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Using Segmentation Techniques for Nuclear Tracking of Images

One of the most used track detectors is the CR-39, which delivers the precise number of particles with high detection efficiency, assuming that the particles connect with it and releases enough energy. However, because of varying environmental factors, as well as the complexities of detection method and the ambiguous nature of the anomaly, it is difficult to detect number of the nuclear trace. in this research three different trace nuclear images have been used with different numbers of track, after the laboratory works three different nuclear images are obtaining, these images differ from each other in the time of etching, after obtaining these images different segmentation methods are applied on it such as global thresholding, canny edges detection, K-mean clustering and watershed transform, these method of segmentation used to allows the nuclear effects to be appear clearly by clearly highlighting the edges of the image and clearly showing the teeny track of the nuclear effects in the images as well as isolating the damaged area from the undamaged area and isolating the region of interest from the background, all these work was done by written program using MATLAB.

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1. Introduction

Nuclear particles passing the material create trails of molecular damage, with these affected areas eroding more rapidly than the surrounding bulk, resulting in voids known as tracks [1]. The main benefits compared to radiation detectors include the comprehensive data on individual particles, the durability of the tracks enabling prolonged observations, and the detectors straightforward and smoothly [1].

For these reasons, Solid State Nuclear Track Detectors “SSNTDs” are commonly used to study: cosmic rays, long-lived radioactive elements, radon concentration in houses, and the age of geological samples [2]. SSNTDs operate on the principle that charged particles create destruction in the detector at a nanometer scale along their path, allowing the track to be etched far faster than the undamaged substrate. Etching [3], usually conducted for several hours, exacerbates the damage to conical pits of micrometer scale observable under a microscope. The track length of a specific particle correlates with its energy. The charge can be established by comparing the etch rate of the track to that of the bulk material. If particles strike the surface at normal incidence, the insure circular; otherwise, the elasticity and orientation of the elliptical pit mouth reveal the direction of incidence [4].

The term track is created when a particle travels across a nuclear track detector and destroys polymeric bonds in a cylindrical area that stretches to a few tens of Nano meters surrounding the particle track [5].

A sample of a SSNTD, is a material subjected to radioactivity (the neutrons or charged particles, and as well as gamma rays). It is then etched in a corrosive chemical and inspected under a microscope. Molecular damage is left in their wake by the nuclear particles as they go through the substance, and these damaged areas erode more quickly than the surrounding material [6].

Image segmentation methods plays an essential role in detecting nuclear traces in all detectors in general, especially in the CR39 solid state nuclear track detector, by Separate the region of interest from the background to facilitate the process of clearly showing the nuclear effects, then to facilitate the process of counting them and finding the density of the nuclear effect on the detector [7,8].

In image processing, image segmentation refers to the division of a digital image into several segments, often termed image regions or image objects (collections of pixels). The objective of image segmentation is to reduce and/or alter the representation of an image into a more comprehensible and analyzable form. Image segmentation is commonly employed to identify objects and delineate boundaries (lines, curves, etc.) inside images. Image segmentation is the process of assigning a label to each pixel in an image, ensuring that pixels with identical labels exhibit shared properties [9].

There are many types of segmentation methods, such as:

a- Global Thresholding Segmentation

A Straightforward technique for object detection is the thresholding method, which distinguishes the foreground from the background by applying a singular threshold to pixel intensity. Let a pixel in a two-dimensional image be represented as f(x,y), with x and y denoting the horizontal and vertical coordinates, respectively. A distinct threshold of T assigned to each image pixel is referred to as a global threshold. A straightforward method for detecting or extracting items from the background involves selecting an ideal threshold t that effectively distinguishes the foreground, namely the object, from the background.

The segmentation image ($g_{(x,y)}$) of an input image ($F_{(x,y)}$) is given by the relation [10]:

$$g(x,y) = \begin{cases} 1 \; when \; f(x,y) < t \\ 0 \; when \; f(x,y) \geq t \end{cases} \qquad (1)$$

When it is a constant applied uniformly over the entire image, referred to as the thresholding value, the method described in equation (1) is termed global thresholding. Numerous techniques exist for establishing a global threshold to separate an object from the background, including the minimum error threshold approach and the Otsu threshold method [11].

b- K-mean clustering

The K-Mean clustering is a technique for pulse code modulation. K-Means clustering is a splitting method applied for cluster analysis. The technique first identifies items as initial cluster locations, then computes the distance from each cluster unit to each item, before assigning each object to the closest cluster. The mean values of all clusters are subsequently adjusted, and this process is reiterated till the requirement value ends Quadratic error criterion for clustering. The equation of K-mean clustering is given by [12].

$$E = \sum_{i=1}^{k} \sum_{j=1}^{ni} ||x_{ij} - m_i|| \qquad (2)$$

where xij represents the j- sample of the i- class, mi denotes the centroid of the i- class, and ni indicates the quantity of samples in the i- class [13]

c- Canny edges detection

Canny edge detection is one of the most thoroughly defined procedures among the several edge detection techniques, offering accurate and effective detection. Due to its effectiveness in satisfying the three parameters for edge detection with the simplicity of execution, it has emerged as one of the most favored algorithms for this purpose [14].

The detection of canny edges is a technique for deriving significant structural insights from diverse physical entities whiles significantly reducing the data to be processed. It has been extensively applied in numerous vision systems for computers. Canny has determined that the prerequisites for implementing edge detection across various vision systems are notably analogous. Consequently, an edge detection method to meet these requirements can be applied in various contexts. The fundamental criteria for edge detection encompass [15].

a. Edge recognition with a low failure rate, signifying that the procedure must reliably identify the maximum number of edges present in the image.
b. The boundary point defined by the operator must accurately correspond with the exact middle of the edge.
c. Each edge in the image must be marked singularly, and image noise should be minimized to prevent the creation of spurious edges.

To achieve these goals, Canny utilized the mathematical method of variations—a technique that determines an equation that maximizes a particular functional. The optimal function of Canny's detector is defined by the summation of four exponential terms; yet, it may be represented by the first-order derivative of a Gaussian [15].

Canny edges detection equation given by [16]

$$\left. \begin{aligned} G &= \sqrt{G_x^2 + G_y^2} \\ \text{angle } (\omega) &= tan^{-1} \left(\frac{G_y}{G_x}\right) \end{aligned} \right\} \qquad (3)$$

The image is orientated in both vertical and horizontal planes in order to obtain the first gradient in the direction that is horizontal (G_x) and the vertical direction (G_y). From both of these images.

d- Watershed Transform

In the field of image processing, a watershed is an alteration implemented on a greyscale image. The phrase literally signifies a physical watershed or irrigation divide that separates adjacent drainage areas. The watershed conversion evaluates an image as a map of the earth, where the intensity of each pixel represents its level and delineates the paths that intersect the peaks of ridges [17].

Multiple scientific terms are available for a watershed. Watershed sections in diagrams can be defined on the nodes, the edges, or as composite lines that incorporate both nodes and edges. Watersheds can also be delineated inside the continuous domain. Numerous algorithms exist for the computation of watersheds. Watershed algorithms are employed in image processing chiefly for the purpose of object segmentation, specifically for distinguishing various objects within an image. This facilitates the enumeration of objects or enables additional analysis of the segregated items [17].

Let u(x,y) be a scalar value representing an image (I), where (x,y) ∈ R^2. The morphology variation of (I) is distinguished by, [18].

$$\delta Du = (u \oplus D) - (u \ominus D) \qquad (4)$$

where $(u \oplus D)$ and $(u \ominus D)$ denote the fundamental deformation and deformation of (u) by the structural element (D), accordingly [18]

The morphological Laplacian is given by [18]

$$\Delta Du = (u \oplus D) - 2u + (u \ominus D) \quad (5)$$

This structural Laplacian enables the differentiation of influence zones for minima and maxima: locations where $\Delta Du < 0$ are classified as impact areas of maxima, whilst regions where $\Delta Du > 0$ are classified as impact areas of minima. Consequently, $\Delta Du = 0$ enables the interpretation of edge positions [18].

2. Experimental Part

In this research, four methods of segmentation were studied on different samples of the images of the nuclear detector CR39. First the detector was irradiated inside the nuclear laboratory at Al-Mustansiriyah University in the College of Science, Department of Physics with a radioactive source (Radium Ra226 with a half-life of 1620 years) for a time of 5 minutes and at a distance of 2 cm between the detector and the radioactive source, After irradiation the detector was placed in a chemical solution sodium hydroxide (NaOH) to etch the detector

This process is very important because the nuclear effect doesn't appear without etching process, in our research three different times (t): 1h, 2h and 3h have been adopted for etching process. After the etching process is finished the detector was placed under the microscope to obtain the images. Three different images (Fig. 1) have been obtained, these images are:

Image (a): the image etched with time equal 1h
Image (b): the image etched with time equal 2h
Image (c): the image etched with time equal 3h

In our research, the main contribution are using four different segmentation technics on nuclear tracking images, to find the best segmentation methods using in this field

3. Results and Discussion

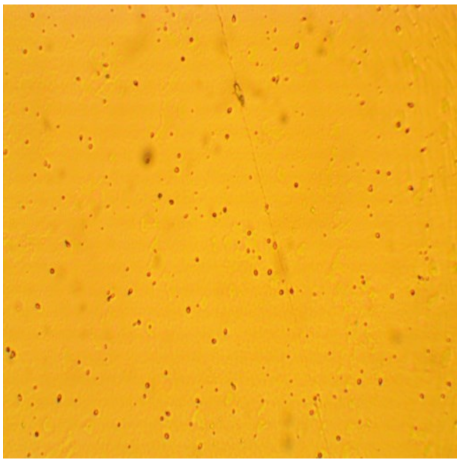
After obtaining these three images the four segmentation methods are applied. The segmentation process is very important to separate the region of interest (nuclear traces) from the background.

In our research four different segmentation algorithms have been adopted, these algorithms are Global thresholding, K-mean clustering, canny edge detection and watershed transform,

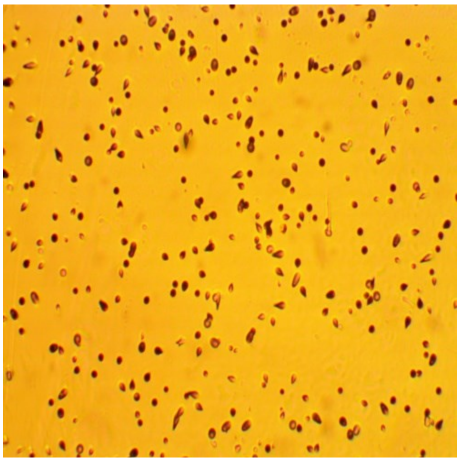
Figure (2) shows the segmentation process applied on image (a)
Figure (3) shows the segmentation process applied on image (b)
Figure (4) shows the segmentation process applied on image (c)

Figure (1) represents:

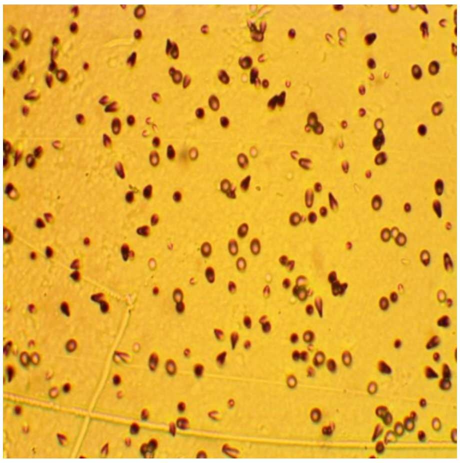
- ✓ Image (a): was etched in (NaOH) solution with time of 1h.
- ✓ Image (b): was etched in (NaOH) solution with time of 2h.
- ✓ Image (c): was etched in (NaOH) solution with time of 3h



(a)



(b)



(c)

Fig. (1) The three different images obtained in the laboratory

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Figure (2) showed that the four segmentation methods (global thresholding, canny edges detection, K-mean clustering and watershed transform) are applied on image (a) etching time 1h, and from Fig. (2) the segmentation using global thresholding and K-mean clustering are the best segmentation methods than canny edges detection and watershed transform, because canny edges detection and watershed transform are very sensitive to the noise, therefor after applied these algorithm's we get false segmented area due to the noise.

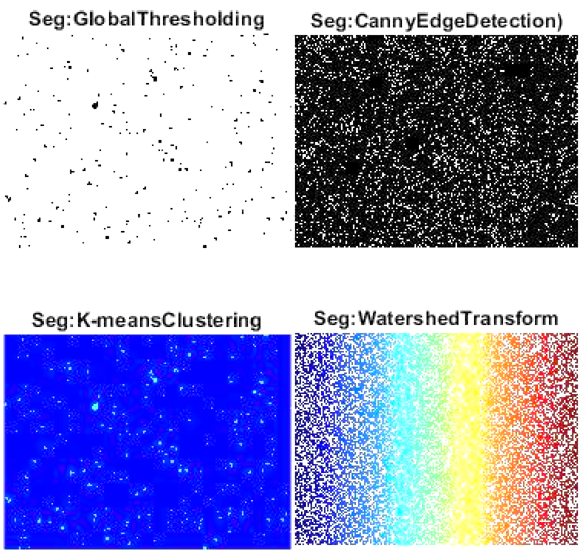

Fig. (2) The four segmentation method applied on image (a)

Figure (3) showed that the four segmentation method (global thresholding, canny edges detection, K-mean clustering and watershed transform) are applied on image (b) etching time 2h, and from Fig. (3) the segmentation using global thresholding and K-mean clustering are the best segmentation methods than canny edges detection and watershed transform, because canny edges detection and watershed transform are very sensitive to the noise, therefor after applied these algorithm's we get false segmented area due to the noise.

Figure (4) showed that the four segmentation method (global thresholding, canny edges detection, K-mean clustering and watershed transform) are applied on image (c) etching time 3h, and from Fig. (4) the segmentation using global thresholding and K-mean clustering are the best segmentation methods than canny edges detection and watershed transform, because canny edges detection and watershed transform are very sensitive to the noise, therefor after applied these algorithm's we get false segmented area due to the noise.

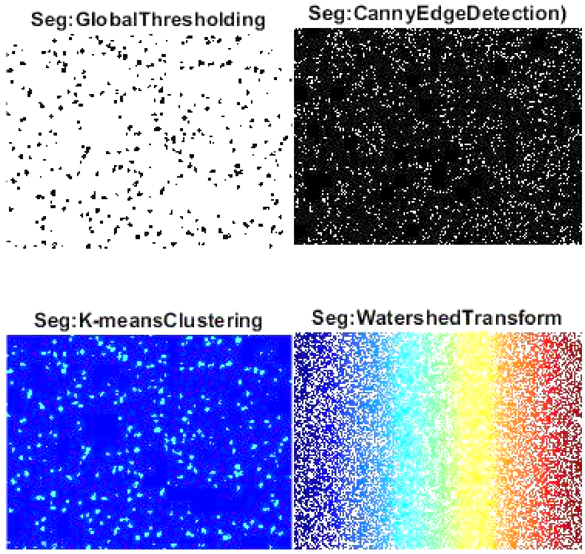

Fig. (3) The four segmentation method applied on image (b)

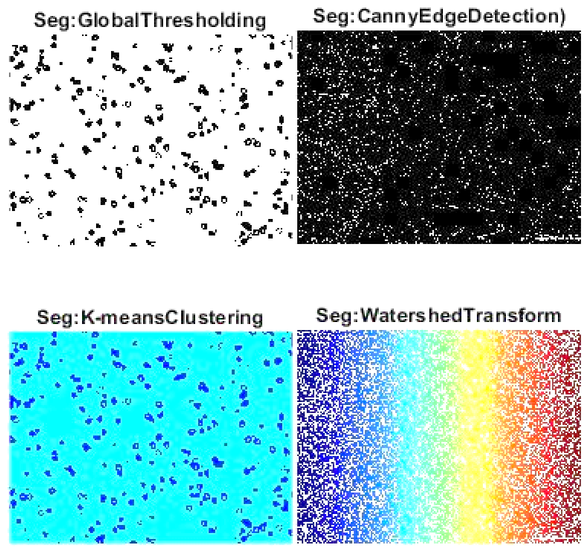

Fig. (4) The four segmentation method applied on image (c)

4. Conclusions

From our research we can conclude that the longer the etching times the clearer and deeper the nuclear traces appeared. This is due to the angle of incidence of the radiation on the detector, as some of the radiation enters the detector at an angle, so its effect on the surface is very small. However, when the time of etching increase, the surface of the detector is etched deeper, and thus the effect is clearer.

Four segmentation methods were applied: global thresholding, K-mean clustering, canny edges detection and watershed transform, and from the above figures we conclude that using global thresholding and K-mean clustering give the best results than other two methods, also we conclude that using canny edge detection and watershed transform are very sensitive to the noise in the image, and that leads to bad segmentation results, which gives false segmented area.

References

[1] N. Stevanovic et al., “Correlations between track parameters in a solid-state nuclear track detector and its diffraction pattern”, *Rad. Phys. Chem.*, 193 (2022) 109-126.

[2] H.T. Hamad, N.F. Kadhim and M.S. Karim, “Radon Gas Questionnaire for Students of the College of Science, Mustansiriyah University”, *Al-Mustansiriyah J. Sci.*, 32(4) (2021) 111-123.

[3] R.S. Ahmed et al., “Evaluation of uranium concentration in the blood breast cancer women with CR-39 detector”, *Appl. Rad. Isotop.*, 182(5) (2022) 110-120.

[4] A.F. Saad et al., “Heavy ion detection in thermally and non-thermally treated CR-39 detectors: Fission fragment ranges and etch able track lengths”, *Rad. Phys. Chem.*, 226 (2025) 112213.

[5] M.Y. Shoeib, D.A. Ahmed and A.F. Abd-Elraheem, “A study of 226Ra concentration and radon exhalation rates in different geopolymer cement samples using CR-39 solid state nuclear track detector”, *Rad. Phys. Chem.*, 216 (2024) 111381.

[6] N.E. Naji, A.A. Aljubouri and R.A. Ismail, “Synthesis and characterization of Al_2O_3 NPs/epichlorohydrin nanocomposites for enhanced gamma-ray shielding performance”, *Appl. Rad. Isotop.*, 226 (2025) 112157.

[7] H. Hammadi and A.A. AL-Ani, “Qualitative and Quantitative Studies of the Effects of Spherical Aberration on the Optical System in the Cases of Coherent and Incoherent illumination”, *Iraqi J. Sci.*, 61(10) (2020) 2599-2609.

[8] L. Hoyte and C. Lisle, “Geometric Representation of the Pelvic Organs”, Ch. 14, L. Hoyte, M. Damaser (eds.), Biomechanics of the Female Pelvic Floor, Academic Press (2016) pp. 291-306.

[9] Z.J. Raheem et al., “Transfer Factor and Related Doses of U-238 from Soil to Root-Plants at Some Areas of al Tarmiyah City, Iraq”, *Iraqi J. Appl. Phys.,* 21(1) (2025) 43-48.

[10] M.A. Shames et al., “Lung Infection Detection via CT Images and Transfer Learning Techniques in Deep Learning”, *J. Adv. Res. Appl. Sci. Eng. Technol.*, (2025) 123-132.

[11] C. Lu et al., “Detection and quantitative enumeration of objects from large images”, *Med. Image Anal.*, (2024) 579-607.

[12] H.A., Abed et al., “Green Areas Change Detection in Baghdad South City Using Remote Sensing Techniques: A Case Study”, *Tikrit J. Agricul. Sci.*, (2024) 223-234.

[13] M. Ueki, “A deflation-adjusted Bayesian information criterion for selecting the number of clusters in K-means clustering”, *Comput. Stat. Data Anal.*, 209 (2025) 108170.

[14] M.R. Naeemah et al., “Advances in Deep Learning for Skin Cancer Diagnosis”, *Adv. Sustain. Sci. Eng. Technol.*, 6(4) (2024) 02404019.

[15] Z. Ping et al., “An Improved Canny Algorithm for Edge Detection”, *J. Comput. Inform. Syst.*, 7(5) (2011) 1516-1523.

[16] A.A. Hasan, I.T. Al-Alawy and H.G. Daway, “Estimate the Relationship between Track Density and Radon Concentration: Hazard Effects in Euphrates River of Karbala-Iraq”, *Al-Mustansiriyah J. Sci.*, 34(4) (2023) 116-122.

[17] F.J.S. Doerr and A.J. Florence, “A micro-XRT image analysis and machine learning methodology for the characterisation of multi-particulate capsule formulations”, *Int. J. Pharmaceut. X*, 2 (2020) 100041.

[18] L.J. Belaid and W. Mourou “Image segmentation: a watershed transformation algorithm”, *Image Anal. Stereol.*, (2016) 93-102.

