Comparison of different markers for the precise positioning of two images of fibrous samples for use in the analysis of the embossing process

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Abstract

Five different positioning markers alongside a sample without a marker were examined in order to align images of speckle-printed fibrous samples as accurately as possible before and after the embossing process. Samples with additionally applied marker elements showed the best results using the "StackReg" algorithm in ImageJ.

1. Introduction

Embossings are important design elements on packaging and are also used for the functionalization of packaging and other products. Here, the embossed structures need to be highly precise. In order to better understand the embossing process, material displacement analyses are to be carried out. For this purpose, the cardboard samples are printed with a speckle pattern, provided with markers. However, the markers are part of the speckle print image, which makes positioning more difficult. The samples were imaged, then embossed and imaged again. Afterwards the two images of the samples are compared. The challenge is to position the two images of the respective sample as precisely as possible to each other in order to be able to quantify possible material displacements. If no positioning would take place, shifts would be detected that do not exist in reality. It is therefore necessary to check if markers are needed and if they are, which marker is best suited for sample positioning. The aim of this paper is to compare different positioning markers for aligning the sample images.

2. Theoretical Background

The embossing of cardboard is used for example as decoration for logos, ornaments, but also on book cover material, brochure covers or high-quality folding boxes. Embossing induces three-dimensional forming of material between the male and the female die. Forming is achieved purely by mechanical pressure. [1]

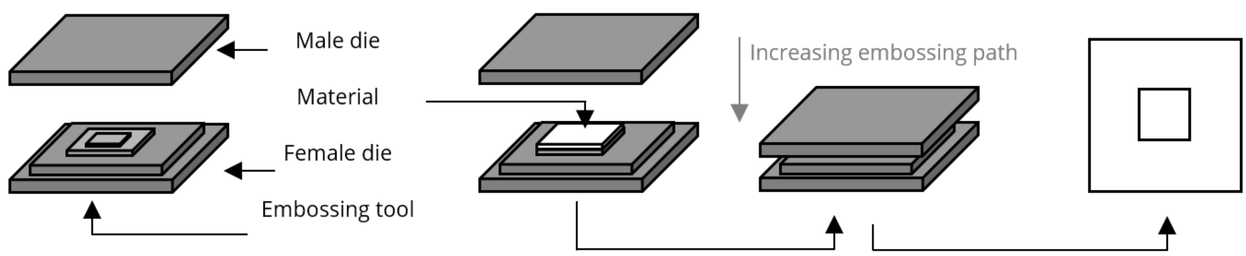


Figure 1: Schematic illustration of the embossing process, in which material is formed solely mechanically between the male and female die of the embossing tool

The material is inserted between the two halves of the embossing tool, the male and the female die (see Figure 1). The tool closes and the material is formed more and more as the embossing path increases. The process ends with complete compression of the material. In the process, the material is presumably stretched, sheared and compressed in the same way as in the creasing process [2].

The embossed samples can be captured using imaging technology. Markers can be used to align the images of the samples with each other. Košťák and Slabý (2021) published research in the field of neural networks and published their results on the design of markers for localization when using neural networks. They state that markers should have different radii, corners and curves. The distance between the markers when positioning several markers on the sample should be as large as possible to reduce matching errors. [3]

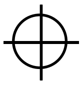
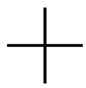
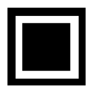
Feldmann et al. (2022) used the Invariant Feature Transform feature detection (SIFT) to recognize and match image elements of embossed markers. Image elements are compared by the algorithm and the closest matches are issued in a list. [4] Thévenaz et al. (1998) developed the ImageJ plugin "StackReg" within the Biomedical Imaging Group at the Swiss Federal Institute of Technology Lausanne. It is a plugin for the alignment of an image stack using a subpixel registration algorithm. The aim of the algorithm is to minimize the mean-square intensity difference between the reference and test data sets [5]. If there are small intensity differences in the image, the use of markers can still be useful.

The congruence of the alignment of the images can be evaluated. Image subtraction is a common method in image processing in which the pixel values of one image are subtracted from the corresponding pixel values of another image. This procedure can be used to identify differences between two images [6]. The mean square error (MSE) is a measure of the difference between the pixel values of two images. The squared difference between the pixel values is calculated. A low MSE value therefore represents small deviations between the images, a high MSE value large deviations [7].

3. Experimental

Table 1 shows five different possible marker elements for image alignment. When selecting the elements, it was important that they could map both translational and rotational displacements. A circle, for example, would only depict a translative displacement, as no rotation can be detected with it. Based on the registration elements for multicolor printing, a crosshair and additional a bar, a square, a cross and a QR code-like position marker were chosen.

Table 1: Selection of five different positioning markers for determining the translational and rotational displacement between two images

Name of the marker	**Crosshair**	**Bar**	**Square**	**Cross**	**QR**
Appearance of the marker					

The markers were positioned in the corners of the sample (see Figure 2). No, one or three markers were used. The sample without markers is to be used to determine whether marking with one or more markers fundamentally improves the precision of the image alignment. Due to the design of the markers, displacements and rotations can already be detected using one marker. Nevertheless, the decision was made to use one and three markers in order to check the extent to which image alignment might be further improved if there are several markers on the printed image. Printing was done using a toner printer on office paper (80 g/m^2). The speckle pattern on the samples was not printed right up to the edge, but had a white frame. The printed image had no color components and could therefore be printed in black and white.

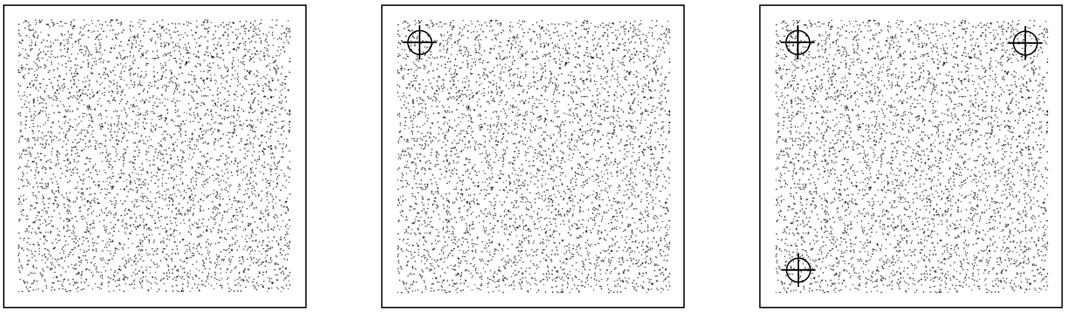


Figure 2: Pressure of the markers on the samples with speckle pattern

The samples were cut to a size of 40 mm hight and 40 mm length. Each sample was imaged twice. Images were captured using the Keyence 3D macroscope (Keyence Deutschland GmbH, Neu-Isenburg, Germany). The samples were placed on the sample table. The sample surface was focused. The measurement software (Keyence VR-3000 G2 Serie Software, Version 2.5.0.116) enables a shadow image of a sample to be recorded so that the subsequent samples can be placed in a nearly similar position to the initial sample. This is shown in Figure 3.

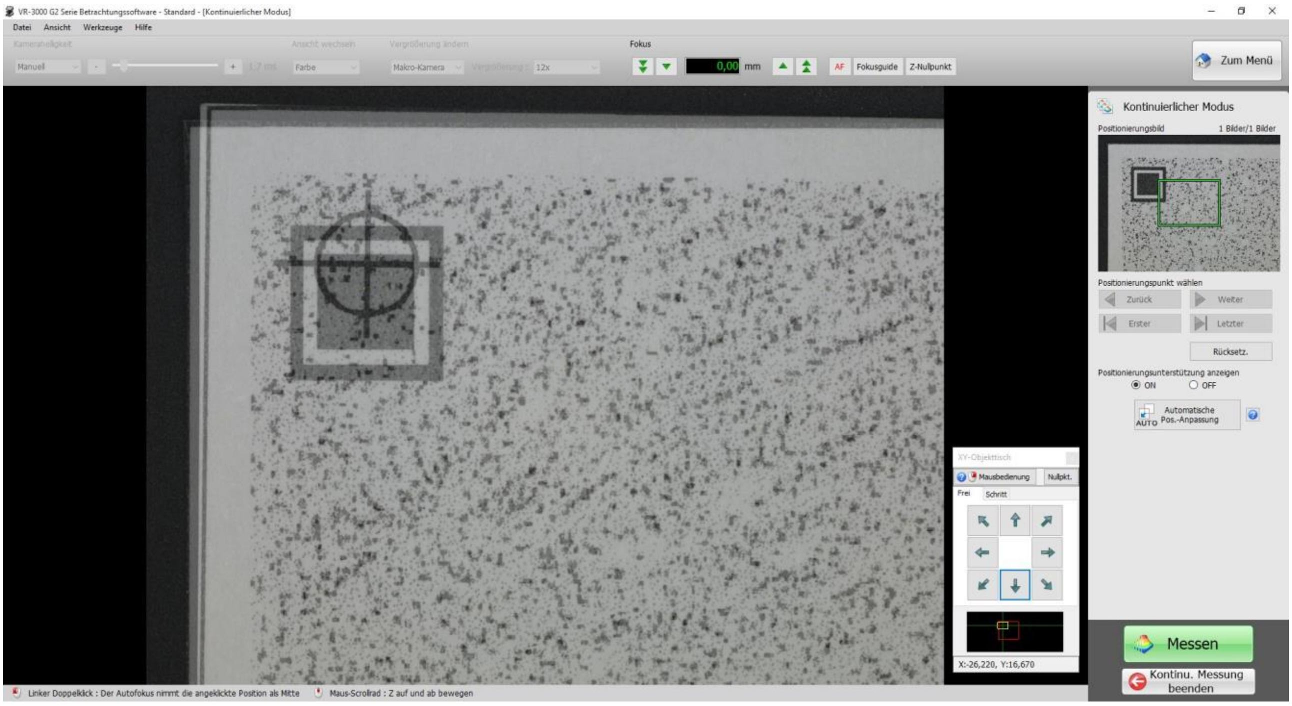


Figure 3: Shadow image for positioning the subsequent samples in the measurement software of the Keyence macroscope using a shadow image of the first recorded sample

Due to the limited measurement area, the samples were stitched, which means that several measurement areas were placed next to each other. The sample was scanned with six measurement areas and automatically assembled as an overall image at the end of the process. For the first image of the sample, the sample was aligned with the shadow image. After the measurement was completed, the sample stage was moved both translationally and rotationally and the measurement was restarted to get a second shifted image.

The task was now to align the two images of a sample that had been shifted in relation to each other as congruently as possible. Therefore one pair of each of the sample images was opened in ImageJ. A stack was formed from the two images. The images were converted into 32-bit images. The images were then aligned using the "StackReg" algorithm, which is a plugin in ImageJ. It is important that both the translative and the rotative scaled displacements were approved before starting the algorithm. The images of the stack were saved. This was repeated for all pairs of samples. Three samples per marker were analyzed. All the aligned images were then reopened in ImageJ and cropped to a uniform size analogous to the sample size.

To calculate the quality of the sample image positioning, the aligned images were subtracted from each other. This allows existing deviations in the image to be detected. The images were subtracted in ImageJ. The images of the same size were subtracted pixel by pixel and the result displayed. This made it possible to visually assess the quality of the alignment of the images.

The calculation of the mean square error (MSE) was used as a measure of the quality of the image positioning to quantify the deviation. The MSE of the images was calculated using a Matlab script (MathWorks, Natick, United States).

4. Results and Discussion

The image alignment was carried out and verified both by subtracting the images and mathematically by calculating the MSE. As an example, Figure 4 shows the subtraction of the initial image and the aligned second image for a sample without markers. The resulting structures are clearly visible, which shows that the positioning of the sample was not carried out precisely, the two images are not congruent with each other.

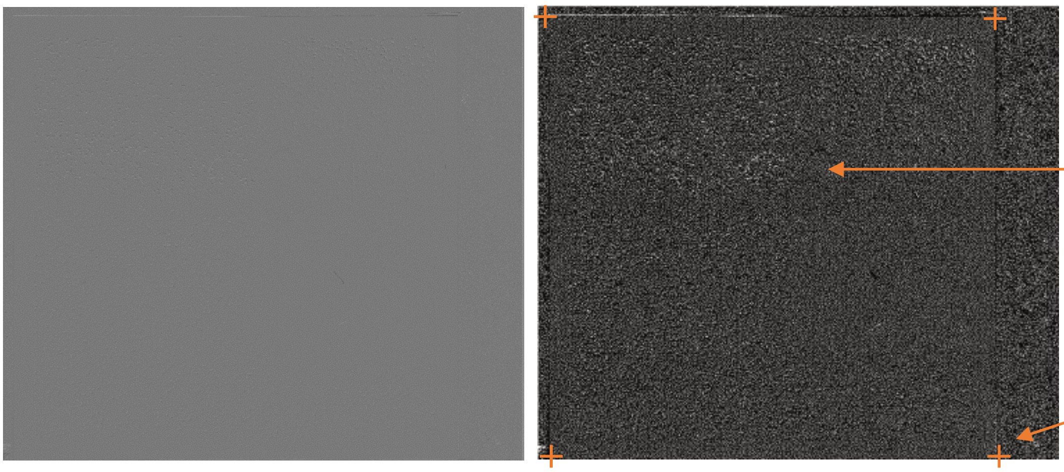


Figure 4: Subtraction of two images of a sample without marker; the resulting structure shows a deviation in the accuracy of fit of the two images (left side: original image; right side: binary image for better visibility of the structures in the image)

This finding is reflected in the calculations. The calculated values of the MSE are roughly higher for the samples without markers than for the samples with markers (see Fig. 5).

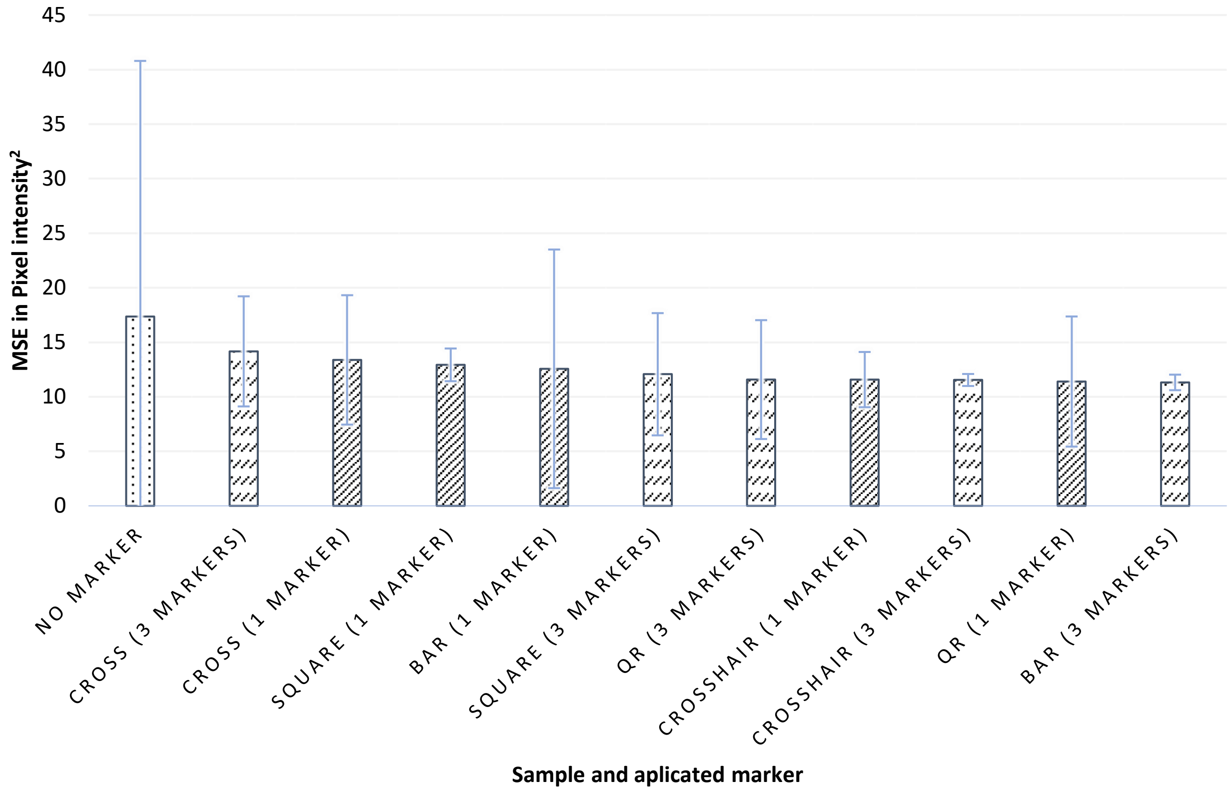


Figure 5: MSE of samples with different number and type of markers

In addition, the confidence interval (p=0.05, alpha = 5%) was even larger for the samples without markers than for the samples with markers. That indicates that the samples were precisely aligned less reliable. The samples with markers showed a lower MSE value than the samples without markers. However, there is no clear differentiation possible between the markers using the selected sample size. Tendentially, the samples with one marker have a higher MSE value than the samples with three markers.

5. Summary and outlook

Five various positioning markers were tested in order to align images of speckle-printed fibrous samples as precisely as possible. When aligning two images, the positioning algorithm "StackReg" in ImageJ in combination with using markers showed the best results. Samples without markers showed a larger MSE, the accurate alignment was lower. For further investigations, the sample size would have to be increased in order to find the best marker design. In addition, markers with different shape elements, sizes or colors could also be tested.

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