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A CASE-STUDY VISION

3D Organ Reconstruction from Computed Tomography (CT) Images Using MATLAB

Reconstrucción 3D de órgano a partir de imágenes de Tomografía Axial Computarizada (TC) usando Matlab

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ABSTRACT

The three-dimensional processing and reconstruction of anatomical regions from medical images allows the application of a set of segmentation and filtering techniques to subsequently perform volumetric reconstructions and thus generate 3D computer representations of human anatomy, which is useful in the field of medicine to facilitate the analysis of human body structures. In this paper, a 3D reconstruction was performed from the segmentation, based on the differentiation by area, of the organ (kidney) and bone structures from a series of images from an abdominal CT. Also, we implemented an interactive interface for the visualization of the planes (frontal, sagittal and transversal). The interface that shows the different planes and also loads the 3D reconstruction that was generated in a separate process, gives the user the option to select any CT study that he has stored in his computer. This procedure, depending on the field of application, complements the interaction and analysis of anatomical structures to the physician, allowing the planning of a timely treatment that will help the preoperative analysis of complex pathologies and the formulation of surgical strategies.

RESUMEN

El procesamiento tridimensional y la reconstrucción de las regiones anatómicas a partir de imágenes médicas permiten aplicar un conjunto de técnicas de segmentación y filtrado para para realizar posteriormente reconstrucciones volumétricas y así generar representaciones computacionales en 3D de la anatomía humana, que es útil en el campo de la medicina para facilitar análisis de las estructuras del cuerpo humano. En este artículo, se realizó una reconstrucción 3D a partir de la segmentación, basada en la diferenciación por área, del órgano(riñón) y estructuras óseas de una serie de imágenes de un TAC abdominal. También, implementamos una interfaz interactiva para la visualización de los planos (frontal, sagital y transversal). La interfaz que muestra los diferentes planos y también carga la reconstrucción 3D que se generó en un proceso aparte, da la opción al usuario de seleccionar cualquier estudio TAC que tenga almacenado en su ordenador. Este procedimiento, según el campo de aplicación, complementa la interacción y análisis de estructuras anatómicas al médico, permite planificar un tratamiento oportuno que ayudará al análisis preoperatorio de patologías complejas y la formulación de estrategias quirúrgicas.

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1. Introduction

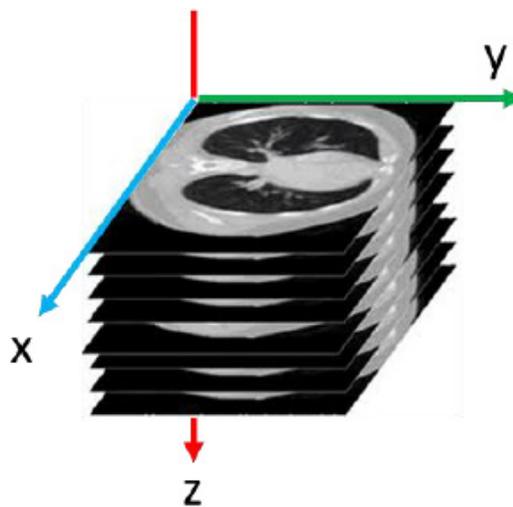
Currently, medical imaging has become one of the main resources for the diagnosis and, consequently, treatment of diseases in their early stages, due to medical images make it possible to recognize structures and organ function inside the body [1] [2].

The medical technologies available to obtain images of the body are varied, both in their principle of operation, as well as in complexity and forms of use. However, many of these technologies (Computed Axial Tomography (TC), Magnetic Resonance Imaging (MRI), Mammography, Positron Emission Tomography (PET), etc.) have standardized the format in which medical images are presented for further study [3].

Most medical images are presented in the standard DICOM format, which establishes the mechanism for codify, storage, and transmit medical image that contain a large amount of information not only graphic, but also personal and clinical information of the patient, as well as the characteristics of the test and the biomedical technology used to generate the image [4] [5]. In the field of medical image processing, there are numerous techniques that make it possible to manipulate the characteristics of the image, in terms of its format, dimensions, color intensities, types of values, pixels, among others [6].

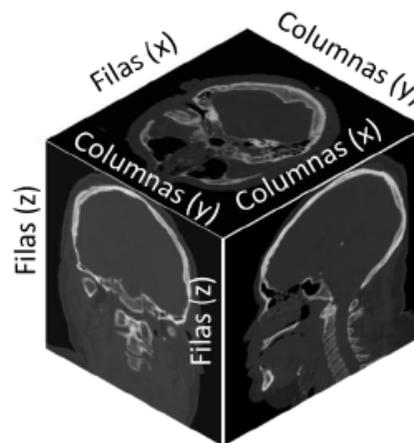
An image, in general terms, is an array of x rows by y columns, each coordinate (x, y) refers to a pixel, which contain different values, usually a gray scale. The shapes present in the image are those interpreted by the specialist to confirm or discard pathologies in patients. These images can be the representation of the body's organs in any of the frontal, sagittal or transversal planes. Technologies such as CT or MRI, take a number of transverse images of the body, called slices. The set of tomographic slices adds the depth coordinate (z) , determined by the thickness of the slice. Then, the cubic unit of three-dimensional elements, associated with the spatial coordinates (x, y, z) , is the main unit called the voxel. The set of volumetric units allows the representation of anatomical structures, processing the images, in a two-dimensional way in any plane (sagittal, frontal or transversal) [7]. Figure 1 shows the representation of a set of axial slice images obtained by CT.

Figure 1. TC images of axial sections. Modified from [8].



The image configuration shown in Fig. 1 is the first notion of volume in 3 dimensions. Because you can reconstruct an image (arrays rows (x) by columns (y)) of any plane, considering the sequence of images (slices (z)). A representation of this is shown in Figure 2, where the images in the transverse plane are an x -by- y array, the images in the sagittal plane are a z -by- x array, and the images in the frontal plane are a z -by- y array.

Figure 2. CT images of axial sections.



Source: own.

Medical image processing techniques currently allow for 3D reconstructions of human body structures. This has made it possible to improve diagnostic analysis in the clinical field, facilitate visualization and interaction for detailed planning of medical-surgical treatment. Innovative techniques and tools in the field of neurology

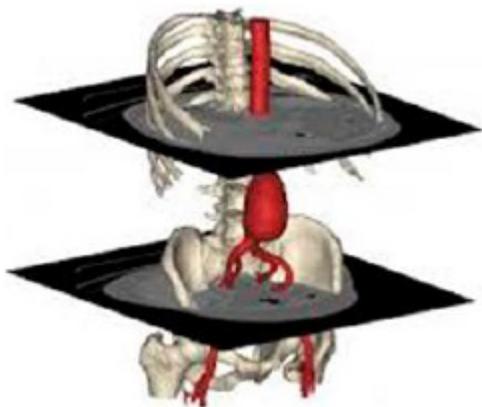
make it possible to segment white matter, gray matter and cerebrospinal fluid automatically from volumetric acquisitions and reconstructions [7] [9].

The extraction of the morphological characteristics of the anatomical structures to be reconstructed in 3D, requires first a process of segmentation, in which the area of interest is delimited. For this, algorithms are developed based on characteristics such as the discontinuity or similarity in the uniformity of certain areas of the image, to isolate them from the rest of the elements that make up the image [10]. In this way, the segmentation techniques allow to select the data that will be included or not in the 3D reconstruction [11].

The reconstruction of three-dimensional images corresponds to a process in which objects or delimited regions of the medical images are reproduced in the computer memory to represent and maintain characteristics in terms of shape, dimensions and volume [12]. Figure 3 shows the result of 3D reconstruction techniques, which incorporate meshing methods to carry out the connection of a set of points that are representative of the structure of interest. This has involved the development of innovative tools in the field of medical imaging.

This study proposes a methodology for processing medical images, to extract characteristics of selected organs from DICOM images, allowing their individualization and subsequent three-dimensional reconstruction. It also shows the implementation of an interactive interface in Matlab's GUI for the visualization of CT studies in their different planes and 3D reconstruction performed in parallel. With the purpose of providing an alternative that allows the development of technologies that facilitate the diagnosis of diseases and the planning of more timely treatments.

Figure 3. CT images of axial sections. Extracted from [8].



2. Methodology

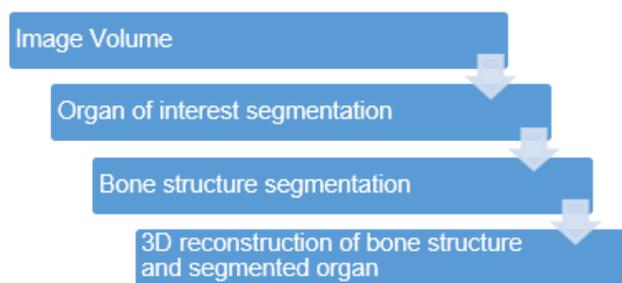
2.1. Description of DICOM images

The DICOM images used in this study were extracted from the DICOM Library web portal, a repository of free online medical images, for educational or scientific purposes. The processed images belong to an abdominal CT, with the following characteristics: 361 DICOM images, resolution of 216 (grayscale), dimensions of 512 x 512 [13].

2.2. 3D Reconstruction

The 3D reconstruction process implemented is described by the following flow diagram Figure 4.

Figure 4. 3D Reconstruction flow diagram.



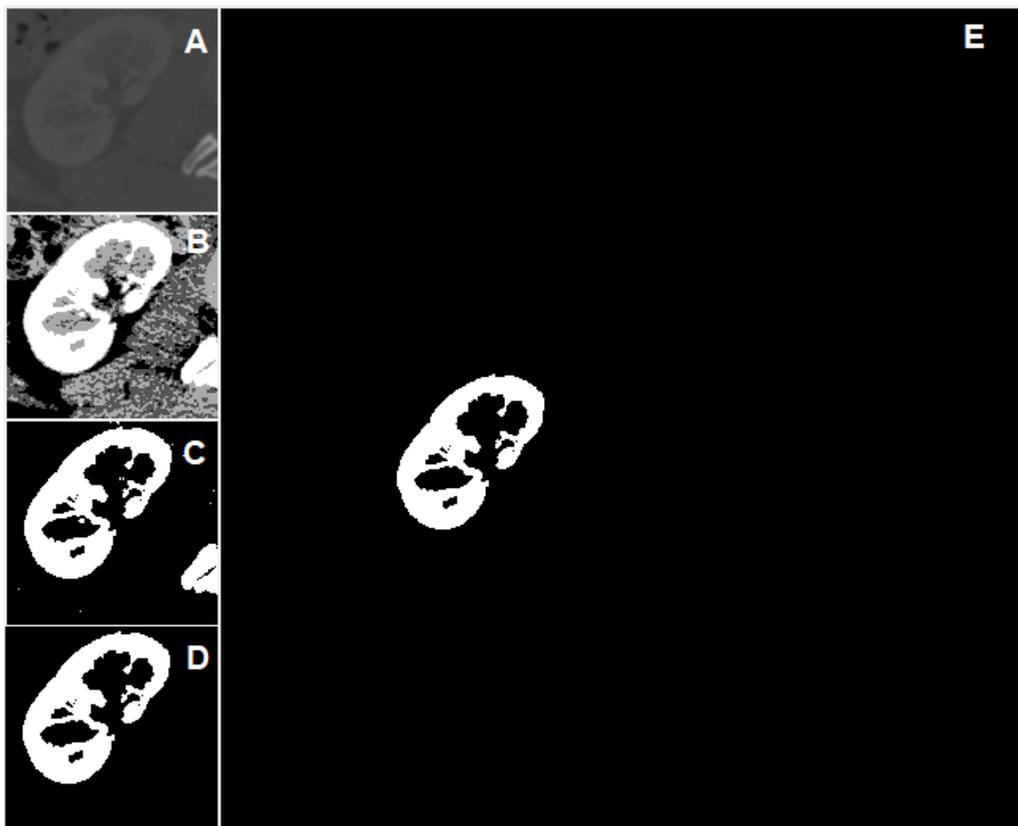
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2.2.1. Image Volume

We use functions intended for processing images in '.dcm' format, belonging to the Matlab software, such as "[D,spatial,dim]= dicomreadVolume(details)"; that reads a series of images and creates a volume of images 'V' defined by the coordinates $V(x,y,z)$, being; X and Y the dimensions of each image, Z the number of images that compose the volume.

2.2.2. Organ of interest segmentation

In the human body, in most cases, the organs occupy a fixed place that facilitates their identification. Therefore, for the process of segmentation, we define and take only areas of interest according to the organ for the images of the study used. Then, from the previously created volume of 'V' images, we delimited different sections or groups of images in which the area did not have significant variations, with the purpose of maintaining the shape of the organ in the elimination of elements that are not part of it. Figure 5 shows the segmentation process.

Figure 5. Segmentation process.

Source: own.

Having the image delimited (A) in Figure 5, the variation of the contrast allowed a clear differentiation of the organ of interest, which now has the highest level of gray, (B). With this it is possible a binarization that will eliminate areas that are not part of the organ (C). However, elements with the same level of gray that are not part of the organ are maintained, and this is eliminated by area discrimination (D).

To preserve the location of the segmented organ in the original image, was created a zero-array, and the segmentation (E) is placed on the same coordinates from which the organ was taken in gray. This process was performed for all the images of each defined section. With these, a volume of images was created that is complemented with images in zero, to maintain the same dimensions of the original volume 'V'.

2.2.3. Segmentation of bone structures

Due to their higher density, the bone structures, in the CT images, are shown in light gray (high values).

For this reason, a traditional binarization was used, comparing the values of each pixel with a high value threshold to reach the greys that represent the bone structures. Pixel values above or equal to the threshold will be replaced by white (maximum value). Pixel values below the threshold will be replaced by black (minimum value). Most organs have much lower gray values, which results in individualization of the bone structure and elimination of all other shapes. This technique works well for the whole set of images. With the images of the bone structures a volume of images was created, in the same way as the previous step.

2.2.4. 3D reconstruction of bone structure and segmented organ

Several 3D reconstruction methods can be used, in this case 3D triangulation was used with Matlab's "patch" function, which uses the so-called "Faces" and "Vertices" given by the "isosurface" function from the contours of the generated volumes. The patch function also allows to give color to each structure, among other characteristics.

2.3. Interactive application

In Matlab's GUIDE, we created an interactive interface that allows: loading different CT image studies selected by the user; displaying views of the transverse, frontal and sagittal planes, and showing a visualization of a 3D reconstruction in a different window.

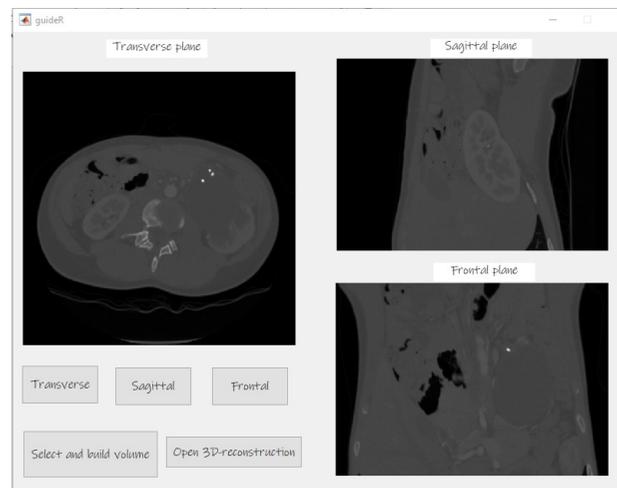
2.3.1. Structure and function

In addition to the DICOM image processing functions mentioned above, functions were used to

select files of interest. This allows the user to select the location of the files and create the volume of images to be studied.

For the visualization of the sagittal and frontal planes, the created volume was rewritten taking into account changes in the axes (rows, columns and slices) as appropriate, in general the CT scan is taken transversely. In the interface each plane is shown separately in a window. The structure of the interface is shown in the Figure 6.

Figure 6. Interface structure and function.



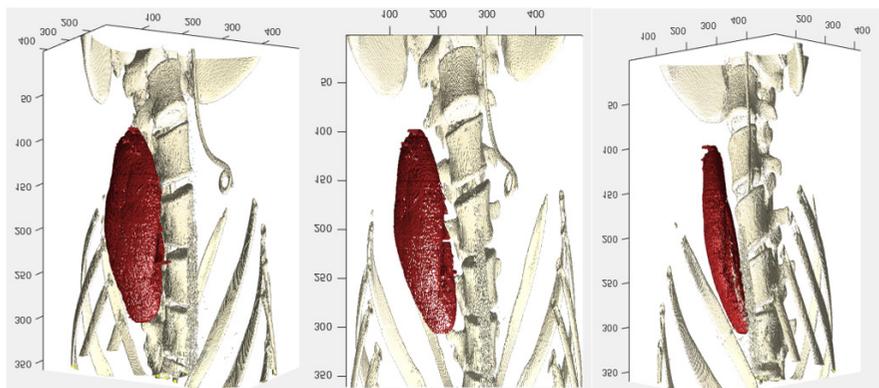
Source: own.

3. Results

In this section, the results obtained in the reconstruction of the selected organ (kidney) and the bone structures, integrated in the same figure, are shown. The scale in Figure 7 and 8 shows, on the vertical axis (z), a range of values from 1 to 361, which corresponds to the number of slices

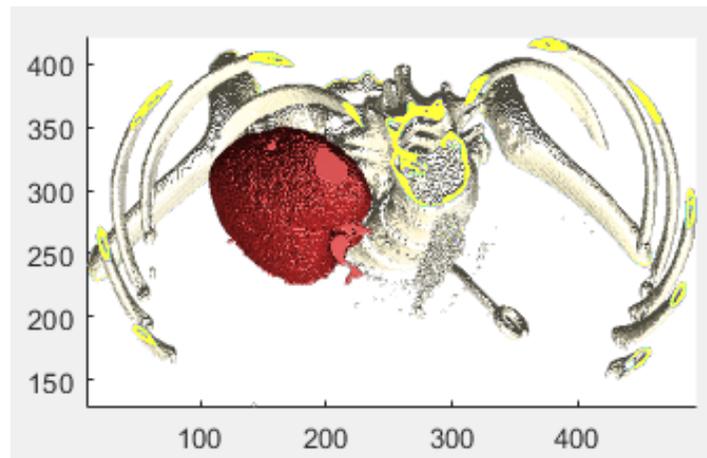
in the DICOM image set. In 3D reconstruction, the z-axis corresponds to the height of the structure and depends on the number of slices in the study image set. The scales at the base of the Figure 7 and 8, the x and y axes correspond to the depth and width of the bone structure respectively.

Figure 7. Left, front and right isometric view of 3D reconstruction of right kidney and bone structure.



Source: own.

Figure 8. Top view of 3D reconstruction of right kidney and bone structure.

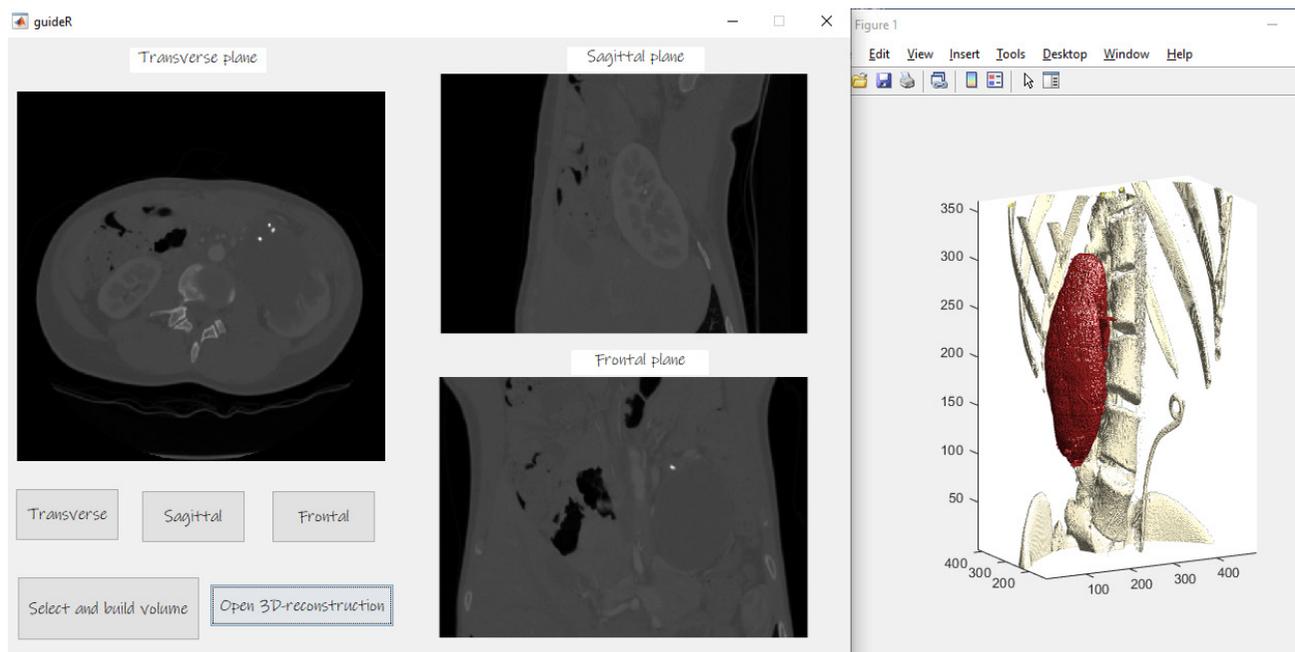


Source: own.

The interactive interface, shown in Figure 9, allowed the visualization of DICOM images in the different planes (sagittal, transversal, frontal) and the 3D reconstruction.

The interface is intuitive and easy to understand. It is composed of 4 buttons: three for the different planes and the fourth button to show the 3D reconstruction.

Figure 9. Interface interactive.



Source: own.

4. Conclusions

In this work we present a 3D reconstruction from images of a CT study. We use a segmented method based mainly on differentiation: by the area of organ of

interest, in this case the kidney, and grey intensities for the case of bone structures. We also created an interactive interface for the visualization of different planes, selected by the user in order to show more details of the studied organs as parallel information to the visualization of the

structure in 3D. This double visual information can be of great interest to the specialist. The 3D images give the possibility of a better location of structures in the real three-dimensional space, gives a greater degree of spatial manipulation, details in the set of structures.

This type of procedure can have several utilities, depending on the field of application, it complements the interaction and analysis of anatomical structures to the physician or user, to plan a treatment or establish a timely diagnosis that helps the preoperative analysis of complex diseases and the formulation of surgical strategies. The 3D processing and visualization platforms also have a potential use as an educational tool that complements the learning process for students in the health area by complementing theoretical concepts and adding interactivity with 3D models of real cases.

This work is part of a research project in which we seek, from the results obtained, lead to an augmented reality software or virtual. The augmented reality allows to integrate reconstructed structures to a real environment while the virtual reality gives the possibility to interact in the virtual reconstruction space. This will give the possibility of studying or analyzing in more detail pathologies of interest, for example, the identification of tumors, adding the advantages provided by virtual reality or augmented.

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