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Omit noise from Computed Tomography (CT) using fuzzy clustering algorithm.

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Abstract

The With the presence of metal implants, metal artifacts added to X-ray CT images are inevitable. These artifacts have three different origins: physical, patient and scanner. The artifacts that are used in the study are often the effect of dental implants and filled teeth and they are made of titanium. Both are the effects of the artifact product which cause disorders that are difficult for a doctor to diagnose. Although many methods of reducing metal artifacts (MAR) have been proposed in the past decades, MAR is still one of the major problems in CT with clinical X-ray. The purpose of this work is to remove metal artifacts from dental CT images. One way to remove a metal artifact is to take a sinogram conversion of the image containing the artifact, segmenting the sinogram, deleting the artifact section in the segmented image, and finally reconstructing the original image. In this work, our aim is to remove metal artifacts of CT images using segmentation with fuzzy clustering algorithm. The simulation results are compared with the proposed reference article algorithm and several other methods. The results will show that clustering using the proposed method is superior to other works due to a powerful fuzzy algorithm is used for clustering, which is one of the most powerful methods in clustering.

key words :CT image ، Metal artifact removal ، Fuzzy clustering ، Image segmentation

حذف الضوضاء من التصوير المقطعي (CT) باستخدام خوارزمية التجميع الغامض.

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خلاصة

ومع وجود الغرسات المعدنية، فإن إضافة القطع الأثرية المعدنية إلى صور الأشعة السينية المقطعية أمر لا مفر منه. هذه القطع الأثرية لها ثلاثة أصول مختلفة: جسدية، ومريضة، وماسحة ضوئية. والقطع الأثرية التي تستخدم في الدراسة غالبا ما تكون من تأثير زراعة الأسنان والأسنان المحشوة وهي مصنوعة من التيتانيوم.

وكلاهما من آثار المنتج الاصطناعي الذي يسبب اضطرابات يصعب على الطبيب تشخيصها. على الرغم من أن العديد من الطرق للحد من المصنوعات المعدنية (MAR) قد تم اقتراحها في العقود الماضية، إلا أن MAR لا تزال واحدة من المشاكل الرئيسية في التصوير المقطعي بالأشعة السينية السريرية. الغرض من هذا العمل هو إزالة القطع الأثرية المعدنية من الصور المقطعية للأسنان. تتمثل إحدى طرق إزالة قطعة أثرية معدنية في إجراء تحويل سينوجرام للصورة التي تحتوي على القطعة الأثرية، وتقسيم سينوجرام، وحذف قسم القطعة الأثرية في الصورة المجزأة، وأخيرًا إعادة بناء الصورة الأصلية. في هذا العمل، هدفنا هو إزالة القطع الأثرية المعدنية من الصور المقطعية باستخدام التجزئة مع خوارزمية التجميع الغامض. تمت مقارنة نتائج المحاكاة مع خوارزمية المقالة المرجعية المقترحة والعديد من الطرق الأخرى. سوف تظهر النتائج أن التجميع باستخدام الطريقة المقترحة يتفوق على الأعمال الأخرى بسبب استخدام خوارزمية ضبابية قوية للتجميع، والتي تعتبر من أقوى الطرق في التجميع.

الكلمات المفتاحية :- الصورة المقطعية، إزالة القطع الأثرية المعدنية، التجميع الضبابي، تجزئة الصورة

1.Introduction

Computed tomography or so-called CT scan, as a new method in diagnostic science in medical physics has many experimental and therapeutic applications. In this method, by scanning the layers of the human or animal body, the internal parts of the body will be visible to doctors.[1] CT scan technology is now widely used in hospitals and research centers around the world. Being relatively low in cost and dose and having a high accuracy are among the advantages of this method. The creation of some artifact2 products in CT due to the nature of image production and the way the image is reconstructed lead to a lack of accurate diagnosis or misdiagnosis. These artifacts have three different origins: physical, patient and scanner. The artifacts that are used in the study are often the effect of dental implants and filled teeth and they are made of titanium. Both are the effects of the artifact product which cause disorders that are difficult for a doctor to diagnose. Metal implants, due to their higher damping factor, are in the form of shadows in the raw projection data, which cause streaked artifacts and affect the image quality. There are many algorithms, including the method of processing projection data, to reduce metal artifacts as a challenge.[2]

Computed tomography with a cone beam shaped is a technique for three-dimensional imaging that is very accurate. CT is an important method for imaging in dentistry due to the relatively low cost and low dose received by X-rays and high accuracy. However, the nature of image creation and the way it is reconstructed lead to the creation of metal artifacts in the image, which will lead to a lack of accurate and even misdiagnosis.[3] Because image reconstruction techniques have similarities, some of these artifacts can also be seen on CT images. Artifacts are generally divided into three groups: artifacts of physical origin, patient, and scanner. In this study, we will look at artifacts created by dental implants and filled teeth that are typically made of titanium. The mentioned

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artifacts will cause image disorders that may make it difficult for the doctor to diagnose. Metal materials, due to their high damping factor, are seen as shadows in the raw reaction data. Thus, these shadows create streaked artifacts that reduce image quality.[4] There are currently many algorithms for removing metal artifacts that the projection data processing technique is more effective. We aimed at finding a practical way to remove metal artifacts in images.

As we transfer location field images to the frequency field for easier and faster application of the filters, medical images containing artifacts can be converted into sinograms. In order to convert the image to a sinogram, the radon transformation (RT) technique must be used [1,5].

Another term for radon transformation, which involves calculating the matrix projection of an image in specific directions, is sine transform. The calculation of the projection of a two-dimensional matrix consists of a set of integrals on certain lines, and its output is a sinusoidal image called a sinogram.[6]

A two-dimensional radon conversion is an integral conversion equal to the integral of the function on straight lines. This conversion is derived from the name of the mathematician Johann Radon6. Radon, who also proposed a formula for inversing this conversion, also proposed formulas for three-dimensional conversion in which integrals are applied to pages instead of lines.[7] Later, these relations were extended to higher dimensions for Euclidean space. The use of radon transformation in computed topography (creating an image of a projection data associated with cross-sectional7 scans of an object) is in abundance. If the function f represents a density of an unknown object, then the radon f conversion will be the projection data from that object as the output of the tomographic scan.[8]

Therefore, in order to reconstruct the original density of the projection data, the inverse radon transformation can be used and the mathematical basis of tomographic reconstruction, also called image reconstruction, can be created. Radon transformation data is also called a sinogram. The reason for this naming is that radon transformation is a Dirac delta function as a sine wave. As a result of radon transformation, a set of objects looks like a sine wave with several different phases and amplitudes.[9]

Algorithms for reducing metal artifacts can be broadly classified into three groups: modification of physical effects, interpolation in the field of projection and iterative reconstruction. A direct way to reduce artifacts is to modify physical effects, for example, beam hardening [10-17] and photon starvation [18]. However, in the presence of metals with large numbers of atoms, the errors are so strong that the above modifications cannot achieve satisfactory results. Hence, affected metal

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projections are assumed to be unavailable and replaced by a number of other items [11-13].

In 2007, Zhang and colleagues proposed a method that removes metal artifacts from CBCT images. They used the threshold algorithm for image segmentation. However, noise in this algorithm may cause the production of small holes, and as a result, the processing of these holes reduces the accuracy of the segmentation result [2,14].

In 2013, Xiaofei and colleagues proposed a random walk segmentation algorithm to modify metal artifacts in CBCT images. Random walk segmentation algorithm from graph theory is used to analyze the features of an image. This method shows clearer boundaries of metal projection than other methods. The following figure shows the result of this algorithm in the projection image segmentation and compares it with the thresholding algorithm method [8,15].

2. Problem statement

Computed tomography or the so-called CT scan, as a new method in diagnostic science in medical physics has many experimental and therapeutic applications. In this method, by scanning the layers of human body or animals, the internal parts of the body will be visible to doctors. This method is used by CT scan machine. In this device, a large number of small detectors are placed in several rows. X-rays reach the detectors after passing through the patient's body. Algorithms such as back projection filtered are then used to reconstruct the received signals[16].

To remove metal artifacts from dental CT images. One way to remove a metal artifact is to convert the sinogram from the image containing the artifact, segmenting the sinogram, deleting the artifact section in the segmented image, and finally reconstructing the original image. Our purpose in this work is to remove metal artifacts of CT images using segmentation with fuzzy clustering algorithm.

3. methodology proposed

The general steps of all techniques for removing metal artifacts from CT images are similar, and the main difference is in determining the method of image segmentation. If the segmentation is done properly, the artifact removal will also be done well. But otherwise we will not see the desired result. Therefore, in this thesis, we chose the FCM clustering algorithm. CT images have a lot of artifacts and noise, so we will use this algorithm to segment the sinogra m image and expect to see better results than the methods presented so far. The flowchart of the proposed method is shown below

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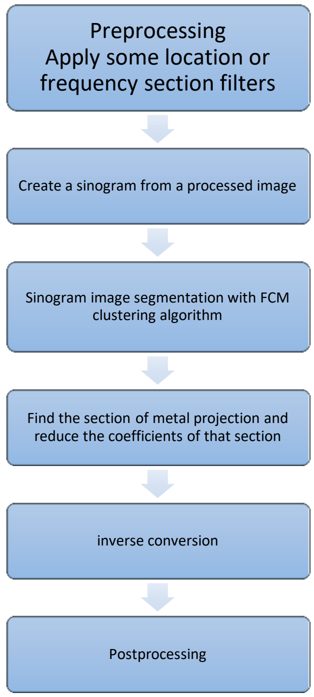

Fig. 1- Flowchart of the proposed method

It should be noted that for image segmentation, each pixel is first assumed to be a cluster center, and then the clustering algorithm is applied to the data clustering. Finally, the final centers obtained by the clustering algorithm are used as the representative of each cluster and replace the pixels of each cluster to obtain the segmented image.

The suggested steps of this work are as follows:

A) Pre-processing stage

At this point, some location or frequency filters are applied to the original image to improve image quality.

B) Sine transform in order to create a projection image or sinogram from the above image

Just as we move location section images to the frequency section for easier and faster filters, artifact medical images can also be converted into sinograms. To convert an image to a sinogram, you must use the radon transformation method. Another name for radon transformation, which involves calculating the matrix projection of an image in certain directions, is sine transform. The calculation of the projection of a two-dimensional matrix consists of a set of integrals on certain lines, and its output is a sine image called a sinogram.

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C) Fuzzy projection image segmentation to find and delete artifact-related sections with the FCM algorithm

Segmentation is done to find sections related to the artifact in the projection image. This is a very important step in removing the artifact. For this reason, we used the fuzzy clustering algorithm for this step to increase the accuracy of the proposed method. Because fuzzy clustering is one of the most powerful methods in image segmentation.

D) Inverse conversion

In this step, in order to extract the reconstructed image from the restored sinogram, the reconstructed image will be obtained by applying inverse conversion on the restored sinogram.

E) Post-processing in order to apply a filter to the final image

It should be noted that the reason for using the FCM fuzzy clustering algorithm is its high ability in clustering, so that in recent years it has been used in many works.

4.Implementing FCM Fuzzy Clustering Method Using Step Sequence

As stated in the previous section, the aim of the FCM clustering algorithm is to find partitions (v fuzzy cluster number) for a set of data points in such a way that the objective function of the relation (3- 7)steps be minimized. But since this objective function cannot be directly minimized, iterative algorithms must be used to do so. The sequence of steps of this algorithm is as follows:

- *First the appropriate values for m, v and a small positive number for ε are determined and the matrix Z (center of the clusters) is filled randomly. Initially it is t = 0.*
- *The membership matrix is updated in the next step (t> 0).*
- *The matrix of the cluster centers is updated with the degree of optimized memberships and according to equation (3-9).*
- *Finally, steps (2) and (3) until the condition <ε ‖Z_i^(t+1)-Z_i^t ‖ يا <ε ‖U_i^(t+1)-U_i^t ‖ is obtained, are repeated.*

The clustering steps of the FCM algorithm are shown in above steps.

5. Evaluation Criteria

In this section, we will introduce the most important image clustering criteria.

RMSE Criteria

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One of the criteria used to evaluate the segmentation of medical images is the RMSE criterion or the mean square error. We will use this criterion to compare our work with a reference article. The relation of this criterion is in the form of the following equation in which f (i.j) of the original image and f^ (i.j) of the reconstructed image in which R and C, respectively, express the length and width of images.

$$RMSE=\left[\frac{1}{RC}\sum_{i=0}^{R-1}\sum_{j=0}^{C-1}[\hat{f}(i.j)-f(i.j)]^2\right]^{1/2}$$

PSNR Criteria

From the signal-to-noise ratio of the following equation, the image segmentation algorithms can be evaluated.

$$PSNR=10\log_{10}\left(\frac{\sum_{i=0}^{C-1}\sum_{j=0}^{R-1}255^2}{\sum_{i=0}^{C-1}\sum_{j=0}^{R-1}[\hat{f}(i,j)-f(i,j)]^2}\right)$$

Reducing the first relation component and increasing the second relation component means performing segmentation optimally.

6. Discussion experiments and results:

several CT images have been used to evaluate and compare different algorithms in CT image segmentation. In addition, the segmentation functions of the mentioned images have been studied and compared for a number of different clusters. In this thesis, the RMSE criterion has been used to evaluate the proposed algorithm.

Evaluating the Results of FCM Clustering Algorithm for CT Image Segmentation

In this section, we will review the results obtained from the clustering algorithm expressed on the CT images presented in Figure 2. The number of iterations used in the simulation is 150, $\varepsilon = 0.00001$ and $m = 2$.

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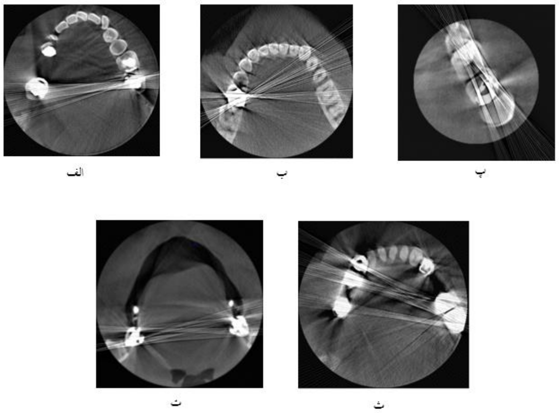


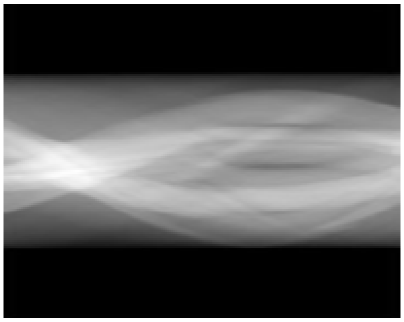


Fig. 3- Sinogram of figure 5-1-c Fig. 2- CT images

In Table 1, the number of sections studied for the clustering algorithm for the CT images shown in figure 2 is 8, 10, and 12 in table 1. It is noteworthy that the CB image sinogram has been used in the segmentation.

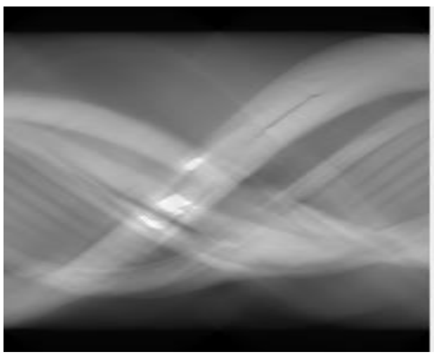
Table 1- Comparison of RMSE criterion of FCM clustering algorithm for CT image segmentation with sections 8, 10 and 12

CT image	Number of sections	RMSE	PSNR
A	8	10/08	5/25
	10	8/06	7/19
	12	7/63	7/66
B	8	8/72	5/83
	10	6/83	7/95
	12	6/04	9/02
C	8	10/94	4/62
	10	7/70	7/67
	12	7/79	7/58
D	8	6/18	7/83
	10	5/21	9/33
	12	4/79	10/05
E	8	10/18	5/12
	10	8/52	6/66
	12	7/62	7/64

Steps to Remove Metal Artifacts from Medical CT Images

As mentioned, the general steps of all methods of removing metal artifacts from CT images are the same, and their main difference is in determining the method of image segmentation. The better the image segmentation quality, the better the artifact removal. In the following, we will explain the steps of our activity step by step.

Step 1) First read the CT image and pre-process to improve its contrast. Figure 4 shows a sample CT image.



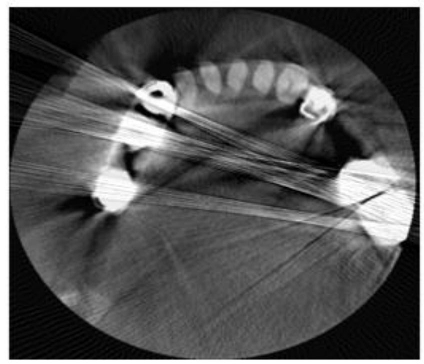


Fig. 5- Sinogram of the input image

Fig4 Input image

Step 2) We get the sinogram of the image above. Figure 5 shows the sinogram of the input image.

Step 3) We perform image sinogram segmentation with FCM clustering algorithm. Figure 6 shows the segmented sinogram of the input image.

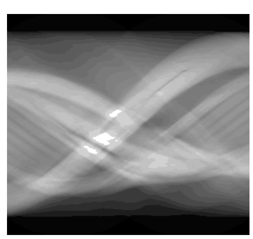


Fig. 6 - segmented sinogram of the input image

Step 4) We modify the largest radon transformation coefficients (the brightest section obtained in the sinogram) that correspond to the section of the metal artifact. To do this, we need to replace the average values of the neighborhood pixels in this section with the pixel values in this section.

Finally, we reconstructed all the images in figure 1 in this way. You can see the reconstruction results in Figure 7.

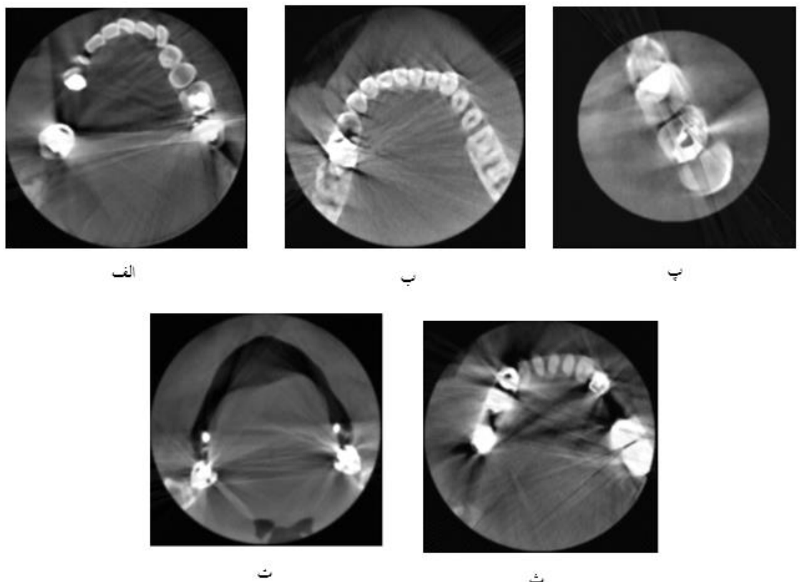


Fig. 7 - Example of CT image reconstruction.

7. Conclusion

image segmentation is one of the techniques to reduce image artifacts. One of the most popular image segmentation techniques is clustering based methods that can be divided into hard clustering and soft or fuzzy clustering. Fuzzy clustering techniques are usually more popular for image segmentation due to the greater detail of the image. The most important image clustering algorithm that is widely used in the field of image clustering is the FCM clustering algorithm. we aimed to find a suitable method for image segmentation to remove artifacts.

A variety of clustering techniques have been proposed to date, and in this study we addressed the clustering technique with the FCM clustering algorithm. To evaluate the performance of clustering algorithms and the results obtained, various components were described and various experiments were performed. Finally, the results for the FCM clustering algorithm indicate that this algorithm had a better result by removing the limitations of the other algorithms.

in future work, can use many method , Given that various clustering methods have been proposed by researchers to date, by examining these methods and choosing a

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more appropriate method than the FCM clustering algorithm, a better result can be achieved than the result presented in this thesis.

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