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Qualitative Analysis of Membrane Filter used for Bacteria Filtration using Feature Extraction Techniques

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Abstract

This paper presents the statistical analysis for the quality check of membrane filter, used for the bacteria filtration, using the image processing techniques. The quality of membrane filter is determined by the uniformity factor of the polymer beads under test. We compare the performance of well known watershed method and active contour method used for the segmentation process. The simulation results are presented to demonstrate that the active contour method based segmentation outperforms the watershed feature extraction technique in case of qualitative analysis of the membrane filter.

Keywords: *Active contour method, Watershed method, Membrane filter, and Polymer beads.*

1. INTRODUCTION

Membrane filters or “membranes” are micro-porous films with specific pore size ratings. Membranes retain particles and microorganisms those exceed their pore ratings by acting as a physical barrier, and thus capturing such particles on the surface of the membrane. This filtration also helps to remove the bacteria from heat labile liquids such as sera and solutions of sugars or antibiotics used for the preparation of culture media. As viruses pass through ordinary filters, the membrane filtration can be used to obtain bacteria free filtrates of clinical samples for virus isolation. Efficient filters also help to concentrate bacteria from liquids, e.g., in testing water samples for cholera vibrios or typhoid bacilli. Bacterial toxins can also be obtained by passing cultures through such filters [1]. Uniformity factor of the polymer beads may be used to determine the quality of the given membrane filter. Specifically, the presented analysis focuses on producing a system, which generates statistical data for the quality check of membrane filter using image processing.

Membrane filters are available in standard as well as custom sizes, shapes and materials. Some common materials used are MCE (nitrocellulose), cellulose acetate, coated PTFE (Teflon), hydrophobic PTFE, nylon, polycarbonate and glass. The membrane filters are constructed from very thin layers of polymers and other advanced synthetic materials. Membrane filter thickness varies from 100 to 300 micro-meters. These are mostly designed and manufactured with approximately 70 to 90 percent porosity. The porosity is normally specified by the filter manufacturer, and it effectively controls the fluid flow rate and the particle capture size. The porosity and effective filtration area should be matched for absorption, flow requirements and medium binding requirements. The polymer beads are the tiny polymer particles used to make membrane filters. These particles are spherical in shape. Since they are of very small size, so their shapes and sizes cannot be judged with a naked eye. A microscope has to be used, under which judging its shape and size is easy. But by just looking at these beads, we can only roughly estimate their uniformity. Here, the aim is to develop a semi-automated system to check the uniformity of polymer beads. The uniformity of beads is needed, as it directly affects the quality of membrane filter. Higher is the uniformity in size, greater will be the quality of produced filters. In this work, we process the image of the sample to get the area of beads, and then statistically analyze it to study its uniformity.

The membrane filter (MF) technique was introduced in the late 1950s as an alternative to the most probable number (MPN) procedure for microbiological analysis of water samples. The membrane filtration technique offers the advantage of isolating discrete colonies of bacteria, whereas the MPN procedure only indicates the presence or absence of an approximate number of organisms (indicated by turbidity in test tubes). In membrane filtration, a solute is passed through a semi-permeable membrane. The membrane's permeability is determined by the size of the pores in the membrane, and it will act as a barrier to particles which are larger than the pores, while the rest of the solute can pass freely through the membrane. The result is a cleaned and filtered fluid on one side of the membrane, with the contaminated solute on the other side.

Nano filtration, ultrafiltration, microfiltration and reverse osmosis are all membrane filtration techniques. In all cases, the size of each pore has to be carefully calculated to exclude undesirable particles, and the size of the membrane has to be designed for optimal operating efficiency. Membranes are also prone to clogging as the pores slowly fill with trapped particles, which means that the system must provide accommodations for easy cleaning and maintenance, so that it can be kept in good working order. Many membrane filtration systems are designed for industrial uses. One of the big advantages to such a system is that it does not require the use of chemicals or additives, which cuts down on operating costs. Additionally, membrane filtration requires minimal energy, and it can in fact be designed to run on almost no energy, with a pressurized system which takes advantage of gravity, and also forces the solute through the membrane at a steady rate. The electronics industry monitors for all microorganisms because they must keep their process-water free from even the smallest organisms. Microbial monitoring in the food and beverage industry typically employs several types of techniques because of the variety of samples those are encountered. Beverage samples can typically be monitored for microorganisms by the membrane filtration technique.

However, the statistical data can be obtained by processing samples of the polymer beads in the membrane filter. The quality of the membrane filter is checked by the number and area of polymer beads. It is concluded from the statistical data that greater the uniformity in the area of polymer beads, better is the quality of the membrane filter.

2. SYSTEM MODEL

In order to use the image of the filter for different analysis, the image has to be pre-processed for its perfect and efficient use in the stages to be followed. The pre-processing includes the removal of any type of noise in the image. The noises are of different kinds and can be removed using different filters. The most common noise that corrupts the images is the salt and pepper noise, which can be removed using median filter for the images of any size mask.

Next, the image segmentation technique is used to find objects of interest from the background. The object pixels would be black (minimum intensity) and background pixels white (maximum intensity). The segmentation refers to the process of partitioning a digital image into the multiple segments. The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Medical image segmentation refers to the segmentation of known anatomic structures from medical images. Structures of interest include tumors, cysts, as well as other structures such as bones, vessels and brain structures.

Further, thresholding [2] is the simplest method of image segmentation. From a grayscale image, thresholding can be used to create binary images. Image thresholding is a common task in many computer vision and graphics applications. The goal of thresholding an image is to classify pixels as either "dark" or "light". However, global thresholding is successful in highly controlled environments. One of the areas, in which this is often possible, is in industrial inspection applications; where the illumination control is usually feasible. Images having uneven illumination make it difficult to segment using global thresholding. This approach divides the original image into sub images and uses the above said thresholding process to each of the sub images.

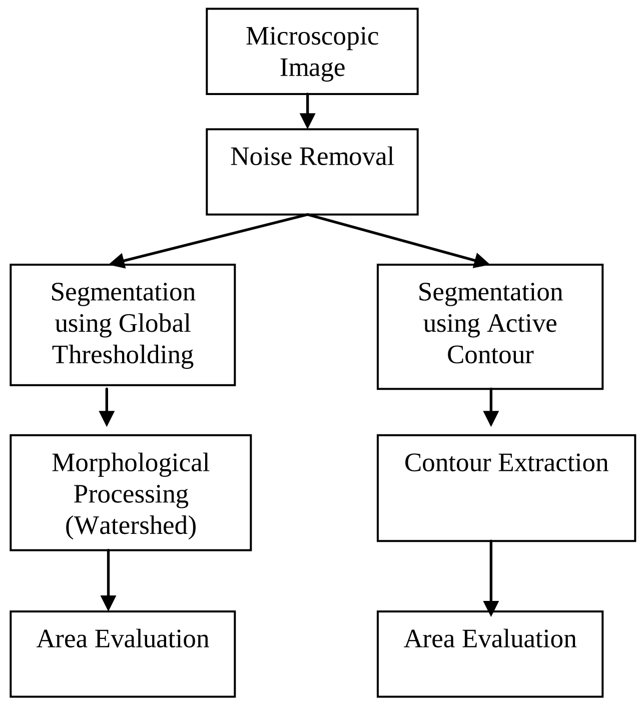

Figure 1. System model to compare the performance of active contour method with watershed technique.

In the present scenario, we compare the performance of active contour method and watershed method by using the scheme proposed in Fig. 1. Besides the challenges due to imaging noise and partial volume effects, the similarity in intensity and texture between neighbouring structures complicates the task of identifying distinct boundaries between the structures. Therefore, the active contour method was introduced, which developed the concept of shape contours [3].While evolving shape contours, the interaction consists of modelling the "forces" of attraction, repulsion and competition by taking into account the relationship between object contours and their shape estimates. The morphological operations [4] are to be performed on grey scale itself for required transformation, which leads to uniformity factor. The process of segmentation results in an image of the same size as the original, but consists of only two levels to distinguish between the elements of interest and background. The segmented images are also known as binary images. In our case, the segmented image of the membrane filter beads results in an image with black background with white beads. The white beads are the elements of interest, which are to be extracted; and their areas are to be calculated for checking the uniformity in the polymer beads of the membrane filter.

However, the watershed transform [5] can be used for the separation of the clustered cells. The simple concept of watershed is that the troughs are filled with water in order to find the watershed ridge lines. However, the over-segmentation problem can occur when we apply the watershed transform. We therefore align the object in order to reduce this problem [6]. On the other hand, the basic idea in active contour models [7, 8] or snakes [3] is to evolve a curve, subject to constraints from a given image, in order to detect objects in that image. For instance, starting with a curve around the object to be detected, the curve moves toward its interior normal and it has to stop on the boundary of the object. After the segmentation process, the boundaries of the polymer beads are extracted, and the areas of different beads are calculated and worked upon to check the uniformity/quality of membrane filter.

3. SIMULATION DETAILS

The approach followed for the simulations is shown in Fig.1. The two techniques applied for the comparison are worked upon various images of the membrane filters, and it is well demonstrated that the active contour based segmentation results in better segmentation of the images and in turn helps in better extraction of the filter beads for their area calculation. The areas which are extracted using the above mentioned techniques are evaluated for the performance. It is apparent from the results that the filter polymer beads' area extraction using active contour method is more accurate than the watershed method. For the evaluation of two techniques in this paper, we worked upon three specimens of membrane filters referred to as A, B, C in the figures shown below. The Fig. 2.1 and Fig. 3.1 show the original membrane filter images with filter polymer beads. Fig. 2.2 and Fig. 2.3 show the segmented images of membrane filter and the bead extraction using watershed technique respectively. In comparison, the results for the segmentation and extraction using the active contour method are depicted in Fig. 3.2 and Fig. 3.3 respectively. The area of the extracted beads in each image is calculated and a histogram of the watershed based method is shown in Fig. 2.4, and the active contour based method is shown in Fig. 3.4.

4. CONCLUDING REMARKS

In this paper, we compared the two well-known techniques for image segmentation and feature extraction namely watershed and active contour based method. The simulation results manifest that the active contour method outperforms the watershed based method on the basis of segmentation and feature extraction, as active contour method results in accurate area evaluation of polymer beads of the membrane filter, which are approximately of the same size in a particular filter. It is clearly observed from the results that the active contour based segmentation results in lesser variance of the area extracted from the microscopic image than the method involving watershed technique. Hence, the proposed active contour based segmentation is better for the analysis of bio-medical images [9].

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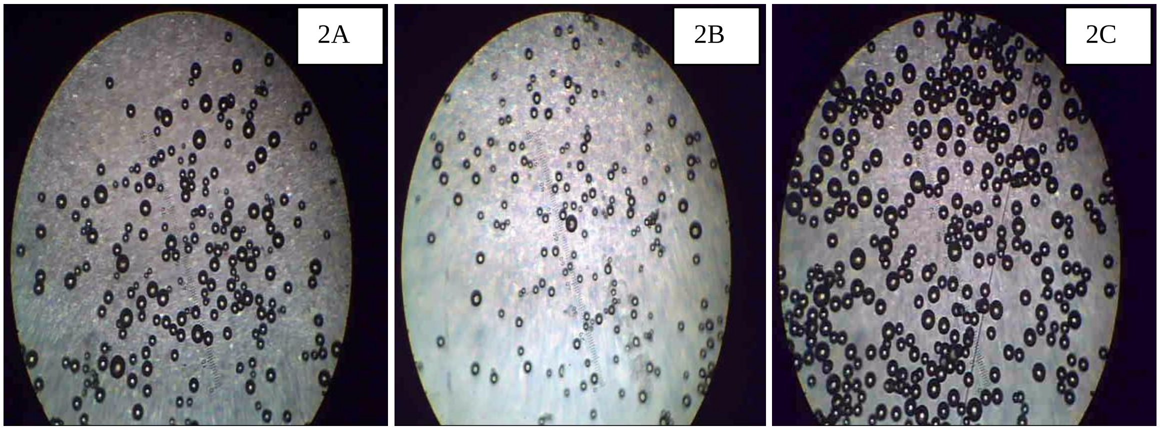

Figure 2.1. Orginal images of a membrane filter.

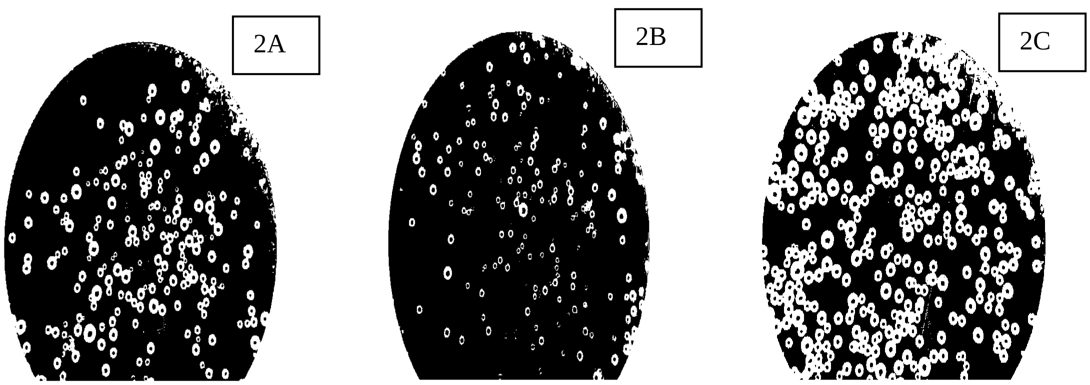

Figure 2.2. Segmentation using watershed technique.

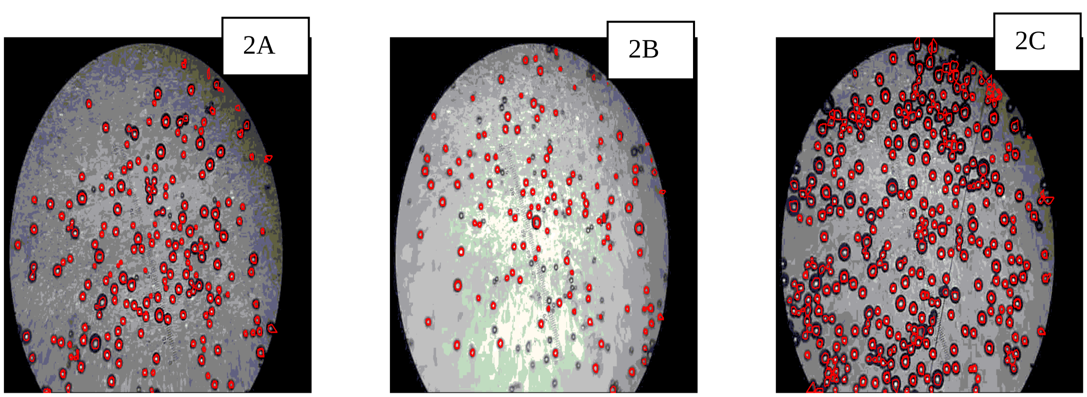

Figure 2.3. Extracted pore boundaries with watershed implementation.

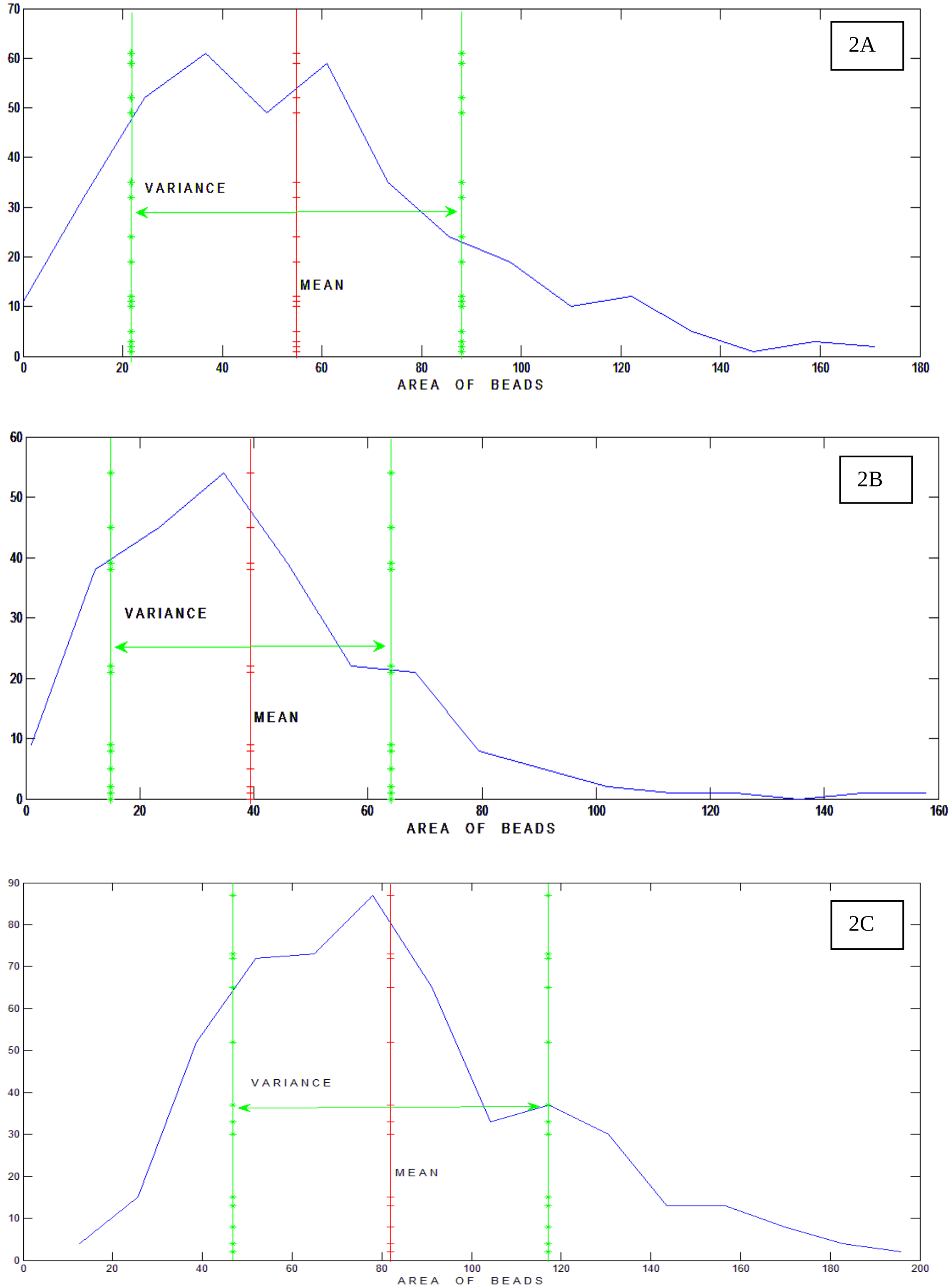

Figure 2.4. Area distribution of the three images with watershed method.

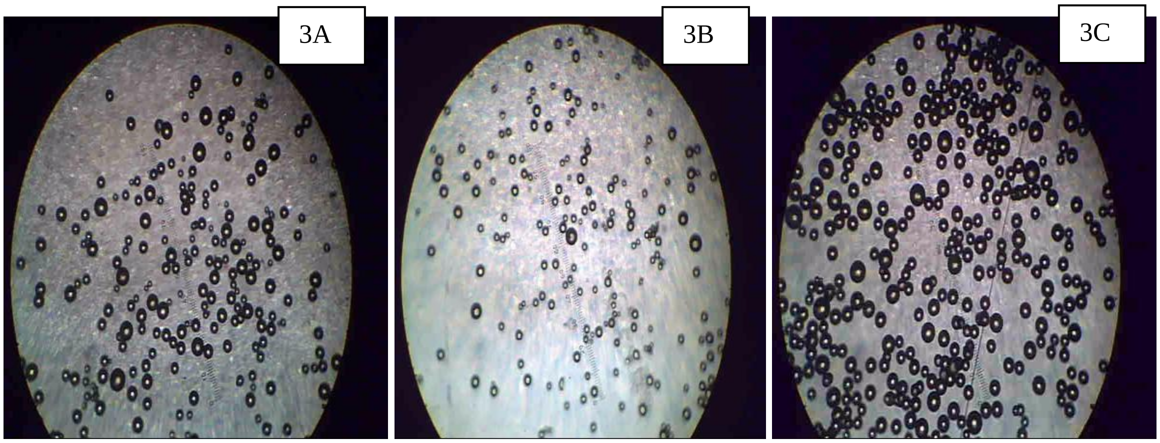

Figure 3.1. Orginal images of a membrane filter.

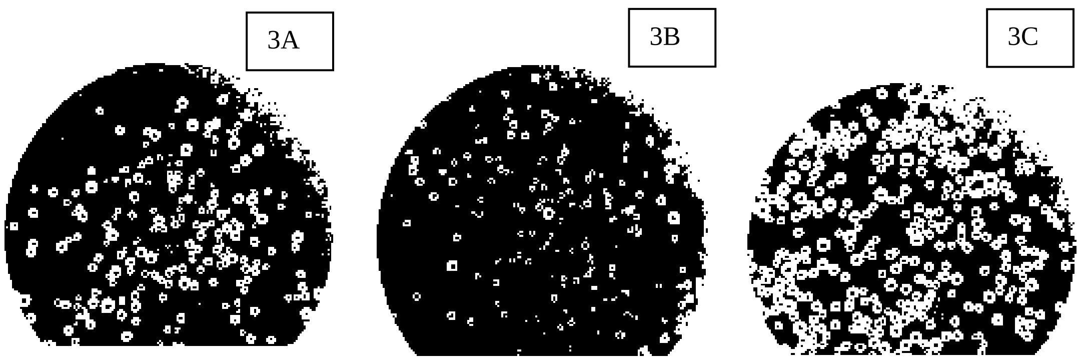

Figure 3.2. Segmentation using active contour technique.

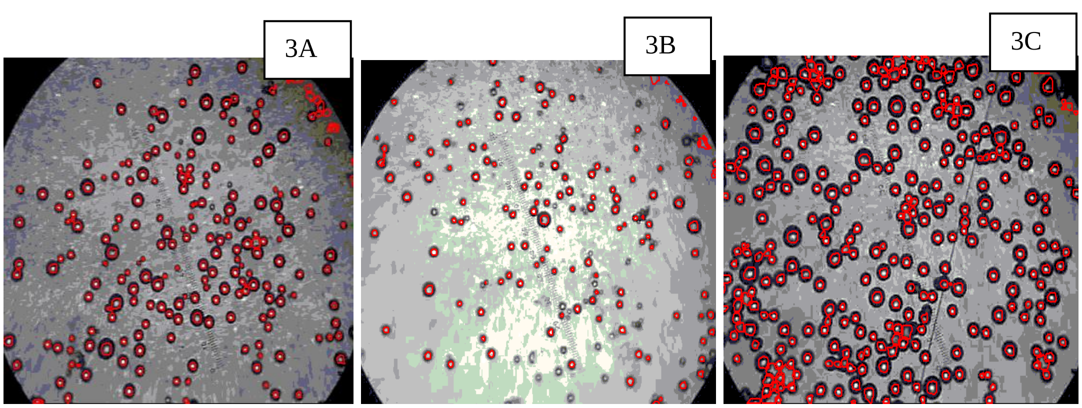

Figure 3.3. Extracted pore boundaries with active contour implementation.

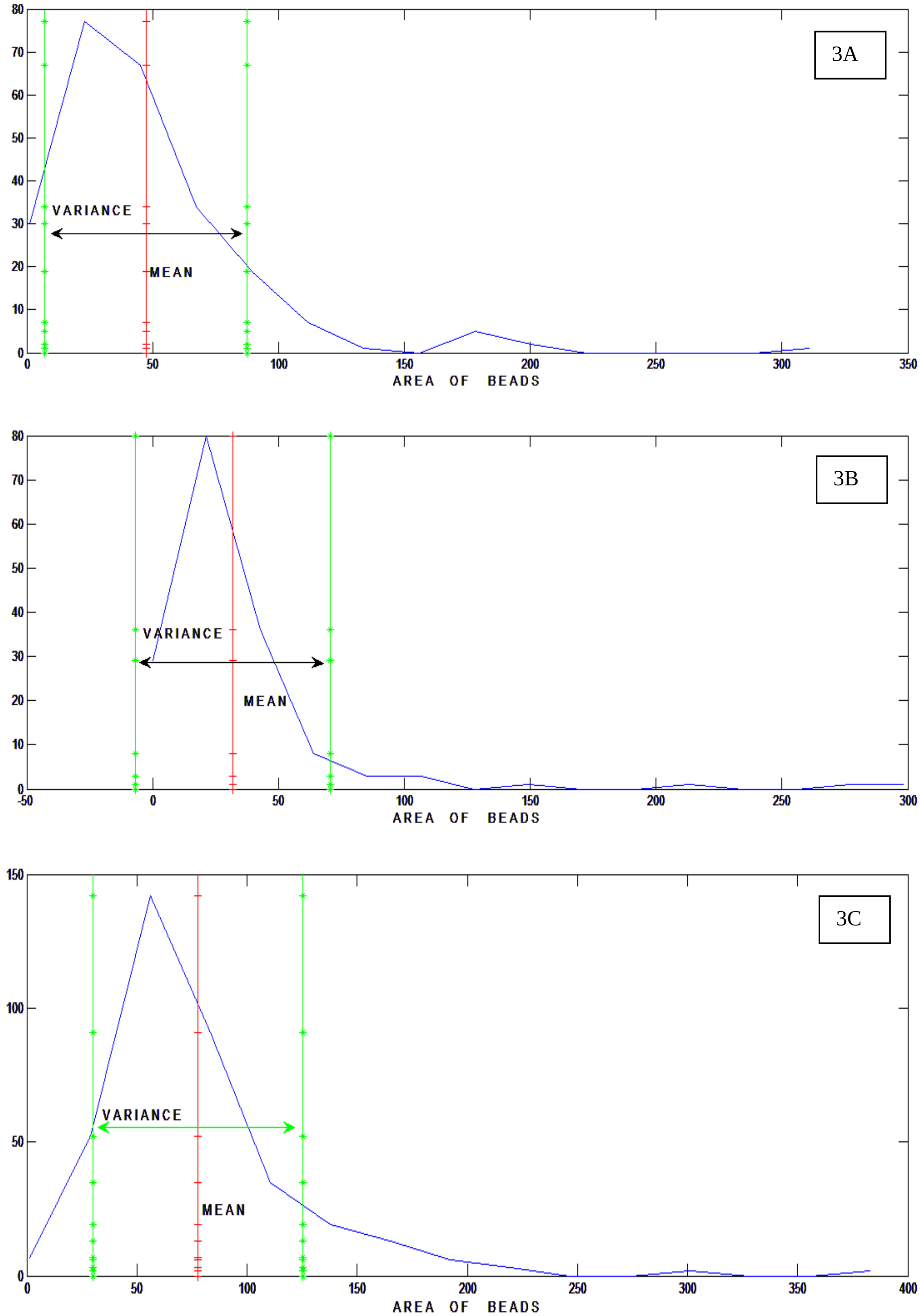

Figure 3.4. Area distribution of the three images with active contour method.

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