COMPUTER VISION SYSTEMS FOR TEXTILES QUALITY CONTROL

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A synthesis of the new quality evaluation systems for textiles, based on the soft computing techniques: neural networks, fuzzy logic systems and genetic algorithms is presented in the paper. The suitability of each method for different kind of applications, case studies and limits are outlined. The contribution of the authors in the field of genetic algorithms (GAs) and semi-algebraic networks applications for textile pattern recognition and quality control is pointed out. The method of GAs was applied for an original computer vision system development and the suitability of semi-algebraic networks is proven for the knitted fabric defects detection.

Keyword: textile patterns, knitted fabric defects, genetic algorithms, neural networks, fuzzy logic, semi-algebraic networks

SOFT COMPUTING TECHNIQUES

In last years artificial intelligence (AI) methods have been intensively developed, leading to the design of computer expert systems to perform the tasks previously carried out by a human being. Among many methods of AI, the most applied soft computing techniques' are: artificial neural networks (ANN), fuzzy logic systems and genetic algorithms (GAs).

Artificial neural networks (ANNs) are optimization methods whose design inspiration comes from the behavior of the biological neural networks. ANN can be used to create computer systems, which can replace human experts. ANNs are widely used for pattern recognition problems, classification, recognition, prediction.

Fuzzy logic systems operate with rule based systems that use flexible definitions of rules. This makes them particularly useful for control systems because their inherent robustness is tolerant towards noisy input signals. These optimization techniques are often used in industry to optimize workflow processes or usage of raw materials.

Genetic algorithms (GAs) are a soft-computing techniques which are used to find an as-good-as-possible solution to difficult optimization problems. Their inspiration comes from natural ecosystems, where organisms compete to survive and reproduce, adapting even better to the environment they live in as generations pass.

Applications of soft computing techniques in textiles

The manufacturing and quality evaluation of textiles involve interactions among a large number of variables, whose relation has to be established convincingly. *ANN* has found application in many fields of science, including textile and clothing industry. The effectiveness of ANN in classification and prediction problems is sustained by many researchers. Being a very powerful data-modeling tool, it has been successfully used to predict yarn strength, elongation, unevenness and hairiness. Jackowska-Strumillo et al.(2004) employed an ANN model for the prediction of cotton-flax blended rotor yarn strength, inputs of ANN being percentage of flax content and yarn count. The accuracy of ANN model was superior to the prediction performance Adaline network. Guha et. al (1998) reported the prediction of breaking elongation of friction spun yarns using ANN. They used two different data sets for open-end friction yarns and core-sheath type friction yarns. The mean absolute error of prediction was 4.43% and 3.0% for open-end friction yarns and core-sheath type friction yarns, respectively. They also applied ANN model to forecast the unevenness CV% of ring and rotor spun yarns from cotton fibre properties and yarn count. Sette et al. (1996), (1997) demonstrated the use of back-propagation ANN to model the stress relaxation behavior of yarns. They used two different ANN topologies, which differ in the presence of time as parameter. The predictive power of ANN has been used to determine accurately the fabric properties. Garment comfort, which is one of the most important attributes of textiles, was subjected to the research by different authors. Fayala et.al (2008) used an ANN approach to predict the thermal conductivity of knitting structure as a function of porosity, air permeability, weight and fiber conductivity. The system was able to predict fabric thermal conductivity with 0.92 as correlation coefficient. Hwang, et. al (1998) and Park et. al (2000) carried out an extensive research regarding the handle evaluation of knitted fabrics using ANN. He proved that the neural network adapted simulation method was in good agreement with subjective test results. Detect and classification of defects in knitted fabrics is another field of ANN applications. Shady and Gowayed (2006) used image analysis in order to detect six different induced defects and they employed two ANN for training and testing. The results show success in classifying most of the defects. One can conclude from these examples that ANNs present an advantage over classic algorithms, where it has to be known the full model of a procedure, which would enable a deterministic rule to be formulated. On the other hand, ANN applications require a large body of inputs data. *Fuzzy logic systems* found the application in development of the sales forecasting systems, in order to improve the textile companies supply chain management. The model created by Thomassey et. al (2002) confirmed the advantages brought by tools like fuzzy logic to perform forecasting in the particular textile context, i.e. on short time series, in a mean-term horizon and with explanatory variables under uncertain environment. Majumdar and Blaga (2008) demonstrated the application of two soft computing tools namely artificial neural network (ANN) and neural-fuzzy system to forecast the unevenness of ring spun yarns. It was found that the prediction performance was very good for all the three models although ANN and neural-fuzzy models seem to have some edge over the regression model. *GAs* are suitable for optimization purposes. Sette et.al used ANN and GAs for the spinning process optimization, in order to get optimal product characteristics and minimal faults. The GAs was applied to optimize the input parameters for obtaining the best yarns. The backpropagation simulation of the process is successful in predicting the two yarn characteristics (yarn strength and elongation), while the GAs algorithm effectively optimizes both characteristics. Blaga and Draghici (2005) developed a software using genetic algorithms principles, for knitting process simulation and optimization of clearing cams profile of weft flat knitting machines.

COMPUTER VISION SYSTEMS FOR TEXTILE PRINTING

The principles of GA were applied by the Dobrea and Blaga (2007) in the field of textiles, in order to solve technical problems, for textile printing pattern recognition. An automatic video system was designed with the purpose to discover different kinds of textile printing errors and to stop the printing process anytime an error appears. The system is able to detect printing defects caused by improper alignment of the printing screens or by an incorrect alignment of the different elements. The new introduced system consists of two main parts: the image processing module (IPM) and the genetic detection module. We proved that the GAs based system is able to identify in maximum 250 generations and without any doubts a specific pattern. The processing time from the image acquisition to the pattern identification is around 3 seconds. If we consider that the image processing unit and the genetic detection module are developed and implemented in the Matlab environment, it is clearly that in order to boost up the execution time the both modules must further are implemented on C or C++ environment. When a different printing error occurs and another specific pattern appears, the only algorithm modifications that must be considered are related to the definition of the new considered pattern.

COMPUTER VISION SYSTEMS FOR KNITTED FABRICS DEFECTS DETECTION

In order to detect the knitted fabrics defects, a new computer vision system, based on semi-algebraic networks (SAN) algorithm is introduced by the authors. Most of the researchers have previously developed systems for detection of the knitted fabrics defects induced by regular technological causes: broken needles, thick yarns, thin yarns, fly fibers. We are proposing the detection of a new type of defect, generated by the programming settings, which cannot be easily detect, respectively the holes of the dropped transferred loops. Specific knitted patterns based on the loop transfer are cables; such an example is presented in Figure 1.a.

Work methodology

The knitted fabrics with cable pattern were designed on the pattern station M1 and the samples were knitted on the electronic flat knitting machines CMS 530 E 6.2, Stoll, Germany. The Sintral Check action of the Sintral program and the knitting simulation were good and the program was loaded into the machine memory to be knitted. The programming option '2 system transfer' was cancelled with the purpose of creating a pattern defect, which actually cannot not be detected by the program checking. These samples were afterwards analyzed and computing research subjected.

In textiles discrimination tasks, in the most general case, one can consider a training set consisting in N, $\{x_1, x_2, \ldots, x_N\}$, d-dimensional feature vectors, labeled by the corresponding values $\{y_1, y_2, \ldots, y_N\}$ in $\{0, 1\}$. In our specific case, x_k ($k = \overline{1,N}$) is a bi-dimensional feature vector that encodes horizontal and vertical textile pixel positions. A *1* value for the label associated with a training sample encodes a pixel belonging to the textile error zone, while a *0* value characterizes a correct image pixel. The aim of the research is to approximate an optimal decision surface S that is able to separate the pixels from the two classes presented above. If the area delimited by S (and encoded by ones) is above a threshold value we can decide that a defect appeared on the textile material.

The semi-algebraic networks are based on semi-algebraic sets defined based on M polynomials $\{P_1(x), P_2(x), \ldots, P_M(x)\}$ of R^d and n subsets $\{J_1, J_2, \ldots, J_n\}$ of $\{1, 2, 3, \ldots, K\}$ described by Deffuant (1995):

$$SAN = \bigcup_{i=1}^{n} \left(\underbrace{\bigcap_{j \in J_i} \left\{ x \in \Re^d \mid P_j(x) \equiv 0 \right\}}_{C_i} \right) \tag{1}$$

The semi-algebraic sets are an extension of the algebraic sets, being defined only by equalities between polynomials (in the relation (1) the "≡" symbol is only "=").For our discrimination problem we used a perceptron membrane defined as the boundary of a semi-algebraic set; this semi-algebraic set is a union of the intersections of half-spaces characterized by the following hyper planes:

$$w_j \cdot x + b_j = 0 \tag{2}$$

Here, the w_j ($j = \overline{1, M}$) are the *d*-dimensional weights vectors and b_j ($j = \overline{1, M}$) are their corresponding biases – in fact, real numbers defining the parameters of the perceptron's cells. The perceptron membrane is defined, based on the relation (1), as the boundary of the set:

$$PM = \bigcup_{i=1}^{n} \left(\underbrace{\bigcap_{j \in J_i} \left\{ x \in \Re^d \mid w_j \cdot x + b_j \geq 0 \right\}}_{C_i} \right) \tag{3}$$

In the textiles discrimination problem we employed an utilization function, $U(dist(x,\mathrm{SAN}))$, that provided the element label. The parameters in the relation (3) are adapted based on the gradient descent on the loss function $L(x, C)$ (the quadratic difference between the approximation label, x_i, and its corresponding correct label, y_i):

$$w(t+1) = w(t) - \mu \frac{\partial L(x_i, C(t))}{\partial w} \tag{4}$$

$$b(t+1) = b(t) - \mu \frac{\partial L(x_i, C(t))}{\partial b} \tag{5}$$

Results and discussion

The algorithm used to detect the knitted fabric defects consists of two main parts: the image processing module and the semi-algebraic network detection module. In the first step, the image processing module acquired the image, Figure 1(a) that was further converted from a RGB image to a gray scale one, Figure 1(b).

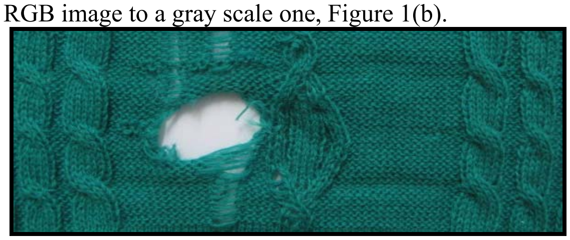


Figure 1 (a) Image processing stages - the acquired image

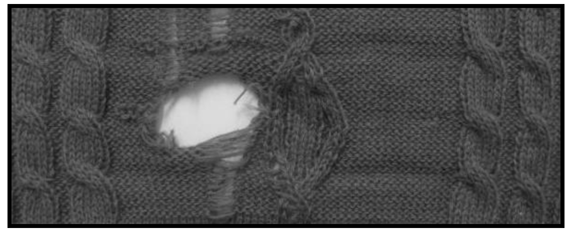


Figure 1 (b) Image processing stages - the corresponding grayscale image

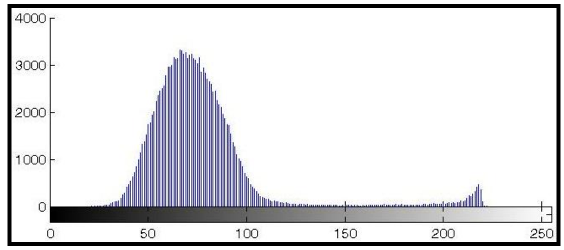


Figure 1 (c) Image processing stages - the histogram of the grayscale image

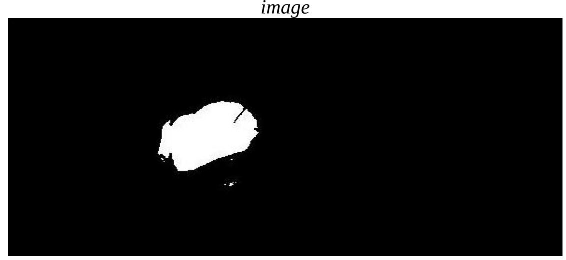
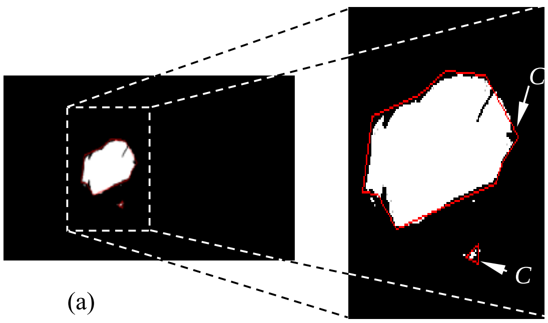


Figure 1(d) Image processing stages - the binary image

In the next step, the blobs (connected regions of pixels within an image) of the textile defects were extracted. In order to extract the blobs, the grayscale image was binarized so that the pixels from the normal textile areas were represented by zero values and the blob pixels were represented by one value, Figure 1(d). Thus, the 0 and 1 value are, in fact, labels assigned to the bi-dimensional feature vectors that encode horizontal and vertical textile pixels' positions. To obtain a binary image**,** Figure 1(d), a threshold level had to be selected. Correspondingly, all the pixels that were below the threshold were changed to the 0 value and all the pixels above the threshold were set to 1. In the case presented in Figure 1 the threshold was chosen at the 150 gray level based on the information obtained from the histogram, Figure 1(c).

The resulting binary image obtained from the image processing module and consisting only of pixels of 0 and 1 values was further processed. Thus, all the pixels having 1 value were separated from the pixels having 0 values by using the decision surfaces. The decision surface was the boundary of the PM set (for details, see relation (3)).

For the particular image presented in Figure 1(d) and after 800 training epochs, the semi-algebraic network generated a membrane consisting of two components C_1 and C_2, see Figure 2(b), that were able to discriminate the feature vectors from the two classes. The C_1 component of the membrane was created from 10 bi-dimensional components (segments, see relation (2)), while the C_2 component incorporated only three decision surfaces. Based on the utilization function all the points lying inside the membrane were labeled to 1 and the algorithm counted all these values and compared the result with the fixed threshold. If the number of features vectors labeled to 1 by the semi-algebraic network inside one or another of the two components was greater than 30 (as it was the case presented in Figure 2(b)) the system generated an error message. This error message had the significance that a textile's defect had been identified.



(a) (b)

Figure 2.
The results obtained by approximation of the optimal decision surface

From the Figure 2(b) one can observe that not all the pixels that are placed inside one of the membrane's components characterize a textile defect. Consequently, these pixels will generate some errors. But, these errors can be neglected mainly because inside the perceptron's membrane the pixels correct classified are dominant.

Implications

In the fabrics worldwide, in order to obtain first quality textile products, the quality inspection is generally made using the manual human inspection. All the limitations of the manual inspection, together with the consideration that the general trend in the textile industry is towards automation, have created an opportunity for the use of the automatic visual inspection systems. The new vision systems represent a further step in the evaluation of textile faults and properties, for both research and production environment. The presented systems can be a powerful tool for the textile managers and technicians at industrial level, in order to reduce the dependance on human inspectors in the subjective and time-consuming process of fabric quality control.
There is also an interesting subject for researchers, considering the artificial methods employed and the results obtained.

Originality

The paper outlines a new type of approach used to detect a new type of knitted fabrics defects, based on the concepts of the semi-algebraic networks. The algorithm is robust and it is able to identify the textile defects in maximum 800 epochs. Compared to the existing systems, the main advantage of the semi-algebraic membranes based system is that the pattern and the position of the fabric defect does not influence the performances of the algorithm.

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