Revista de la Facultad de Ingeniería Industrial
Vol. 11(1): pp 79-84 (2008) UNMSM
ISSN: 1560-9146 (Impreso) / ISSN: 1810-9993 (Electrónico)

IMAGERY-37: A Virtual Lab for Computer Assisted Education on Digital Image Processing

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Recepción: Mayo de 2008 / Aceptación: Octubre de 2008

ABSTRACT

Imagery is a Virtual Lab for computer-assisted training on Digital Image Processing (DIP), currently including 37 modules. This software allows the user to experiment with DIP algorithms, enabling him to see their effects on real images; it may be used in the classroom, in the laboratory or at home. Imagery not only operates on images included by its creator (the author of this report), but also on those provided by the user. Some supporting theory is included in Imagery, which may be used as a complement to specialized textbooks or classes.

Key words: Computer assisted education, digital image processing, algorithms, virtual lab

IMAGERY-37: UN LABORATORIO VIRTUAL PARA EDUCACIÓN ASISTIDA POR COMPUTADORAS EN PROCESAMIENTO DIGITAL DE IMÁGENES

RESUMEN

Imagery es un Laboratorio Virtual para Entrenamiento Asistido por Computadoras en Procesamiento Digital de Imágenes (PDI), incluyendo actualmente 37 módulos. Este software permite al usuario experimentar con los algoritmos de PDI, visualizando los efectos de esos algoritmos sobre imágenes reales; puede ser usado en el aula, laboratorio y hogar. Imagery no solo opera sobre imágenes incluidas por su creador (el autor de este reporte), también lo hace sobre aquellas proporcionadas por el usuario. Una teoría básica sobre cada tema es incluida en el software, el cual puede ser usado como complemento a libros especializados o clases.

Palabras clave: Educación asistida por computadoras, procesamiento digital de imágenes, algoritmos, Laboratorio Virtual.

INTRODUCTION

Most books on Digital Image Processing (DIP)1-5, expose the theory and Mathematics of this field including one or two examples 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 an image transformation with a given algorithm. If a student feels interested on a given topic, he has to make the computer program to visualize the outcome, thus wasting time and effort. In these cases it would be much better if the instructor had a software with which he shows the students what he is talking about. The class would be not only much more dynamical but also more interesting and easy to follow by the students.

Some books and research papers report having used and 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 carried-out 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).

When this author taught DIP at the graduate level to a group of different background students, the experience resulted extremely hard, as a consequence he decided to create Imagery, a software for Computer Assisted Education on DIP. Imagery is based on books and research papers used by its author to teach 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 software the transformations can be appreciated right away, the exposition is not limited to original and final image (even intermediate steps on an image

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transformation may be shown), and very many examples can be visualized in a short time.

Imagery includes some images supplied by its creator (the author of this report); however the users may also operate on images of their own, the only restriction being the size. Every module in Imagery includes some relevant theory; this software nonetheless is a complement to specialized textbooks or classes, it is not self-sufficient, however it is a great help for both, teacher and student.

IMAGES FROM THE VIEWPOINT OF DIP

In the field of DIP an image -may be 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 transform them. DIP software like Imagery makes use of those mathematical transformations to carry out the operations on the images. A few examples of these transformations include (1) Cleaning a noisy image, (2) Detection of straight lines (illegal airports) in aerial photographs through a cloudy day, (3) Detection of contours in poor quality images, etc. DIP deals with the transformations that can be made on images to extract some information from them.

CURRENT TOPICS (MODULES) IN IMAGERY 37

1	Colour Synthesis
2	RGB Colour Mixing
3	Colour To Grey-Level Transformation
4	Representing a Straight Line
5	Geometrical Transformations: Translation
6	Rotation
7	Size Scaling
8	Shearing
9	Image Transformations
10	Image Difference (Subtraction)
11	Graded Difference of Images
12	Signatures: Pattern Centroidal Profile Representation
13	Point and Small Hole Detection Mask
14	Line Detection Masks: Horizontal, Vertical, Slash, Back Slash
15	Binary Image Boundary Detector
16	Histograms
17	Binarizer: Conversion of Grey-Level To Binary Images. Thresholding
18	BorderLiner: Histogram-Assisted Edge Detection of Gray-Scaled Images
19	Erosion of Binary Images
20	Dilation of Binary Images
21	Binary Image Segmentation through Wrapping
22	High Boost Filter
23	Edge Enhancement by First Derivatives and Gradient
24	Edge Enhancement by Gradient: The Roberts Operator
25	The Prewitt Operator
26	The Sobel Operator
27	Generalized Sobel Operators
28	Edge Enhancement via the Laplacian Operator
29	Edge Direction Detection through Gradient
30	Spatial Operators (Convolution Filters)
31	User-Defined Convolution Filters
32	Comparison of Sharpening Filters
33	Noise-Reduction Median Filter
34	Massive RTS-Invariant Moments
35	Boundary RTS-Invariant Moments
36	The Polar Hough Transform
37	Hough-Transform-based Line Detection

DESCRIPTION OF SOME MODULES

The rather large number of modules in Imagery makes it impossible a description of all of them, hence only a few are concisely described straightaway.

Colour Synthesis and RGB Colour Mixing

These two modules deal both, with the analysis of colour from the standpoint of the RGB (Red, Green and Blue) representation. The RGB components of any colour can be detected. Also the percentage 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, a line may be a set of aligned points but it may also be a set of line segments. Additionally in order to make a line it may be developed by either x or y, depending on its orientation.

Geometrical Transformations (Translation, Rotations, Size Scaling and Shearing)

In these three modules the user designs his/her own objects (polygons) with the mouse over the screen and then sets the parameters for the corresponding transformations, which are visualized straightaway.

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: $g(x,y) = f(x,y) - h(x,y)$

Detection of dots and lines on images

These are two modules used to detect small lines and dots on images. Lines may be horizontal, vertical and diagonal. Lines may also be detected and identified through the Polar Hough transform, and Imagery allows the user to analyse and compare both algorithms.

Dot (point) Detection Mask

-1	-1	-1
-1	8	-1
-1	-1	-1

Detects isolated points different from a constant background

Lines at 135° Detection Mask

2	-1	-1
-1	2	-1
-1	-1	2

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.

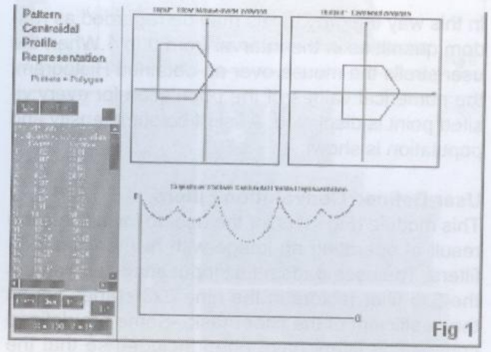


Fig 1

Pattern Centroidal Profile Representation

In this module (Fig. 1) the user must design a polygon with the help of the mouse. A single polygon at a time and this does not need to be centered on input region.

The Pattern Centroidal Profile reduces the 2-D pattern boundary representation to a 1-D function (the signature), which is supposed to be simpler than a 2-D representation. This signature is invariant only to translation, however it is dependent on rotation and scaling. This signature is possible only as long as the object is not solid but edged, has no holes and the image is noiseless.

Histograms

The histogram (Fig. 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

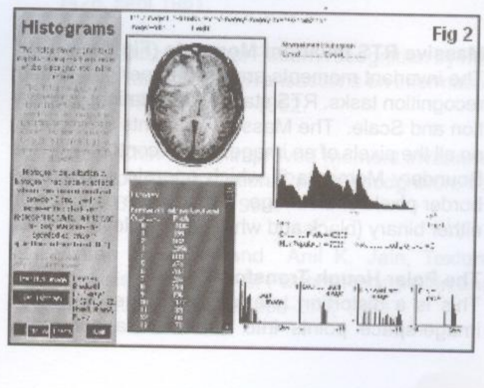


Fig 2

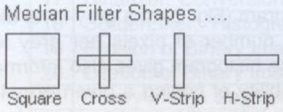
grey level in the image, and vice versa. Histogram equalization: A histogram has been equalized when it has been normalized between 0 and 1, with 0 representing black and 1 representing white.

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 (Fig. 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 9 may be quickly tested with the convolution module included in Imagery

Noise-Reduction Median Filters
In a Noise-Reduction Median Filter, (Fig. 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. Median filters are classified as non-linear filters, their size depends on the application. In this module 3x3 Median filters are 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:

Median Filter Shapes ....



The filter shape of a Median filter considerably affects the results.

Massive RTS Invariant Moments (Fig. 5)
The invariant moments are used to perform pattern recognition tasks. RTS stands for Rotation, Translation and Scale. The Massive Moments 6-7 operate on all the pixels of an image, this in contrast with the Boundary Moments 8, which operate only on the border pixels of an image. This module operates on either binary (black and white) or grey level images.

The Polar Hough Transform
This is a distortion tolerant technique that maps image-space points into curves in a parameter space (Fig. 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 (**r**,**q**). by means of

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 (**r**,**q**) space, hence the representation of aligned points as (**r**,**q**) pairs results evident.

Hough-Transform-based Line Detector
This is a powerful algorithm created by the author10 of this report (Fig. 7), it deals with the invariant pattern recognition of polygonal objects, it has been successfully applied to detect flaws in chocolates and biscuits11 and also in mechanical pieces. This module is a description of the method developed by the author.

Binary Image Segmentation through Wrapping
This segmentator (Fig 9) operates on binary images containing several objects (shapes). Segmentation is carried out by encapsulating (surrounding) the objects in an image, and then extracting every capsule. This algorithm was developed by the author of this report.

Sobel's Edge Enhancement by Gradient (1st Derivative)
Sobel (first derivative, Gradient) Operators are used to detect edges (Fig. 10). These operators also enhance noise and sometimes this constitutes a drawback. In this module the user may control the Sobel's threshold for edge detection, and the resulting images for three different thresholds can be shown on screen, so that comparison is possible

Gradient Operator :

NW	N	NE
W	●	E
SW	S	SE

$$\vec{\nabla} \mathbf{f} = \left[\overrightarrow{Dx} + \overrightarrow{Dy}\right] \mathbf{f}$$

Sobel Derivatives:

Dx = (NE + 2E + SE) - (NW + 2W + SW)

Dy = (NW + 2N + NE) - (SW + 2S + SE)

magnitude of the Gradient: $\left|\vec{\nabla} \mathbf{f}\right| = \sqrt{D_x^2 + D_y^2}$

Edge enhancement via the Laplacian (2nd derivative) operator

The sign of the 2nd derivative determines whether an edge pixel lies on the dark (positive sign) or light (negative sign) of an edge.

The result of the operations on the neighbourhood of pixel at position (x,y) is the new value of the pixel at (x,y).

High boost filter

This is a Highpass Filter, hence it performs Edge enhancement. As a side effect, it also produces Noise enhancement. Highpass filters carry out sharpening, which means that noise and other sharp intensity transitions are enhanced.

High-boost Spatial Filter

$$\frac{1}{9} \times \begin{array}{|c|c|c|}\hline -1 & -1 & -1 \\ \hline -1 & W & -1 \\ \hline -1 & -1 & -1 \\ \hline \end{array}$$

$$W = 9A - 1, \quad A \geq 1$$

In the High boost spatial filter, A is an Amplification factor. The larger the value of A, the higher the Edge Enhancement. When A = 1 the filter is the standard highpass filter. When A > 1, part of the original image is added back to the resulting image. Imagery allows the user to vary the value of A so that he can visualize the corresponding effect, displaying up to three different results on screen at a time.

ACKNOWLEDGEMENT

Imagery would not have been possible without the deep and decisive influence of Prof. Luciano da Fontoura Costa, from The Cybernetic Vision Research Group, Sao Paulo University, (USP Sao Carlos Brasil), who introduced the author to the field of Computer Vision, specifically Pattern Recognition. The author expresses his sincere and special gratitude to Prof. da Fontoura Costa for all the time, dedication and very especially for the transfer of knowledge

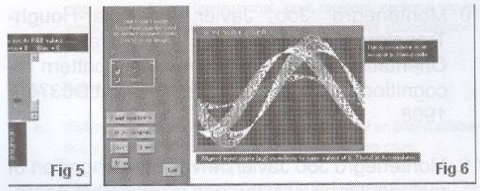


Fig 5 Fig 6

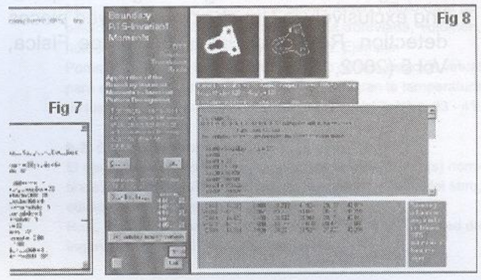


Fig 7 Fig 8

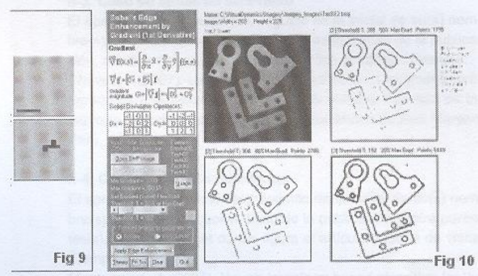


Fig 9 Fig 10

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