

Appendix F

An Application for the Comparison of Popocatépetl Volcano's Fumaroles

In this appendix we will describe the paradigm of Image Based Reasoning described by [Jurisica, 00] and whose basis consider the combination of the Case Based Reasoning and Image Processing and Analysis (Section F.1). The combination of those areas arises from the fact that not always the information is, according to [Jurisica, 00], symbolic; however, sometimes that information is associated to multimedia content (images, for example). Moreover, in section F.2, we will propose the consideration of some procedures in order to obtain new options to apply the paradigm (we will assume that the reader has revised section 7.4: Comparing color 2D-images through their extrusions to the 5D colorspace). Finally, we will describe an application of this paradigm, with our proposed procedures, under the context of the comparison of Popocatépetl volcano's fumaroles (section F.3).

F.1 Image Based Reasoning

F.1.1 Images Storing

[Jurisica, 00] defines two ways for storing an image in a cases base:

- **Explicit Storing:** An image is stored as a bitmap that contains all its associated visual information.
- **Implicit Storing:** There are stored only some useful descriptors of the image. For example, by transforming the raster image in a vectorial representation and by selecting only some of its polygons, lines, etc.

F.1.2 Image's Retrieval

In the images' domain one of the most important aspects to consider is the selection of the set of the most important characteristics in order to determine the similarity between two images and thus to achieve the retrieval process.

Independently of the process for comparing two images, it is necessary to consider the previous preparation that they require. [Jurisica, 00] resumes that previous preparation by considering the images' segmentation in order to reduce their complexity and to identify some objects in them. The procedures for images' segmentation can be grouped in two categories:

- **Region Oriented Segmentation:** Which is based in the searching of regions with similar coloring. An example is the Multilevel Thresholding [Kurmyshev, 02] (we will consider and explain this method in the following sections).
- **Edge Oriented Segmentation:** Which is based in the searching of abrupt changes in the coloration that could indicate the presence of an edge between two or more objects.

Basically, [Jurisica, 00] performs the comparison between two images by using as similarity metric the number of the required transformations in order to made them equivalent (in section F.2 we will propose an additional metric). Among these transformations we can find rotations, reflections, removals, substitutions or translations. It is useful to consider if the images are implicitly stored then the segmentation process can be performed before they are added to the cases base, by this way we would concentrate only in the segmentation process of the new image to compare.

F.1.3 The Process of the Image Based Reasoning

A system that implements the paradigm proposed by [Jurisica, 00] can be resumed in the following way (See **Figure F.1**):

- a) Input. An image represented through a bitmap.
- b) Originally [Jurisica, 00] didn't propose a way for indexing images (in the following section we will propose an indexation scheme), therefore all the images in the cases base are candidates to be similar to the input image.
- c) If the images in the cases base are stored explicitly, then each one must be considered for the segmentation process (see **Figure F.1.a**); otherwise, only the input image is segmented (see **Figure F.1.b**).
- d) The pair of images (the input one and each image in the cases base), both in a vectorial representation, will be compared. The similarity metric proposed by [Jurisica, 00] will have as principle the number of transformations applied to the input image in order to made it similar to each one of the images in the cases base.
- e) Output: There are returned those images which are similar to the input image.

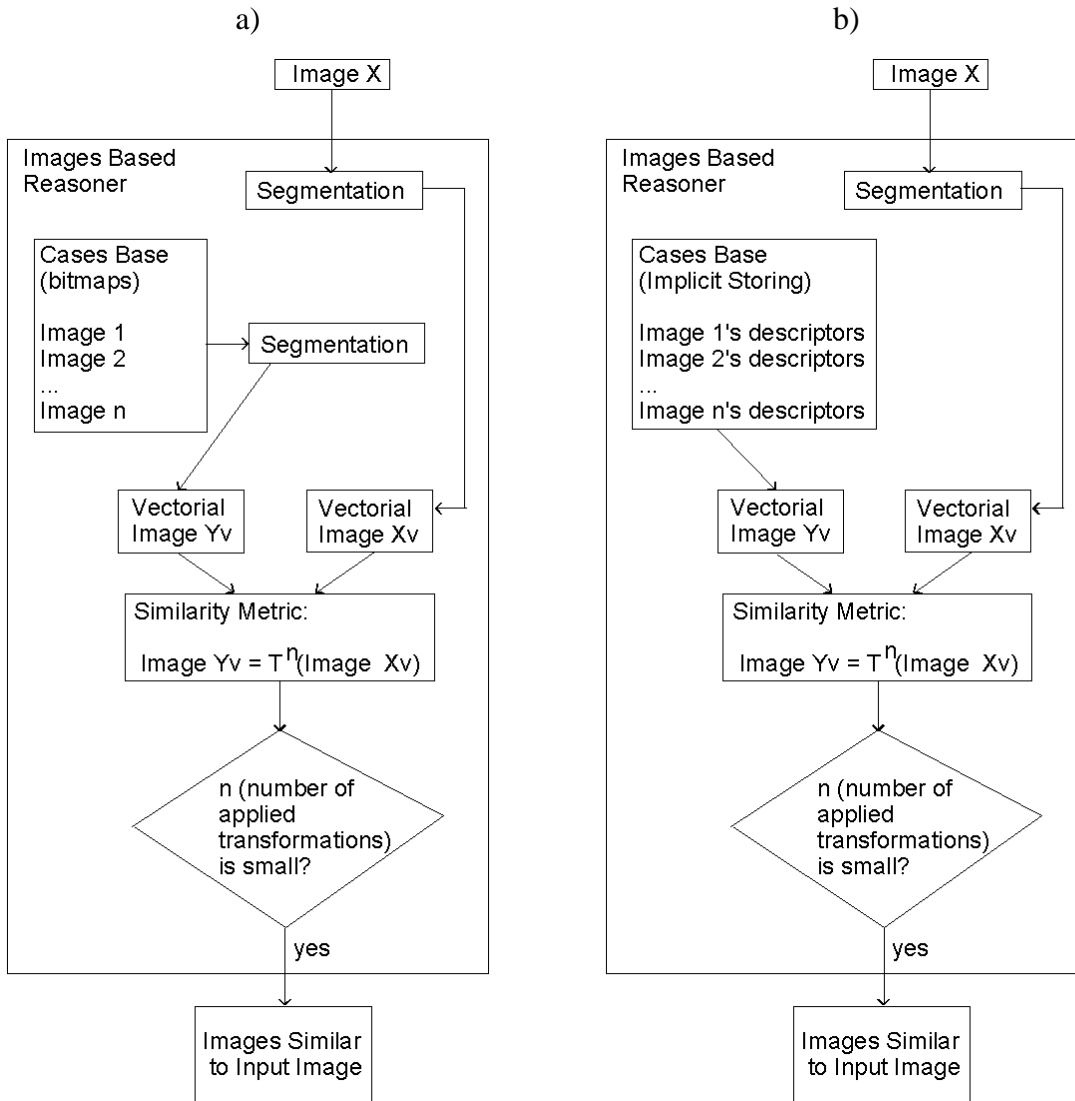


FIGURE F.1

An schematic view of an Image Based Reasoner. a) By considering the images' explicit storing. b) By considering the images' implicit storing (Own elaboration).

F.2 Other Options for Retrieval in Image Based Reasoning

Now we will propose a second similarity metric: the comparison of images through their extrusions to the 5D colorspace (see section 7.4). According to our procedure, there will be returned those stored images classified as similar to the input image (see the

algorithm presented in section 7.4). Due to our process requires the computing of 5D geometric and Boolean operations, the implicit storing seems to be the most suitable by considering the following descriptors for the images:

- The set of 5D hyperprisms (extruded pixels) associated with the original 2D-image.
- The total 5D hypervolume of the set of 5D hyperprisms.

[Jurisica, 00] didn't propose an indexation associated with the images. This means that in order to select the most appropriated images stored in the cases base it will imply to consider all of them. However, our proposed comparison procedure has to verify, as one of its first steps, whether or not two images are "*initially similar*" (see section 7.4). This verification can be achieved by comparing the 5D hypervolumes associated to both images and doesn't require any Boolean or geometric operation between them (as seen in section 7.4, these operations take place when the final images' comparison is performed). In fact, the 5D hypervolume of the images in the cases base is one of their descriptors while the input image's 5D hypervolume can be immediately computed after its extrusion to the 5D colorspace. Finally, we will select only as candidate cases those whose 5D hypervolumes' numeric differences, compared with the input image, are minimal, i.e., the cases that are "*initially similar*" to the input image. See in **Figure F.2** the schematic view of an Image Based Reasoner by considering the proposed options.

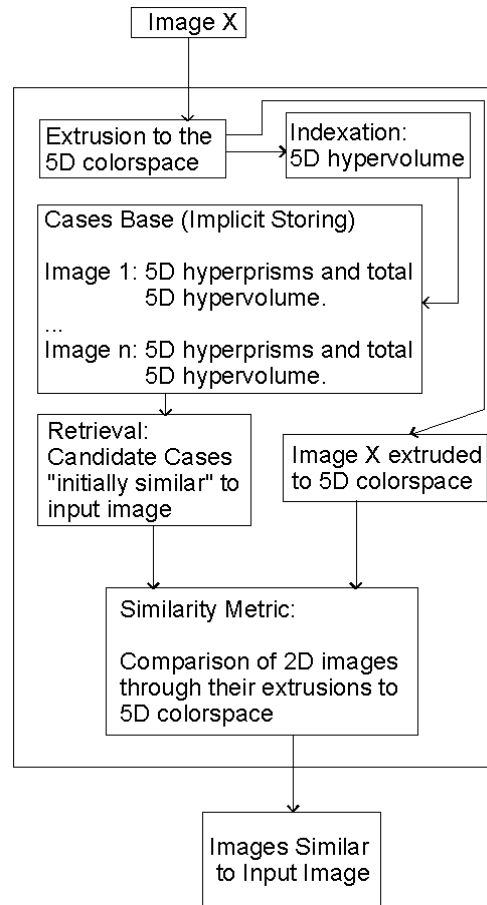


FIGURE F.2

An schematic view of an Image Based Reasoner by considering the images' comparison through their extrusions to 5D colorspace (presented in section 7.4; own elaboration).

F.3 Application's Description

F.3.1 Preprocessing and Storing Images in the Cases Base

We selected a total of 76 images from [Cenapred, 03]'s archives. These images represent some of the Popocatepetl volcano fumaroles during the year of 2003. The selected images have a resolution of 640×480 pixels and 24-bits color under the format JPG.

In order to store the selected images in the cases base (the input image will pass through this procedure too), they were scaled to a resolution of 320×240 pixels and segmented through a process of Multilevel Thresholding [Kurmyshev, 02]. Through this procedure we converted each 24-bits color image (with 16,777,216 possible colors or 256 possible values for each one of its color components) to a 4,096 colors image (where red, green and blue components have each one only 16 possible values). The following is an example of the function of Multilevel Thresholding over one of the color components (where $g(x,y)$ is the value of green component for the pixel in (x,y) and $G(x,y)$ is its new assigned value):

$$G(x, y) = \begin{cases} 8 & \text{if } 0 \leq g(x, y) < 16 \\ 24 & \text{if } 16 \leq g(x, y) < 32 \\ \vdots & \\ 120 & \text{if } 112 \leq g(x, y) < 128 \\ \vdots & \\ 248 & \text{if } 240 \leq g(x, y) < 256 \end{cases}$$

Or equivalently

$$G(x, y) = 16 \left\lfloor \frac{g(x, y)}{16} \right\rfloor + 8$$

Once the image has been scaled and the values of its color components have been reassigned, it will be extruded towards the 5D colorspace (according to the procedure commented in section 7.4).

Due to we are interested in compare images by considering only the volcano's fumaroles, we will try to eliminate some “noise” that could have impact on the retrieval

process. We will consider the volcano's silhouette as a source of “noise” because it has been observed that some images present that silhouette covered by snow while others don't present that situation and therefore the volcano's silhouette is visualized as a darker region (For example, see **Figure F.2**).



FIGURE F.2

Two possible situations related with the visualization of a volcano's silhouette. a) The silhouette covered by snow. b) The silhouette visualized as a dark region (Images obtained from [Cenapred, 03]).

As commented in section 7.4, the 5D hypervolume of an extruded lighter (darker) pixel will have a greater (lesser) value. The situation related to the silhouette's visualization is closely linked with the final 5D hypervolume of an extruded image. Because two images with similar fumaroles could have different silhouettes and therefore their total 5D hypervolumes could have important differences that could classify them as not “*initially similar*”. We will eliminate this “noise” by assigning to all the images in the cases base (and the input image) the same volcano's silhouette. This will be performed by computing the union of each one of the 76 extruded images with a image (also extruded to 5D colorspace) that contains a completely white volcano's silhouette and a black background (see **Figure F.3**).

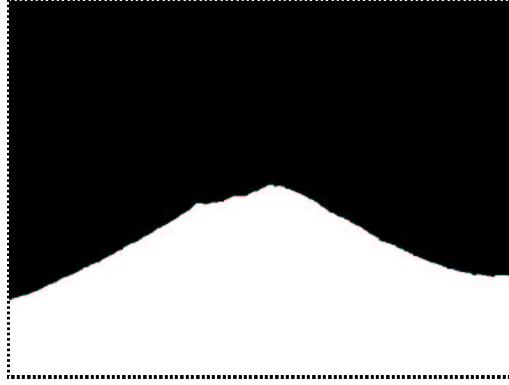


FIGURE F.3

The volcano's silhouette to assign to the images in the cases base
(own elaboration).

The union of two extruded images can be performed in a very simple way by considering all the intersection's process (commented in section 7.4) except in the new 5D hyperprism's determination. In the intersection's case, we determined one of the points in the new 5D hyperprism's main diagonal as:

$$(X_1 + 1, X_2 + 1, R_k, G_k, B_k)$$

Where

$$R_k = \min\{R_i, R_j\}$$

$$G_k = \min\{G_i, G_j\}$$

$$B_k = \min\{B_i, B_j\}$$

If we are performing the union's case, then we change the new point's determination by:

$$R_k = \max\{R_i, R_j\}$$

$$G_k = \max\{G_i, G_j\}$$

$$B_k = \max\{B_i, B_j\}$$

Independently of the silhouette's coloration in the original images, the union of them with image of **Figure F.3** will assign the white silhouette because all its color components are the highest possible, while the black background of **Figure F.3** won't affect the original images' background because its color components are the lowest possible (see two examples in **Figure F.4**).

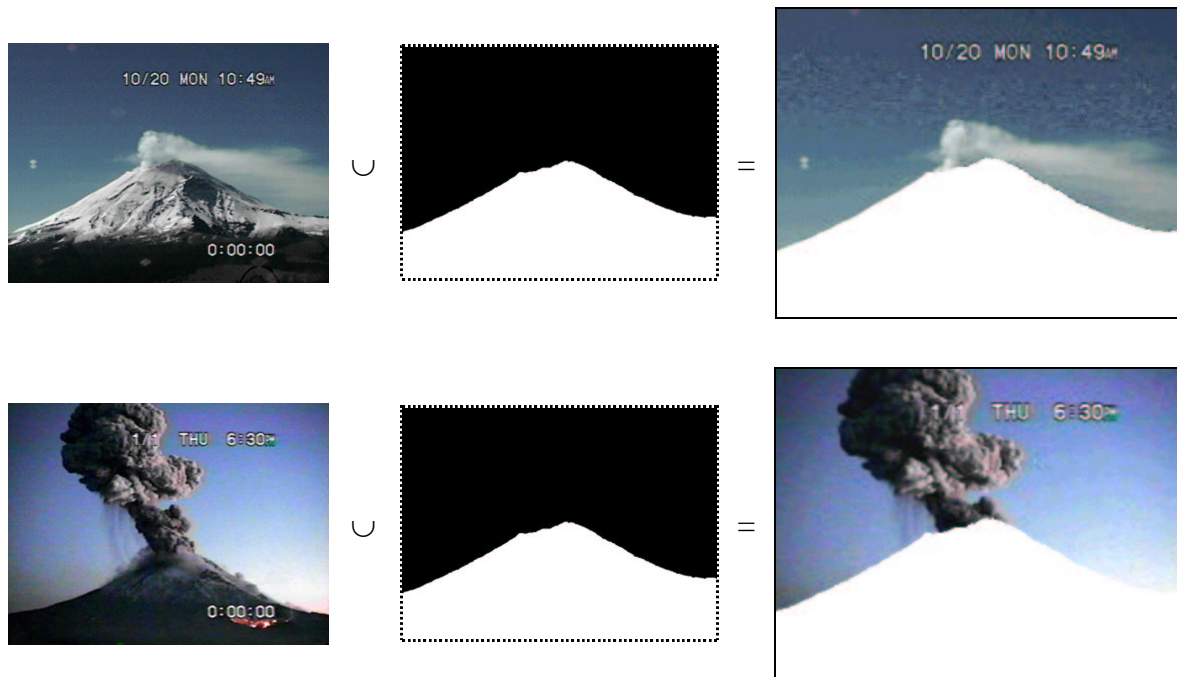


FIGURE F.4

Two examples of the assignation of the same volcano's silhouette by performing the union of images (original images obtained from [Cenapred, 03]. Remaining images: Own elaboration).

F.3.2 Implementation

F.3.2.1 Java Classes

The application was implemented under the Java Language (see the language's specification in [Gosling, 00]). In the **Figure F.5** is presented the classes diagram for the implementation.

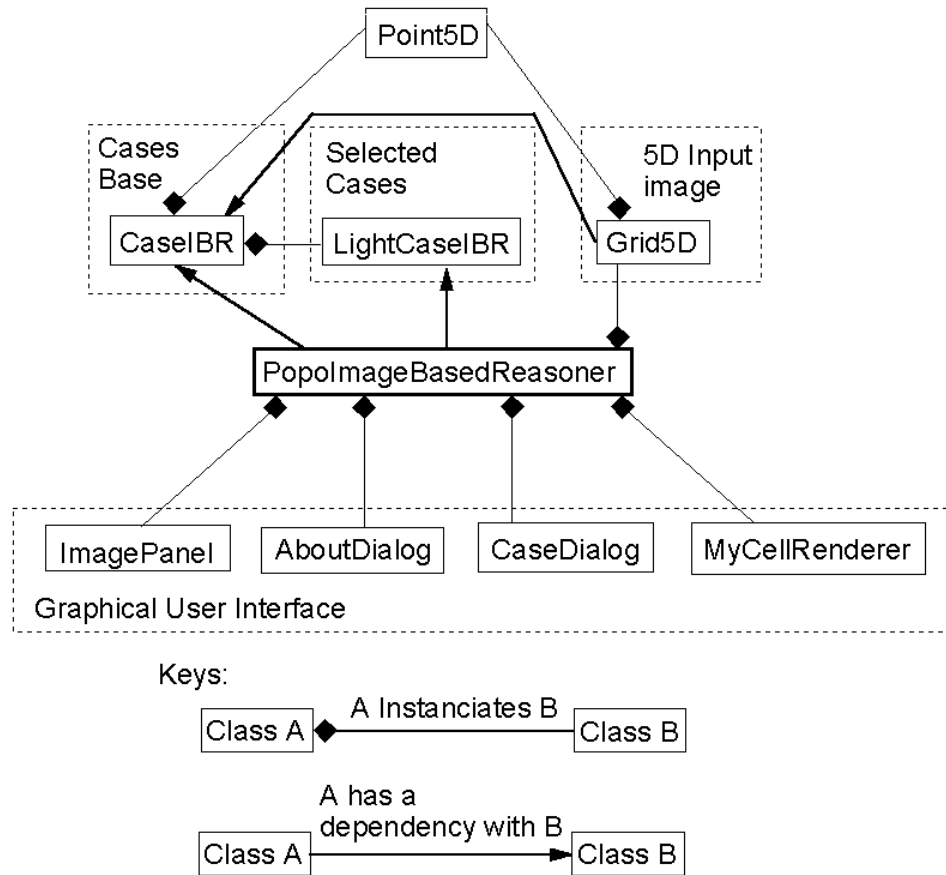


FIGURE F.5

Classes' diagram for the implemented Image Based Reasoner (own elaboration).

As can be seen in **Figure F.5**, the Java classes were grouped according to its context in the system. Now we will describe them briefly:

- Classes ***ImagePanel***, ***AboutDialog***, ***CaseDialog*** and ***MyCellRenderer***: This set of classes is related with the system's graphical user interface. They control events related to input devices (as the mouse) and the aspects related to the input and output of information, that is, the input of a new image and the output of the similar cases.
- Class ***Grid5D***: This class implements the methods for extruding a color 2D-image to the 5D colorspace (according to section 7.4). Moreover, an instance of this class contains the extrusion of an image (formerly, the input image), that is, its set of 5D hyperprisms.

This class also performs the procedure to compare two extruded images (according to section 7.4), that comparison is performed between an instance of this class and an instance of class *CaseIBR*.

- Class ***CaseIBR***: This class contains the descriptors for an stored case, that is, its set of 5D hyperprisms and its total 5D hypervolume, the original color 2D-image, and some additional information such as the image's date and description (text). Each one of the cases (instances of the class) are physically stored in devices as hard disks or CD-ROM.
- Class ***Point5D***: A class that contains only the five coordinates of a 5D space's point. It is extensively used in classes *Grid5D* and *CaseIBR* to describe the 5D hyperprisms that compose the extrusion of an image.
- Class ***LightCaseIBR***: When an stored case (an instance of class *CaseIBR*) is classified as similar to the input image then an instance of this class is used because the amount of data in an stored case is excessive to be used in the graphical user's interface (particularly due to the 5D hyperprisms). In fact, an instance of class *CaseIBR* provides to an instance of this class with the case's original color 2D-image and the additional data (date and description).
- Class ***PopoImageBasedReasoner***: The system's main class. It controls the user's events and the reading of stored cases.

F.3.2.2 The Graphical User Interface

There are four excepted inputs from the user (see **Figure F.6**):

- An image which will be compared with those in the cases base. The system only allows the input of images in formats JPG and GIF (button "Push to Select New Input Image").

- The three values corresponding to ε_1 (the allowed numeric difference between two images' corresponding 5D hypervolumes; text field "Allowed Difference Between Images"); ε_a (the allowed numeric difference between the extrusion of the input image and the intersection between the extrusions of the input image with each one of the stored cases; text field "Allowed Difference Between Input Image & Intersection"); ε_b (the allowed numeric difference between an stored case and the intersection between the extrusions of the input image with that stored case; text field "Allowed Difference Between Cases and Intersection). The values for ε_1 , ε_a and ε_b are respectively initialized with 0.05, 0.1 and 0.1, however, the user can modify them. See section 7.4 for more details about these input values.

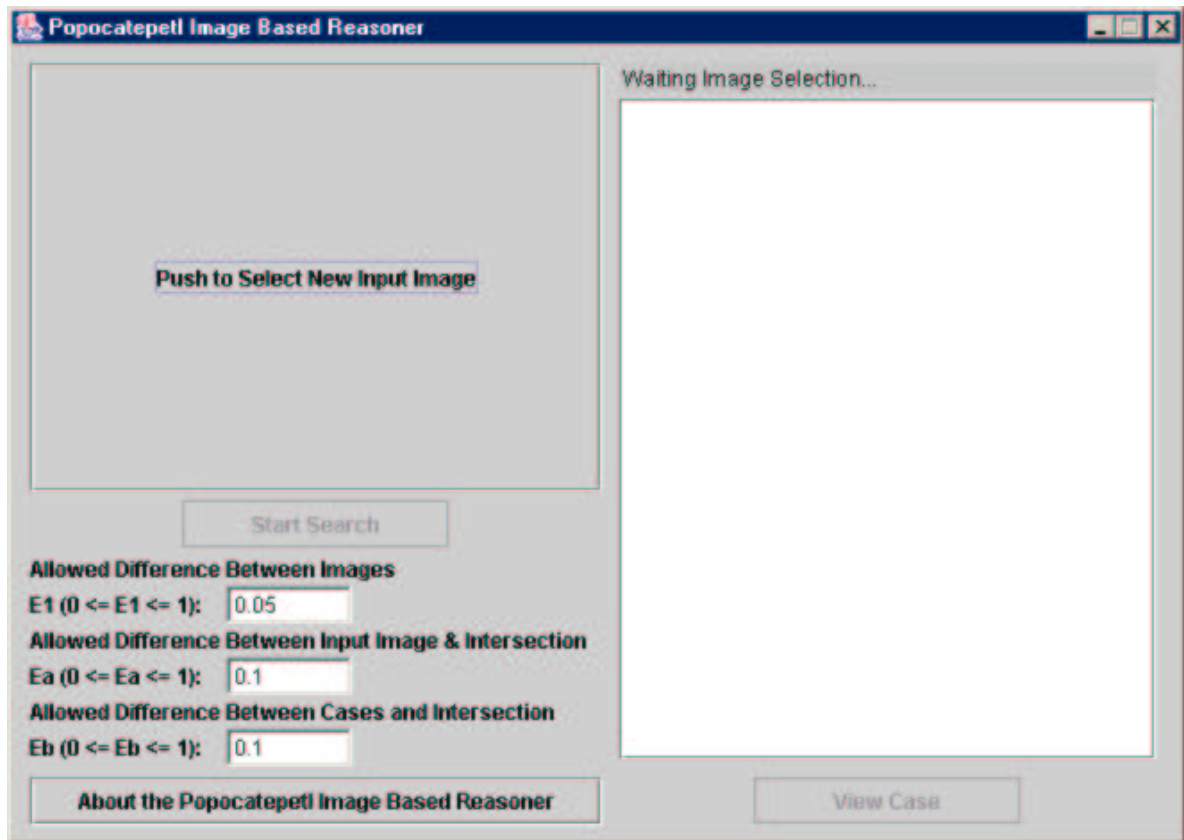


FIGURE F.6
The System's main graphical interface (own elaboration).

F.3.2.3 Querying the System

In the **Figure F.7** is presented an example of the input of an image. When the user press the button “Start Search” the system automatically starts the processes related to the input image’s extrusion to 5D colorspace, stored cases’ reading and the comparison between the images and cases. Finally, when the system presents the cases whose images were classified as similar (the icon’s list at the interface’s right side).

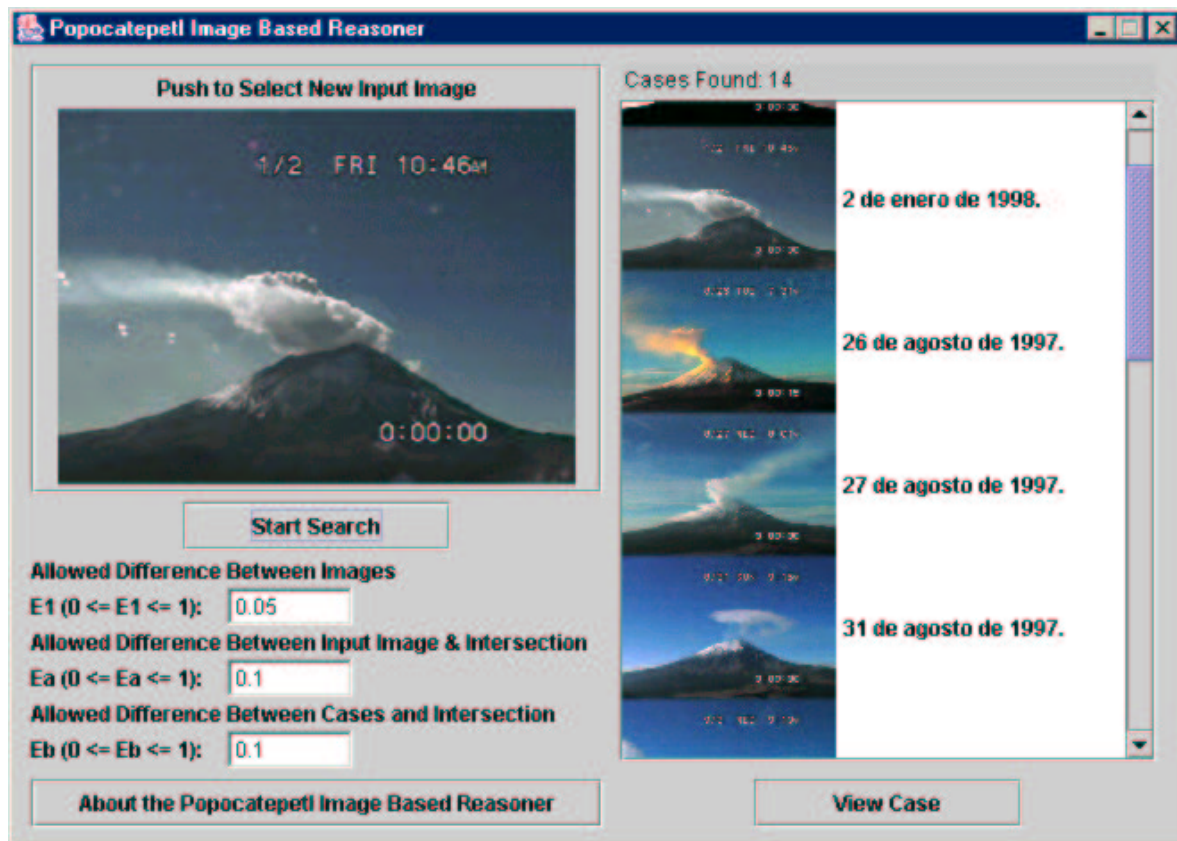


FIGURE F.7

An example of the System's input/output (own elaboration).

In the found cases' list, the user can select one of them in order to get a more detailed related information's case. Basically the user selects a found case and push the button "View Case". See in **Figure F.8** the information's visualization for the case labeled "26 de agosto de 1997" where can be appreciated, besides the case's original image, a detailed description of the volcano's activity and its proper alert's color.



FIGURE F.8

A case's detailed information (own elaboration).

