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MRI Image Segmentation by K-Means Clustering Method and Detection of Lesions

Azzeddine Riahi

IMC Laboratory, Department of Physics, Chouaib Doukkali University , Faculty of Sciences ,PO Box 20, postcode 24000, El Jadida, Morocco

Abstract: ***Despite the technological advances in the medical field, particularly in medical imaging, the study of the human brain is a difficult topic and remains a topic of strong current research because of a still incomplete understanding of its operation and the availability of computer systems increasingly powerful with the evolution of imaging techniques, high capacity computing machines ... etc. One of the most used imaging modalities, which is the main subject of this work, is the Magnetic Resonance Imaging (MRI), which has become an indispensable tool for any clinical examination. It has the advantage of being non-invasive and allows the acquisition of two or three-dimensional images in which different contrasts are available. This method also allows the production of brain anatomical studies as well as functional. Through this paper, we present the MRI characteristics which will help in its analysis. But first we'll discuss a few brain imaging and brain anatomy that will allow us to introduce the different anatomical structures to be localized and identified in the images.***

Keywords: Brain imaging, brain MRI, tumor segmentation, Clustering, K-means

1. Introduction

The magnetic resonance imaging (MRI) has been booming in recent years. This imaging modality has become a tool increasingly important in medicine of the brain and in research in cognitive neuroscience. Indeed, the fields of exploration that this technique offers are wide: the anatomical MRI for observing with fine resolution brain tissue, functional MRI offers the possibility to visualize brain activity and MRI broadcast that explores the aspect of the connectivity of brain areas. To diagnose diseases related to internal brain injuries, the doctor must analyze medical images. To study the evolution of a tumor, it is necessary to know precisely the changes in the images. The visual interpretation of brain MRI is not always right. This is why the need for automatic interpretation that assists physicians in their decision making was felt. Precision is a necessary factor when it comes to reliable identification and diagnosis in the medical field. The accuracy of segmentation is very necessary concerning image analysis. The possibilities of automatic processing of these images nevertheless seems difficult because of such mundane skills to the human eye as the recognition of an object pose real difficulties for computers. Image segmentation is a low-level processing; it operates at the heart of the discipline called "analysis or image processing."

It is undoubtedly the backbone of this area, but also the part that poses the most problems and that proves the most difficult to automate. The objective of this work is to design a method of segmentation of medical images, particularly of brain MRI images. Our method extracts the different majors components of the brain (the brain, the tumor ... etc.).

There are various image segmentation algorithms, as appropriate to solve. But each method has its advantages and limitations. In this article, we use the K-means method, and we only use the advantages of this method. Indeed, we take advantage of a segmentation method using the image as a whole for the segment, combined with an algorithm that takes into account local characteristics of the image. This paper is structured around five parts that will allow us to present the various aspects of work. The first part is dedicated to the introduction. It introduces the basic terms and concepts to understand the analysis of brain MRI. In part two, we present some concepts of brain anatomy that will introduce the principles of cerebral magnetic resonance imaging. We then presented in Part Three, image segmentation methods, where we described a number of conventional segmentation methods either by Contour approach or regional approach. Part four is devoted to the presentation and analysis of results of different simulations we have implemented. This paper ends with a general conclusion.

2. Diagnostics of Brain Tumors

2.1 Physical Examination

When a doctor suspects a brain tumor, it will first perform a complete physical examination to locate the suspect brain area. Indeed, each brain area is associated with a specific body function; detection of peripheral symptoms may indicate that it is the brain that is affected. [1]

2.2 Investigations

Depending on the patient's condition, other tests may be needed. A lumbar puncture, which involves taking a little spinal fluid through a needle, arteriography during which injected iodized product in the arteries of the brain to better clarify their journey[2].

2.3 The Brain Biopsy

The biopsy is to perform a surgical removal of a fragment of the tumor. This very delicate procedure is performed by a surgeon in the operating room under general anesthesia. The objective and direct risks are well represented especially

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with surgery (infection, bleeding ...) or his surroundings (including the anesthesia) [3].

2.4 Medical Imaging

The review is supplemented by imaging techniques: MRI brain scanner [4]. In this work, we focus on the brain picture resulting from the magnetic resonance imaging (MRI), as it allows us to obtain excellent brain images. In the following we present the general principle MRI [5].

2.4.1 Magnetic Resonance Imaging (MRI)

The nuclear magnetic resonance imaging (MRI) is a medical imaging technique of recent onset, non-invasive and without side effects allowing to have a 2D or 3D view of a part of the body including brain [5]. It is based on the physical phenomenon of nuclear magnetic resonance. This is simply to observe the nuclear magnetic resonance (NMR) of water protons in the body. The principle is to measure the magnetization of biological tissues and reconstruct an image from the magnetization. The latter is induced by hydrogen, which is there in abundance in the human body.

The patient Placed in a strong magnetic field, all the hydrogen atoms are oriented in the same direction: they are then excited by radio waves for a very short period. After stopping this stimulation the atoms return energy accumulated by producing a signal which is recorded and treated as an image by a computer system [6].

After stopping the stimulation, the hydrogen atoms restore the energy that is dissipated in different planes of space under the action of the magnetic field of magnet. Energy is then sensed by other antennas (receiving antennas) then analyzed by a computer. Next, the water component of tissues analyzed, their possible pathologies, images will be different and the computer produces black and white images of a very high sensitivity and very valuable for diagnosis, especially with regard to tumor or infectious disease. It is thus possible to make cuts of any part of the body in all plans of the space [7].

2.4.1. a Main components of MRI:

A magnetic resonance imaging system consists mainly of the following [8]:

- The magnet that produces the field $\overrightarrow{B0}$.
- The magnetic field gradient coils which are used to code the signal in space.
- Antennas (emission of Radio Frequency waves and signal reception).
- And a powerful calculator that provides synchronization, acquisition and processing of signals in order to reconstruct the image.

The magnet: is the heart of the operation of the MRI machine. Its role is to produce the main magnetic field called B0 which is constant and permanent. The unit of measurement of the magnetic field strength of MRI is the Tesla.

The magnetic field gradient coils: They are three metal coils enclosed in a cylinder of glass fibers and placed around the tunnel of the magnet. Passing an electric current through these coils creates variations in intensity of the magnetic field in the tunnel, linearly in time and in space. Depending on its geometry, each coil varies the magnetic field along a specific axis, they enable to select a particular thickness and a cutting plane (transverse, coronal, sagittal or oblique) and perform the spatial localization signals in this plan [8].

Aerials: They are able to produce and capture a radio frequency (RF) signal [9]. They are provided to correspond to the resonant frequency of precession of protons that are in the magnetic field.

The calculator: A vector processor manages all of the acquisition and processing. It switches the gradients, control pulse sequences, gathers signals, performs the Fourier transform (FT) and stored on a magnetic medium the image on a pixel matrix.

The screens: In MRI, we talk about shields for some devices for containment of magnetic fields produced by the machine and the isolation of it external magnetic fields that would disturb the acquisition [9].

2.4.1. b. Acquisition of MRI:

MRI provides digital three-dimensional images of a lower millimeter precision, cortex, white matter, cerebrospinal fluid and the basal ganglia [10]. Two clinically adjustable parameters are involved in the acquisition: the time of repetition of pulse sequence (RT) and echo time (ET). An acquisition made with RT and ET short time and expressed in T1 (Figure 1).

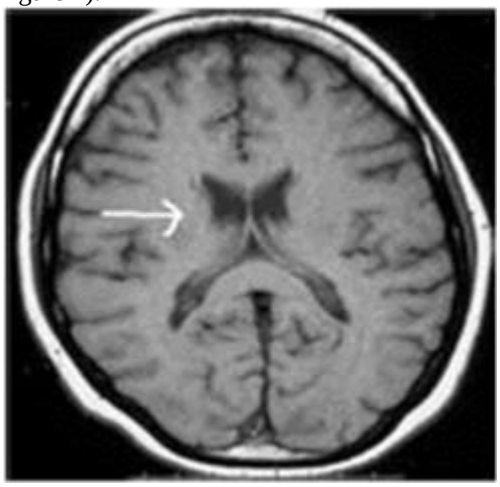


Figure 1: T1-weighted Acquisition

When these times are long, it is called T2 (Figure 2) .Finally when TR is long and TE is short, it is said in rho or proton density. Any acquisition can be characterized in relation to these three individuals. Thus, it is called T1-weighted image if the acquisition is closer to the type of acquisition in Q1 as two different types: Similarly, we speak of weighted acquisition in T2 or ρ. In addition, it can enhance the signal of certain structures on T1-weighted images through the use of a contrast agent such as gadolinium [11].

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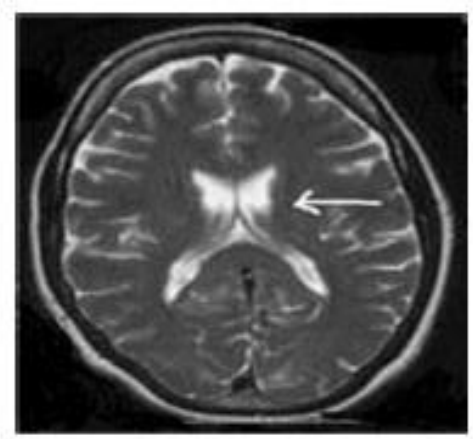


Figure 2: T2-Weighted Acquisition

In the brain, MRI also allows studying the arteries of the neck and brain (Figure 3).

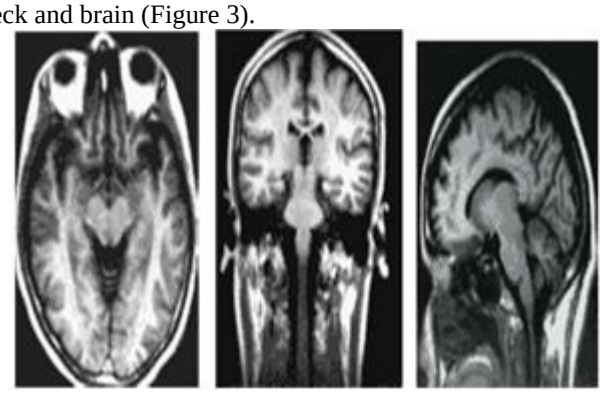


Figure 3: The different sections of the brain Axial, Coronal, sagittal (left to right).

2.4.1. c. The artifacts:

The artifacts in MRI can distort the actual anatomical image and simulate a pathological process [12]. The artifacts are due to:

- **Motion artifact:** The motion artifact is one of the most frequent artifacts. It is when there is translation in the space segment studied in the acquisition [12].

- **RF inhomogeneities:** The inhomogeneities in the main magnetic field and the field generated by the RF pulses can cause inhomogeneity in the distribution of image intensities obtained by MRI, which handicaps purely photometric approaches. This type of artifact is not inherently awkward for clinician. Instead it can be a problem for automatic image processing system [13].

- **Partial Volume:** Scoring partial volume is not specific on MRI, but concerns all imaging techniques. These artifacts are related to image resolution. Thus, at an interface between two tissues in the direction of the slice selection, the use of fine cut allows to separate the tissue. However, a thicker section contains both, the two fabrics: then the resulting signal will be an average of the tissue signal, whereby a loss of information in terms of contrast [14]. This also results in a loss of spatial resolution since the signal of small structures will be averaged with the adjacent structures, which can make them invisible or indistinct.

- **Noise:** The image noise is the presence of hashes in addition randomly to detail in the acquired images. It is particularly visible in low-light areas, where the signal / noise ratio is low [15]. It results in the loss of sharpness in the details.

2.5 Segmentation cerebral RMN images:

During cerebral segmentation MRI images, several levels of description can be chosen depending on whether it is interested for a given application [16]:

- Tissue present in each pixel: three materials are then essentially considered, cerebrospinal fluid, gray substance or white substance (which can be added air, skin, and muscle and bone if one is interested in these subjects outside the brain).
- In structural brain or region of the structure that the pixel contains mainly: we then seeks mainly to define the cortex and the central cores (made of gray matter), or to discriminate the cerebrospinal fluid present within the cortical furrows, from that present in each of the ventricles. The description may in this case be of varying complexity, depending on whether or not we try to define anatomical structures and subdivisions according to the description helps or not distinguish between different brain areas.

In both cases, the presence of artifacts inherent in the acquisition process makes images segmentation more complex [17].

Faced with these difficulties, it is sometimes necessary to introduce a priori knowledge:

- Radiometry tissue, to segment the image into materials: this knowledge affects the shape of the tissue of the intensity distributions.
- Cerebral anatomy, to segment the image into anatomical structures: this knowledge then concerns the form and location of structures.

We have shown that despite the care taken with the acquisition, the information contained in the picture may be disturbed by external events. In this context, the image processing is indispensable [17]. Among these methods, the segmentation is to partition or segment the image into a set of coherent areas. Therefore, in what follows, we conduct a retrospective of different methods of image segmentation and particularly the segmentation of brain MRI images [18].

3. Cerebral Segmentation MRI Images

The image segmentation plays an important role in image processing and computer vision. This step is between the acquisition of the image and its improvement and also its description and decision consistent final decision [19]. It must make the difficult task of extracting from digital image information useful 'to locate and delineate the entities present in the image. The aim of all methods of segmentation is the extraction of attributes to characterize objects [20]. These attributes correspond to points of interest or characteristic areas of the image.

Segmentation is a low-level processing which is to perform a partition of the image into homogeneous regions in

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relation to one or more criteria [21].Regions obtained are distinguished from each other by significant differences according to the same criteria. After these steps, we can introduce a sectoral treatment in different ways [22]. The segmentation is to extract points, lines or regions. The choice of a technique of segmentation is linked to several factors such as: the nature of the image, the vesting conditions (noise), primitives to be extracted (outline, texture ...). Segmentation refers to the notions of similarity as the perception, the human visual system and this gives rise to two approaches commonly qualified, "region" and "border" approach [23]. We discuss in this part the main methods of segmentation, with brief descriptions and some illustrations.

3.1. Image processing:

3.1.1. Medical imagery:

Medical imaging is the set of techniques to obtain images from various kinds of radiation (ultrasound, X-rays, etc.) [24]. Over the past two decades the medical image has become a fundamental tool in medicine and the treatment of brain images is a paradigm [25]. The fast development of techniques for acquiring medical images has allowed the medical staff to have a wide variety of data belonging to images of various modalities, for example ultrasonic ultrasound, CT, positron emission, positron tomography, single photon emission, and magnetic resonance imaging MRI [26].

3.1.2. Definition of Treatment:

The general principle of image processing is for some details still the same, a system receives images, applies a treatment, and produces a kind of information related to the intended application [26]. A radiation source sends waves on an object, which are then reflected and collected by a sensor. The sensor converts these waves into a set of points. These are discussed and information is in the output of the system [27].

3.2. Image Segmentation

3.2.1. Definition of Segmentation

The image segmentation is a treatment of low- level and critical steps of image analysis that aims to gather pixels according to predefined criteria. Each pixel group then forms a region. A region is therefore a connected set of pixels having common properties (intensity, texture ...) that differentiate the pixels neighboring regions. If the number of regions is two, the segmentation is also called binarization [28]. More precisely, we can define the segmentation as a partition of an image I into n sets C_i called areas such as:

1) $\bigcup_{i=1}^{n} C_i = I$

2) $\forall i, j \in \{1,...,n\}^2 \; and i \neq j \Rightarrow C_i \bigcap C_j = \varnothing$

3) $\forall i \in \{1,...,n\}^2 \; C_i is connected$

4) $\forall i, j \in \{1,...,n\}^2 \; P(c_i) = true$

5) $\forall i, j \in \{1,...,n\}^2 \; C_i is adjacent to C_j et i \neq j \Rightarrow P(C_i \bigcup C_j) = false$

To test the homogeneity P predicate is in charge.

The first condition means that the image I is partitioned into n classes. And the second explains that all classes are disjoint in pairs. The third step, the fourth and fifth require each pixel of a class to meet the same property within the meaning of the predicate P. The predicate P is true for the two adjacent classes meeting.

So segmentation allows data analysis by grouping formants classify image pixels such that the pixels belonging to a class are more similar to each other than those of different classes, we assign to each entity of the scene treated label indicating membership in a particular class. The entity used generally characterizes a pixel or set of pixels, while the label is a theme chosen by the user [28].

3.2.2. The various approaches to segmentation

Essentially, image analysis is to extract the characteristic information contained in an image. This information may take the form, color, contour, texture ... Therefore, it is necessary first to do the segmentation of the lesion. This segmentation is usually approached from two complementary models: the approach and the border region approach. The border approach includes the techniques associated to a variation of intensity: edge detection. However, the contours obtained are often related, so she has to face the contours of closing issue [29].

The approach considers region pixel groups having common properties; each pixel is assigned a unique region after a partition of the image. However, there is no specific algorithm to determine the regions and borders in an image. In general the ideal segmentation does not exist; the right segmentation technique will be one that will arrive at a correct interpretation [30].

3.2.2. a. Segmentation based on the contours:

The contour detection is often the first problem that we encounter while treating a picture. The difficulty increases with the amount of noise present [31].

Definition (contour):

Approximately a contour can be defined as a boundary between two regions or pixel intensity changes suddenly. Generally the use of such a contour operator combines with a threshold and as it's usually imperfect, there is obtained, on the one hand, the contours which do not restrict the closed regions. So we must make use of algorithms Closures contours. On the other hand, areas of strong variations do not necessarily correspond to an outline object. While a post-treatment is necessary to analyze the different contours obtained [32].

Method of active contours (snake)

The idea of this method is to move the points to bring them closer to areas of high gradient while maintaining characteristics such as curvature of the contour or the distribution of points on the contour or other constraints related to the arrangement of the points. At the start of the algorithm, the contour is arranged evenly around the object to crop then it will retract to best match the shape. At each iteration, the algorithm will try to find a better position for

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the contour to minimize deviations from the constraints used [33].

The algorithm will stop when it is no longer possible to improve the positioning or simply when the maximum number of iterations has been reached. The concepts of internal and external energies are used to characterize respectively the shape of the contour and its positioning on the image taking into account the gradient lines.

Method of sets of zero (LEVEL SETS):
The method of Zero Level Sets is a numerical simulation method used for the development of curves and surfaces in discrete domains [34].The basic idea of the level sets method is to consider a curve or moving interface as the zero level of a higher dimensional function. For a 2D curve, this interface (Ψ) is the intersection of a surface with a hyper plane [35]. The points with that interface will move to the normal at a rate F according to the following equation:

$$\psi_{t+1} + F\left|\nabla\psi_t\right| = 0$$

This speed F is composed of three terms: a constant term, a term dependent on the local curvature at each point and a term dependent on the image. The numerical scheme of the interface of movement equation is described by the following equation:

$$\psi_{n+1} = \psi_n - dt * k_1(x,y) * (U_n - \varepsilon K) * \left|\nabla\psi_t\right| \varepsilon \in [0,1]$$

With:

$U_n(m,\sigma) = \pm 1$, Membership function defining the area or object to search.

$K = \nabla . \dfrac{\nabla\psi}{\left|\nabla\psi\right|}$, Local curvature at each point of the interface.

$kI(x,y)$, Stopping criterion depending on the gradient image.

3.2.2. b. Segmentation approaches by region:
The regional approach is to group items according to common properties.

Definition of Segmentation by region: Overall, it can be defined as a partition of an image I in one or more regions R1... Rn such as [36]:

$$I = U_{i=1}^{n} R_i \text{ and } R_i \bigcap R_j = \varnothing \text{ for } i \neq j$$

Methods by growth regions: The principle of these methods is to iteratively assemble a set of points connected in a region increasingly wide, depending on homogeneity criteria. [37] To define a region, we define a germ in the region of interest that serves as a starting point for the aggregation [38].

Morphological Segmentation: The Watershed Line is a widespread image segmentation technique. This tool is to look for contours watershed in the image segment. After determining the contours of these basins that form the local minima, a region map is obtained. The major drawback of this technique is its sensitivity to the number of germs generally local minima which turns often very important and therefore generates an over-segmentation of the image [39].

The K-means algorithm: This method involves combining pixels into K groups (clusters). K is a predetermined parameter that determines the number of regions. And after determining the parameters (eg: color) of any region, each point is assigned to the nearest center, and then recalculate the parameter of each region, until they are stable [40].

The algorithm of K-Means is one of the most used unsupervised clustering techniques. The method involves placing randomly in space K "centroids" to determine K clusters. We assign to each of these "centroids" the nearest objects and then calculates the average position of the objects associated with "centroids" that is moved at that point. The object allocation operations and centroid of displacement on average identified until each centroid has reached a stable position [41].

Despite its simplicity, this algorithm is effective. However it's necessary to predetermine the number of categories and the starting position prototypes that has an impact on the division into classes. The main steps of this algorithm are:

- Random choice of initial position of K clusters.
- Reassign them to a cluster according to a criterion of minimizing distances.
- Once all objects placed, recalculate K centroid.
- Repeat steps 2 and 3 until more no reassignment is made.

Segmentation is an important step in image processing and the fact that there is no single method of segmentation, it is difficult to define, absolutely, a good segmentation. Segmentation is not an end in itself; its quality depends on the results obtained by the treatments downstream that use the extracted primitives [42].

4. Simulation and Analysis of Results



Figure 4: initial image MRI of the brain.

The choice of interactive software to perform complex numerical calculations particularly useful in the field of image processing encourages us to use the MATLAB software in our work to achieve these simulations.

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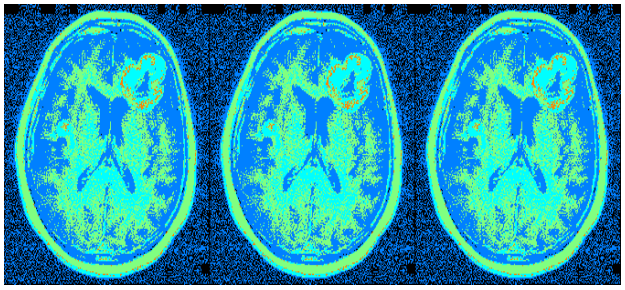


Figure 5: Result of segmentation by k-means for the number of class (K = 3), 1st class, 2nd class, 3rd class.

Note that (Figure 5) the tumor appears well in these results when using the k-means algorithm. Use several times the k-means algorithm gives different results, because these attributes are not representative of the popular classes and the result will be poor. The conventional k-means algorithm leaves a free parameter: the number of clusters, which in the case of image segmentation is the number of intensities used to represent the image. Generally the choice of k is made empirically by selecting the value of k that minimizes the energy. Various criteria are used to estimate the number of clusters by minimizing the intra-class distance and maximizing the inter classes distance, eg, for color image segmentation.

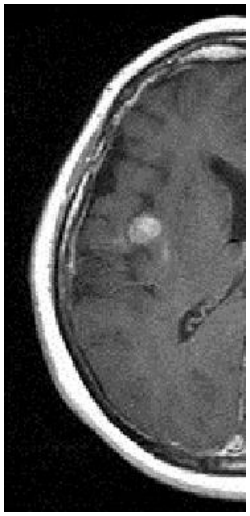


Figure 6: Left half image

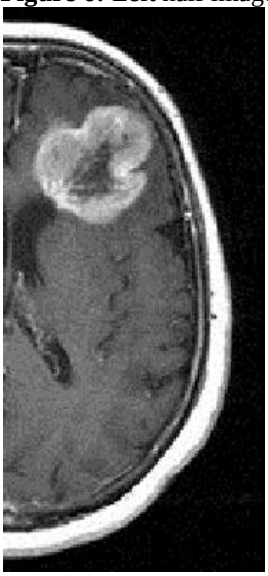


Figure 7: Right half image

To validate our segmentation algorithm, we used MRI cerebral images. In this part, we applied this method to detect tumor portion (Figure 6 and Figure 7) and to detect the brain (Figure 4). In this application one is interested in detecting the tumor portion (Figure 7). These results require a large number of iteration and a larger run time. We selected for each image a number of specific iteration; this is due to the size of the tumor to be detected.

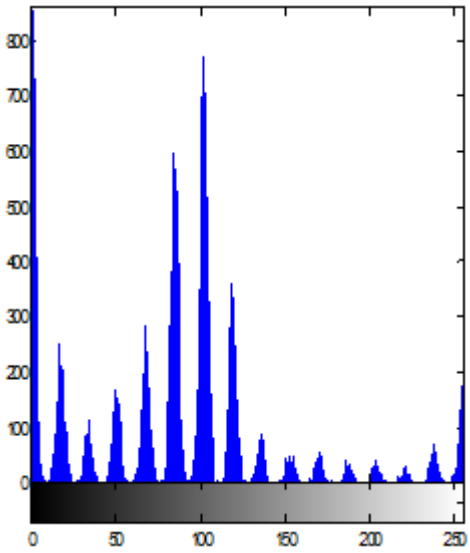


Figure 8: Histogram corresponds to figure 6

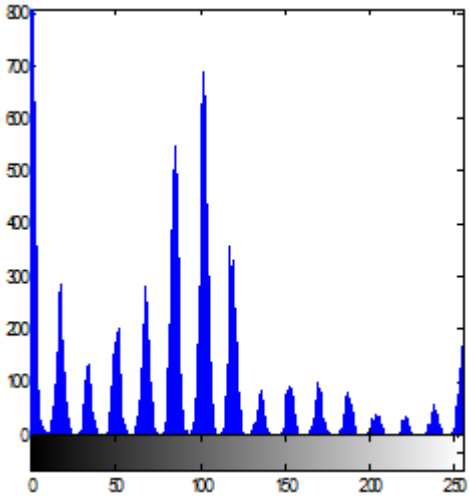


Figure 9: Histogram corresponds to figure 7

The image segmentation is the process of partitioning a digital image into regions, not overlapping, homogeneous vis-à-vis certain characteristics, such as the gray level, texture and movement. We can observe in running the initial curve converges correctly to the border of the tumor. So good to locate the tumor, we must initialize the initial contour and the initialization parameters. These parameters are selected following the size of the tumor to be detected. Therefore, these results show the effectiveness of the method used.

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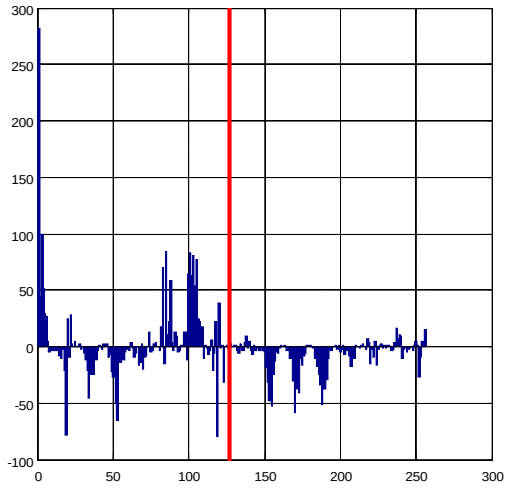


Figure 10: difference between the two gray level histograms

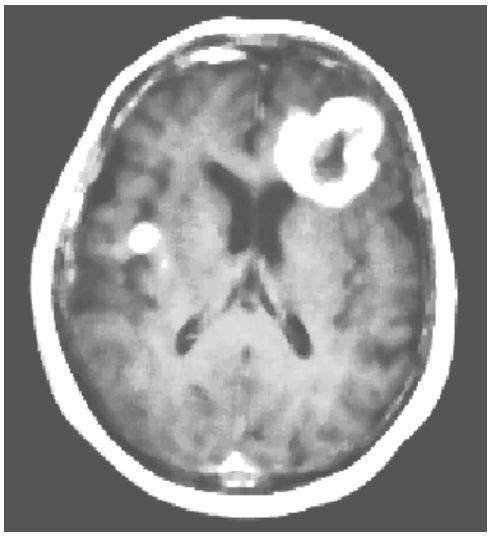


Figure 11: Image enhancement



Figure 12: X-ray binary image

To detect and localize the tumor (Figure 11), we passed by a thresholding operation. The result (binary image, Figure 12) is used as an initial contour for segmenting the brain. Segmentation is guided by the choice of intrinsic parameters of the geometric active contour (Level set) for the detection of tumor part. For each figure, we used the same parameters. On the number of iteration, this changes depending on the distance between the original contour and the contour of the part to be detected. The results are very satisfying.

5. Conclusion

The segmentation of brain structures not only give the chance to better characterize their roles, but also to isolate markers for certain diseases to aid the physician in his diagnosis. The objective of the work is on the implementation of three technical automatic segmentation of brain structures using magnetic resonance images (MRI). The final goal is to evaluate each method based on several criteria. We began by describing the essential concepts related to brain anatomy, and key brain regions that are important in the examination and clinical diagnosis, and the principles of image acquisition. We also presented the different ways of acquiring the medical image with their specific technologies, based on MRI. We then reviewed the different methods in the field of segmentation of brain MRI images. This diversity is representative of the complexity of the segmentation problem of brain MRI images.

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Author Profile

Professor Azzedine Riahi received his PhD in Nuclear Physics in 1987 CENBG at the University of Bordeaux, France, he graduated in Nuclear Medicine, he is a professor the upper education at university chouaib Doukkali since 1988, it is currently Director of laboratory instrumentation, measurement and control (IMC).

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