

Reliability of statistic evaluation of microscopic pictures taken from knitted fabrics

A Ehrmann¹, T Blachowicz², H Zghidi³ and M O Weber⁴

¹ Faculty of Engineering Sciences and Mathematics, Bielefeld University of Applied Sciences, 33609 Bielefeld, Germany

² Institute of Physics – Center for Science and Education, Silesian University of Technology, 44-100 Gliwice, Poland

³ Faculty of Automatic Control, Electronics and Computer Science, Silesian University of Technology, 44-100 Gliwice (Poland)

⁴ Faculty of Textile and Clothing Technology, Niederrhein University of Applied Sciences, 41065 Mönchengladbach, Germany

E-mail: andrea-ehrmann@gmx.de

Abstract. One of the techniques which can be used to quantitatively evaluate images statistically is the so-called random-walk approach. The resulting Hurst exponent is a measure of the complexity of the picture. Especially long, fine elements in the image, such as fibres, influence the Hurst exponent significantly. Thus, determination of the Hurst exponent has been suggested as new method to measure the hairiness of yarns or knitted fabrics, since existing hairiness measurement instruments are based on different measurement principles which are not comparable. While the principal usability of this method for hairiness detection has been shown in former projects, the absolute value of the calculated Hurst exponents depends on the technique to take the photographic image of a sample, to transfer it into a monochrome picture, and on possible image processing steps. This article gives an overview of edge detection filters, possible definitions of the threshold value between black and white for the transformation into a monochrome image, etc. It shows how these parameters should be chosen in case of typical textile samples and correlates the challenges of this novel method with well-known problems of common techniques to measure yarn and fabric hairiness.

1. Introduction

The description of textile fabrics is often related to their structure and to yarn parameters such as material, fineness, hairiness etc. While the structure, e.g. of a woven or a knitted fabric, can be defined well, the yarn parameters can often be evaluated only by extracting the yarn from the fabric, resulting in a destruction of the original textile sample.

One of the parameters which can hardly be detected in a textile fabric by a non-destructive method is the yarn hairiness, being defined as number of hairs per yarn length which have a defined minimum length. Since yarn hairiness can be measured by different devices, based on different definitions which are not always compatible, with different results for different yarns [1-6], a novel approach to measure yarn hairiness optically was suggested [7]. While this approach, based on the statistical evaluation of microscopic pictures, was successfully tested for single yarns and knitted fabrics [8,9], several parameters of microscopy and image processing have shown to significantly influence the results.



This article aims at depicting the influence of image processing – i.e. reduction of a coloured microscopic picture to a monochrome image by different methods – on the statistical evaluation process.

2. Methods

Single jersey fabrics were knitted on a Stoll flat knitting machine CMS 302TC with machine gauge E8, using a blended staple fibre yarn with 70 % polyacrylonitrile (PAN) and 30 % new wool (WV) (Nm 30/2) and a filament yarn 100 % viscose (CV) (2 x 330 dtex).

Photographic images with a nominal magnification of 20 x were taken using a digital optical microscope VHX-600D by Keyence with an objective VH-Z20R. Fig. 1 (1st row) shows two photographs of knitted fabrics after 10 washing cycles, leading to an enhanced hairiness compared with the untreated fabric.

These pictures were transformed into 1-bit monochrome images by two different methods. Using the first method, they were imported into CorelDRAW[®] X5 and transformed into a monochrome line graphic with different threshold values of 70, 90, 110, and 130, with a value of 0 resulting in a nearly completely white and a value of 255 in an almost completely black picture. For the following statistical evaluation, the pictures were inverted afterwards. The results for the extreme values of the threshold, 70 and 130, are depicted in Fig. 1 (2nd and 3rd row, respectively). Using the second, automatic method, the pictures were transferred into black-and-white images by a self-prepared algorithm which denoises the image by means of median filtering, unsharp masking and a special filter based on a feature vector and a given noise sample. Next the algorithm segments the image and extracts fibres by subtracting high pass filtered image from the denoised part and then skeletonizes it to make length measurement possible. The results of this process are depicted in Fig. 1 (last row). Here, structures inside the yarns become visible, while the fine fibres outside the threads vanish.

Afterwards, a so-called random walking experiment is performed on the monochromatic pictures. Starting from a random point on the textile (i.e. on the black areas), a defined number of steps $t = 1, 2, \dots, 1000$ is carried out, with the same probabilities for all four possible directions (up, down, left, right). The starting and ending point of this random walk differ by distance $R(t)$. By plotting $\log R(t)$ vs. $\log t$, a linear correlation is visible. The slope of the linear fit is the so-called Hurst exponent H . This process is repeated 1000 times to get a statistical distribution of Hurst exponents. A more detailed description of the method can, e.g., be found in [10].

While a completely black area results in $H = 0.5$, all white areas – which are forbidden for the random walking process, thus restricting the possible movements – lead to a reduction of this value. Especially long, tiny structures – e.g. single fibres – result in a decreased Hurst exponent. Thus, this method can be used to give a quantitative measure of the fabric structure, with smaller values of H for finer yarn and higher hairiness.

3. Results

Fig. 2 shows Hurst distributions calculated for the monochrome pictures shown in Fig. 1. Obviously, the pictures with large black areas (Fig. 2, 1st row) result in Hurst distributions with large peaks near $H = 0.5$, as expected due to a black square having $H = 0.5$. The large disadvantage of this method is that the Hurst distributions of clearly different pictures look quite similar.

On the other hand, in pictures with significantly more white areas (Fig. 2, 2nd row) the fine structures are mostly lost – amongst them the single fibres or hairs in which we are interested.

The automatic algorithm, however, results in the peak near $H = 0.5$ being completely deleted, since the picture is broken up in single stitches without connections. This concentration on smaller features, suppressing the influence of long-range effects in the whole fabric, may support the differentiation between different fabrics, since the average value is now dominated by the short-range effects. To test this idea, the average Hurst exponents were calculated using the previously described methods of creating a monochrome image from the same coloured microscopic picture.

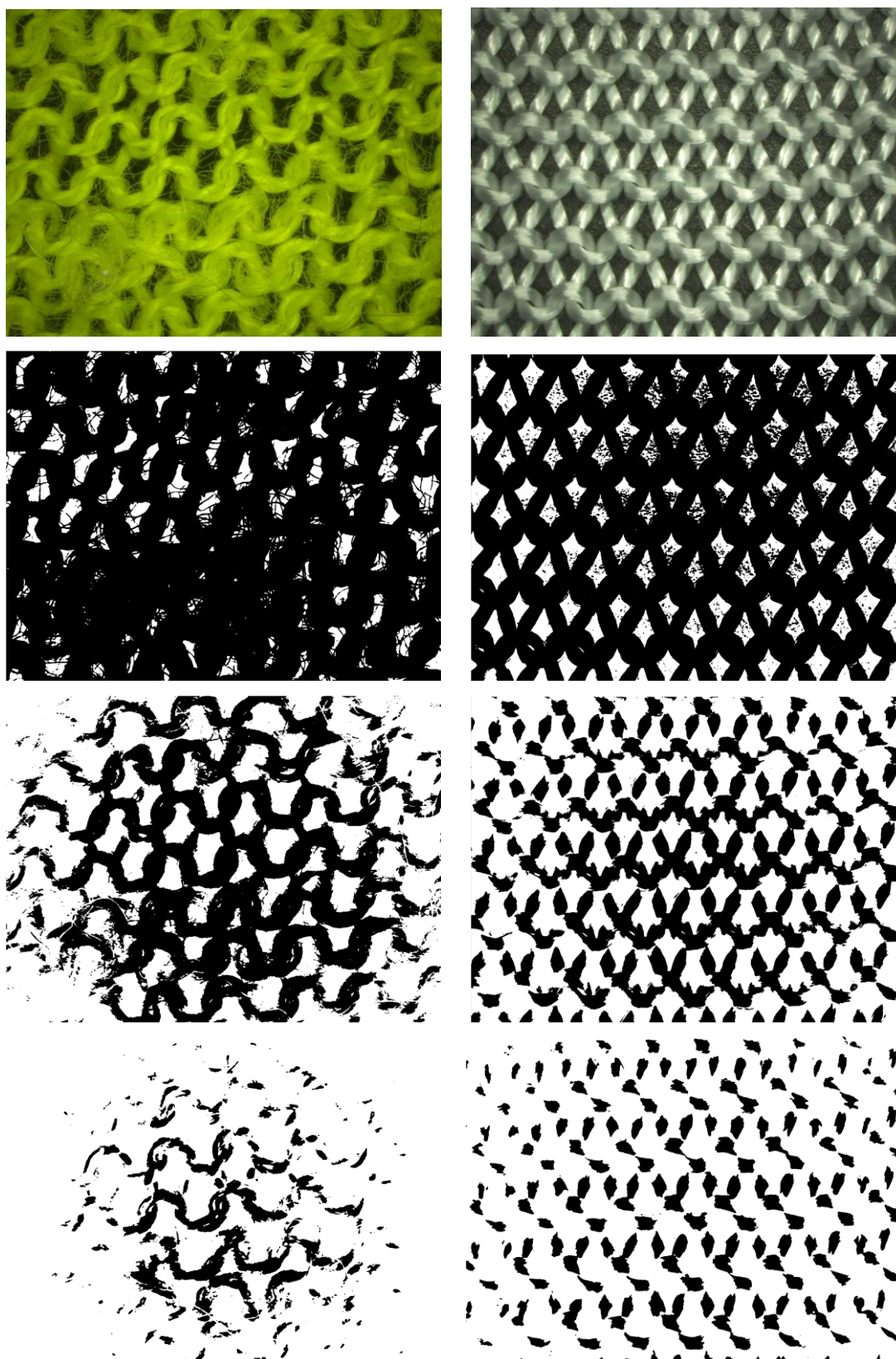


Figure 1. Microscopic pictures of PAN/WV (left column) and CV (right column) knitted fabrics (1st row), inverted monochrome images with threshold values of 70 (2nd row) and 130 (3rd row), automatic reduction to black-and-white images (last row).

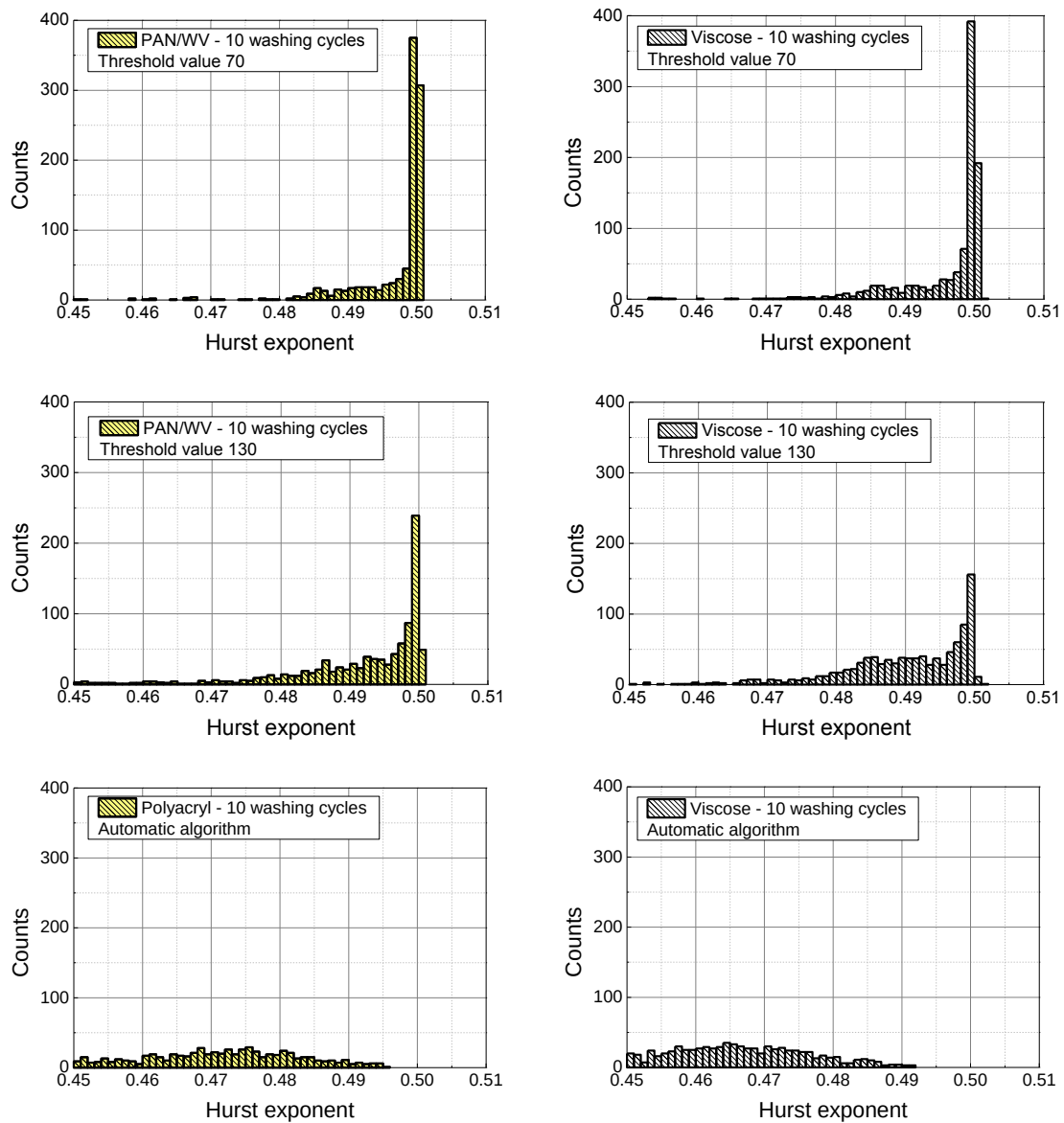


Figure 2. Hurst distributions, calculated for PAN/WV (left column) and viscose (right column) knitted fabrics from monochrome pictures with threshold values of 70 (1st row) and 130 (2nd row) as well as automatic reduction to black-and-white images (last row).

Fig. 3 depicts the average Hurst exponents, calculated for each set of 1000 single measurements. For small threshold values (i.e. mostly black pictures), the average H is larger for PAN/WV, what is changed for the largest threshold value (i.e. pictures with more white regions). This finding is based on the different colour uniformities of the materials under examination as well as on the different hairiness of both samples.

Based on the structure, the viscose sample is more open, thus a *smaller* Hurst exponent would be expected than for the PAN/WV sample. On the other hand, the viscose sample shows less hairiness, thus a *larger* Hurst exponent would be expected. Apparently, the pictures with dominating black areas – resulting in a smaller H for viscose – probe mostly the structure, while the brightest pictures probe mostly the hairiness.

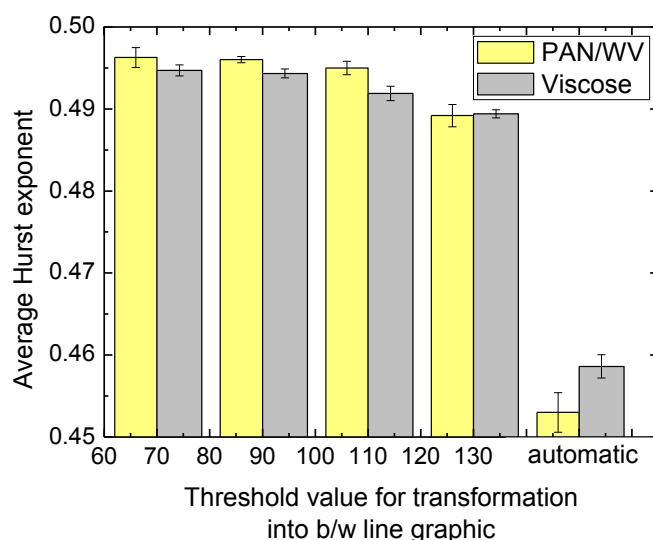


Figure 3. Average Hurst exponent, calculated for Hurst distributions (cf. Fig. 2) of monochrome pictures with different threshold values as well as automatic reduction to black-and-white images.

The automatic algorithm, however, pursues this trend even further. While both average Hurst exponents are, as expected from Fig. 2, significantly smaller than those calculated from the other pictures, the random walk on the automatically created monochrome image shows a significant difference between the PAN/WV and the CV sample, obviously probing the small-scale structures.

Future examinations will show whether different automatic algorithms can be used to probe the hairiness and the stitch structure independently, which would allow for detecting two important parameters of textile fabrics unambiguously from a single microscopic picture.

4. Conclusion

To conclude, we have shown the significant influence of different image processing methods and parameters on the calculation of Hurst exponents from pictures of knitted fabrics.

Depending on the transformation process of the original colour picture into a monochrome image, different parameters of the pictures are probed. While this effect has to be taken into account to avoid evaluation errors, it can also be utilized to gain more information from one picture by choosing different image processing parameters.

References

- [1] Basu A 1999 *Indian Journal of Fibre & Textile Research* **24** 86-92
- [2] Canoglu S, Yukseloglu S M 2008 *Fibres & Textiles in Eastern Europe* **16** 34-38
- [3] Tyagi G K 2004 *Indian Journal of Fibre & Textile Research* **29** 35
- [4] Alay S, Göktepe F 2008 *Tekstil ve Konfeksiyon* **18** 28-34
- [5] Kilic M, Okur A 2014 *Indian Journal of Fibre & Textile Research* **39** 49-54
- [6] Standard Guide for Measuring Hairiness of Yarns by the Photo-Electric Apparatus, *ASTM D5647-2007*
- [7] Blachowicz T, Aumann S, Pruß B, Reiners P, Ehrmann A, Weber M O, Weide T 2014 *Proceedings of Aachen-Dresden International Textile Conference*, Dresden / Germany, November 27-28, 2014
- [8] Blachowicz T, Ehrmann A, Zieliński M, Weber M O 2015 Quantitative estimation of textile structural complexity using random walking approach, *submitted*
- [9] Blachowicz T, Ehrmann A, Domino K, Weber M O 2015 Examination of washing relaxation of knitted fabrics by random walking approach, *submitted*
- [10] Schepers H E, van Beek J H G M, Bassingthwaighe J B 1992 *IEEE Engineering in Medicine and Biology* **11** 57-71