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APPLICATION OF INFORMATION ENTROPY TO DEFECT CHARACTERISATION IN LEATHER

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Summary

The difficult task of producing automatic machines to identify defects in leather needs new concepts to ensure an easy and reproducible way of making decisions about the type and extent of the defects in leather.

This paper suggests *a* possible approach for the characterization and location of defects based on a new concept which *could* he *a* candidate as a one parameter decision maker This parameter *is* informational entropy.'

Introduction

fn the past two decades, the quality control performed in a laboratory somewhere in the plant has integrated itself into the manufacturing process. Quality control has evolved into process control. This change came about for obvious reasons of competitiveness. To achieve this major change, quality is no longer regarded as an absolute concept. By quality production we do not necessarily mean the production of superior goods. To produce quality, quality itself has to be quantitively defined as a desired degree of excellence or worth.

This definition implies that a certain number of properties have to be achieved in connection with the desired properties of the product. In the final judgment, all the factors including the ever present economical considerations must be taken into account.

Quality, in this context is obviously a function of a number of parameters. In this sense, quality has a vectorial nature with several components. In practice, the larger the number of the components which have to be measured to certify the predefined quality, the more time consuming is their monitoring. Also, the more difficult it will be for an expert system built into the manufacturing process to decide whether the desired quality has been attained. It is a well known fact that decisions based on a multiparameter set are very elaborate and highly time consuming.

In leather the definition of quality is, in most instances, very elusive. The number of the right physical or chemical properties required to accommodate the necessary attributes of leather, either finished or undergoing an intermediate process, is large.

There is a long way to go before on-line quality monitoring of production can be achieved in practical time and using the multiple parameter definition of quality. Measuring and taking into account all of the different parameters requires extensive computing facilities. Further it may not be feasible to adopt such a scheme to machinery with reasonable costs.

To change the following state of affairs: long measurement times, multiparameter decision and excessive computing, new concepts must be brought into play to facilitate the measurement of quality in the leather industry.

Quality is in most instances linked to a particular state of order in the spatial arrangement of leather. In essence, if one quantity exists, which is directly related to the degree of order and can characterize the effect of a process; that parameter, when measured, could be used to monitor and judge the quality of the materials. That parameter does exist, and could be described as entropy (in an information sense). It is shown in this paper that it can be readily measured. This paper will present the application of the entropy concept to the leather field.

All systems, including leather, exchange mass, energy and information with their environment, these systems have exchanges of energy which are characterized by thermodynamic entropy. In the case of leather, the exchanges take place in the form of messages which are characterized by the Informational entropy of the leather, regarded as a source of information.

In this paper, the term entropy does not mean the thermodynamic entropy; it refers to the entropy of a source of information as described by Shannon.' A leather material *will* be envisaged as a source of information. The privileged vehicle of that information is the light transmitted through or reflected by the material.

Informational Entropy

Information carried by light can be organized by a lens as an image. Computers can calculate the entropy of the image referred to as 'Informational Entropy', using the Shannon Formula.'

If the source of information sends a bunch of chaotic messages, its entropy is high; if the source sends just one message, its entropy falls to zero. Entropy of a source of information is then a measure of the quality of the information emitted by the source.

In any object, the optical messages depend on the physical, chemical properties and on the geometrical arrangement of its constituents.

The Informational Entropy of the information emitted by the materials and carried by light is a measure of its state, any departure from this state will be shown as a deviation in the entropy parameter.

Defects represent a deviation from a certain pattern, this means that defects in leather can be characterized by a single parameter, i.e. 'Informational Entropy'.

In the following we present a brief historical note on the discovery of this quantity and a method of characterizing defects in leather.

Application of the Concept of Entropy to Characterization of Defects in Leather

A **brief note on entropy:**

Thermodynamic Entropy:

At the peak of the industrial revolution, Rudolf Clausius, in 1850, invented a new word and discovered a new quantity. The name for this quantity was the result of joining up, `en', from the word energy, with the Greek word, `trope', which means evolution. This new quantity, `entropy', came to signify a residue of energy which is not accessible in any system undergoing a physical transformation. Any physical system left to itself would show a tendency for an increase in its inaccessible energy, i.e., its thermodynamic entropy will increase. Of course, this could not happen if work was performed on the system.

In order to produce a microscopic explanation for this new quantity, Ludwig Boltzmann, in 1869, showed the existence of a direct relationship between entropy and the distribution function of the energy of the atoms of the system. He also demonstrated that entropy was a measure of that distribution. He proved that, if the distribution function of the energy levels (e) of the constituents of a system is fe) then the entropy of the system is given by:

$$S= -\int f(\varepsilon) \log f(\varepsilon)\, d\varepsilon$$

The more homogeneous the distribution function, the greater is the degree of disorder and the higher is its entropy. This entropy is thermodynamic entropy.

The Entropy of a Source of Information - The Informational Entropy

Ludwig Boltzmann also showed that entropy is an intrinsic property of a system as its mass, electrical or geometrical properties and is a measure of its intrinsic order. He also pointed out how it could be measured.

Any existing system exchanges mass, energy and/or information with its environment. It is within this exchange of information that the distribution functions is to be found.

In 1949, Shannon[2], unraveled the way to penetrate the whole keyboard of messages which any physical system is emitting into its environment. Shannon found that if a message (x) has a probability p(x) of being received, its content of information to the receiver is given by:

$$\ln[1/p(x)] = - 1n\, p(x)$$

If *n(x)* of such messages are received, the resulting content of information is:

$$n(x)^* \ln[1/p(x)]$$

If enough time is allowed for all the different messages to be received, the content of information of the distribution function p(x) of the messages, (x) is:

$$S=-\int p(x) \ln[p(x)]\, dx$$

This is a key result. The similarity between equation (1) and equation (2) is striking. Shannon called the result of equation (2) the 'entropy of the source of information'.

It proves that the degree of order of any system, a fundamental quantity, can be measured by analyzing the distribution function of the messages it sends. These messages come in all forms, from sound waves to electromagnetic radiation and namely, light.

The question is then to choose the most appropriate means of being able to compute the degree of order of a particular system by computing the content of its messages using equation (2).

Informational Entropy

The entropy of a source of information is inferred from the messages sent by the system. In case of a leather product, most messages are carried by light, it is these messages that create its visual aspect, its image. Light is the privileged vehicle of information.

One of the types of messages that could be treated according to Shannon's results is images.

In these conditions, measuring the uniformity of a leather is reduced to the problem of calculating the informational entropy of its image. As indicated earlier this entropic measure of a leather is an intrinsic property just as any other physical or chemical macroscopic property. Only, this entropy is the measure of its state. This can be used to great advantage in studying entropy as a measure of the spatial arrangement of leather. The entropic measures of leather both finished or part-processed can provide the criteria for quality.

Entropy measurement can also allow comparisons to be made between methods and processes in industry as regards their ability to produce the right product, as this will be related to the degree of order.

If a leather material having an initial entropy S(i) is worked upon, using an amount of energy, E, the resulting material will have a final entropic measure, S(f). The relation between the initial S(i) and the final entropies S(f) depends on whether the work performed was effective. Informational entropy being as characteristic a parameter as for example mass or space or time are, it is not suitable for making direct comparisons between different types of objects, but it is very suitable for following the evolution of an object.

This evolution can either show an increment or decrement in the entropic value. In either case it will show whether these are variations (defects) from a standard.

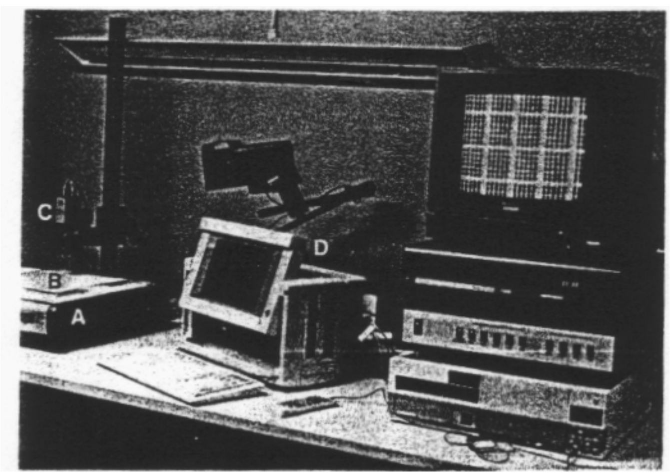

Figure 1. Equipment Layout.

Figure 2. Leather 1 Without Defects. Informational Entropy 5. 462

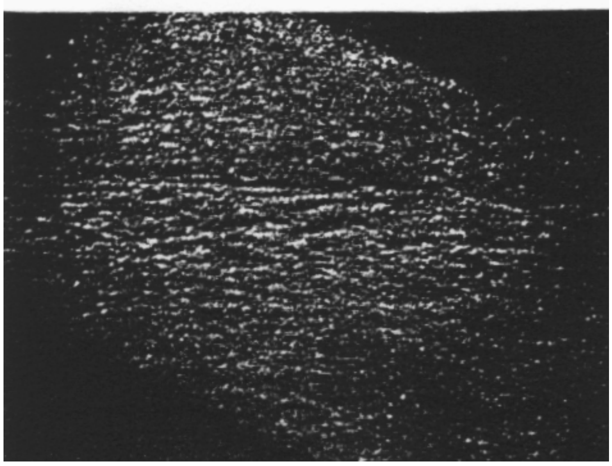

Figure 2A. Leather 1 With Defects: Informational Entropy: *5.492*

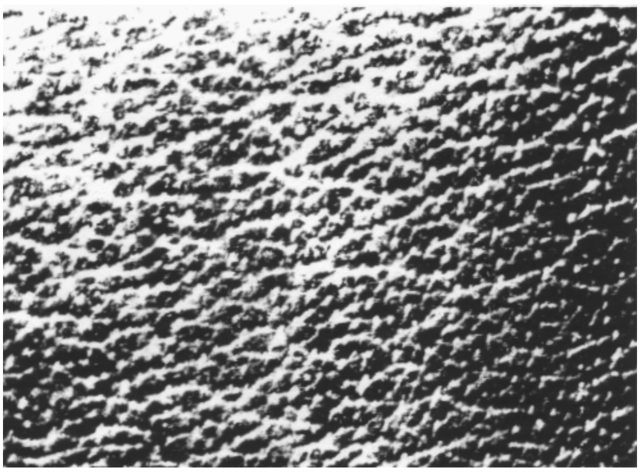

Figure 3. Leather 2 Without Defects: Informational Entropy 6.284.

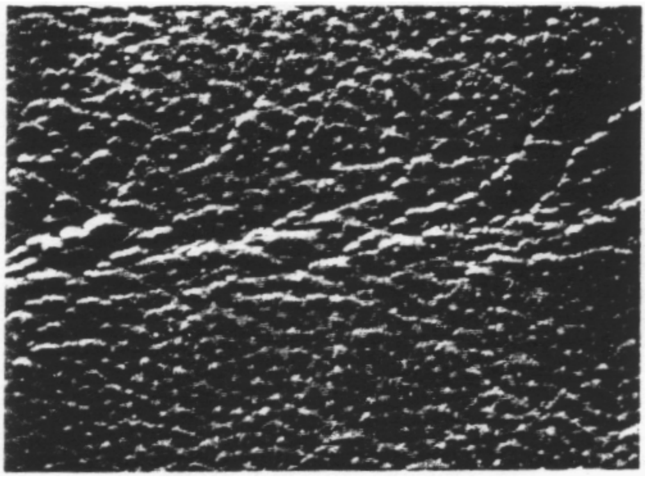

Figure 3A. Leather With Defects: Informational Entropy: 6.160.

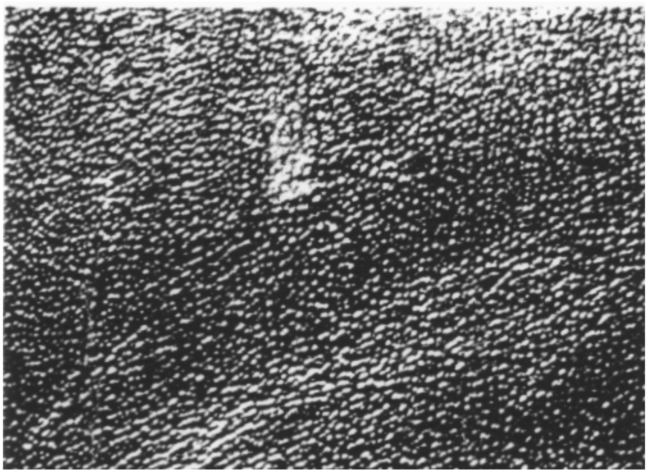

Figure 4. Leather 1 Without Defects: Informational Entropy: 6.286

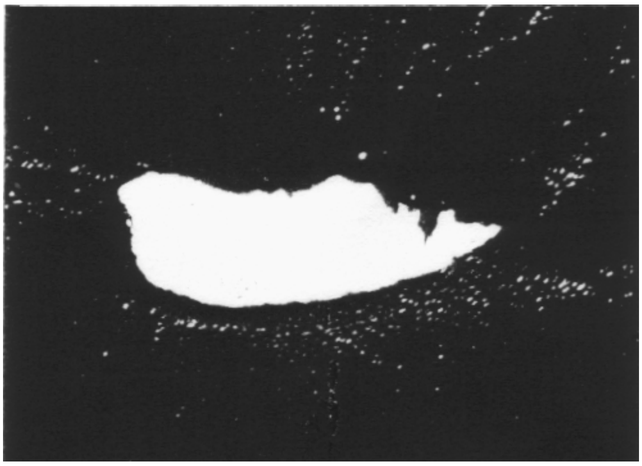

Figure 4A. Leather 3 With Defects: Informational Entropy 5 843.

Method of Measurement

The Theory

An optical system gathers the light transmitted or reelected by the leather and produces its image. The method is based on the computation of the informational entropy of this image.

Computing the information content or entropy of an image by a computer is very rapid. An image is composed of finite areas which constitute the picture's elements (pixels). Each of these pixels has a certain Illumination. This illumination is the elementary message (x). By counting the number of pixels which have he same level of illumination and dividing this number by the total number of pixels in the image. the probability p(x) of the illumination level (x) is found, After this has been done for all levels of illumination. then. Equation 2 gives the informational entropy of the image.

The Equipment Layout

Figure 1. shows the set-up for measuring the vision entropy of the image of a leather. It consists of an

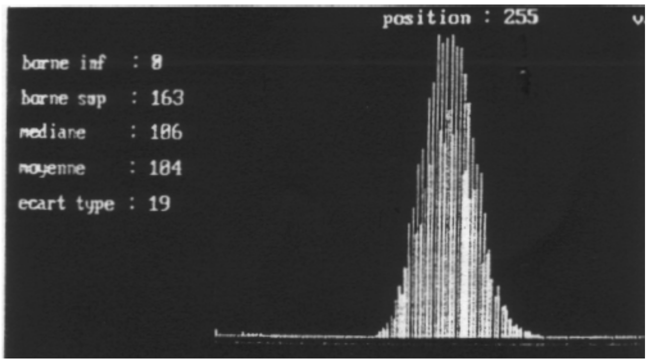

Figure 5. Grey Level distribution function of the Leather shown in Fig. 2.

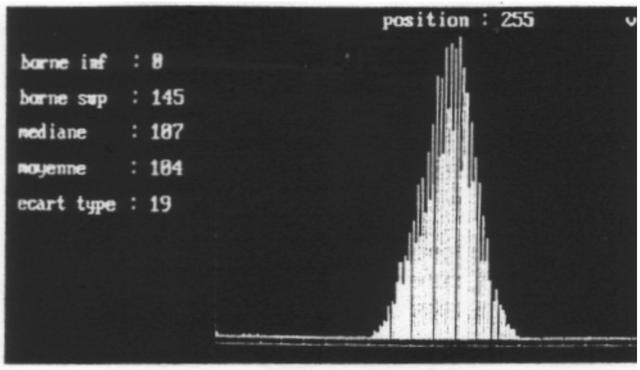

Figure 5A. Grey Level distribution function of the Leather shown in Fig. 2A.

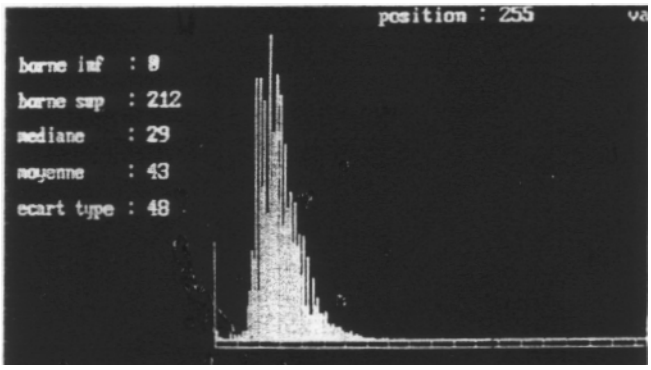

Figure 6. Grey Level distribution function of the Leather shown in Fig. 3.

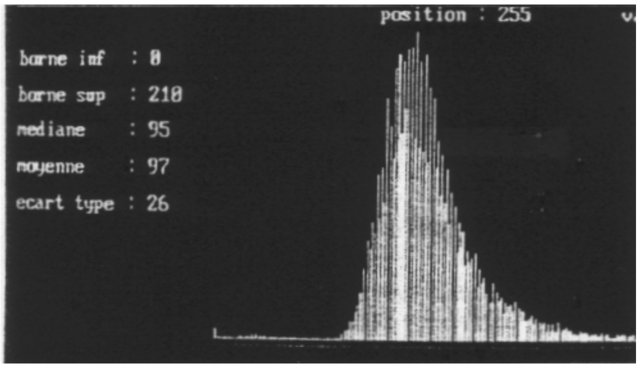

Figure 6A. Grey Level distribution function of the Leather shown in Fig. 3A.

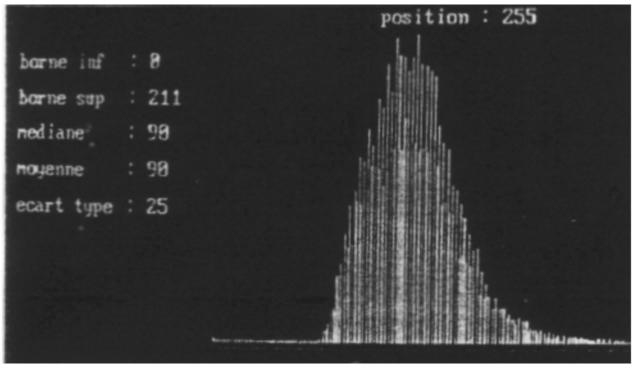

Figure 7. Grey Level distribution function of the Leather shown in Fig. 4.

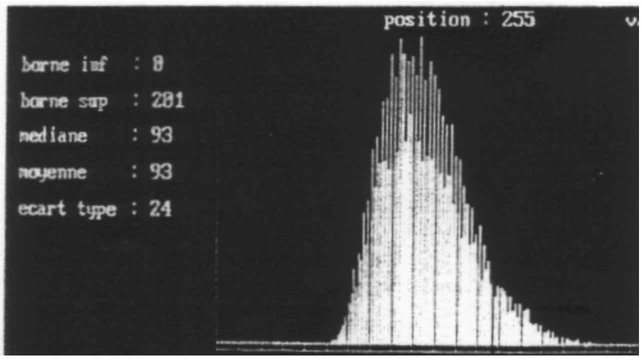

Figure 7A. Grey Level distribution function of the Leather shown in Fig. 4A.

illumination source (A), which remains spectrally stable and also uniform over the length and breadth of the material located on the illuminated stage (B).

A CCD camera (C), creates the electronic image of the material. The CCD and the electronics associated classify the levels of illumination in a certain number of what is called in image jargon, `gray levels'.

The number of gray levels in most standard image digitizers is 28, this means that the integral in Equation 2 becomes, in practice a summation (as in Equation 3):

$$S = - \Sigma p_i . \log p_i \quad (3)$$

where i represents the gray levels. The computer (D) linked to the camera digitizes the image, allocates to every pixel one of the 256 gray levels, calculates for every gray level the corresponding probability and follows the above equation to calculate the entropy. If base 2 is used to compute the logarithms in equation (3), the entropy of the material is expressed in bits.

The system, as it stands now, can acquire and compute the entropy at 30 frames per minute. This rate will be improved by many orders of magnitude by specific hardware built just for computing the informational entropy of the leather's image.

Results

The results in this report are aimed at providing the first experimental evidence that the introduction of this measure of the informational entropy in leather can be envisaged as being able to replace the multiparameter, multi measurement technique concept for quality control (Table I).

TABLE I
Informational Entropy Results

Leather	Defect free	With defects
Figs. 2 and 2A	5.462	5.492
Figs. 3 and 3A	6.184	6.160
Figs. 4 and 4A	6.289	5.843

In this first report we show the results obtained for four standard leather defects as well as the gray level distribution characteristic of changes in the aspect of leather (Figures 2 to 7A).

The defects show that informational entropy changes whenever a different aspect of structure is viewed by the imaging lens.

Conclusions

The method of measurement employed simple, standard, computerized vision systems which can be readily introduced in any existing or future machinery.

The informational entropy of a leather (understood as a source of information) is clearly correlated to its quality.

Every time defects or deviations are introduced the entropy changes. The informational entropy of a leather material is clearly a measure of its visual appearance and is related to the characterization of leather defects. It has also been demonstrated that informational entropy is an overall quantity encompassing the messages coming from the leather and is a parameter sensitive to defects.

Informational entropy of a leather as defined here and measured by the method described can be a candidate as a single parameter decision for defect characterization.

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References 1 The Hidden parameter in the textile process, Carvalho-Rodrigues *et al.. J. Textile Institute, 1989, 80, 4.* 2 Shannon. *The Mathematical Theory of Communication, (1964).* 3 Carvalho-Rodrigues *et al., SPIE Proceedings, 1989, 1075, 394.*