Software Tool in *Java* for Infrared Image Processing: *TermUV*

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Abstract

This paper presents the design, implementation and results of a thermal image processing tool, which allows the capture, pre–processing and processing of thermal images through a graphical script interface, then, generate reports and store results in a data base. Each stage (capture, pre-process, process and reports) was designed and implemented keeping in mind modularity, flexibility and portability criteria.

Key Words: Thermal Image Processing, Thermography, Thermal inspection, Software Architecture, Graphical Programming.

1.Introduction

Currenlty, there is an increasing necessity for standardization in thermal images processing for inspection and maintenance. The methods currently used are becoming more complex and their integration is necessary in order to achieve a more efficient inspection. Several tools that integrate these methods have been developed for commercial or academic purposes. The commercial tools, such as *Display IMG, TeamSoftware, Irmotion, Goratech Ireport*, etc, are generally linked to a specific type of infrared camera and allow the capture, storage, report generation, analysis and processing of images. Moreover, some of these tools allow the processing in real time.

On the other hand, academic tools have also been created in order to promote the use of infrared TNDT (Thermal Non Destructive Testing) from the laboratory in the industrial environment [1]. In addition, they are used to solve three dimensional heat conduction problems of heating a layered solid that contains several subsurface defects [2].

Both commercial and academic tools can be used in several platforms (Windows 98 / Windows 2000/Windows NT/Windows XP version) and they do not include algorithms for the use of AI (Artificial Intelligence) methods. On the other hand, they do not provide the user with the opportunity of adding new processing modules to the existing ones, and they do not offer especial profiles for users depending on their level of expertise.

The subject of this article is to present the structure and the application of *TermUV (Térmico Universidad del Valle),* a flexible and modular software tool for the analysis of infrared images. It was implemented in *JAVA* and some functions are based on *ImageJ* [3] (open source code for image processing) permitting the addition of preprocessing, processing and AI modules devoted to the TNDT (Thermal Nondestructive Testing) field. Moreover, it allows graphical programming.

The first section of this article describes the software system design and image processing tools. Then, it presents several results of its application. Finally, it describes directions for further development of the tool.
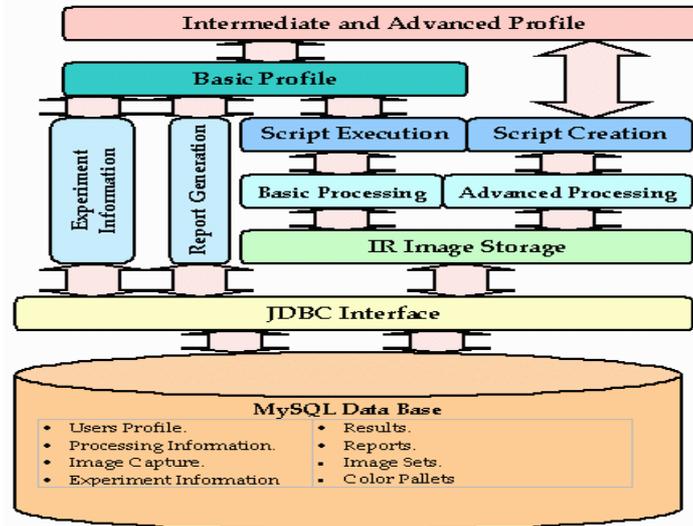
2. Software Architecture

Figure 1
Software structure

The figure shows the software structure implemented in *TermUV*. This is explained in a top – bottom fashion:

- There are three user profiles: Basic, Intermediate and Advanced, which are implemented as a Wizard in order to help to develop all the application stages.
- Regardless of user profile, tools like: Experiment Information, Report Generation and Script Execution are available. Nevertheless, the Script Creation tool is only available for advanced users, in such a way that more processing and analysis tools can be used such as: Wavelet Transformation, Pattern Recognition using Neural Networks and special processing tools used in thermography.
- Intermediate and Advanced users can use the Image Storage Tool in order to save results obtained in middle stages meanwhile a Script is created.
- The whole of these tools are supported on a JDBC interface, which instantiates Image Sets, Processing and Experiment Information, Reports, Results and Project objects taking into account the information stored on a data base.
- Finally, in our case we use a MySQL data base to save the whole project information about each user profile.

Other important software structure characteristics are:

- The Image Processing Tool is supported on the *ImageJ* package.
- The Script Execution and Creation Tools are supported on the *ImageAPP* package, allowing the execution and creation of scripts using a graphical approach.
- The Artificial Neural Networks tool for data processing is based on the well-known *Joone* package

2.1 General Image Processing

The tool provides a set of useful algorithms for general-purpose image processing in addition to those provided specifically to support thermography. These algorithms include image acquisition, image arithmetic, image enhancement, pseudocolor display and image examination.

Several images with different sizes and formats can be manipulated with *TermUV*. The formats supported are: GIF, JPEG, BMP and TIFF. Images can be converted to 8, 16 and 32 bits.

2.1.1 Image Mathematics and Logic

The image mathematic and logic commands provide pixel-by-pixel operations on one or more images. The commands *Sumar, Restar, Multiplicar* and *Dividir* take the corresponding arithmetic operations (Addition, Subtraction, Multiplication and Division) and store the result in another image. Moreover, the logical operations allowed are NOT, AND, OR and XOR.

2.1.2 Image Enhancement

The image enhancement commands provide the design of several standard convolution and frequency filters to emphasize or smooth selected features of an image and facilitate interpretation by the user.

The size and parameters of convolution filters masks can be specified by the user allowing the creation of a wide range of filters that can be used to eliminate noise or emphasize image details.

On the other hand, it is possible to design a bandpass filter that filters out large structures (shading correction) and small structures (smoothing) of the specified size by Gaussian filtering in Fourier space. It is also possible to apply the Sobel edge detector in order to highlight sharp changes in intensity in the image. Furthermore, the tool is able to remove smooth continuous background from images and to modify the bright and contrast of the image in order to facilitate its interpretation. In addition, the command *Surface* plays a three-dimensional graph of pixel intensities in a grayscale or pseudo color image. On the other hand, the algorithms *Correccion de Vignetting* and *Remocion de pixels* allows the correction of vignetting effect [4] and the removal of bad pixels presented in thermographic images, respectively.

2.1.3 Pseudocolor display

The use of pseudocolor is an image enhancement that increases contrast or color codes an image to correspond to temperature or gray level. The tool can create a reversed image, similar to a photographic negative, of the entire image or selection. Similarly, it is able to apply the LTU (Lookup table) *Fire* to the image in order to assign color to image grey values.

2.1.4 Image Analysis

The image examination commands provide quantitative information about the image. For this purpose the *TermUV* has these algorithms: *Detección de defectos, Histograma, ROI* and *Profiler*. Moreover, it allows image feature extraction such as: mean, standard deviation and seven invariant moments [5] that can be used to train a neural network specified by the user. Similarly, the FFT (Fast Fourier Transform) and 2D DWT (Discrete Wavelet Transform) can be obtained from the image.

The command *Deteccion de Defectos* is able to automatically detect defects. This algorithm is based on the fact that TNDT images have a limited number of spatial frequencies [6]. The first step is to localize the defect and then specific thresholds are found in the image to estimate the border of the defects. Each threshold is found by means of a region growing approach [7], which starts at the central point of a defect and stops when either an image border is hit or the number of pixels agglomerated

together around the seed (central point) increases abruptly. On the other hand, the command *Histograma* computes image histogram, mean, standard deviation, maximum and minimum grey level values of the image. In addition, the ROI (Region of Interest) command permits working with oval and round area selections to compute the histogram in these areas and extracts their statistical parameters. Likewise, the *Profiler* command displays a two dimensional graph of the intensities of pixels along a line within an image.
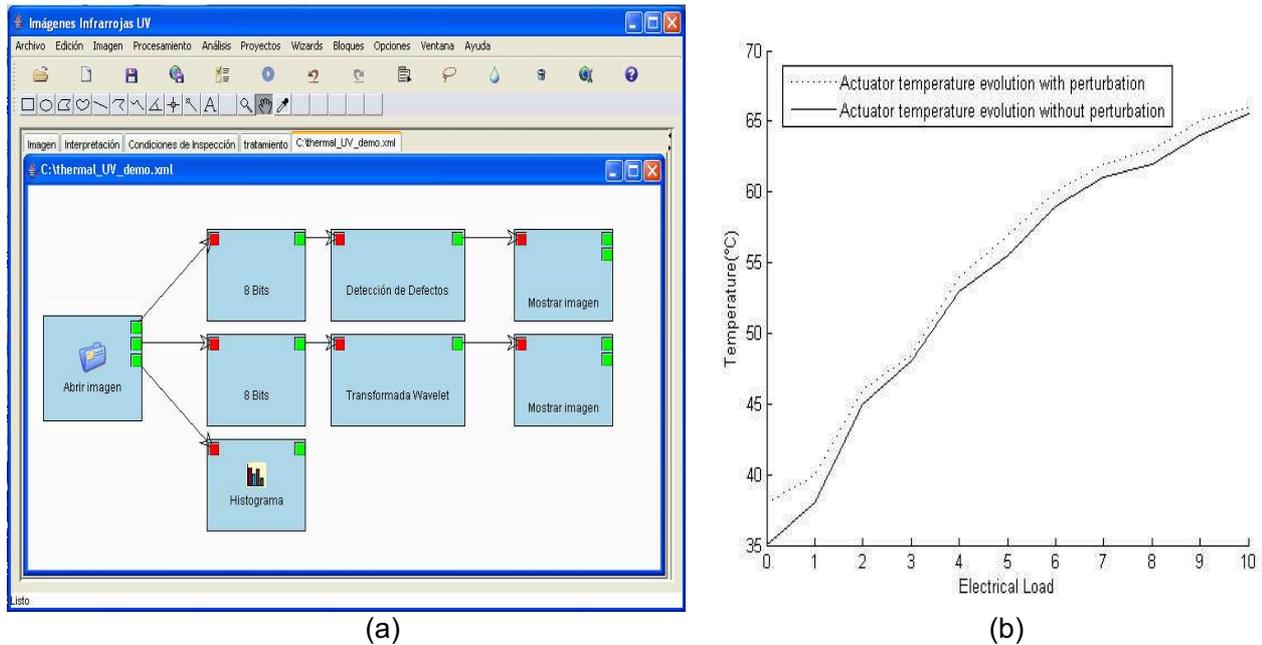
3. Results and Discussion

(a)   (b)

Figure 2

(a)Graphical programming structure for actuator unit thermogram analysis (b) Actuator Temperature Evolution

The sample graphical program in Figure 2a shows the use of several blocks implemented in *TermUV* applied for thermogram analysis using the graphical script interface. This thermogram represents the function of an actuator unit and was obtained with the IR camera Thermovision A20 whose thermal sensibility is 0.12°C at 30°C. For this experiment the distance between the camera and the target is 0.7 m and the electrical current consumed by the actuator is 1.7 A when a mechanical perturbation is applied to the actuator. Figure 2b describes the actuator temperature evolution with perturbation and without perturbation. The absolute actuator temperature at which the thermogram was taken is 63 °C.

The first block is used to open the image file, this file may have extensions bmp**,** tiff or jpg. The following blocks, *8 bits* and *Histograma*, are used to change the image to an 8 bits image and then calculates the image histogram, respectively. From this point, two algorithms are applied for the thermogram analysis. The first one is used for defect automatic detection and the other one is used to calculate the thermogram Wavelet transform.
On the other hand, the 2D DWT is applied for one level of decomposition, and for horizontal, diagonal and vertical details. The objective of this test is to highlight image details and detect hot spots produced either by friction or excessive electrical load.

(a)   (b)
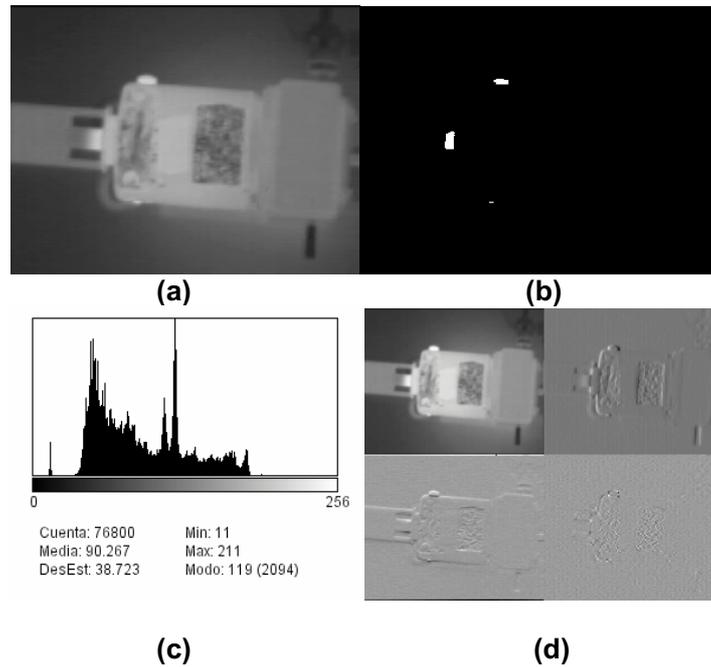
(c)   (d)

Figure 3
Results after applying the graphical programming structure of Figure 2a

Figure 3 shows the results of applying the image processing graph presented in Figure 2, figure 3a is the thermal image to be processed and figure 3b is the defect map produced by the automatic defect detection algorithm. The algorithm detected three *hot spots* in the actuator, which has an overheating between the shaft and the actuator body due to friction.

For this case the input parameters were: 3 for the maximum number of defects that can be found in the image and 10 for the MND (Maximum Neighbourhood Distance). On the other hand, figure 3c is the histogram and provides statistical image parameters such as: mean, standard deviation, Mode, Max and Min of the statistical grey level distribution. Figure 3d represents the application of 2D DWT with Haar basis function and one level of decomposition showing horizontal, vertical and diagonal details. Furthermore, *TermUV* is able to apply other Wavelet basis functions such as: *Daubechies* up to 9th order and *Biorthogonal* with different orders of decomposition and reconstruction.

4. Conclusions and future developments

TermUV is at its initial development stage and our group is working on testing and inclusions of new algorithms that implement new procedures that are currently arising from the prolific TNDT field such as: Differential Absolute Contrast (DAC) [8] and thermal PCA (Principal Component Analysis) [9].

The need for fast processing makes *ImageJ* more appropriate for this application than *JAI (Java Advanced Imaging)* since the former is able to work directly with the pixels while *JAI* creates a new data type and operates the pixels with this data type.

On the other hand, only the algorithms devoted for the beginner user will be available for the public domain given the copyright category of some algorithms implemented.

TermUV allows the integration of the principal methods using in NDT and is useful as an educational tool for academia as well as a practical tool aiding in the everyday tasks of inspection in the field. Finally, *TermUV* might encourage the development of experimental platforms at lower prices and make arise the research interest about TNDT in Colombia and other Latin-American countries.

5. Acknowledgements

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