APPROACH TO NORMALIZING THE TISSUE MACROIMAGES SET TO DETERMINE RAW MATERIAL COMPOSITION

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In the current conditions of digitalization of light industry, methods of automated analysis of fabrics, focused on the operational determination of their raw material composition by visual signs, are becoming particularly relevant. Such a task has applied significance for primary quality control, warehouse sorting, support of technological solutions in garment production, as well as for textile materials recycling systems, where rapid preliminary identification of the fiber type affects the efficiency of further distribution of raw materials. [1]. Unlike spectral, chemical or laboratory methods, macro image analysis is much cheaper, more accessible and suitable for integration into mobile and production software and hardware. [2]. At the same time, the availability of such images creates a significant problem of their heterogeneity: the material is photographed under different lighting, with different distances to the object, with a variable background, different orientation of the texture, as well as with different camera settings. As a result, the intraclass variability of features increases, which complicates further recognition of the raw material composition and reduces the reproducibility of the results.

The practice of using computer vision in the textile industry demonstrates that the quality of fabric classification depends to a large extent not only on the choice of model, but also on the stability of the input data [3, 4]. Even high-precision classifiers lose reliability if the training and test samples are formed from differently prepared images. For fabrics, this is especially critical, since the final appearance of the macro image is affected not only by the general conditions of shooting [5], but also by the shine of the threads, the direction of the weave, the presence of small shadows between the fibers, local surface heterogeneity, and different texture density. In the absence of normalization [6], the system actually begins to study the accompanying artifacts of image acquisition instead of the actual features of the material [7, 8]. That is why the preliminary preparation of a set of macroimages should be considered not as an auxiliary stage [9], but as a separate important component of the methodology for determining the raw material composition [10].

Known approaches to the analysis of textile images traditionally focus either on microscopic images of fibers or on the textural characteristics of the surface obtained using descriptors such as GLCM, LBP, brightness histograms, local gradients and other statistical features [11]. A separate direction is convolutional neural networks [12], capable of automatically forming texture representations, however, in this case, the effectiveness of the models is significantly determined by the quality of data preparation [13]. For real production conditions, macroimaging is more accessible than microscopic research [14], but requires a special approach to unification of the input set [15]. Therefore, it is of scientific and practical interest to develop an approach to normalizing tissue macroimages that, on the one hand, reduces the influence of technical and environmental variations, and on the other hand, does not destroy informative features associated with the raw material composition.

The aim of the work is to develop an approach to normalizing a set of tissue macroimages to increase the reliability of automated determination of their raw material composition. To achieve this goal, it is advisable to ensure the unification of spatial, photometric and statistical characteristics of the images, while preserving the textural structure of the material, which is a carrier of diagnostically significant information.

In general, the proposed approach is based on the sequential normalization of input tissue macroimages in order to eliminate those factors of variability that are not directly related to the structure of the material as an object of analysis. Its logic involves a phased transformation of the image from the initial, heterogeneous representation to a state in which the spatial, photometric and statistical characteristics become more consistent with each other. This allows to reduce the influence of shooting conditions, random quality deviations and technical artifacts, while preserving textural features that carry information about the raw material composition of the tissue.

At the first stage, the selection of the informative area of the image is performed. For macro images of fabrics, this step is of fundamental importance, since in real conditions the frame often contains elements that do not properly characterize the material itself. These include background areas, folds, foreign objects, local shadows, overexposed fragments or areas where the fabric surface is presented atypically. For this reason, it is advisable to use a cropping procedure that allows you to focus the analysis on a representative part of the textile surface. Preference is given to those areas that are characterized by sufficient textural expressiveness, do not contain signs of oversaturation or defocus and better reflect the actual structure of the interweaving of threads. This creates the prerequisites for further analysis to be based on stable and meaningful fragments of the material.

The second stage is associated with the geometric normalization of macro images. For textile materials, especially with a pronounced interweaving structure, the orientation of the texture significantly affects the value of local textural features. If the same fabric is presented in images from different angles or at different scales, this can cause noticeable differences in the feature description, although the physical properties of the sample do not change. That is why it is advisable to align the images along the dominant texture direction with their subsequent reduction to a fixed size. Such unification ensures the comparability of local structures between different samples, reduces the influence of random geometric differences and makes the subsequent feature selection more correct.

The next component of the approach is photometric normalization, aimed at reducing the influence of uneven lighting, exposure changes and color shift. For fabrics, this task has a special specificity, since excessive suppression of color and brightness differences can lead to the loss of features that are partly related to the physical nature of the fiber or the nature of light reflection by the surface. In this regard, it is more advisable not to completely neutralize photometric differences, but to their controlled stabilization. The main focus should be on equalizing the illumination and contrast in a way that reduces the influence of the shooting conditions, but does not destroy the local texture of the material. The result is a more consistent representation of the textile surface, in which diagnostically significant textural patterns are better preserved.

An important component of the proposed approach is also the coordination of sharpness and overall quality of input images. In real samples, some macro images can be obtained with slight defocus, compression distortions or uneven local contrast. Such deviations directly affect the stability of the calculation of texture characteristics and can cause the appearance of false dependencies in the process of training the classifier. Therefore, it is advisable to include image quality control in the preprocessing procedure, focused on identifying insufficiently clear, overexposed, darkened or technically unreliable samples. Their removal or special marking allows you to increase the homogeneity of the data set and reduce the risk that the model will begin to consider technical distortions as significant features of the class.

After completing the above steps, a more stable basis is formed for further selection of features suitable for determining the raw material composition of tissues. In conditions where it is important to combine sufficient accuracy with the ability to interpret the results, it is advisable to use not only deep representations, but also understandable texture descriptors. These may include statistics of gray-level adjacency matrices, local binary patterns, entropy indicators, intensity distribution characteristics, as well as gradient and contrast features. Multi-scale selection of such characteristics allows us to take into account different levels of manifestation of the textile pattern, from local details of the weave to a more general organization of the surface. Normalization of input images in this case is a necessary prerequisite for the formation of a feature space in which the difference between classes reflects the properties of the material, and not the technical conditions of fixation.

The fundamental feature of the proposed approach is that normalization is considered not only as the processing of each individual macroimage, but as a procedure for harmonizing the entire data set. It is at the level of the full sample that systematic differences between series of images obtained under different conditions or by different operators become noticeable. If these shifts are not taken into account, the model may begin to classify not the tissue as such, but the conditions of formation of the dataset. Therefore, along with local alignment of individual images, it is advisable to perform a global analysis of the distributions of brightness, contrast, scale parameters and quality metrics. This allows you to bring the set to a more uniform range of characteristics and weaken the influence of domain differences.

To assess the effectiveness of this approach, it is advisable to compare several data processing modes: using the original macroimages without normalization, applying partial normalization, and using the full set matching procedure. In this case, training and testing of the model should be carried out on balanced samples with control of the class ratio and repeatability of runs. It is advisable to carry out the assessment not only by the integral indicators of classification accuracy, but also by the degree of reduction of intraclass variability of features. It is such an assessment that allows us to understand how effectively the normalization procedure eliminates unwanted disturbances and increases the model's resistance to changes in shooting conditions. From a methodological point of view, the expected effect of the proposed approach is that the features formed on the basis of normalized macroimages become more resistant to random technical differences, but retain sensitivity to the real textural features of the textile material. Natural fabrics, in particular cotton and linen, are usually characterized by more irregular micro-heterogeneity of the surface, softer brightness transitions and a different nature of local contrast. For synthetic materials, more regular texture repetitions, more uniform areas and specific features of light reflection are more often observed. Without proper normalization, these patterns are partially masked by technical disturbances, but after matching a set of images they appear more clearly, which increases the separability of classes in the feature space. At the same time, it is important to avoid excessive normalization, which can erase those differences that are actually related to the nature of the material. If the preprocessing procedure completely suppresses color, brightness or contrast features that carry useful information about the fabric, this can lead to a decrease in the informativeness of the input data. That is why the proposed approach is focused on the balance between invariance to the shooting conditions and the preservation of the subject-specific characteristics of the textile sample. This is its difference from simplified processing schemes, where only basic scaling or global alignment operations are performed without taking into account the nature of the texture data.

The practical value of the approach lies in the possibility of its application in systems of low-cost automated quality control and preliminary identification of textile materials. Initial training of the model on the full set without prior data ordering demonstrated quite high results: the average Accuracy value was 0.9775, F1-score – 0.9769, and ROC-AUC – 0.9993. At the same time, even with such formally high indicators, a certain variability between individual sample partitions remained, which indicated the heterogeneity of the input data and the possible influence of repeated or excessively similar examples on the training process. This confirms that for textile macroimages, it is the preliminary normalization and ordering of the data set that is a necessary condition for increasing the reliability of the model, and not just an auxiliary technical step.

Unlike expensive laboratory technologies, macro images can be obtained using a conventional digital camera or mobile device, and subsequent normalization and classification are implemented software. This opens up prospects for implementation in fabric sorting production lines, in technological decision support systems, as well as in the problem of textile recycling, where rapid preliminary separation of materials by type of raw material is of significant economic importance.

Thus, the proposed approach to normalization of a set of fabric macro images forms a methodological basis for a more reliable determination of the raw material composition using computer vision data. Its application allows to increase the homogeneity of the input sample, reduce the influence of technical imaging artifacts, improve the comparability of features between samples, and create prerequisites for improving the quality of classification. Further development of the work should be associated with the expansion of the number of classes, the transition from binary division into natural and synthetic materials to a more detailed assessment of the mixed composition, as well as with the combination of normalized macroimages with multi-scale interpreted texture descriptors and neural network models.

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