



## IMAGERY: A VIRTUAL LABORATORY FOR TRAINING ON DIGITAL IMAGE PROCESSING

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### Resumen

Los libros de Procesamiento Digital de Imágenes (PDI) exponen algoritmos para operar digitalmente sobre imágenes e incluyen algunas figuras para mostrar el efecto de los mismos. En este trabajo se reporta la creación de Imagery, un Laboratorio Virtual para educación (enseñanza y aprendizaje) asistido por computadora. Este software ha sido creado para ser usado como laboratorio de PDI, permitiendo al usuario experimentar con los algoritmos de PDI, visualizando sus efectos en sus propias imágenes; Imagery puede ser usado en clases, en el laboratorio o en el hogar, en clases, ayuda al profesor a exponer los temas que se están cubriendo; en el laboratorio puede ser usado para realizar experimentos de temas cubiertos en clase; en el hogar, sirve al estudiante para revisar y afianzar los conocimientos adquiridos en clase. Imagery puede también ser usado por el estudiante independiente en un sistema de Aprendizaje a Distancia. La ventaja de usar un software para enseñar transformaciones sobre imágenes, como aquellas ejecutadas en PDI, es que con la ayuda del software dichas transformaciones pueden ser apreciadas en tiempo real. Aparte de tratarse de un software intuitivamente fácil de usar, Imagery no solo opera sobre imágenes proporcionadas por su autor, sino también sobre aquellas del usuario. El autor ha incluido alguna teoría en Imagery, la cual es un complemento a libros o clases especializadas, no es auto suficiente, pero es una gran ayuda.

**Palabras clave:** Procesamiento digital de imágenes, visión computacional, visión cibernética.

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### Abstract

Digital Image Processing (DIP) books teach algorithms to digitally operate on images and include some figures to show the effects of those mathematical tools. In this report the creation of Imagery, a Virtual Laboratory for computer-assisted education (teaching and learning) of DIP is reported. Imagery can be used in the classroom, in the laboratory or at home. This software was developed to be used as a DIP laboratory, allowing the user to experiment with DIP algorithms, enabling him to see their effects on his own images. In the classroom Imagery helps the teacher in the exposition of the DIP topics he is covering; in the laboratory, Imagery can be used to carry out experiments supporting the topics covered in class; at home, this Virtual Lab can be used by the student to practice and thus reinforce the knowledge acquired in class. This software may also be used by the independent student or by that under a Distant Learning program. The advantage of using software to teach a given image transformation like those performed in DIP, is that with the help of the software the transformations can be appreciated in real time. Besides being intuitively easy to use, Imagery not only operates on images included by its author, but also on those provided by the user. The author has included some supporting theory in Imagery, which is a complement to specialized textbooks or classes, it is not self sufficient, however it is a great help.

**Keywords:** Digital image processing, computer vision, cybernetic vision.

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## 1. Introduction

Most books on Digital Image Processing (DIP) <sup>1-5</sup>, expose the theory and Mathematics of this relatively new field including one example (maybe two) and from this the student has to appeal to his/her imagination in order to assess the power of the algorithm the book is dealing with, the teacher has to make use not only of chalk and blackboard but also he must use images in order to show the original image and the final one after the image transformation with a given algorithm.

If a student feels curiosity or interest for a given topic, he has to make the computer program to visualize the results, thus wasting time and effort. In these cases it would be much better if the instructor had a software with which he can dynamically show the students what he is talking about. The class would be not only much more dynamical but also interesting and easy to follow by the students.

Some books and research papers report having used an algorithm to perform a given task, which may not be assessed unless the corresponding computer program is made, this is the case with some Convolution Filters, it is then when Imagery can be used to very rapidly visualize the mentioned results.

A meticulous understanding of DIP is important when developing software for automatic (unsupervised) Pattern Recognition, because in these cases it is necessary to develop algorithms capable of deciding autonomously the operations to be done over an image before extracting information from it, not all images in a given set might need exactly the same operations, this is the case of the computerized detection of flaws in pieces being transported over a conveyor band, this is, automatic quality control.

The author of this paper had to teach DIP at the graduate level to a group of students with different backgrounds, seeing that the experience resulted extremely hard, he decided to create Imagery, a software for Computer Assisted Education of DIP. Imagery is based on several books and research papers used by its author while teaching DIP, it is also based on the

research the author carried out on pattern recognition.

The advantage of using software to teach image transformations like those performed in DIP, is that with the help of the software the transformations can be appreciated in real time, the exposition is not limited to original and final image, because even intermedial steps on an image transformation may be shown, and very many examples can be appreciated. Imagery includes some images supplied by the author; however the users may experiment with images of their own, the only restriction being the size.

Every module of Imagery contains some pertinent theory but it is important to mention that this software is a complement to a specialized textbook or classes, it is not self sufficient, however it is a great help for both teacher and student.

## 2. Images from the standpoint of DIP

In the field of DIP an image, maybe a photograph, is discretized as a two-dimensional light intensity function  $f(x,y)$ , where  $(x,y)$  are the coordinates of every point and the value of the function  $f$  at point  $(x,y)$  is the light intensity at that point. A digital image is a matrix with rows and columns indicated by  $x$  and  $y$ , and the matrix element indicates the colour (light intensity) at that point.

Digital image researchers have developed mathematical operations over functions like  $f(x,y)$  so as to carry out transformations of them. Software for DIP like Imagery makes use of those mathematical transformations to carry out the operations on the images. Some examples of these transformations include (1) the cleaning of a noisy image, (2) The detection of straight lines (illegal airports) in aerial photographs through a cloudy day, (3) the detection of contours in poor quality images, etc. The field of DIP deals with the transformations that can be done on images, to extract some information from them. The images are treated as two dimensional functions in  $x$  and  $y$  and the transformations are mathematical operations carried out over these functions so as to transform them.

### 3. Topics Included in the Imagery Software.-

At the time of writing this report Imagery includes 29 modules dealing with:

1	Analysis of Colors: Color Synthesis
2	RGB Color Mixing
3	Straight line representation
4	Geometrical Transformations: Translation
5	Rotation
6	Size Scaling
7	Shearing
8	Image Transformations
9	Point detection mask
10	Line detection masks: Vertical, horizontal, slash, back slash
11	Binary image boundary detector
12	Image Subtraction
13	Pattern Centroidal Profile Representation
14	Histograms
15	Binarizer: Conversion of Grey-Level To Binary Images. Thresholding
16	Erosion of binary images
17	Dilation of binary images
18	BorderLiner: Histogram-Assisted Edge Detection of Grey-Scaled Images
19	Surrounder: Segmentation
20	Edge enhancement by Gradient. (The Sobel Operator)
21	Edge enhancement via the Laplacian operator
22	Spatial Operators (Convolution Filters)
23	High boost filter
24	User-Defined Convolution Filters
25	Noise-Reduction Median Filter
26	Massive RTS Invariant Moments
27	Boundary RTS invariant moments
28	The Polar Hough Transform
29	Hough-Transform-based Line Detector

### 4. Description of some modules

Due to lack of space only the screen shots of some modules are included in this report. All modules are fully interactive; they operate on some images supplied by the author and also on images supplied by the user. Every module also includes the pertinent but very succinct theory. Imagery operates all types of images (medical, mechanical, biological, etc)

#### Color Synthesis and RGB Color Mixing:

These deal both with the analysis of colour from the standpoint of the RGB representation. The Red, Green and Blue components of every colour can be detected also the combinations of R, G and B are dealt with.

**The straight line representation:** deals with the difficulties encountered when making a line, due to the discretization of image space, in order to make a line the researcher must develop the

line either by x or by y, depending on its orientation.

**Geometrical Transformations (Translation, Rotations, Size Scaling and Shearing):** In these modules the user designs his/her own objects (polygons) with the mouse over the screen and then sets the parameters for the corresponding transformations and the software produces the corresponding geometrical transformations.

**Image Transformations:** This module deals with Color Inversion, Horizontal mirror effect, Turn Image Upside Down, 90° Rotation, 180° rotation, and Vertical Flip, 270° Rotation and Vertical Flip.

**Image Subtraction:** This module allows the user to visualize the difference between two apparently equal images and reports the percentage of difference between two given images.

**Detection of dots and lines on images:** these modules show the corresponding effects. In the case of line detectors, these may be horizontal, vertical and diagonal. Lines may also be detected through the Polar Hough transform, and Imagery allows the user to analyse and compare both algorithms.

**Erosion and Dilation:** These two modules may be used to show the use of these algorithms to get rid of some minute imperfections on images.

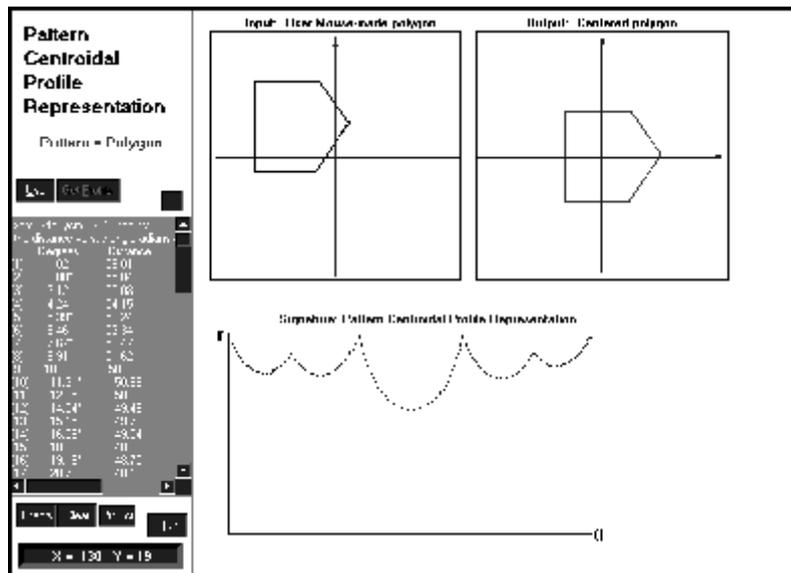


Figure 1

**Pattern Centroidal Profile Representation:**

In this module (Figure 1) the user must design a polygon with the help of the mouse. Only one polygon at a time. The input polygon (pattern) does not need to be centered on input region. Given a pattern (polygon) in input image, this software detects its Centroid (geometric center), then displaces the whole pattern in such a way as to place its centroid in the origin of coordinates (0,0), Since no rotation is carried out, the orientation of the translated pattern is the same it has originally. Next the angle and distance of

every border point (x,y) with respect to (0,0) is computed, this constitutes the Centroidal Profile Representation of the pattern. The Centroidal profile representation seems to be possible only as long as the object is not solid but edged, has no holes, the image is clean.

**Histograms:**

The histogram (Figure 2) of a grey-level digital image gives the number of pixels per grey level in the image. The histogram gives also information about the probability of finding a given grey-level in the image, the higher the

number of pixels for a given grey level, the higher the probability of finding that grey level in the image, and viceversa. Histogram equalization: A histogram has been equalized when it has been normalized between 0 and 1, with 0 representing black and 1 representing white. In this way the grey levels may be regarded as random quantities in the interval from 0 to 1. When the user strolls the mouse over an obtained Histogram, the numerical values of the population for every visited point is displayed. A list of colour intensity and population is shown.

User-Defined Convolution Filters: This module (Figure 3) is for the user to investigate the result of operating an image with his/her own 3x3-filters. The user loads a test input image and enters the 3x3-filter factors in the nine 3x3-entries and in the coefficient of the filter mask. Some pre-defined convolution filters have been included so that the first-time user can easily see how this module operates. Many of the filters used in Texture Analysis <sup>9</sup> may be

quickly tested with the convolution module included in Imagery

Noise-Reduction Median Filters: In a Noise-Reduction Median Filter, (Figure 4) the grey-level of each pixel in the image is replaced by the value of the Median of the grey levels in the neighbourhood of the pixel, not by the neighbourhood average as Smoothing filters do. Median filters are classified as non-linear filters, their size depends on the application. To set up a median filter order from min to max the values of the grey levels of the pixels in the neighbourhood of each pixel p, take the Median of this set (including p) and replace the grey level of pixel p with the Median. In this module a 3x3 Median filter is being used. The filter may be applied to an image in any of its four versions: Square, Cross, Vertical and Horizontal Strip. Two successive filter applications are possible, not necessarily with the same filter: Filter image (A): Operates on input image (1), and generates image (2). Filter image (B): Operates on image (2), generating image (3).

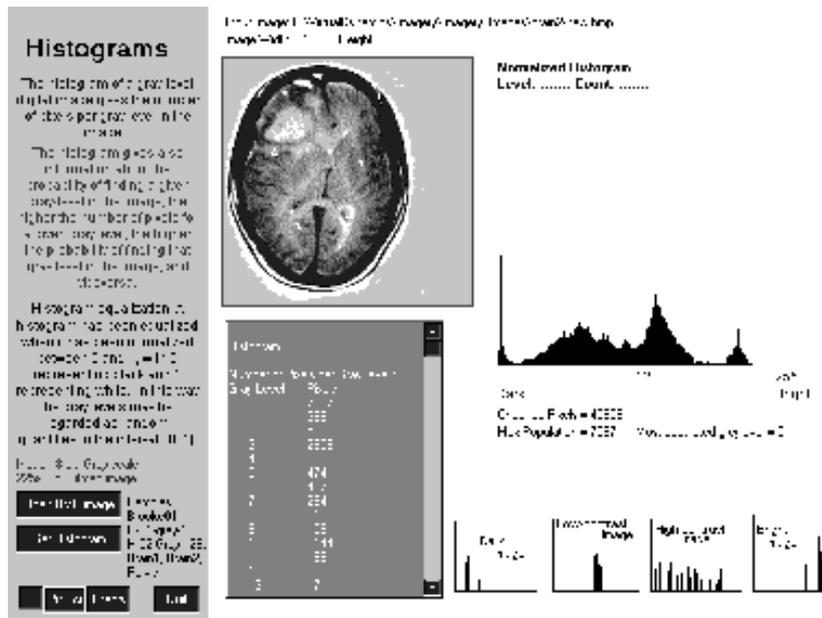


Figure 2



Figure 3

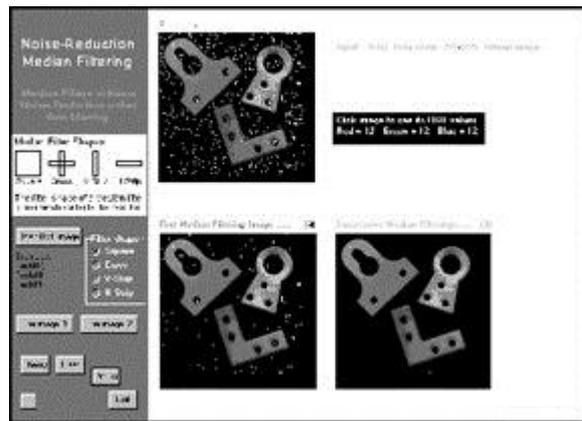


Figure 4



Figure 5

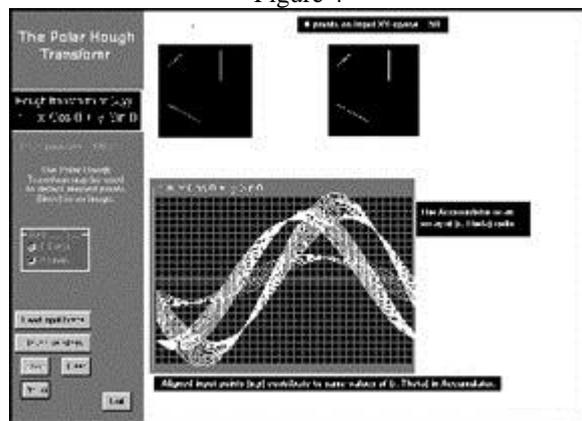


Figure 6

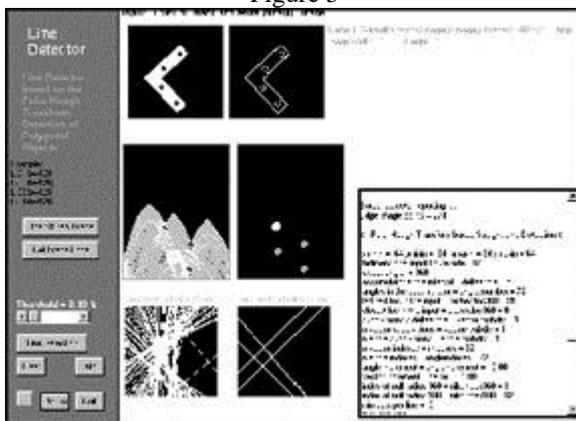


Figure 7

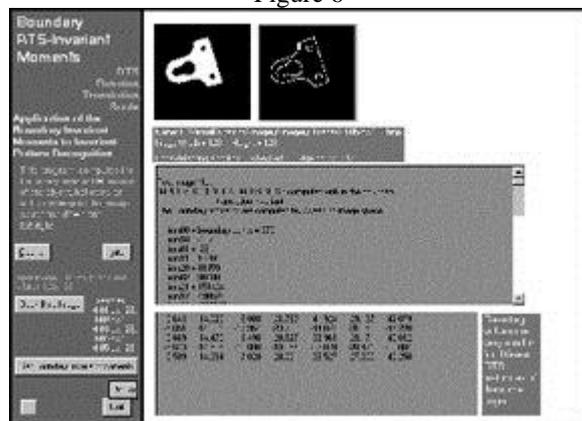


Figure 8

**Massive RTS Invariant Moments:** RTS stands for Rotation, (Figure 5) Translation and Scale. These are Massive Moments <sup>6-7</sup> because these operate on all the pixels of an image, this in contrast with the Boundary Moments <sup>8</sup>, which operate only on the border pixels of an image. This module operates on either binary (black and white) or grey level images.

Binary images are straightforwardly submitted to the RTS invariant moments computations. When

operating on Grey-level input images, these are binarized (converted to black and white images) before being submitted to the invariant moments computations. Binarization is achieved with the user-defined Grey-Level-Threshold deciding which grey levels must be considered background and which as the object pixels. Grey levels of the image pixels above the user-defined Grey Level Threshold are treated as being part of the object in the input image, all the other grey levels are regarded as background. In a pattern

recognition session all images must have been obtained under the same conditions (light, etc) and the grey level threshold must be kept the same for all of them.

**The Polar Hough Transform:** this is a distortion tolerant technique that maps image-space points into curves in a parameter space (Figure 6). The Polar Hough Transform may be used to detect aligned points (lines) in an image, it maps image-space points of coordinates (x,y) into a parametric accumulator space ( $\rho, \theta$ ), by means of

$$\rho = x \cos \theta + y \sin \theta$$

In this module, the user uses the mouse to put single dots and/or lines on an input region on screen, then the software reads this input and makes the corresponding Polar Hough Transform, point by point, in this way the user can clearly see how every point (x,y) is mapped as a sinusoid in the Accumulator space. It can also be seen that those sinusoids corresponding to aligned points (lines), meet all in a single point in ( $\rho, \theta$ ) space. Hence the representation of aligned points as ( $\rho, \theta$ ) pairs results evident.

**Hough-Transform-based Line Detector:** This is a powerful algorithm created by the author<sup>10</sup> of this report (Figure 7), it deals with the invariant pattern recognition of polygonal objects, it has been successfully applied to detect flaws in chocolates and biscuits<sup>11</sup> and also in mechanical pieces. This module is a description of the method developed by the author

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