those obtained through the use of a traditional method, namely the dry mass method.

Morphological image processing is a kind of processing where the spatial structure of an object is modified. Erosion, dilation, and skeletonization are some of the main morphological operations applied. In dilation the object grows uniformly; in erosion it shrinks; skeletonization, in turn, creates a thin representation of the object.

As the only information about the fungus is a raster image, it is necessary to define a way to extract the relevant two-dimensional data in the image and use it to produce the three-dimensional figure. The information that can be extracted from the fungus image is its central and border lines. Considering that the fungus has a circular body, the relation between these two parameters allows the calculus of a medium radius of the fungus body in each point of the central line. Supposing that the fungus has a cylindrical shape, it is possible to calculate the central area and render the fungus’ body using a 3D graphics library for this, we used the OpenGL [Neider et al.93]. Another option is to use a scientific visualization system. wk [Schroeder98] is an object oriented scientific visualization system that can be used for the same purpose.

In the culture of this filamentous fungus there is a wide variation of morphology which ranges from a pelleted form, or spherical aggregates, to a filamentous or mycelium form, which is normally seen as a dense clump of filamentous. Filamentous mycelium produce a high viscosity in fermented environments, making difficult the provision of oxygen for the microorganism itself, as well as for the homogenization of the culture. On the other hand, pellets mycelium produces low viscosity in fermented environments; that is because their spherical and compact form facilitates agitation and therefore energy is saved.

Monitoring morphologic characteristics is of paramount importance for the bioprocess control and therefore for obtaining a high productivity of it. Traditional monitoring techniques present some drawbacks, such as: responses delay, stress of the operator and, very often, results with low precision. With all these disadvantages, the bioprocess control becomes difficult and not very reliable.

In the traditional method, results cannot be obtained in real time; that is, the measurement of the process’ variables takes a considerable amount of time. This difference in time makes difficult to update the controlled variables. On the other hand, other kinds of methods for the quantification of the morphological state, which use image analysis techniques, have proved to be quite efficient. In this work, it is shown how mathematical morphology techniques have helped in the treatment of image analysis of the fungus in mycelium form. The use of morphological operators automates the control process of growth of these funguses, which in their initial stage are filamentous and for which the establishment of geometric measurements is of great importance. In the final stage, this fungus form agglomerated colonies; thus, the analysis of their final form is crucial. However, this will be the subject for a future work.

Image segmentation is part of the analysis process and consists of dividing an image in parts or constituent objects. The desired level of segmentation is directly dependent on the application. Each object or part of the image is established according to its attributes. Usually, methods available for images in gray levels are based on two basic properties: discontinuity and similarity. Sudden alterations in gray levels characterize discontinuities and are usually associated with
change of objects in the scene. The main interest of segmentation based on discontinuities is the search of lines, curves and edges in images. Approaches based on threshold, growth, division and fusion of regions are aimed at segmentation based on similarity. In addition to these categories, characteristics such as movement, among others, can be used for improving the segmentation performance.

2. Morphological Techniques Used

Let A and B be contained in \( Z^2 \) and let \( \emptyset \) be the empty set. The following basic definitions can be established. The translate of A by x is defined by:

\[
(A)_x = \{ c | c = x, \text{for } a \in A \}
\]

The reflection of B, is given by:

\[
B^r = \{ x / x = -b, \text{for } b \in B \}
\]

The complement of A is:

\[
A^c = \{ x / x \notin A \}
\]

And finally, the difference of A and B is:

\[
A - B = \{ x / x \in A \land x \notin B \}
\]

Using these definitions, widely used operations are:

\[
\text{Dilation}: A \oplus B = \{ x / (B)_x \cap A \neq 0 \}
\]

\[
\text{Erosion}: A \ominus B = \{ x / (B)_x \subseteq A \}
\]

These operations are dual in relation to complementation and reflection, that is:

\[
(A \ominus B)^c = A^c \oplus B^c
\]

B is called structuring element.

Image segmentation is possible with the use of different techniques, among which MM, which is now being described. The original image shown in Figure 1, with black and white inverted, is initially submitted to a “Top-Hat” by opening, in order to eliminate the great variation of gray levels of the background. The “Top-Hat” by opening detects the peak of the image. This detection is obtained through an opening applied to the original image and then subtracting the resulting image from the original one.

Figure 1 - Original picture of the mycelium.

In other words, the result of Top-Hat by opening can be defined by:

\[
T = A - \text{Opening}(A)
\]

where A is the original image. Figure 2 shows the result of this operation.

Figure 2 - Image after the Top-Hat operation.

The structuring element to be used is important because it determines how much the image will be enhanced in contrast to its background. A disk-shaped structuring element, with a diameter of 6 pixels, was used. This element proved to be very efficient for the elimination of the background without