Non-Linear Image Processing applied to Template Matching

J.M.Sebastian*, R.Aracil*, F. Torres†, L.M.Jimenez†, O.Reinoso*

* Polytechnic University of Madrid. Dept. of System Engineering and Automatica,
José Gutierrez Abascal, 2. 28006 Madrid (Spain)
e-mail: aracil@disam.upm.es

† University of Alicante. Dept. of System Engineering and Communications,
Crtra. San Vicente, s/n. 03080 Alicante (Spain)
e-mail: medina@disc.ua.es

Abstract

In this paper we present the problem that arise when template matching is applied to two images of the same objects displaced in both axis, and how this problem has effect at the detection of imperfections with precision near to pixel.

Also, we show up a solution, through the use of two master images. These images achieved through non-linear processing applied to original image based on morphological processing. In this way, we demonstrate that is possible to detect imperfections with resolution near to pixel-level.

Key Words : Non-linear processing, template matching, morphological processing, automated visual inspection, high resolution.

1 Introduction

The sought purpose with an Automated Visual Inspection System, as in any human or artificial inspection, is the analysis of a set of features sensed from the parameters of an object to be controlled, proceeding from pattern matching or a set of off-line pre-stablished rules. [1][2].

The more commonly used inspection algorithms, in both binary and grey-scale images, make use of different methods based around techniques as: matching with a reference image or pattern [3][4]; checking of a set of rules [5][6]; combined use of pattern-matching and rules based techniques [7][8]; morphological analysis [9][10]; differential scanning [11]; spatial filtering [12][13].

One of the areas where the field of Automated Visual Inspection has been more developed, is the inspection of printed products, specially in printed circuit board and microelectronics printed process. Most of the before refereed inspection algorithms have application in this type of inspection. Although probably the more used is the matching with a pattern image.

Matching with a pattern or reference image, constitutes one of the more used methods in the detection of defects by means computer vision. A large variety of research lines in the field of automated visual inspection have been developed around the use of this technique. However, the algorithms based in the feature extraction by pattern matching [3][4] presents some disadvantages, centred mainly around the need of storage memory for the pattern [11]; sensitivity to the lighting and sensors [14]; high requirements in the product registration [15]; subpixel discretization effects [16].

2 Template-Matching: registration with pixel precision. Effect in the comparison process.

The process of detection through template matching requires searching for specific significant points which then facilitate the comparison process with master image, where the master image is previously acquired in, or an image is generated artificially from a CAD design [17].

However, usually in template matching is used the detection and later registration with pixel precision, which is insufficient if it is necessary to detect small imperfections at pixel precision.

Figures 1 and 2 show two acquisition the same objects - in this case a partial view of the bill-sheets - with displacement in both axis between the two. The detected position for one significant point on the Figure 1 is the value (429’3, 255’2); Figure 2 shows the analogous significant point, in this case is at point (434’6, 254’6). The difference between two images is (-5’3, 0’6).

Figure 1. (429'3, 255'2)

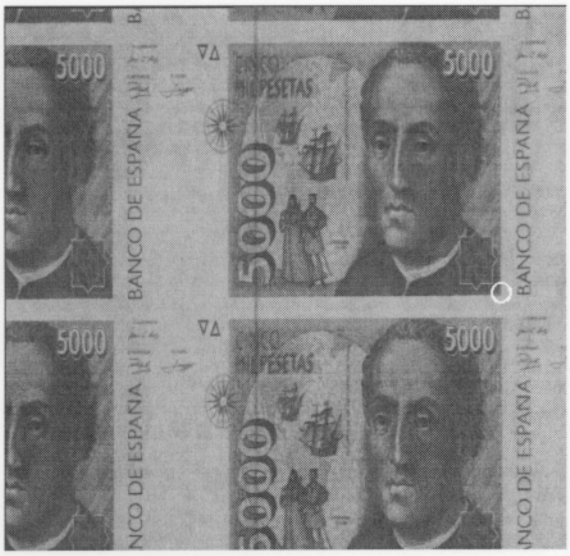

Figure 2. (434'6, 254'6)

When image 1 is matched with image 2, although the positions of the two images does not correspond to an integer number of pixels, physically the displacement of one to the position of the other must be done by an integer number of pixels. There is four possibles displacements: case a (-5, 1); case b (-5, 0); case c (-6, 1); and case d (-6, 0). This effect can be observed in Figure 3.

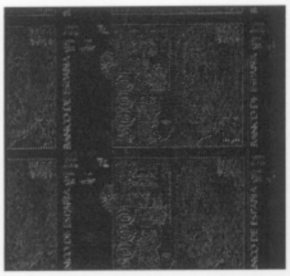

Figure 3.a. (-5, 1)

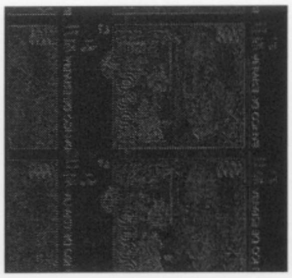

Figure 3.b. (-5, 0)

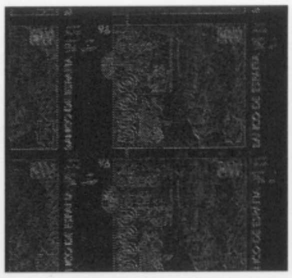

Figure 3.c. (-6,1)

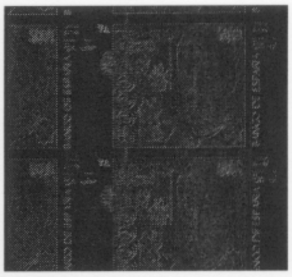

Figure 3.d. (-6,0)

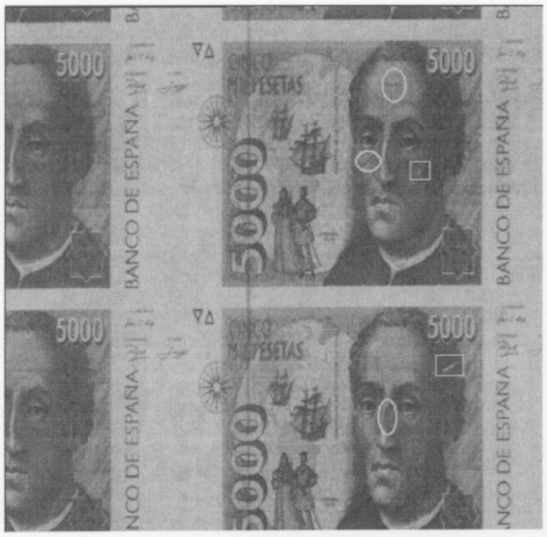

Figure 4. Image with imperfections

As can be seen, there is not zero error image when are matched the same objects in different acquisition. These differences make it impossible to detect flaws of a resolution near that of a pixel, which makes for a less effective method, then it is necessary to make the filtering of the error image.

Figure 4 shows the original image with five imperfections, three of them - marked with a circle - are excess ink imperfections, and the other two - marked with a rectangle - are lack of printings imperfections.

Image 5 shows one case of the matched between the image 4 and the original image. As can be seen, it is impossible to differentiate the real errors from those caused by the comparison process, as the imperfections are of the exact same magnitude as the edges in high-contrast areas, due to the digitalisation of analogue signals. Furthermore, the filtering of the error image does not solve the problem, since it is evident from image 6 that this can cause an irreparable loss of data.

Figure 5. Case (-5, 1)

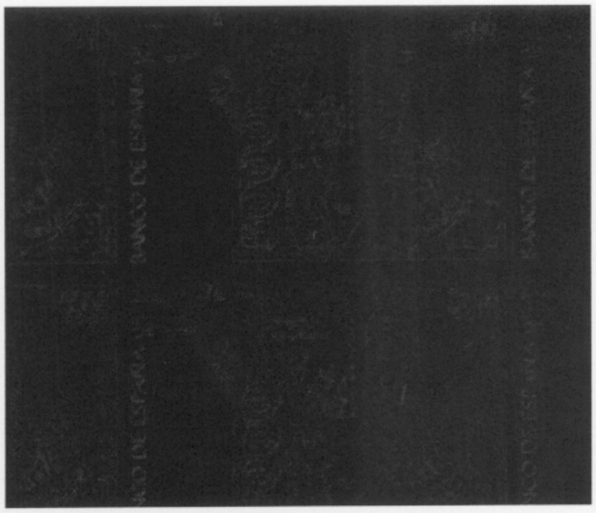

Figure 6. Filtering of the image 5

3 Extension of the morphological analysis to the Template-Matching

The morphological processing of images, pioneerly developed for Georges Matheron [18] and Jean Serra [19], is today a important tool for the image analysis with pre-defined shape, problem that is presented at the automatic visual inspection of images with printings.

This section describes an original algorithm which solves the problems that arise applying the template matching technique. The algorithm is based on morphological operators for the gray-scale digital images [20][21], and facilitates detection of imperfections at near-pixel precision.

The essence of this method consists of the use of two master images, so that between the two a validation range is defined for the product - excessive and default imperfections - while differences due to bad positioning of the images are assumed. These variations produced during digitalisation of the image are due to two factors: one due to improper physical positioning, whose upper limit is 0'5, and the other is the error produced in the process of detection of characteristic points, both in the image to be analysed and that of reference and which is estimated at 0'1.

An image with valid shades must have the values associated with all of its pixels between those existing on each one of the two master images, corresponding to the upper and lower limits. The master image which defines the upper image in the range of intensities is referenced as the maximised master image. Similarly, the image which corresponds to the minimum intensity values is referenced as the minimised master image. Equation (1) describes the condition that each pixel at co-ordinates x,y must meet for an analysed image to be validated:

$$\forall\, x,y \in \mathrm{Image} \Rightarrow f_{p_{min}}(x,y) < f_{image}(x,y) < f_{p_{max}}(x,y) \qquad (1)$$

Under the above conditions, the pattern of excess imperfections is obtained by multilevel eroding of a valid image with a flat structuring element [21] whose value is 0'5+2×0'1=0'7. The defect master image is obtained in a similar manner, except that on this occasion the process applied is a multilevel dilation with the same structuring element. Figures 7 and 8 show the minimised master image - eroded image- and maximised master image - dilated image-.

Figure 7. Minimised master image

Figure 8. Maximised master image

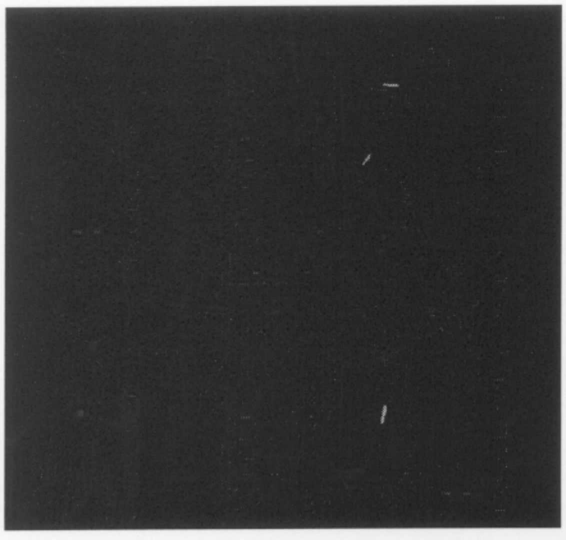

Figure 9. Excess ink imperfections

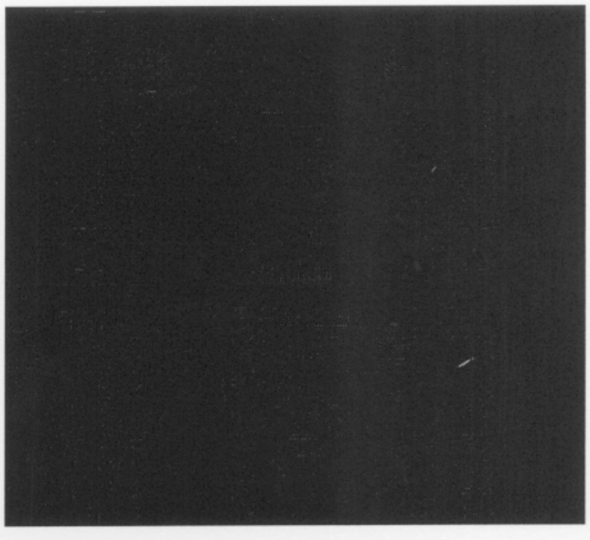

Figure 10. Lack of printings imperfections

When the comparison is made between the image 4 with five imperfections and these master images, as can be seen in images 9 and 10, only the imperfections appear.

The results obtained through the application of the technique described are substantially better than those obtained through mere comparison, which is the more traditional method of detecting imperfections through comparison with reference images.

4 Conclusions

It can be remarked the inspection methodology expressed through the use of two master images, which a non-linear morphological processing is applied at. This methodology allows to solve the problem that arises from the correspondence between two images through template matching. With this technique is possible to achieve the detection of imperfections with a pixel-level resolution.

This methodology allow to provide a powerful tool in applications of computer vision in the field on automated industrial inspection, in the way to increase the performance of the system.

References

[1] *Machine Vision Techniques for Integrated Circuit Inspection*, Machine Vision for Inspection and Measurement, Academic Press, B. Dom, 1989.

[2] *Automatic Defect Classification for Integrated Circuit*, Proc. SPIE 95-102, P.B.Chou, A.R.Rao, M.C.Sturzenbecker, 1993.

[3] *Parameterized Point Pattern Matching and its Applications to Recognition of Objects Families*, PAMI-15, 136-144, S.Umeyama, 1993.

[4] *A Theory of Image Matching*, 3rd International Conference on Computer Vision, 200-209, J.Weng, 1990.

[5] *Automated Optical Inspection of Multilayer Printed Circuit Board*, Proc. SPIE Optics in Metrology and Quality Assurance, 102-109, W.A.Bentley, 1980.

[6] *A Knowledge-based System for the Image Correspondence Problem*, International Journal of Pattern Recognition and Artificial Intelligence, 4, 45-55, C.M.Lee, T.C.Pong, J.R.Slagle, 1990.

[7] *An Integrated Pattern Inspection System*, Proc. 8th International Conference on Pattern Recognition, G.Odawara, I.Ogata, M.Arase, H.Tekeya, 1988.

[8] *A System for the Automatic Visual Inspection of Bare Printed Circuit Boards*, IEEE Trans. System Man Cybernet, 767-773, G.A.W.West, 1984.

[9] *Image Analysis using Mathematical Morphology*, PAMI-9, 532-550, R.M.Haralick, S.R.Strenberg, 1987.

[10] *Object Representation and recognition using Matehmatical Morphology Model*, Journal Systems Integration, 1, 235-256, F.Y.Shih, 1991.

[11] *Automated Visual Inspectionc*, CVGIP, 41, 348-381, R.T.Chin, 1988.

[12] *Industrial Optical Sensing and Metrology: Applications and Integration*, Proc. SPIE, K.G.Harding, 1993.

[13] *Algorithms for a Fast Confocal Optical Inspection System*, Applications on Computer Vision, 298-305, A.R.Rao, N.Ramesh, F.Y.Wu, J.R.Mandeville, P.J.M.Kerstens, 1993.

[14] *Optics, Illumination, and Image Sensing for Machine Vision VI*, Proc. SPIE, D.J.Svetkoff, 1991.

[15] *Arquitectura Paralela para el Procesado de Imágenes de Alta Resolución. Aplicación a la Inspección de Impresiones en Tiempo Real*, PhD E.T.S.I.I.M., U.P.M., F.Torres, 1995.

[16] *Análisis y Generalización de Algoritmos de Visión Artificial con Precisión Subpixel*, PhD E.T.S.I.I.M., U.P.M., O.Reinoso, 1995.

[17] *A Survey of Automated Visual Inspection*, Computer Vision ans Image Understanding, 61-2, 231-262, T.S.Newman, A.K.Jain, 1995.

[18] *Ramdom Sets and Integral Geometry*, Wiley, G.Matheron, 1975.

[19] *Image Analysis and Mathematical Morphology*, Academic Press, J.Serra, 1982.

[20] *Image Analysis and Mathematical Morphology II: Theoreical Advances*, Academic Press, J.Serra, 1988.

[21] *An Introduction to Morphological Image Processing*, SPIE Tutorial Text Series, E.R.Dougherty, 1992.