High resolution adaptive colour printing verification system for quality control of distorted elements

Artzai Picón Ruiz
Junior Engineer INFOTECH Dept.
ROBOTIKER, TECNALIA technology coporation.
Parque Tecnológico, Edificio 202. E-48170 Zamudio
(Bizkaia) SPAIN
apicon@robotiker.es, www.robotiker.com

Estibaliz Garrote Contreras
Senior Engineer INFOTECH Dept.
ROBOTIKER, TECNALIA technology coporation.
Parque Tecnológico, Edificio 202. E-48170 Zamudio
(Bizkaia) SPAIN
egarrote@robotiker.es, www.robotiker.com

Prof. Jose Angel Gutierrez Olabarría
Head Engineer INFOTECH Dept.
ROBOTIKER, TECNALIA technology coporation.
Parque Tecnológico, Edificio 202. E-48170 Zamudio
(Bizkaia) SPAIN
josea@robotiker.es, www.robotiker.com

Dr. Evaristo Kahoraho Bukubille
Head of Automatics and electronic Dept.
ESIDE (Univ. Deusto)
Avda. de las Universidades, 24. 48007 Bilbao
(Bizkaia) SPAIN
kahoraho@eside.deusto.es, www.eside.deusto.es

Prof. José Ignacio Larrauri Villamor
Prof. Automatics and electronic Dept.
ESIDE (Univ. Deusto)
Avda. de las Universidades, 24. 48007 Bilbao
(Bizkaia) SPAIN
ilarrau@eside.deusto.es, www.eside.deusto.es

Antton Azpiazu Kaltzakorta
Project Manager
Grupo Dam
C/Olaspe Nº18 20870 Elgoibar
(Guipuzkoa) SPAIN
a.azpiazu@gorosabel.com, http://www.gadia.com

Abstract: The growing quality needs, the importance of brand image and the market globalisation (texts printed in other languages (Cyrillic, Chinese, Arabic,…) make necessary total quality control specifically designed for printed elements. Quality control and verification of planar geometry elements have been resolved using classic techniques of pattern matching, histograms, difference image and other algorithms.
However, verification of elements which present minor deformations (plastics, clothes, metallic cans) produced by the nature of the material or by the printing method (rolls) is quite complex and has not been resolved yet because the printing can be considered correct although it presents minor deformations while it maintains certain visual features, but at the same time they must be very sensitive to tiny spots or other defects. The objective of this article is to present a novel verification method for printed elements which allows the quality control in this sort of products.

Key-Words: - **Machine vision, Colour Verification, Quality Control, Pattern recognition, Learning System, Printing**

1 Introduction.

The importance of the corporate image of trademarks is increasing and the companies are sensitive about their importance in the sales balance. The current market of printed products demands:

- Complete flexibility in the graphical design more and more sophisticated in form, patterns, and colour composition.
- Texts and symbols of other international codes (Oriental, Arabic, Cyrillic, etc.) due to the increasing market globalisation.
- Quality control of text printing of legal aspects, with a big importance in dangerous substances or pharmaceutical products.

These conditionings make a 100% printing quality control indispensable for this kind of products, even when this control is traditionally made in a visual and statistical way, with samples inspected by an operator. These controls efficiency is low due to the complexity of patterns, international codes, etc.

Image processing techniques are more and more used, mainly in quality control and verification of flat geometry and low elasticity elements. These applications are solved with classical image processing techniques of pattern matching, histograms, image difference and other similar algorithms.

Additional problems crop up either element material nature or printing techniques, because slight differences appear between product series that are correct at first sight and do not make the product defective, but they are detected as errors with classical methods, more sensitive to these differences than other small defects like little spots in the background. This does not imply that this application can be solved with a low exigency level control, because the process must be very robust and potent to detect small spots and defects around 0.1 mm^2, combined with a flexible interpretation of the image.

Other aspect that must be taken into account is that non defective characteristics are made with a “triptychs” or scale sets more than absolute values.

Due to the great number of characteristics that must be tested, the tolerated colour variations must be in some cases, stricter in certain zones (product quality, error visibility).

In this article a system capable of inspecting quality control of printed elements is presented, with the following characteristics:

- It classifies the (correct or defective) elements attending to their printed characteristics.
- It tolerates printing deformations produced on printing process.
- It detects a complete set of typical printing defects spots, blots, colour absence, off-centre prints…
- It is capable of self-adapting automatically to every element’s adequate tolerances.

This solution has been successfully tested on an automated system, but further details can not be given due to confidentiality reasons. Anyway, these techniques can be applied to any printing method.

2 Situation and Problem description.

In general terms the defects can be classified in these types:

1.- Off-centre prints: radial and axial. One of the layers of impression is shifted regarding the rest.

2.- Lacks of impression. Zones with partial or complete lack of impression.

3.- Variation of colour. Different intensities of colour are admissible.

4.- Folds in stamping. In some cases of impression by silkscreen (offset impression) the possibility of shifting, exists producing a small deformation in the printed details that can be considered tolerable.

The tolerances in these faults are determined using golden sets which estimate the actual allowed tolerances.

The problems detected in the previous tests were mainly the difficulty to distinguish between non acceptable errors and normal production variability produced by different causes such as:

- Acceptable progressive deformations caused by the production process.
- Changes in illumination not only in intensity but also in chromatic spectrum.
- Acceptable ink variations .

3. Classic image processing and their inconvenient for this application.

Next, a brief analysis of the classic processing technologies related to the quality control of printed elements it is shown.

3.1. OCR

OCR technology (Optical Character Recognition) is based in the automatic character recognition. The advantages and disadvantages of this technology for the printed elements problem are the following:

🡻 Quality control objective is not only to identify written characters.
🡻 Text is presented in any language including chinnesse, arabic,... and any sort of word.
🡻 Furthermore, the printed figures are normally at least, as important as the text.

3.2 Colour processing

The colour image processing [6] presents additional difficulties with respect to the monochrome processing, mainly related to the difficulties of colour representation.

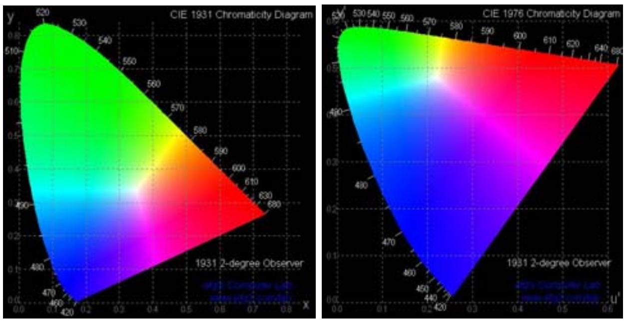

Fig 1. Colour Spaces.

Several studies on characterisation of color have been developed to search a useful description of colour. One that may solve the problem of colour processing in a similar way than human does. A physiological-like interpretation of colour could respond to the new difficulties arising with the advance of the technology and the fields of use of the colour.

3.2 Classical Histogram

The histogram is a fundamental image analysis tool that describes the distribution of frequency of the pixel intensities in an image. The histogram can be used to determine whether an image contains distinct regions of certain colour values. This method can be useful in easy color analysis. However, the main disadvantage that offers is the following:

- It uses color component information instead of real color information.

Current application needs to perform color verification similar to human perception which perceives real colors, not color components.

HSI components can solve the problem partially, but they do not consider colors in a global sense.

3.3 Difference Images

There are different methods for image differences. This sort of algorithms are used normally for image comparison using not only the presence of some elements but also their location.

The real difficulty of using this technique is to measure when a RGB components difference is a defect or when it is an admissible variation.

In most cases, the differences produced by tolerable variations are higher than the differences caused by real defects as shown in Fig 2.

Fig 2. a) Image with spot b) valid model with tolerable geometric deformation 5% c) conventional difference (geometric effect is greater than spot effect).

3.4 Pattern matching

Pattern recognition techniques are used for model location and identification. These techniques are based on the extraction of some features in a region which is called pattern and its later location of these features in another image.

It is a very time consuming technique so it is not useful to be used in large pattern or large regions search because of the amount of required time.

4. Developed algorithms.

Due to the explained limitations, it has been necessary to explore and develop new processing algorithms.

4.1 3D Histograms

3D Histogram [2] is a technique that has been used in searches in image database. It is obtained considering the number of image's pixels that have the same colour. It is called 3D because a colour has three components (RGB). This approach describes the frequency of appearance of colours. However, it does not provide position information.

With this 3D values the algorithm performs the comparison between an obtained pattern of one or several reference images and the image to verify. This comparison is done using histogram distances and statistical values from the 3D histogram.

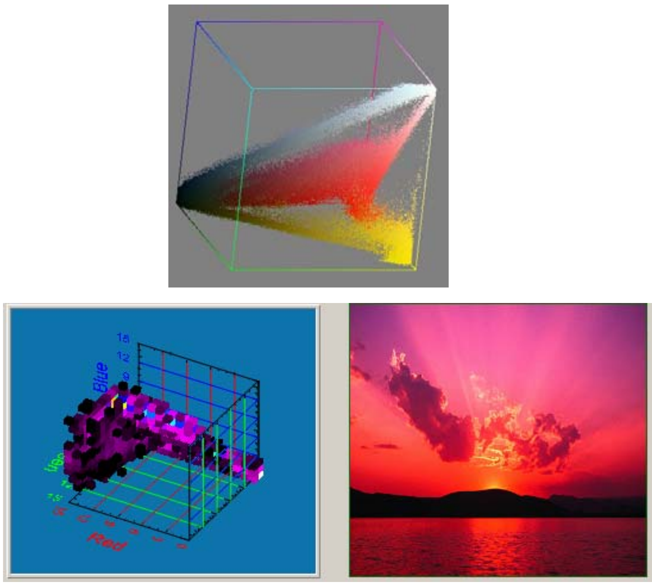

Fig 3. 3D Histogram of an image. The density of points shows the amount of pixels of each colour.

The results of this technique were not enough to reach the proposed requirements. So, its use as main algorithm was discarded, however this approach is used as statistical estimator in the autopattern search.

4.1.1 Distance measurement

From a mathematical point of view there are several different ways to measure distance [3] [5]. Next, the ones related to the project are explained.

4.1.1.1 Euclidean distance

It is the classical concept of distance between two points. It measures the distance between two curves in the y axis.

$$d_E(h,g) = \sum_{m=0}^{M-1} (h[m] - g[m])^2$$

The disadvantages are:

↓ It does not take into account small displacement that the histogram may have because of the illumination or printing changes.

4.1.1.2 Quadratic distance

It is a more complex way of measurement, where the distances are introduced with a weight factor $a_{mo,ml}$ that indicates the resemblance between two colours mo and ml.

$$d_Q(h,g) = \sum_{m_0=0}^{M-1} \sum_{m_1=0}^{M-1} (h[m_0]-g[m_0]) \cdot a_{m_0,m_1} \cdot (h[m_1]-g[m_1])$$

The advantages and disadvantages are:

↑ It allows measuring horizontal displacements in histogram's curves.
↓ It needs too much time for processing that makes it, at the moment, unviable.

4.1.1.3 Intersection

It measures the intersection of two histograms, the grade of similarity.

$$d_\cap(h,g) = \frac{\sum_{m=0}^{M-1} \min(h[m], g[m])}{\min(\sum_{m_0=0}^{M-1} h[m_0], \sum_{m_1=0}^{M-1} g[m_1])}$$

The disadvantages are:

↓ It only measures the lackness of colours.
↓ It is highly dependent on the illumination.

4.1.2 Inertia

This method measures the morphological characteristics of the 3D Histogram. (see figure 3.) This mesh of points is considered as a solid with a centre of mass, inertial moments…

This method can detect small defects as it allows illumination changes.

4.2 Adaptative modelling

Adaptative modelling is a method that integrates the possible changes in size, position and rotation of the image's elements. It is obtained a normalised image that can be compared with the original model.

Due to printing techniques the defects include geometric and color changes. In some cases, there are changes considered acceptable although they have printing offset up to 1mm. But at the same time, a color lackness of 0.5 mm^2 is considered unacceptable. As the kind of defects are not easily characterizable, it has been necessary to develop an adaptative tolerance-learning system that takes into account this matter.

5. Final Implemented Solution.

Based on the research's results the final solution consists of the following steps.

5.1 Geometric Correction

A group of patterns distributed all along the image is located. Using this information the image is normalized by a geometric fit.

5.1.1 Automatic obtaining of candidate patterns

Patterns location is made automatically using a selection algorithm.

First of all, several patterns are chosen as candidates. The image is divided into cells, being each cell a possible pattern candidate. All these patterns are not suitable for being a useful pattern, because there are elements which have not enough information or they can be located in different positions.

Fig 4. Samples of correct patterns (white) and incorrect ones (grey).

To solve this, a selection algorithm identifies the incorrect patterns using several sample images of the inspected element.

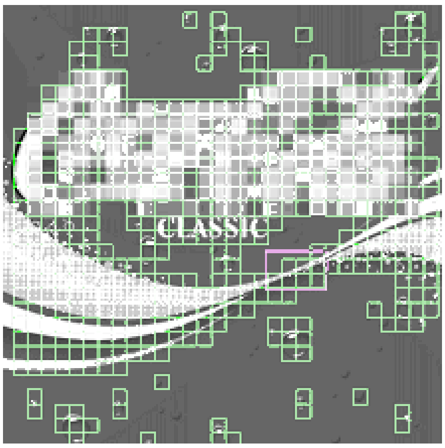

Fig 5. Patterns located by the autopattern algorithm.

The patterns that do not have certain values in 3D Histogram statistics are erased. In a second stage, the patterns which have similar matches in their neighborhood are removed. Finally, the presence of the pattern in the rest of samples is verified, being excluded if:

- It is not found in a n% (~90%) of the images.
- There are similar patterns in its surroundings in anyone of the images.

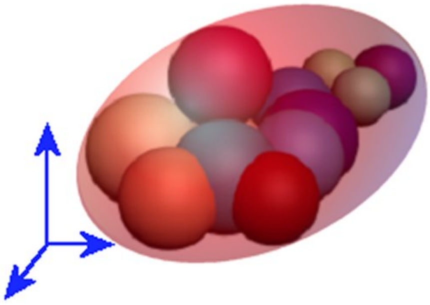

Fig 6 Model' s representation in 3D Histogram.

5.2 Geometric relation between patterns

When a new image is presented, patterns are located and a normalized image is made up accomplishing the corresponding geometric transformations and using the distances between the real patterns and the distances between the patterns of the present image.

5.3 Establishment of maximum tolerance in geometric deformations.

Using a group of correct images, the system learns the geometric deformations between them. With these values the system sets the threshold level cataloguing as erroneous elements those which exceed the previously calculated values.

5.5 Establishment of tolerances for colour variations

Introducing a group of correct images the system is able to learn the tolerances in colour variations, being more restrictive in those zones in which a greater tolerance is allowed and less restrictive in those ones where higher tolerance is allowed.

5.6 Count of errors.

Dividing the image into cells, the system evaluates each cell looking for areas that do not comply with the tolerance. If the features of these zones have enough size to be considered as erroneous, the printing element is considered incorrect.

Fig 7. Printing with variation of tone of a 5%, conventional difference (the effect of the tone variation is greater than the spot) and image obtained with adaptive models and filters.

5.7 System acceleration

The amount of data to be processed is high (12Mb per image), so it has been necessary to increase the processing speed. In order to reach the production rates (60 images/ minute) and dedicated structures, functions and MMX programming have been developed. With this new procedures a 66% time reduction has been achieved.

6. Results.

This project has been developed inside the SPRI (Basque Government) program “I+D INTEK”. In attention to the confidentiality requirements the real application has not been mentioned.

At the moment the project is nearly finished, the system is installed in final-users facilities where the final tests are been carried out. The system offers a 100% quality control of the printed elements.

0,1 mm^2 defects are detected inside surfaces of 40.000 mm^2. The inspection speed objective is about 60 verifications per minute.

As especial features of the application, apart from the previously mentioned ones, it must be commented the machine vision intrinsic problems: illumination uniformity, colour quality and brightness, position control and synchronisation.

7. Conclusions.

A fully operative colour system has been developed to perform the verification of distorted printed elements. All the complex problems related to the manufacturing process have been successfully solved.

Besides solving colour inspection problem in deformable elements it also offers the following relevant features:

- Reliable.
- Self- learning.
- Adaptative.
- Flexible.
- User friendly.
- Economically viable.
- Fully operative.

A new way in the printing quality control inspection has been opened.

8. Acknowledgements.

The authors are grateful to Basque Government for its partially supporting of this project though the project VICON.

References:

[1] Malacara Daniel, Color Vision and Colorimetry, Theory and Applications. Ed SPIE Press.

[2] Gouping Qiu, Storing and retrieving images. G5AIVI *Introduction to Vision and Image Processing, 2003.*

[3] Xuequn Li and Irwin King. Gaussian mixture distance for information retrieval. In *Proceedings of the 1999 Internation Joint Conference on Neural Networks (IJCNN'99),* volume CD-ROM, page #2070, Washington DC, July 10-16 1999. IEEE..

[4] Garrote Contreras Estibaliz ROBOTIKER, State of the art in colour machine vision. *1.999 www.robotiker.com*

[5] J.R.Smith, Single color extraction and image query. *www,ctr.Columbia.edu/ ~jrsmith*

[6] T.F. Syeda, Finding distinctive colored regions in images in *Proc. SPIE Conf. on Intelligent Robots and Computer Vision IX : Algorithms and Techniques, Boston, Nov. 1990.*