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Studies and researches for the implementation of quality assurance systems in the textile industry

Abstract

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Introduction

If twenty years ago, the term of “quality” referred only some exquisite products, especially those of the American or Japanese industry and those products where designated to a small group of clients, today it became a reality of our lives.

Nowadays, together with the liberalization and globalization of markets, the concept of quality emerged in importance, becoming a measure unit and a trademark, vanishing the borders and creating progress. This has made a change in the producer mentality and especially in the consumer mentality, educating and cultivating his taste and choice, and placing him in the center of his universe. From this point of view, quality can be considered as a state of mind.

We cannot imagine a world without textiles. Their primary function is to clothe, protect, embellish and insulate the human body. In this symbiose, it’s normal that humans are willing for the best. If the industrial revolution started due to textile production necessities, the quality concept is also very close to the domain. If quality was for a long time considered an intrinsic attribute, it was also often confound with luxury. Even so, in theory, the concept of quality was not so precocious as in other fields as electronics, car industry etc.., remaining as a company internal practice, protected with discretion.

In our bibliographical research, we have found few publications in the field of textile quality management. Even if in the past decade, scientific interests had grown, few had exposed and introduced aspects of quality assurance for the textile industry. The present thesis is a pioneer in the research and synthesis of this domain.

Chapter 1 presents the quality concept together with quality management in the case of globalization. We have motivated the standardization and uniformity process present in al fields and domains. After a short introduction, we have structured all the chapters following the quality spiral, starting from planning and ending with control and assurance. Through the work, we have emphasized the practical aspects discovered during our documentation visits in many romanian textile firms. Among all, we can remark the contributions to the analysis and the implementation of quality control in jeans production and our research for a textile defect detection system.

Zero defects cannot be achieved only in a high technological field and completely automated. The human factor, the subjective process and the leak of automation are the most frequent causes of non-quality. These causes are omnipresent in the case of textile industry. This was the challenge for the analysis and original contributions in chapters 3 and 4.

Chapter 3 presents elements of control and quality assurance in the textile industry. A high level quality cannot be achieved without a real-time control system, providing data regarding the production process and reacting operative and efficient to discard perturbing causes. In this respect, we have presented the control techniques and methods used in the textile industry, emphasizing the statistical control. Based on this control technology, we have answered the following questions: “why to control?”, “how to control?”, “who controls?” and “what is used to control?” at every operation during the garment fabrication process.

In chapter 4, we have started by investigating the defect causes and by classifying them. We have referred the textile industry, and from all inspection and control practices, we have created a synthesis and proposed a control and analysis system for the jean product. Using statistical techniques we have proposed a plan for the improvement of products and processes quality.

A large number of defects found have a similar cause: fabric defects. In this respect, in 2003, we have proposed an incoming inspection system, using image-processing techniques. From bibliographic research, one can realize the leading concept, employed today in many industrial systems. All the aspects of this idea are introduced in chapter 5.

By the original contributions and the analysis accomplished, the present thesis is offering a broad perspective on the textile industry quality systems, often covered by patents and secrecy. And they are maybe right, because "Craft must have clothes, but truth prefers to go naked".

Chapter 1

Quality and quality management

Quality has many senses and implications, starting by the project quality, goods production and services quality to quality of the whole company. In any case, quality remains a mean to attain an object, and not a scope itself. So, quality is defined as "fitness for intended use", "conformance to specifications" or "the totality of features and characteristics of a product or service that bears on its ability to satisfy given needs". In modern acceptation, quality is a complex notion, relative and dynamic, which implicate technical, economical, esthetical and ergonomically exigencies. It is measured by the grade of the utility and economical efficiency, assured by the product or activity, considered in outside of the consumers.

In this chapter, we complete a global image of the orientations and specifically aspects about product quality and quality management. The concepts and actual trends in the quality domain are presented, emphasizing the dynamic and global character of quality in the present context. Therefore we conceive a quality spiral applied to the clothing industry complex.

Due to the fact that until recently, it was a complementarity between the implementation of the quality system in the means of ISO 9000 and Total Quality Management, we highlight the introduction of some TQM principles inside of the eight principles of quality management, defined in ISO 9004:2000 for the first time.

Chapter 2

Textile Products Quality Planning

In this chapter, we present the problematic of the clothing quality planning, with the following aspects:

- The methods of determining garment markets, identifying target markets and classifying of customers needs regarding clothing, the relation between the customer needs, functions and quality characteristics, together with the quality dimensions of textile products.

- Customer perceptions of textile products quality, the performance expectations and measures methods of the product quality, applied to “jeans” product.
- The techniques used to identify quality characteristics and to describe into specifications and standards, applied both for automotive industry textiles and sport garments.
- We emphasize the quality control structure and conformability, corresponding to a specified quality level, applied in the case of the laminated fabric complex used for seat covers
- The process of quality costs planning, concretized to a garment company

The chapter is ended with applications of the quality planning methods and techniques, like “Quality function deployment” (QFD) and process design “Poka–Yoke” or “fool proofing” and Taguchi technology in textile industry.

Chapter 3

Quality control and assurance elements in textile industry

In this chapter we analyze the quality control and assurance methods in textile industry regarding the following aspects:
- Statistical process control is distinguished between the other analytical techniques to identify and minimize unacceptable variations in a firm’s products or process
- Sampling, with advantages and limitations resulted from the difficulty to select a reasonable number of products to represent the production lot. We underline the human aspect of sampling and we proposed sampling plans adequate for the garment production
- We had answered the questions “what is the scope of control?”, “how to control?”, “who is controlling?” and “what are the means of control?”, at each level in the technology control plan in a garment company.

Chapter 4

Practical aspects regarding nonquality in garment industry

If the product functions aren’t partially or totally fulfilled, the client is unsatisfied. In this case, analyzing the product can emphasize a lot of defects and non-conformities, which are considered nonquality characteristics. The nonquality characteristics are defined by the following:

Defect. ISO 8402 defines a defect as “the non-fulfillment of intended usage requirements or reasonable expectation”. This definition covers the departure or absence of one or more quality characteristics from intended usage requirements, including the security ones during the product using process.

Nonconformity. EN ISO 8402 defines nonconformity as, “non-fulfillment of a specified requirement”. The definition covers the departure or absence of one or more quality characteristics or quality system elements from specified requirements. It can be determined on comparing the product attributes with the specifications and standards or with a sample product.

To prevent the defects generation it is necessary to study them. In this direction, we have realize a presentation of the defect typology with a classification, pattern of defects and causality. All are necessary to establish an inspection technique adapted for every type of defect.

We had accomplished a synthesis of the most used methods of IM&T theory in the clothing industry. Because the AQL concept is the closed to Zero Defects policy, it tends to be the most used. In the past, customers would accept goods with 1%, 2%, or even 5% defects; today they satisfy their needs with companies whose production error levels are measured in ppm (parts per million), ppb (parts per billion) or ultimately ZD. To guarantee 100% quality through examination is impossible. Therefore, manufacturers are increasingly abandoning the control of products, preferring instead to control the system producing that product.

We have also performed an applied study to the "jeans" product in a local company and we had proposed a quality improvement plan:

- establishing the quality zones for this product
- specifying the dimensions and tolerances for inspection
- achieving a defects classification after their importance and conceiving a methodology of defects prevention and remediation
- using the Pareto diagram, we had analyzed the defects formation during the sewn process and we had established measures for Quality Control System reorganization and for the automation of defective operations.

Chapter 5

Applications of image processing in textile defect detection

Existent industrial applications of computer vision systems are directly connected to quality assurance requirements. The task of fabric defect detection is carried out by human visual inspection, in most of the traditional textile industry. The possibility of automated defect detection is investigated and a solution leading to improved productivity and high quality in the weaving process is proposed. We are introducing an unsupervised and robust system for the inspection of textured materials, based on multi-channel filtering. The Gabor function is employed for the filter bank and a cost function is used for filter selection. An appropriate thresholding of the filtered image followed by segmentation accomplishes the defect detection. Real image tests shows that our algorithm is robust and computationally efficient for the inspection of textured materials.

5.1. Introduction

Quality assurance systems have been developed in the aim of providing the client with a high level of trust in the producer's capacity to maintain permanently the product specifications according to standards and original technical design. The efficiency of these systems has already been confirmed by several international top corporations such as Motorola, Hewlett Packard, etc., whose specific implementation have become *de facto* standards (for instance *Six Sigma*). These aspects have persuaded client companies to migrate into producers certified for their efficacy and efficiency by quality assurance certification organizations.

Automatic production control is an important phase of quality assurance and its major scope is to prevent client supply with defective products. In the textile industry, due to the fact that all operations are hand-made, high productivity and quality can be achieved only by intensive quality inspection before and between the manufacturing stages. The high production speed and the large flexibility required by customers' urge to automated defect detection of the quality assurance system. In the traditional textile industry, this task is carried out by human visual inspection.

Manual inspection is usually a difficult task due to the small scale of detects and the large scale of inspected surface. In the case of the weaving sector, inspection is performed at the end of the manufacturing stage. Large batches of fabric rolls are manually inspected and actions are performed off-line of the production system. Employing computer vision automation directly on the production stage will improve the on-line reaction of the manufacturing staff and reduce the number of defects. Besides the high processing speed, computer vision systems can offer robust detection and large flexibility. Automation based on image processing does not suffer of human limitations and could entirely replace traditional methods.

Automated visual inspection relies on material properties as texture. Texture analysis techniques for fabric defect detection allows determining texture features and statistically segment defects. Gray-levels texture properties and statistics [Liu et al. 1998] are employed for local segmentation. Characterizing the fabric texture using a Markov random field model in [Özdemir et al 1996], detection is derived by hypothesis testing. In [Campbell et al. 1996], model-based clustering is used for woven fabric defects.

Since texture can be defined as a function of spatial variations in pixel intensities and possess a high level of periodicity, Fourier transforms and Fourier-domain analysis [Tsai et al. 1999], [Chan et al 2000] are convenient tools for discriminating texture variations. Multi-resolution approaches are decomposing fabric images in several scales using a bank of filters. Gabor function based filters are popular in the area of web defect detection [Kumar et al 2002] and texture inspection.

5.2. The Vision System Test Unit

5.2.1. Control System Design

The efficiency of a manufacturing control system depends on its accuracy and processing speed. A typical regulation system indicator is the reaction time, between the defect detection and the corrective action. The reaction time can be shortened by the use of efficient techniques for detection, analysis and data communication. These goals can be achieved by installing control points in specific manufacturing stages.

The manufacturing control system comprises the following operations:

- process / product control for deviation detection
- control data analysis for the determination of deviation causes and requested corrective actions
- information of the process operator on corrective actions (feed-back)
- process adjustment

Such a modern concept of manufacturing control system offers all the benefits of a short time reaction and the self-consciousness of quality among the manufacturing personnel. Thus, the activities must be carried out as close as possible of manufacturing points.

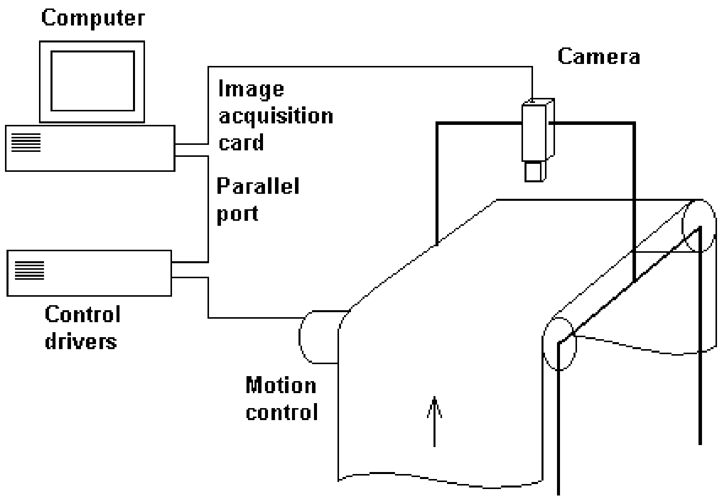


Figure 5.1. The vision system schematic

The unit designed for testing and implementation of a textile manufacturing control system is presented in figure 1. It consists of a PC based computer, equipped with an image-grabbing card and interfaced via the parallel with a loom motion control driver. Only one B/W camera was employed in our test, but the use of multiple units is overviewed for a complete coverage of the weave.

5.2.2. Vision System Design

The Gabor filters are resulted from a modulation product of a gaussian and sinusoidal signals. Gabor has introduced these elementary signals as optimal transmitional signal in telecommunication. Application of Gabor filters starts from edge detection and ends with texture classification and image compression. In the two-dimensional plane, the Gabor function has the following general form:

$$f(x,y) = \frac{1}{2\pi\sigma_x\sigma_y} \exp\left[-\frac{1}{2}\left(\frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2}\right)\right] \exp(2\pi j u_0 x) \qquad (5.1)$$

where u_0 is the radial frequency of the filter and σ_x, σ_y are constants defining the gaussian envelope along x and y axis.

Using function in equation (1) as a base, similar filter bank can be obtained by dilatation and rotation of $f(x,y)$ by way of the following expression:

$$f_{pq}(x,y) = \alpha^{-p} f(x', y') \qquad (5.2)$$

where

$$x' = \alpha^{-p}(x\cos\theta_q + y\sin\theta_q) \text{ and } y' = \alpha^{-p}(-x\sin\theta_q + y\cos\theta_q) \qquad (5.3)\ (5.4)$$

and $\alpha > 1$; $p=1, 2, ..., S$; $q=1, 2, ..., L$

The scale parameter p controls the dilatation of the original function to the maximum number of S scales and the rotation parameter q defines the number of possible orientations. For every value of q, the orientation angle is defined by:

$$\theta_q = \frac{\pi(q-1)}{L} \tag{5.5}$$

It has been proved that all filters in the bank have the same energy independently to their scale or orientation. In most applications, symmetric filter having $\sigma_x = \sigma_y$ are employed but one can imagine the use of an asymmetrical form.

The feature detection characteristic of the Gabor filters relies on the possibility of tuning the orientation of his frequency selectivity. Thus, choosing different values for p (scale) and q (orientation) will generate a series of filters. As resulted from equation (1), each filter has a real and imaginary part. For a given image $I(x,y)$, the filtered image $I_{pq}(x,y)$ is obtained as follows:

$$I_{pq}(x,y) = \sqrt{\left[f_{pq}(x,y)_r * I(x,y)\right]^2 + \left[f_{pq}(x,y)_i * I(x,y)\right]^2} \tag{5.6}$$

where $f_{pq}(x,y)_r$ and $f_{pq}(x,y)_i$ are the real and imaginary parts of the filter in equation (5.2).

Texture defect detection can be defined as the process of determining the location of various defects based on the textural properties of the input image. A quality control system implies an unsupervised process for defect detection, dealing especially with unknown texture defective patterns. As presented above, Gabor filters have a special feature that allow to texture tuning and consequently to respond in a different manner to texture irregularity. Unsupervised inspection is achieved by both local and global investigation. A bank of Gabor filters processes the input image. Each filter is chosen in order to respond on a small frequency and scale domain. In our method, the filter bank is generated using equation (5.1) and (5.2).

In order to perform the convolution in equation (5.6), the required S x L number of filters (real and imaginary parts) are computed in an M x M matrix form. The original image $I(x,y)$ is divided in N regions of k x k pixels. Each filter in the bank is applied to the each of the N regions and the filtered result is obtained using equation (5.6). Figure 5.2 presents the results of a defect texture filtering using different scale and orientation generated Gabor filters.

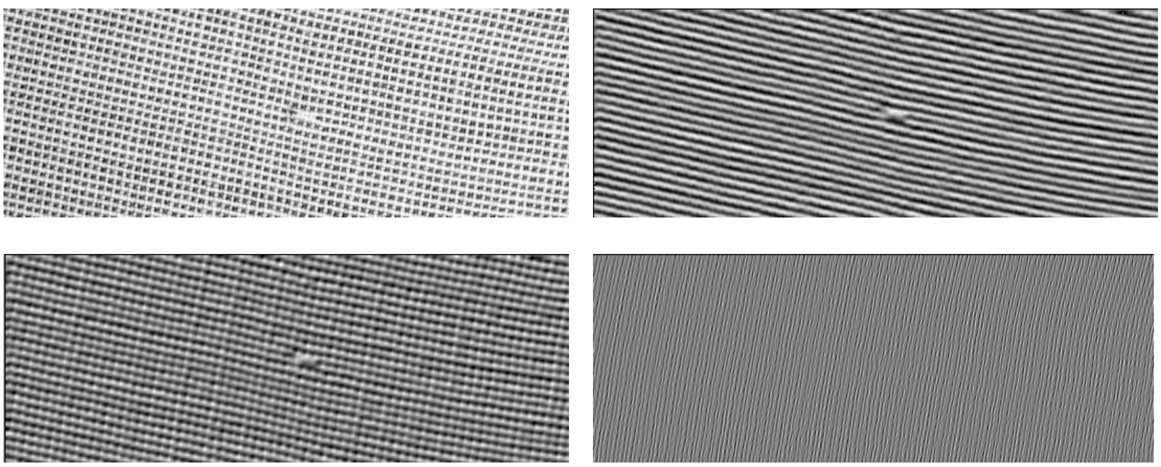


Figure 5.2. Results of texture filtering for different orientations and scales

The average result for every ith filter in the bank for any region n in N is computed by the following:

$$A_n^i = \frac{1}{kxk} \sum_{(x,y)\in n} I_{pq}(x,y) \qquad (7)$$

For every *i*-th filter among the *N* regions, a maximum $A^i_{\max}$ and minimum $A^i_{\min}$ average value is retained. The cost function will be the normalized difference between the two values:

$$C(i) = \frac{A^i_{\max} - A^i_{\min}}{A^i_{\min}} \qquad (5.8)$$

The filter having the highest cost function will be selected for defect detection and the original image will be subject to filtering. Then, a thresholding operation is required for the final segmentation of texture defects. Segmentation of the filtered image will perform defect detection. Choosing the appropriate filter represents the key to correct results. An unsupervised algorithm can be developed for the selection of the filter that performs large outputs in the case of defect texture and small output for defect-free. A cost function [Kumar et al. 2002] is required for the discrimination of the filters bank results.

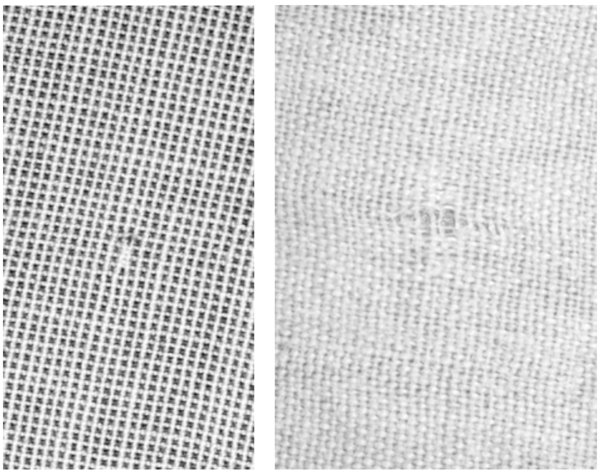


Figure 5.3. Samples of fabric defect images

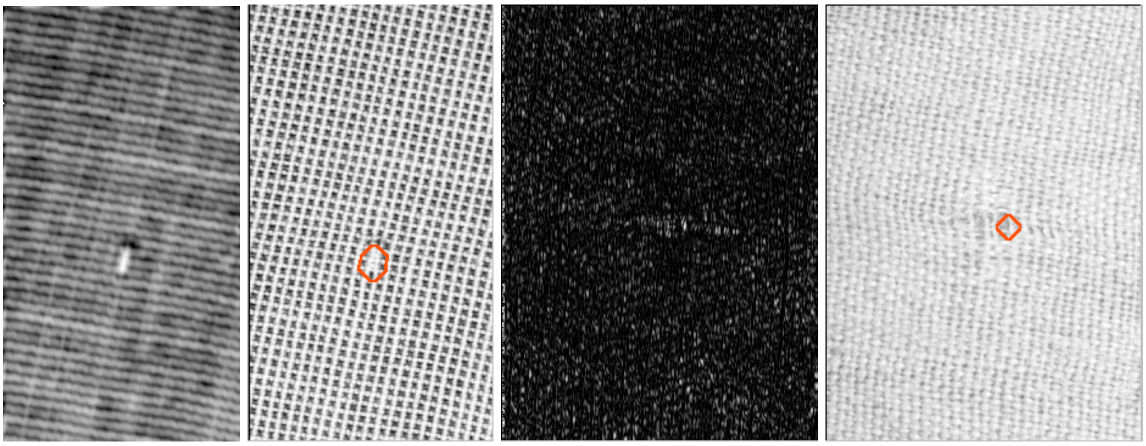
Selecting the threshold has been another challenging task. Some authors recommend using the maximum value resulted on the filtered image, having as original a defect free sample. In order to eliminate the pre-processing of a defect-free image, we are proposing an original method using as a threshold, the median value of maximum values obtained by applying the selected filter on all image regions:

$$Th = median(m_1, m_2, ..., m_N) \qquad (5.9)$$

where m_i is the maximum value of the *i*th filtered block in the partitioned image. As shown in the next section, our original method succeeds in emphasizing defects on the resulted binary image.

5.3. Experimental Results

Our experiments employed images of fabric texture and defects acquired with the vision test unit presented in figure 1. A bank of 24 Gabor filters processed the 256 gray level image. 4 scales and 6 orientations where considered for the filter convolution mask. After a series of experiments, the size of the filter was set at 9 x 9. Test images where grabbed at different resolutions and partitioned in 32 x 32 pixels regions. Figure 3 shows samples of textile defects considered in our work (break-out). Mispick, dirty-yarn and stains have also been investigated in [Brad et al. 2003].



a) b) c) d)

Figure 5.4. a) and b) results of original images filtered by optimal Gabor filter; c) and d) deffect detection after thresholding and region growing

Original images have been partitioned in regions and the Gabor filter bank is applied. Using equation (5.7) and (5.8), the best characterizing filter for the given texture is then selected. Figure 5.4 a) b) shows the resulting filtered images for the two considered samples. A binary image is obtained using an appropriate threshold, selected by the method proposed in section 5.2.2. Defect is emphasized on the original image using a region growing algorithm and considering pixels in the binary image. Final results of fabric defect detection are presented in figure 5.4 c), d).

5.4. Conclusions

The main goal of the proposed method is the improvement of quality assurance techniques. A bank of Gabor filters have been generated and a cost function based on maximum filter response for the given texture is used. In order to eliminate pre-processing of a defect-free image, a novel method for threshold selection is introduced. Based on a region-growing algorithm, the segmented binary image provides defect identification and localization.

The results have shown successful detection of a variety of fabric defects. Even if it covers most of the common defects from the weaving and knitting industry, tests will be conducted on other possible situations. Being computationally feasible, PC-based implementations of on-line fabric inspections can be developed. Future work will include the application of the proposed framework to other types of textures and an extensive investigation on Gabor filter bank design. Furthermore, research on a self adapting defect detection algorithm will be intended.

Using such defect detection systems can achieve:

- rapid and immediate improvement of technology and reduction of production detects
- detection of 90% of the defects (an human operator detects maximum 60%)
- 100% inspection
- possibility of usage 24/7
- lowering of the production costs

Chapter 6

Final Conclusions

This work presents the author's contributions in the field of quality assurance for the clothing industry, especially in defects detection by statistical means and image processing. From the author's point of view, it can be emphasized the following aspects:

The problematic tackled in chapter 1, started with a general view of specific aspects and directions regarding product quality and quality management. The concepts and actual trends in this field are presented, underlining the dynamic and global quality character in the economic and social context of the moment. The training program as part of quality improvement process with his role in motivating the organization members to improve the quality level, is analyzed at each level, with the principles and practices for each employee.

Having in view the entire product cycle, starting from marketing to sale, the author structured in this way the following chapters, permanently giving references and examples from the clothing industry. In chapter 2, a presentation of the problematic regarding product quality planning is made, starting from customer requirements and finishing at the same point. The author analyzes and particularizes the methods of determining garment target markets, the techniques used to identify quality characteristics and to describe into specifications, applied both for automotive industry textiles and sport garments. It's emphasizing the quality control structure and conformability, corresponding to a specified quality level, applied in the case of the laminated fabric complex used for seat covers. The chapter ends with the process of quality costs planning, illustrated for a garment company, together with the methods and techniques used for quality planning in the textile industry.

Chapter 3 is centered on the elements of control and quality assurance in the garment industry. First, the author presents the organizational structures for the quality assurance program, then these aspects are particularized in the case of the textile domain. Because this field is less theorized, a synthesis of the quality control methods and techniques was made, combining the common practices in Romania and other countries. Though in many cases total inspection is prevailing, the advantages of statistical control with a serial-sampling plan were emphasized. Procedures for maintaining the system of quality control were proposed.

Chapter 4 presents another important concept in quality assurance: nonquality. It starts with a state-of-the-art of defect typology, pattern of defects generation and drifts. Specific practices about inspection, measuring and testing in textile companies are presented. All type of inspection are reviewed and applied to jeans product in a Sibiu factory. In this respect, the author accomplished a detailed study of inspection systems in the manufacturing process with underlining the defect typology, causality, remediation and prevention measures. In each checkpoint in the sewing process, nonconformities are recorded within a month. Using statistical techniques, the author has proposed a plan for the improvement of products and processes quality, accepted by the company.

Every year, milliard of meters of weaving or knitted fabrics are checked, repaired and classified for sale or prepared for the next manufacturing process. These fabrics are verified two to six times for defects. The textile product control is accomplished manually, and because of long reaction time and leak of focus of human operators, an automated control system is required. Thus, a high control speed and precision can be accomplished. In chapter 5, the author presents a state-of-the-art of modern defect detection techniques using image processing. The Gabor function is employed for the filter bank and a cost function is used for filter selection. An appropriate thresholding of the filtered image followed by segmentation accomplishes the defect detection. Real image tests shows that our algorithm is robust and computationally efficient for the inspection of textured materials.

Due to the good results in texture image processing, the method was presented at 2003 and 2004 conferences. At present time, a simple search on Internet can show us that many commercial applications are using these methods, which denotes the foresight of the author's idea.

The methods, analyses and synthesis presented in the thesis were the subjects of more than 12 scientific articles published in the volumes of prestigious international conference, organized under Textile Institute, proving the scientific value. One of them was cited in a book with an international reference (Springer Verlag). The author had also participated at 1 CNCSIS grant in the image-processing field. We consider that one can appreciate the author's contributions to the development of defect detection techniques and analysis of apparel inspection methods.

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