Defect Detection and Localization in Textiles Using Co-Occurrence Matrices and Morphological Operators

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Abstract

Texture properties are ‘natural’ in textiles. There can be considered mainly two types: those resulting from the weaving process and those related to the printing to get patterns of one or more colors directly on the textile materials.

Texture characterization in digital images is an established technique. Reported successful applications include segmentation by texture types, classification of images according to textural properties and narrowly delimited problems. The co-occurrence matrices method is one of the approaches. Its main usage relates to the extraction of some coefficients to texture characterization. Although successful for microtextures – when the textural dimensions are more or less the same as the pixel – the extrapolation for ‘larger’ structures is usually reported as non-functional, attributing the blame to the complexity required to the description of the larger textures that the use of those coefficients cannot provide.

This report relates to the use of co-occurrence matrices for the ‘larger’ textures, by quantifying and correcting some usually overlooked problems in the set-up and the revision of the matrices for a more usable data collection scheme. A functional characterization of the texel and a method of texture extraction are also presented. Defect detection and localization in textiles is the envisaged application.

1. The imaging set-up

The normal set-up used to acquire the image of a textile fabric places the optical axis orthogonal and centered to the object plane. Object size, available distance and sensor area dictates the focal length to be used. Recurring to a wide angle, for larger than 45 degrees of field of view, is usually avoided and only justifiable when there is no space for a normal lens. The illumination can be frontal (from the same side as the camera or by back-light, where the fabric is placed between camera and light source, and inserting a diffuser between light and fabric [1-3]. Sometimes the angle of incidence of the light on the object surface is rather high, approaching 90 degrees, to enhance surface relief and texture.

Figure 1. Geometry of the image forming system

2. The imaging system problems

For the textural analysis by co-occurrence matrices, the value of each pixel is paramount. In ideal situations, equivalent object regions should produce same intensity pixels. But some changes may occur, due to several factors. Also the pixels should be related to geometrical positions in the object according to their position indexes in the digital image matrix; but due to some inevitable deformations, it can be otherwise [3].

2.1 Illumination

Without illumination the image cannot be formed. Usually uniform and from a non-punctual source, should not manifest itself by modulation of the light that the camera receives from the object. Unfortunately, some intensity modulation is produced by light source positioning and non-lambertian object surfaces [2, 4, 5]. This results in light intensity changes due to small relative orientation of elementary object surfaces and light source.
2.2 Optical image formation

The image, that should be a simple linear mapping of the object surface onto the image plane, is prone to distortions [2-3], either in position and intensity. Image position errors are mainly from lens uncorrected distortions, namely pincushion and barrel types, that are more difficult to correct in wide-angle lens.

Intensity differences from the ideal situation can also be noted [2]. This is caused by decrease in efficiency with larger incidence angles on the image plane - square cosine law. This is larger again for wide-angle optics [3].

![Image of textile, with defects to be detected (512x512x8)](image)

2.3 Sensor response

The response of the sensor is not linear, and relative differences may be amplified. Fortunately, modern solid state sensors are more closely linear than old vacuum-tube type [4] and these are lesser problems today.

2.4 Digitalization

The process to obtain a digital image implies some sort of analog to digital conversion. Although much better nowadays, the unavoidable errors can translate into digital image intensities differences that should be accounted for. The scanning process, necessary for 2D images, means that different spots are usually analyzed at different times. If the light intensity of the source is not practically constant (as in tungsten lamps, compared to fluorescent), fluctuations in the intensity are a consequence both in analog values their digital translations. Also, when the scanning process implies an intermediate time varying signal (video signal) the jitter errors in signal generation, transmission, analysis and digitalization can change geometric relations between object and image and impose some limitation to the derived results [6].

3. The texture characterization

The texel, once determined, can be used to detect and locate defects in the textures. The statistical approach to texture characterization usually recurs to co-occurrence matrices; although a data intensive task, it can be modified to suit the task.

3.1 Co-occurrence matrix

The co-occurrence matrix method relies on building a square matrix for each angle/distance combination. The dimensions of the matrix are the number of different intensity levels in the digital image.

The amount of data generated in the process usually limits the number of intensity values to 4 up to 16 (2 to 4 bit depth); regarding angles, usually only four directions are considered (0, 45, 90 and 135 degrees) [5]. Usually just one value is considered for distances and between 2 and 4.

From the matrices a set of coefficients are computed and used to differentiate textures [7-8]. Texel dimensions are not under consideration.

3.2 The modified co-occurrence matrix

The limited distance information extraction from the co-occurrence matrices suggested a new approach: the modified co-occurrence matrix (MCM) [9]. In this approach, a larger number of intensity levels can be considered and also a larger set of distances, in exchange for the dissimilar intensity levels that are no longer accounted for.

![Partial numeric data from MCM](image)

In this method, 128 intensity levels are considered and distances up to 128 (departing from 512x512x8 bit images); occurrences are accounted for equal intensities. This can be organized in four 128x128 matrices of integers, one matrix for each of the usual directions. The reduction from 256 to 128 intensity levels (disregarding
the least significant bit of intensity) is used to compensate for noise in the digitizing process.

Figure 4. Graphic presentation of MCM

The MCM output is, for each direction, a square matrix, where occurrences develop according to distances along each line and each column relates to certain intensity.

3.3 Texel size estimation

The repetition of the structure element manifests in a larger number of hits in the co-occurrence for the distance that corresponds to the translation period [9]. As the total number of hits for each intensity is highly dependent on the respective histogram value, a better approach is to consider not the absolute number of hits but its variation rate to distance (derivative). The larger found values are used as size of the main texel.

For the case of the image in Fig.2, the computed size corresponds to 35x35.

3.4 Texel Characterization

Vertical and horizontal dimensions of the texel are taken as the medium distance to travel on the image to find a similar intensity region. Its use for texture decomposition has been proposed [9].

The purpose of the application here reported is to identify the regions of possible textural defects. A simplified image, where defects are marked is needed. Texture extraction schemes, as the one reported in the following section, are the next step of the process.

4. The texture extraction

The co-occurrence approach is very sensitive to intensity and geometrical distortions, when large distances are to be considered [3, 9-10]. Nevertheless, when considering regions of the same size as the texel, local errors are manageable [9] and a procedure for texel decomposition and extraction can be implemented. This can be done using the top-hat morphological operator using the model texel as the structuring element [11-13].

For the model texel, two approaches can be used: either an object region with the computed dimensions or a simple flat (uniform) model, for which the intensity changes are to be accounted as resulting from superposition effect of other coexistent texel or texels of smaller dimensions. For the first case, as we are dealing with strongly ordered textures, any area with the appropriate size is reasonable (unless it happens to be where the defect is located).

Figure 5. Image from Fig. 2 after top-hat processing (low level)

The general top-hat operation can be implemented for gray-level images either in the usual difference between the image and its opening or by the difference between the closing and its original (dual form) [1, 11-13].

Figure 6. Image from Fig. 2 after top-hat processing (high level)
5. Defect localization

For the envisaged task we are trying a combination of normal and dual top-hat transforms, to be able to detect defects either by lighter and darker spots.

Figure 7. Difference of images from Figs. 5 and 6, in enhanced contrast

In the example of Figure 7, there is a brighter spot corresponding to a blob in the thread.

From the MCM, a 35x35 size texel was considered for the top-hat. A flat element was used for both transforms and results are in Figures 5 and 6. Their difference, after histogram stretching [1] is displayed in Figure 7.

There we can see highlighted the defect region.

Figure 8. Fabric with distortions

Also some other regions, with possible defects are marked. Minor defect markings extending horizontally and vertically from the main ones suggest an interesting relation to thread problems that usually occur for some length.

Not only the localization of defects is promising but also a means of classification, according to the intensity of the spots.

Figure 9. Defect map of distorted fabric

The method presented itself insensitive to fabric distortion, as they did not show in the resulting image (Figures 8 and 9).

5. The setup

In the setup, frontal lighting by tungsten lamps is used. Camera axis is normal to the fabric surface.

The camera is a standard CCD type, with a standard lens. Output is CCIR.

Images were acquired using a VFG-100AT board, from Imaging Technologies Inc. They were horizontally resized, for square pixel size, and cropped for 512x512. No more processing was done prior to MCM computation and top-hat transforming.

References