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Characterization of Myocardial Diseases Using Image Processing Technique

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Abstract: ***Recently, the nuclear cardiology imaging has been broadly used as a key method to assist in determination of the different cardiac pathologies and monitoring the management prognosis. Myocardium perfusion is considered the most common assessment tool in the nuclear cardiology that used to assess the myocardium of the heart by using both SPECT and PET. Those modalities have ability to recognize the myocardial area precisely. Full and half automated computed-based images registration and segmentation of the myocardium pathologies was performed to increase the visibility of the image and increase its diagnostic role. This study was performed in nuclear medicine department of Rabit Nation University in period of January 2016 to December 2020. In this thesis, the novel medical image analysis methods were presented to characterize myocardial diseases using SPECT to differentiate between myocardial infarction and myocardial ischemia as well as the quantification of the normal heart tissues. There are many problems due to absence of SPECT imaging protocol which is very essential in diagnosis of cardiovascular disease and can be used to compare its effectiveness of other diagnostic modalities. The automatic delimitation technique was proposed of the SPECT cardiac images. The automated image enhancement, noise reduction and segmentation algorithms were used in this study to accurately delineate the myocardium structures compared with the other similar approaches. Automated methods of image processing, mainly of image registration, are integrated in a computational solution to automatically compute a set of features from myocardial perfusion SPECT images and use them to statistical analysis and classification of patient exams as from a healthy patient or with an associated disease. The image registration algorithms used, including the watershed-based segmentation, similarity measure, optimization, and interpolation algorithms, will be described and discussed, as well as the computational processing, analysis and classification techniques employed. The segmented images were projected onto the original images to demonstrate those projections and correlate them with the manual delineations. The experimental results of this study showed that the automated methods and visualization with high corresponding and matching rates. Indicate that the mean values of 0.82, 0.92 and 0.90 are achieved for comparison when the K-means clustering methodology is employed in three clusters and watershed segmentation, when utilized as gold standard and clinical professional.***

Keywords: Nuclear medicine, image processing, filter technique, cardiac images

1. Introduction

Computed tomography that employs radioactive tracers to track the circulation and metabolic processes of the patient or object under study is a nuclear imaging modality known as single photon emission computed tomography [1]. In SPECT studies, photon electronic sensing is used to generate three-dimensional images of the radiopharmaceutical distribution, through an Angus Gamma camera, intravenous injection into the body [2]. The development of three-dimensional algorithms was critical to the evolution of SPECT to the present day. The improved Anger camera with a rotating collimator attachment will allow for better image reconstruction, and better image reconstruction will make it possible to enhance the blurry SPECT images' low contrast characteristic [3-4]. The efficient modality of molecular imaging has been contributed by high-speed digital computer systems for the acquisition and display of dynamic processes in the body including high speed dynamic radionuclides, dual and triple camera. The time used as an additional coordinate in SPECT is gathered through collecting various pieces of information in terms of time and, after processing, is translated into spatial information. This means that it is an essential imaging modality for diagnosis. Respecting single photon emitting radiopharmaceuticals, it must be taken into consideration that the large number of available radioligands makes the labeling process relatively easy, which is because of the availability of oxygen [5-6]. The SPECT is therefore able to detect and monitor the use of radiographic peptides and medication for biological and pathophysiological processes. The radiopharmaceuticals contain radioisotopes that emit gamma rays through an isometric transition, also known as internal conversion. The radioisotopes are anisotropic, described by longer lifetimes compared to the short-lived isotopes, making them suitable for in vivo imaging [2-3] [7].

In a single study, a combined analysis of myocardial perfusion and left ventricular function is performed using electrocardiographic GSPECT as it enables the grades and extent of the functioning of LVs to be quantified [8]. In contrast, while useful for measuring the RV, it is unsuitable for accurate RV function measurement due to a lack of visibility on the perfusion images [1] [5] [8]. This technique aids in the assessment of both the LV function and perfusion, which assists in the diagnosis, assessment of the risk, and determination of the viability of the heart after revascularization. The research noted above also has in common that the tracer needs to be injected and injected into the myocardium for the SPECT study, and the GSPECT study must perform a perfusion study. Luminal and epicardial delineation on the perfusion image identify the LV myocardium and the LV cavity [1-2], [7], [9]. The LV function depends on quantitation of the end-diastolic (ED) to end-systolic (ES) volume change, diastolic endocardium excursion, and the brightening of the myocardium from the ED image to the ES image. GSPECT imaging has seen consistent growth due to the emergence of two additional imaging techniques. These are first-pass radionuclide angiography (FPRNA) and equilibrium gated radionuclide angiography (ERNA). It is simple and tells the reader if an area is under perfused or perfused normally. The kinetics of 90mTc-labeled perfusion tracers are favorable, allowing for more flexible acquisition protocols. Further improvements in multidetector γ-cameras have significantly cut acquisition and processing times. Computers and image processing automation have made SPECT a simple, practical, and user-friendly technique in clinical practice [5], [8].

For the physicians to be able to comprehend visual interpretation, the definition of normal limits and criteria for abnormalities are important [4], as visual analysis depends on the reader's familiarity with the normal LV contraction pattern in different segments of the LV. In the scientific literature, there is an atlas that provides the reader with image recognition as well as an understanding of the basis for myocardial perfusion SPECT image interpretation [5]. In nuclear medicine, radiotracers have been widely used for imaging as they provide a physiological diagnosis by mapping metabolism and fluid flow on tissues or organs. Whereas other imaging techniques like computed tomography or nuclear medicine imaging only examine structural information, emission tomography modalities check both the perfusion and metabolic activity, even if there are no structural changes. It is often used to further examine and confirm a diagnosis in oncology, cardiology, and neuropsychiatric disorders [4-6], [9-10].

2. Methods and Materials

A solution that automatically computes and uses a series of features from SPECT myocardial perfusion images in order to conduct statistical analyses and classify images as belonging to or not belonging to subjects with myocardial infusion has been developed because of the integration of image recording and other computational techniques for medical image analysis. All the image registration algorithms that were used in detail, including the transformation, similarity measure, optimization, and interpolator algorithms, in addition to the segmentation and segmentation steps will be described in this study. When image classification methods are used in conjunction with the segmentation method's feature subset, the diagnostic performance of the system is significantly improved. The steps involved in developing a computational solution can be divided into the following categories: The alignment of the slices under investigation in the gated myocardial perfusion SPECT images with the pre-built template image is called data registration. The statistical analysis and image classification are called image classification. Following that, each step, as well as the experimental results obtained at each stage, will be thoroughly explained. With this implementation, it is not intended to replace physicians' clinical judgment, but rather to assist them in clinical decision-making, for example, by supplementing cardiology medicine teaching.

Implementation of the study

Instrumentations:
On a notebook computer equipped with an Intel® Core i5-5200U CPU (4.0GHz) and 8 GB of RAM, this computation was carried out in MatLab (64-bit). Several image processing and classification technologies, including Matlab (2020b) and the Insight Toolkit (ITK) 4.3, were used to implement the image segmentation procedure.

Dataset of the study:
This study was performed in nuclear department of National Rabit University. The control group also contains SPECT myocardial perfusion images, which include both female and male images. These images depict 8 healthy individuals and 10 individuals who have been diagnosed with heart disease. The imaging system required only a daul head SPECT camera and a low-energy, high-resolution collimator. Each time the sensor scanned, an image was created as a 256 x 256 matrix for each of the 32 projections, each lasting 25 seconds, on a 180-degree arc, with the probe positioned 45 degrees RAO and 45 degrees LPO (LOP). They were created using a low-pass filter and a Butterworth filter (cut off: 0.4-order: 5).

Image segmentation techniques
Using segmentation, users can simplify or modify the representation of an image into different areas of interest by dividing it into multiple pixel sets called segments. Using the solution to the problem as a starting point, we can determine the level of subdivision needed. Using labels assigned to each pixel in an image, it divides the image into the areas, objects, and contours that make up the image. Within a segmented region, each area has properties that are like pixels but are significantly different from the next area in terms of certain calculated properties. Most image segmentation algorithms work by separating images into groups based on intensity or region. Make use of the first approach to partition an image based on abrupt intensity changes, such as border lines, to create a new image. Several predefined criteria must be met in order for areas to qualify as regions under the second approach Figure 1.

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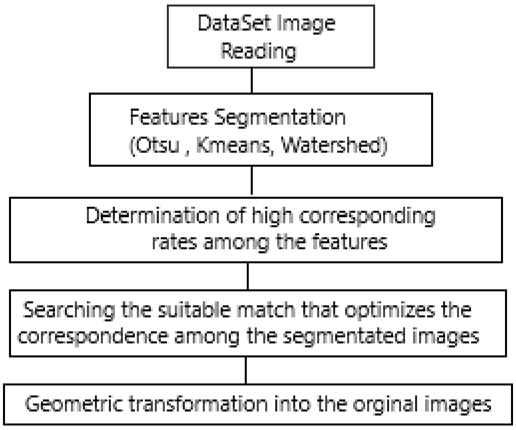

Figure 3.1: Diagram of a typical feature-based

Medical Image Registration

The goal of image registration is to find the optimal transformation that best aligns the structures of interest in the input images [120–122]. The images are transformed into this system after a common system of coordinates has been assigned. Feature-based and intensity-based registration methods are derived from geometric approaches. Feature-based methods first establish the feature correspondence between images and then compute the geometric transformation that aligns the features. Using intensity-based methods, the transformation aligns the input images by minimization of a cost function. most of the time, registration algorithms use the cost function, which incorporates the similarity measure. A linear transformation followed by a translation can be used to model an affine transformation:

$$X_{out} = Ax_{in} + b, \qquad [1]$$

And more precisely, in 3D,

$$\begin{bmatrix} x\ out,_x \\ x\ out,_y \\ x\ out,_z \end{bmatrix} = \begin{bmatrix} a_{51} & a_{52} & a_{53} \\ a_{61} & a_{62} & a_{63} \\ a_{71} & a_{72} & a_{73} \end{bmatrix} \begin{bmatrix} x\ in,_x \\ x\ in,_y \\ x\ in,_z \end{bmatrix} + \begin{bmatrix} b_x \\ b_y \\ b,_z \end{bmatrix} \qquad [2]$$

This equation maps the coordinate space xin to the transformed coordinate space xout. Appropriate transformations geometrically include turning, escalation, shear, reflecting and translating. Stiff transformations are a subset of the larger class of affinity. They are also determined by Eq. (1), but A is limited to an orthogonal matrix, i.e. its orthogonal foundation, its columns are equal to 1. This reduces the transformation resulting from rotations and translations alone. The registration problem can be reduced to an optimization of a clustering algorithm between the IF-fixed image and the IM-moveable image converted in relation to the deformation feature:

$$E(\Phi ; I_F , I_M) = Sim\ (I_F , I_M\ \Phi\ ) \qquad [3]$$

Linear filtering techniques

In this study, linear algorithms were used to process the 2D cardia images. The most common lean technique which used were the F-special technique. The following equitions illustrate this technique and generates Gaussian models.

$$h_g(n_1, n_2) = e^{-(n_1^2+n_2^2)/(2\sigma^2)}$$

$$h(n_1, n_2) = \frac{h_g(n_1, n_2)}{\sum_{n_1}\sum_{n_2} h_g}$$

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$$

$$\nabla^2 = \frac{4}{(\alpha+1)}\begin{bmatrix} \frac{\alpha}{4} & \frac{1-\alpha}{4} & \frac{\alpha}{4} \\ \frac{1-\alpha}{4} & -1 & \frac{1-\alpha}{4} \\ \frac{\alpha}{4} & \frac{1-\alpha}{4} & \frac{\alpha}{4} \end{bmatrix}$$

$$h_g(n_1, n_2) = e^{-(n_1^2+n_2^2)/(2\sigma^2)}$$

$$h(n_1, n_2) = \frac{(n_1^2 + n_2^2 - 2\sigma^2) h_g(n_1, n_2)}{2\pi\sigma^6 \sum_{n_1}\sum_{n_2} h_g}$$

3. The results

IN this project, Matlab image processing toolbox was used to create an array, use algorithms, simulate, visualize, and plot data, as well as process signals and images. Nuclear medical images obtained using a variety of techniques (SPECT, PET, and Hybrid System), which were previously unable to be quantified and visualized, can now be quantified and visualized with this tool. The primary objective of this study was to determine whether or not the Filtering Technique could be used to improve the contrast of cardiac SPECT imaging.

Experimental results

Otsu thresholding method

The use of a threshold value allows researcher to distinguish between objects and the background in the image. As soon as the threshold is set to T, the object point is defined as any point (x, y) for which T is the object point. It is referred to as the background in order to distinguish it from the rest of the picture. It was once known as global thresholding when the method was solely based on gray-level values; however, when certain local properties were taken into consideration, it was known as local thresholding. It is possible to convert a grayscale image to a binary image using the method developed by Otsu, which is based on thresholds (Figure 2).

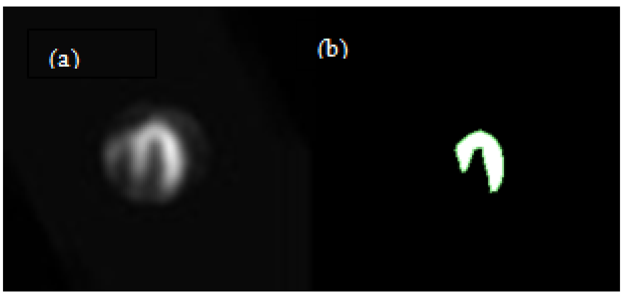

Figure 2: Shows Otsu technique: (a) original image; (b) the processed image

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K-means algorithm:

The K-means clustering algorithm is a segmentation procedure that divides input data points into different classes based on how close they are to one another in terms of distance. A vector space is assumed and their centroids are selected by the algorithm, which then locates the following clusters. As a result, this method is a vector measurement technique that divides n observations into k clusters, each of which has a meaning that is the most like the observation in question, and each of which contains observations that are members of the cluster. The most common applications of this method are vector quantization, cluster analysis, and feature learning, to name a few examples. This is illustrated in Figure 3-6.

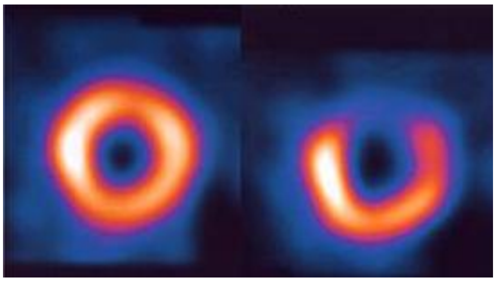


Figure 3: Shows the original image

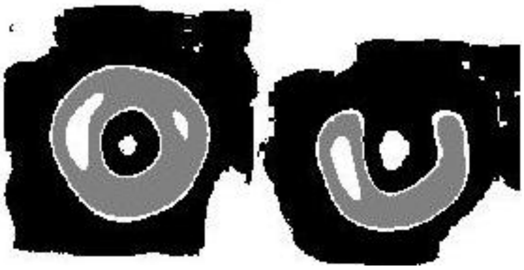


Figure 4: Shows image labeled by cluster index

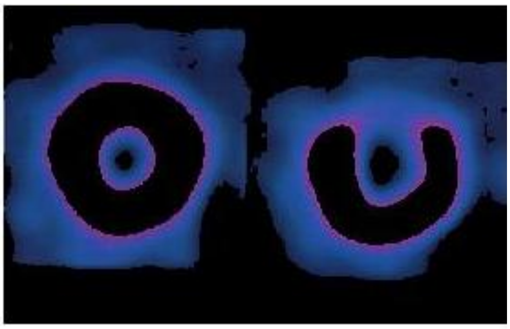


Figure 5: Shows segmented image in cluster 1

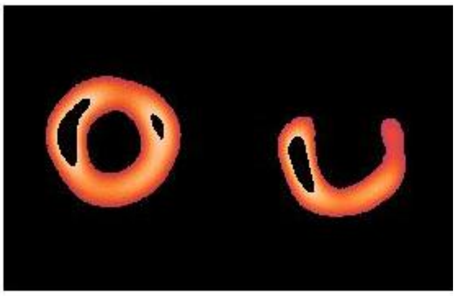


Figure 5: Shows segmented image in cluster 2

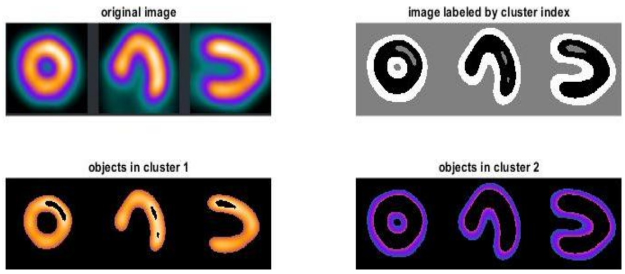
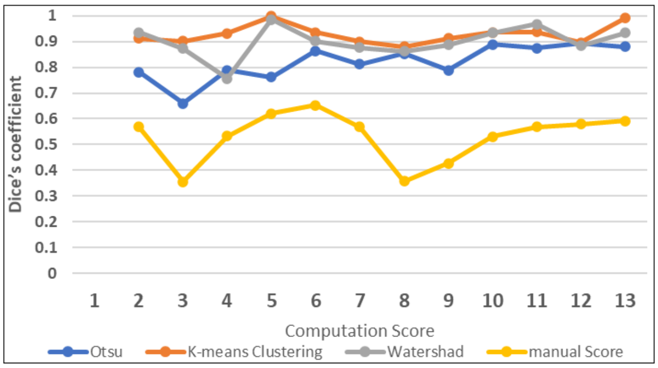


Figure 6: Shows segmented SPECT cardiac image

The quantitative analysis of the segmentation results

Prior to proceeding, the segmentation method was manually validated by manually segmenting 13 slices of a myocardial SPECT image using a gold standard as a guide**.** Dice's coefficient was calculated using MATLAB, whose findings were shown in Table 1.

N=11	Otsu Multiple threshold	K-means Clustering	Watershed	Manual Scoring
Mean	0.8210	0.9276	0.9001	0.5295
SD	0.0689	0.0362	0.0600	0.0976
Minimum	0.6597	0.8795	0.7561	0.3564
Maximum	0.8935	0.9982	0.9861	0.6521



4. Conclusion

The intensity was too low and the border in SPECT cardiac pictures was too narrow, making it impossible for typical segmentation methods to achieve acceptable results, such as binary thresholds or gradient segmentation. Figures 2–6 also indicate that the mean values of 0.82, 0.92 and 0.90 are achieved for comparison when the K-means clustering methodology is employed in three clusters and watershed segmentation, when utilized as gold standard and clinical professional Manual segmentation. While the parameters for this segmentation are accurate, the maximum values should be extended to improve the confidence of the segmentation. The methodology provided begins with an approach for reducing image noise using average imagery and picture morphology to minimize noise while boosting borders. This method decreases noise and reinforces the border.

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