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2D image processing algorithms for kidney transplantation

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Abstract. Currently, among medical imaging equipment, multislice computed tomography scanner is widely used in diagnosis because it has the function of 3D modeling using cross-sectional images of the patient’s body. This equipment is important for kidney transplantation, it uses 2D image data to form 3D modeling. The high quality of the images obtained by the equipment, i.e. free of noise and other types of distortions and normal contrast, increases the accuracy of 3D modeling. This research work is devoted to the issue of image processing and the algorithms used in it, which is important in the implementation of kidney transplantation through MSCT 3D modeling.
Keywords: *MSCT, 3D modeling, 2D image, noise, contrast, blood vessel, donor, BM3D, CLAHE.*

Introduction

Kidney transplantation is a major life-saving medical procedure for patients with kidney failure. Among modern medical technologies, the use of 3D modeling of images obtained from multislice computed tomography scanners has made significant progress in the successful implementation of kidney transplantation. The use of this method provides the opportunity to provide comprehensive and real-time information in planning surgery.

Performing a kidney transplant depends on a variety of factors, including donor and recipient compatibility, surgical technique, and preoperative assessment of the patient’s anatomy. MSCT image is used for transplant monitoring and early detection of complications during surgery. Since the 3D format consists of 2D images of the patient's structure taken from different angles, the quality of its modeling directly depends on the quality of the two-dimensional images.

Image contrast and image noise can be cited as important parameters determining image quality [1,2]. Low-contrast images make it difficult for medical professionals to distinguish structures in patient images. The presence of noise in the image hinders the automation of image processing and reduces the recognition accuracy [3]. Because, if the image is not denoised, false information can occur in image segmentation and contour analysis. This means that it is necessary to normalize the contrast parameter, which affects the image quality, and eliminate noise.

After the image quality is increased, segmentation algorithms, feature formation and information extraction algorithms are applied to this image. Information about these algorithms is detailed in works [4-12].

This research work is devoted to the issue of contrast enhancement and noise reduction in the processing of MSCT images, using the approaches developed by the researchers, the processing of MSCT images and the creation of a 3D model of the kidney through software were carried out.

Methods

Among image contrast enhancement methods, histogram equalization, contrast stretching, morphological contrast enhancement, and contrast limited histogram equalization (CLAHE), based on the research results of many researchers [13-15], CLAHE was selected. This method is implemented as follows:

- Begin with an input image.
- Divide the input image into smaller tiles.
- Calculate the histogram for each of these tiles.
- Use a Transform Function (TFM) to determine the clip limit.
- Adjust the contrast within each tile based on the calculated clip limit.
- Examine the result to ensure an enhanced image.
- Obtain the final enhanced image.

After the CLAHE method is applied to the image, the image noise reduction step is performed. Among the noise reduction methods developed by researchers, Block Matching and 3D (BM3D) is recognized as a filter that effectively removes Gaussian noise in many literatures [16-18], so it was used in this research work.

BM3D filtering is a noise reduction technique that applies a filter to specific local image sections within the transform domain. This noise reduction method can be broken down into four key steps:

- Identifying image patches that closely resemble a given image patch and organizing them into a 3D block.
- Performing a 3D linear transformation on this block.
- Reducing the coefficients within the transformation spectrum.
- Inverse 3D transformation.

The process of locating a similar block can be described as follows:

$$\rho(p) = \{Q : d(P,Q) \le \tau^{hard}\}$$

where P *- denotes an image loop patch of size* $k^{hard} \times k^{hard}$. $d(P,Q)-$ *is the Euclidean distance between blocks.*

Results

In this study, multislice computed tomography images of 128 donors undergoing kidney transplantation among close relatives were used for the experiment. According to the examination results, 97 (75.78%) donors were selected for kidney transplantation, of which 14 donor kidneys had 2 arterial blood vessels, and 5 donor kidneys had 2 venous blood vessels. The remaining 31 (24.22%) donors had 3 or more renal artery and vein blood vessels. Donors of this category were denied the practice.

CLAHE mentioned above as a contrast enhancement method and BM3D filter as a noise reduction method were used in the processing of MSCT images in the experiment (Fig. 1).

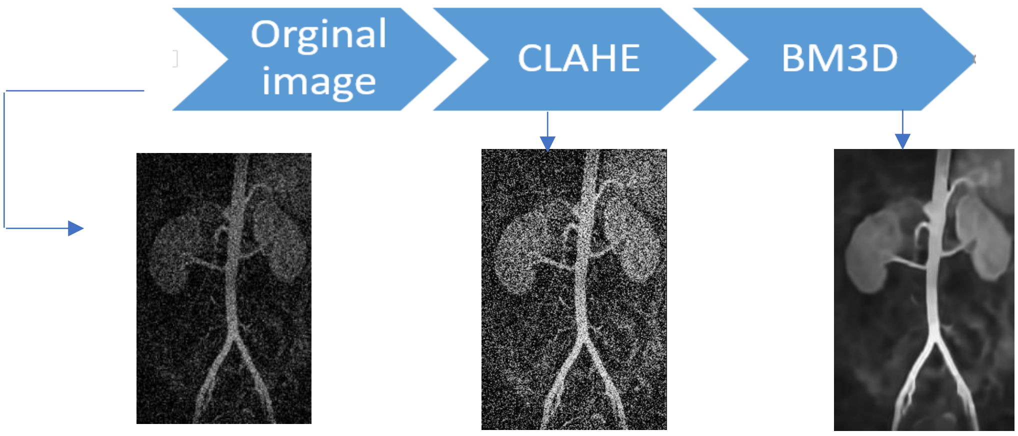

Figure 1
A sample image after the processing of an MSCT image with low contrast and added Gaussian noise

By using processed images, the quality of the 3D view of the kidney from its original unprocessed state has an impact on the accuracy of medical diagnosis.

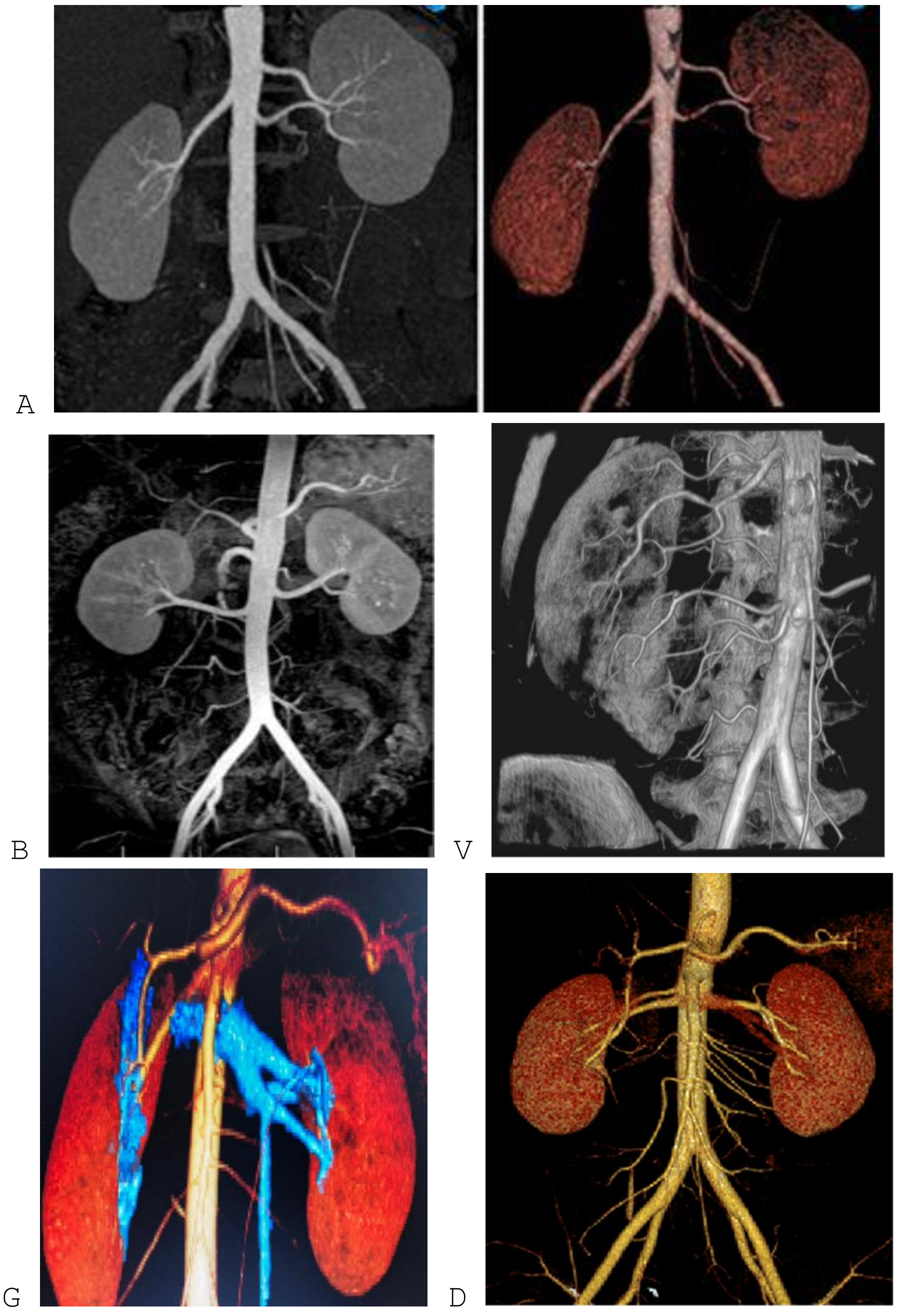

Figure 2

A – MSCT of renal arteries with a 3D view (2 arteries). B – MSCT of renal arteries (1 artery). V – MSCT of renal arteries (more than 3 arteries). G and D – MSCT 3D view of the renal artery and vein

After multislice computed tomography examination, angiographic examination of the upper mesenteric artery in 3 donors, lower mesenteric artery in 2 donors, and renal artery in 5 donors out of 97 donors selected for kidney transplantation was performed. The results of the examination were compared with the results of the multislice computed tomography examination and the data consistency was checked.

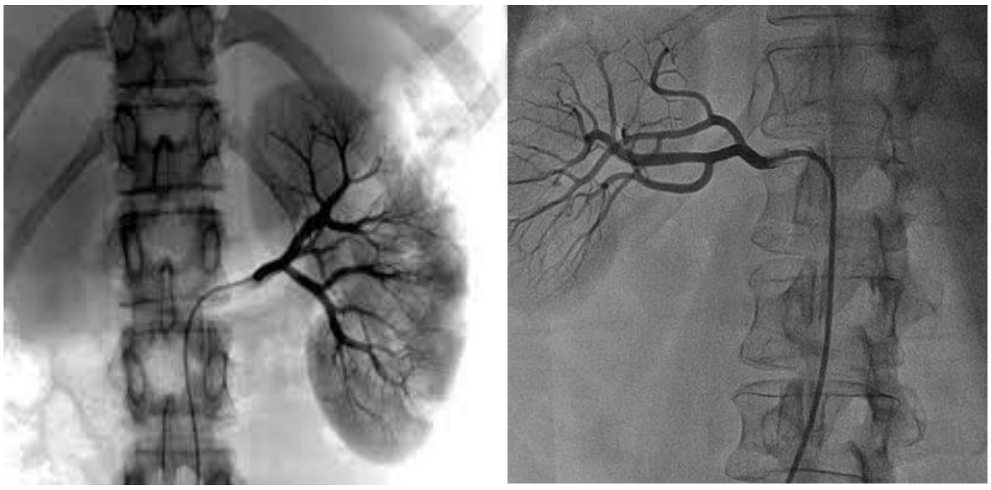

Figure 3
Selective angiography of renal blood vessels

Conclusion

In this study, the problem of improving the quality of images obtained as a result of MSCT examination, that is, improving the 3D view of the kidney by using methods of increasing the contrast of 2D cross-section images and reducing noise, was studied. Medical professionals can monitor important processes such as monitoring patient health and early detection of complications by using MSCT 3D modeling in kidney transplant patients.

CLAHE to increase image contrast and BM3D to eliminate Gaussian noise in the image were used in the research work. Out of 128 donors screened for kidney transplantation, 97 were selected for the procedure. In 31 donors, the operation was denied due to the large number of renal blood vessels. The processed images obtained as a result of MSCT examination were examined by medical experts and positive conclusions were obtained. The indications obtained through these images have been proven to be consistent in practice. MSCT data have been shown to provide more preoperative information than angiography data.

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