appreciated. For the cameras calibration aluminous calibration targets with the field size of 8mm, 11mm and 15 mm as well were used.

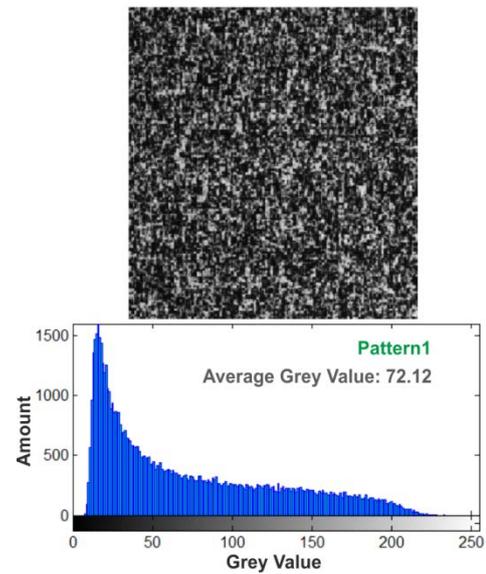


Figure 2. Pattern1 captured by the reference camera and its histogram

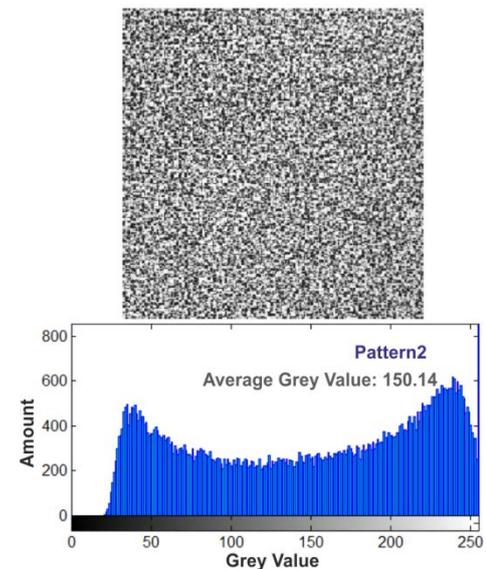


Figure 3. Pattern2 captured by the reference camera and its histogram

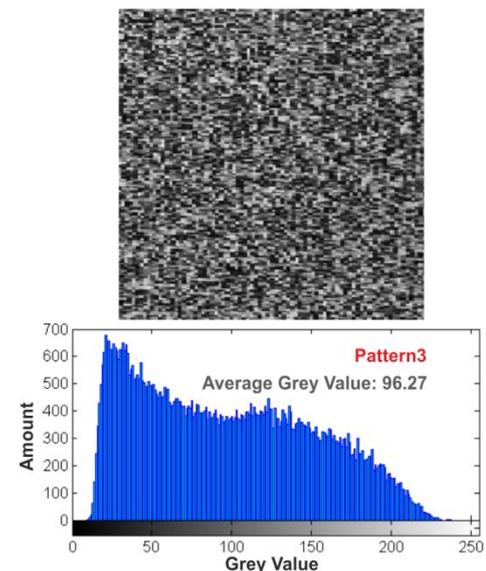


Figure 4. Pattern3 captured by the reference camera and its histogram

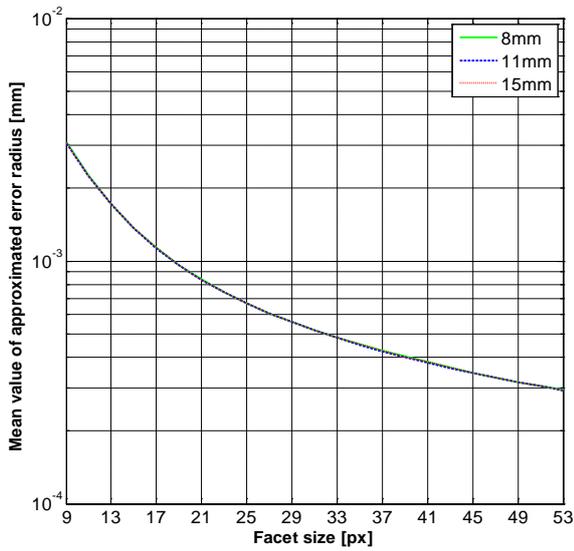


Figure 5. Dependence of the mean value of the approximated error radius of the pattern 1 on the facet size by the use of three different calibration files

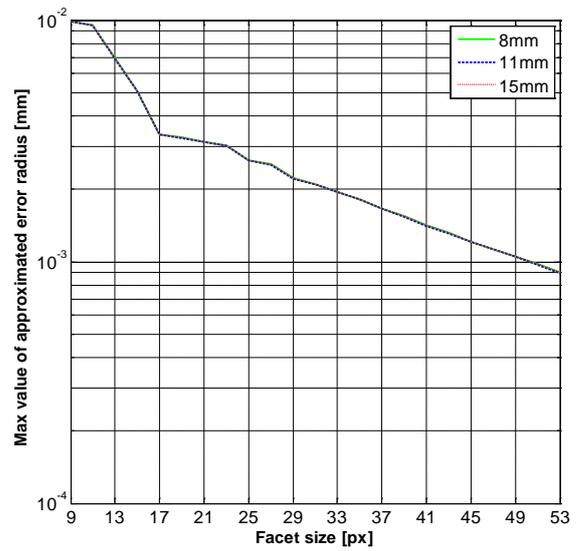


Figure 8. Dependence of the maximal value of the approximated error radius of the pattern 2 on the facet size by the use of three different calibration files

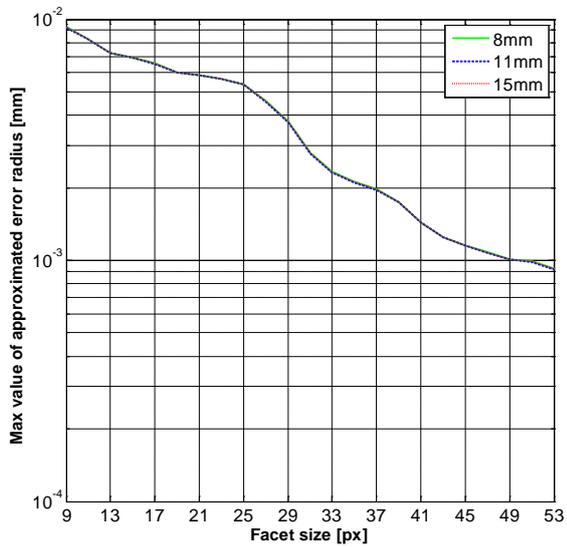


Figure 6. Dependence of the maximal value of the approximated error radius of the pattern 1 on the facet size by the use of three different calibration files

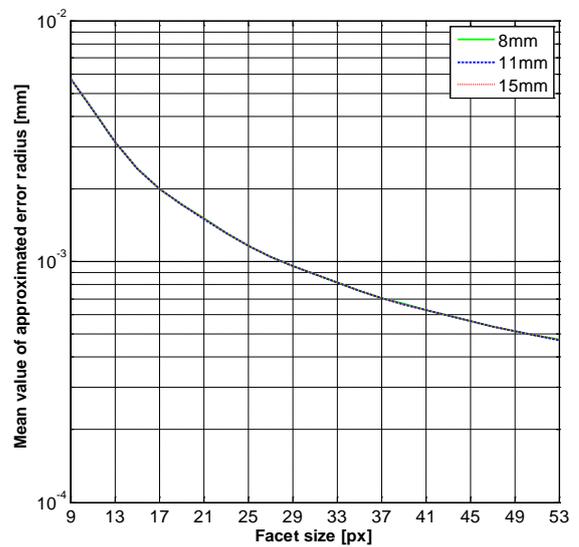


Figure 9. Dependence of the mean value of the approximated error radius of the pattern 3 on the facet size by the use of three different calibration files

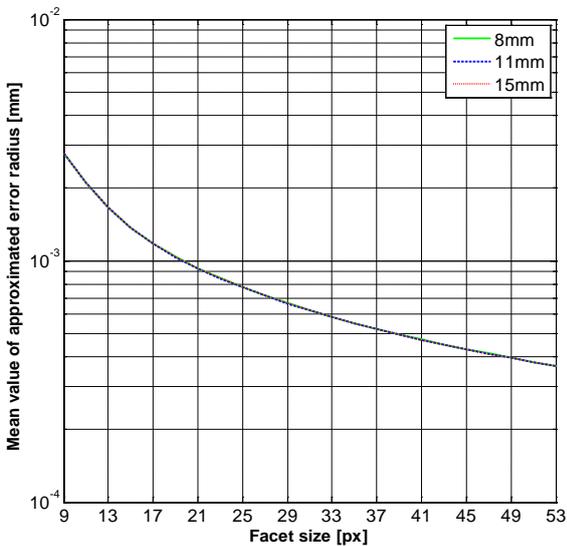


Figure 7. Dependence of the mean value of the approximated error radius of the pattern 2 on the facet size by the use of three different calibration files

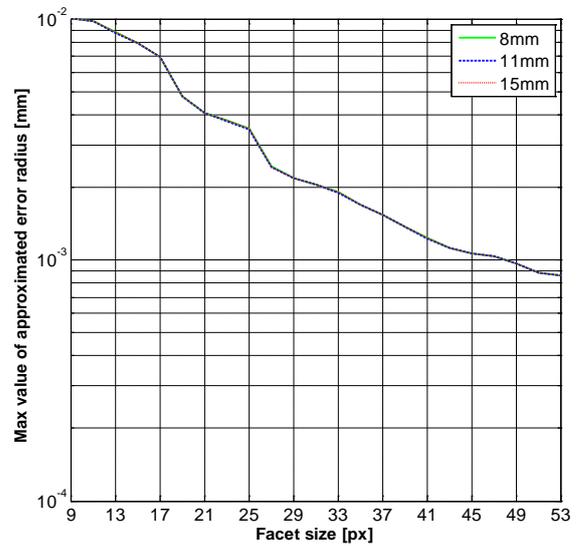


Figure 10. Dependence of the maximal value of the approximated error radius of the pattern 3 on the facet size by the use of three different calibration files

As can be seen from the [Figure 5-Figure 10](#) the use of calibration targets of different sizes does not have substantial influence on the value of the approximated error radius of the specimen contour points coordinates.

For that reason the next analysis of the facet size influence on the percentage of non-correlated regions and the approximated error radius of the specimen contour points coordinates as well was performed only for the cameras calibration carried out by the calibration target with the field size of 11 mm.

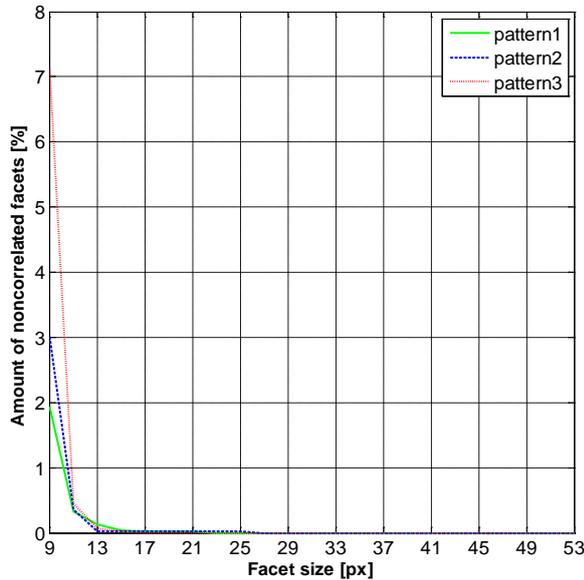


Figure 11. Dependence of the amount of the non-correlated regions of each pattern on the facet size

From the comparison of the dependences of the non-correlated regions amount on the facet size it is obvious, that with the increasing facet size the amount of non-correlated regions is decreasing. For each pattern from the facet size of 25x25 px the amount of non-correlated regions is zero. The highest percentage of non-correlated regions became evident by the facet size lower than 13x13 px. From the compared patterns the worst results allocated the pattern 3, which speckles have the lowest contrast and sharpness.

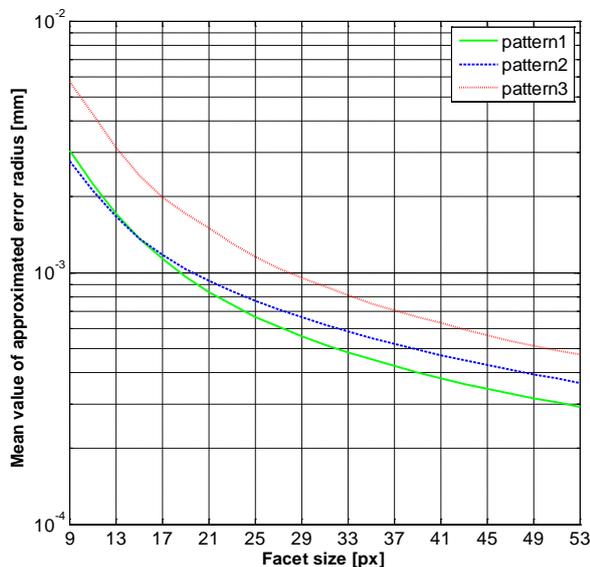


Figure 12. Dependence of the mean value of the approximated error radius of each pattern on the facet size

Pattern 3 allocates the highest mean value of the approximated error radius of the specimen contour points coordinates. Pattern 2 accounts the smallest mean value of this parameter until the facet size of 15x15 px, from this size Pattern 1 seems to be the most suitable. This phenomenon is due to the fact, that although Pattern 2 contains more contrasty and finer speckles than Pattern 1, by the higher facet sizes the considerable portion of white regions in Pattern 2 negatively affects the correlation of the images.

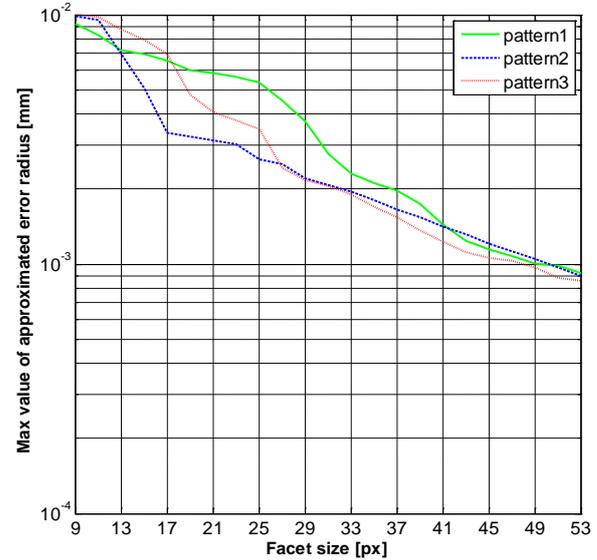


Figure 13. Dependence of the maximal value of the approximated error radius of each pattern on the facet size

By the comparison of the maximal values of the approximated error radius of the specimen contour points coordinates Pattern 1 allocates the best indicators for the facet size from 9x9 px to 13x13 px. It seems, that from the facet size of 17x17 px Pattern 1 achieves the worst results, however it is obvious from the [Figure 12](#), that the number of regions with maximal error in Pattern 2 is less than in Pattern 1 and Pattern 3.

3. Conclusion

We regard the use of printed stochastic patterns by the deformation analysis of flat specimens performed by digital image correlation method as more suitable technique than manual spraying of the speckles. We assume the homogeneity of the created pattern, the simplicity of its creation and the possibilities of its finesse adjustment as its biggest advantages. From the results of the analysis it is possible to formulate subsequent recommendations:

- the calibration performed by the calibration targets of different sizes does not noticeably influence the approximated error radius of the specimen contour points coordinates,
- each of the correlated facets has to contain a characteristic part of black and white pattern,
- a lot of empty white regions in the pattern are not suitable for the investigation with bigger facet sizes
- contrast between black speckles and white background has to be sufficient to ensure the sharpness of the investigated images.

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