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Analysis and Visualization of the Center Line in Large Intestine by Virtual Colonoscopic and Processing Algorithms: A Brief Study

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Abstract— The analysis showcases a virtual colonoscopic algorithms to detect and visualize 'polyps' and cancerous outgrowths in the large intestines of patients along with bringing forth a way to materialize the process. Virtual colonoscopic approach targets patients to provide a relaxed and less painful option for spotting cancerous and pre-cancerous outgrowths in the colon. Several 3D image processing algorithms of image skeletonization are used to find the location and shape of colons in the large intestine.

Index Terms— CT Scan Image, Image Segmentation, 3D Componenet Labelling, Image Skeletonization, Parellel Thinning Algorithm, , Ma And Sonka's Algorithm, Seeds, Voxel Coding Algorithm

1 INTRODUCTION

VIRTUAL colonoscopy is a procedure used to look for signs of precancerous growths, called polyps, cancer and other diseases of the large intestine. Images of the large intestine are taken using computerized tomography (CT). It is a promising technique for exploring the colonoscopic area hinging on volumetric 3D image data. It uses medical imaging, computer graphics, and image processing techniques to examine the interior structure of the human organs, Computer tomography (CT) is a procedure that takes hundreds of cross-sectional rays in a few seconds. Like putting together a loaf of bread from its many slices, a computer puts cross-sectional x-ray pictures together to form whole images of internal organs. In Virtual colonoscopy an animated, 3D view of the inside of the large intestine is reconstructed using images of the large intestine and the inner surface of the model is rendered for the detection of the location, size and shape of the Polyps.

This paper assumes the availability of CT scan images and divides the images into following steps

- Extraction of Colon present in Large Intestine
- Finding the center line of Colon in Large Intestine
- Surface rendering to reconstruct the inner surface of Colon present in large intestine.

2 THEORY

2.1 Strategy and Method to design a Virtual Colonoscopy System

In this section, I want to present an overview of the proposed virtual colonoscopy system on the PC platform. To extract the inner surface of the patient colon, there are several preprocessing steps including patient preparation, air inflation into the colon, and surface extraction. Before we present to you the proposed technique let us give to you the algorithm which is as follows;

A. Use of Computerized Tomography procedures to take the 3D volumetric images of colon present in the intestine.
B. Several high resolution sliced images are obtained with a single breath hold, which formed a volumetric data set.
C. Extraction of colon that includes image segmentation and 3D region growing.
D. Skeletonization process to find the center line detection by using Ma and Sonka's Algorithm, Parallel Thinning Algorithm, Sub-iterations Parallel Thinning Algorithm, Voxel Coding algorithm
E. Surface Reconstruction and surface rendering based fly through a virtual camera.

The procedure for center line extraction of the colon produces a center line along with many branches due to that fact the inner surface of the colon is irregular in nature leading to cross sections of various types.

2.2 Theory of 3D Volumetric Images

The 3D Volumetric images and Volumetric image processing includes the 3D crack images which is also called as 3D Binary volume data set. This set consists of set of voxels, which is the smallest unit of the cube. The voxel is represented by a quadruple(x, y, z, u) represents a 3D location of the voxel in an image and u represents its membership value. When u value is 0 its shows voxel is belong to the background, whereas value denotes voxel belongs to the entire location of the image. Considering a voxel in a unit cube results to three kinds of voxel neighborhood. For a voxel p and q is called F –neighbor, E- neighbor and V- neighbor of p, if q shares a face, vertex or an edge with p. Two voxel are at least V-connected, if they are adjacent and neighbors. If a voxel present inside the object, it is called as inside voxel otherwise called boundary voxel.

2.3 CT Imaging System

Using a conventional Computed Tomography imaging system we first obtained the images of the entire abdomen of the patient which are obtained in form of a number of 2D images. When such images are combined using specific computer programs we get a highly detailed multi-dimensional view of the colon of the large intestine.

2.4 Image Segmentation

Image segmentation aims to group the image elements, or voxels, of the same tissue in a 3D space. The unique feature in the image segmentation is the use of the similarity of same tissue types. Various methods for the segmentation of colon from the 3D CT data are proposed [1] [5]. We used multi-thresholding; 3D region growing and 3D connected component labelling algorithms for the purpose of segmentation.

2.5 Multi-Thresholding Technique

I set two intensity levels as lower and upper thresholds and any vowel having intensity in between the thresholds belongs to the colon otherwise it is a background voxel. This in turn converts the volume image into a binary image leading to saving of a huge amount of memory.

The value of the upper threshold and lower threshold is decided by the user by observing the two dimensional images or these value can be decided automatically by the seed point entered by the user. In the developed virtual colonoscopy tool there is a provision to enter the upper and lower threshold value by using a dialog box. The drawback of this method is we have to enter the lower and upper threshold. Another drawback is that the technique is very sensitive to noise and intensity in homogeneities.

2.6 3D Region Growing Algorithm

3D Region growing is a technique to extract a connected region from a 3D volume based on some predefined connecting criterion. The 3D region growing algorithm used here is based on the queue and a three dimensional flag. The algorithm is as follows:

1 Clear all the points in 3D flag volume.
2 Set the flag value corresponding to seed point and push the seed point on the queue.
3 While queue is not empty
 3.1 Take out the a point P(x, y, z) from the queue
 3.2 check the 26 neighborhood points of P(x, y, z) if Flag is equal to zero then flag is set to one and that point is added to the queue.

4 Check every point in 3D flag volume if it is equal to one set that point .Otherwise reset that point to zero.

The primary disadvantage of this algorithm is that it requires seed points which generally mean manual interaction. Region growing can also be sensitive to noise and partial volume effect causing the extracted region to have holes or disconnections.

2.7 Image Skeletonization

I used Modified Ma and Sonka's algorithm, Parallel Thinning Algorithm, Sub-iterations Parallel Thinning Algorithm and Voxel Coding Algorithm proposed by Ma and Sonka for the thinning of the colon. But the result obtained after this in not a thin single line. It includes many branches because the cross section area of the colon is different at different location and also the shape is not uniform. To trim these redundant branches we used another algorithm named two pass tracking method.

2.8 Fully Parallel Thinning Algorithm

This is a general proposed algorithm proposed by Ma and Sonka belong to a topological thinning group. This algorithm tests all border voxels on each iteration. Once the voxel is visited the algorithm checks whether it meets atleast one of the prior deleted contraints. The iteration continues until no more voxel is deleted. Points which are not deleted form the final skeleton image. Ma and Sonka algorithm is based on fully parallel strategy which uses a set of predefined deleting templates to test the neighbourhood of each border pixel. When a voxel and its neighborhood match at least one template then the voxel is marked to be deleted. After inspection of all border voxels the marked ones are deleted by changing their values to 0.

2.9 Sub-iterations Parallel Thinning Algorithm

The next algorithm which we have tested follows different thinning strategy than the first one. Detailed presentation of the strategy has been published in [9] by Palagyi. In this type of thinning strategy each iteration of a thinning process is divided into sub-iterations. Common sub-iteration algorithms use three or six sub-iterations; however Palagyi proposed an approach which uses twelve sub-iterations. In each sub-iteration the algorithm can use different deleting conditions. This is the main difference compared to fully parallel strategy where the thinning process uses global and predefined delete constraints. Palagyi's algorithm uses sub-iterations in order to test only specific set of voxels. These sets of voxels are determined with rules called directions. Figure 3 shows twelve directions proposed by Palagyi. Each object boundary voxel in an actual direction can be tested using predefined, for this Sub-iteration, deleting templates. Palagyi defined 14 deleting templates which are final templates used to test voxels in US direction [9] (see fig. 1). Other direction templates are formed by translation of the final US templates using rotation or reflection according to the actual direction rules. Deleting templates can be presentedin similar way to Ma and Sonka ones. That is, black dots correspond to object points while white dots represent background points. Other points in template can be both object or background voxels. When all voxels which match deleting templates are marked, the algorithm deletes them and continues to the next sub-iteration. The algorithm stops if there is no marked voxel for deletion in each sub-iteration. In that case undeleted voxels form a final skeleton.

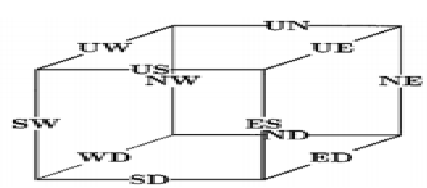

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Fig.1. 12 Direction planned by Palagyi

The above algorithm flow chat is as follows:
Repeat
For i= 1 to i=12 do
Mark all the border points which match the deleting templates predefined for i-th direction.
Delete all the marked points
Until no point for deletion in each direction remains.

2.10 Voxel Coding Algorithm

This algorithm is quite complex including the part of its decryption. So the basic operation of the algorithm is presented by two steps:

1. Initial skeleton generation
2. Refinement

The first step results in initial skeleton and utilizes a voxel coding scheme – a procedure similar to a discrete minimum distance transform. It uses the coding scheme "n_f-n_e-n_v" ("n_e-n_v" for 2D images) which is described with three integer values greater than 0: nf, ne, nv, (nf < ne < nv). First, all the object O voxels are initialized with a code (value) of infinity. Than the propagation starts from seed voxels which are given code 0. Then all the seed F-neighbours, E-neighbours, V-neighbours within an object are given a code of n_f, n_e, n_v, respectively. In the ith iteration, all neighbours of voxels which have been assigned with a code value during the ith-1 iteration are processed. Assume that voxel p is assigned with a value of n for the ith-1 iteration. Thus for the ith iteration all its F-neighbours, E-neighbours, V-[neighbours within an object are assigned with value $n + n_f$, $n + n_e$, $n + n_v$, respectively, provided that the new code values are lower than the actual ones (i.e. an infinity value replaced by a code 2, or a code 4 replaced by a code 2). This method prevents voxels coded during iteration from being coded again in the following one. This coding procedure stops when there is not any voxel to process in the next iteration or the constraint conditions are fulfilled (e.g. a particular voxel is met). The voxel coding procedure applied to 3D (2D) image results in a 3D (2D) image respectively which is called voxel field.

The skeletonization algorithm described in this section utilizes two types of voxel codings:

1. BS-coding which uses object boundary voxels as a set of seeds and the generated field is called BS-field.
2. SS-coding which uses a seed set which consists of only one specific object voxel called reference point (RP). The coding results in a field called SS-field.

2.11 Two pass tracking method

To trim the redundant branches obtained after applying the modified Ma and Sonka's algorithms Two pass tracking method is used .Before trimming the branches, the two-end points (starting and ending fly points) of the flight path are specified. To automate the process starting point is automatically calculated from the lower portion of the colon and end point is obtained after the first pass.

2.12 Surface reconstruction using Marching Cube Algorithm

Marching Cubes [11] [9] is a computer graphics algorithm for extracting a polygonal mesh of an isosurface from a three dimensional scalar field (called as voxels) There are two primary steps in Marching Cube Algorithm to the surface construction problem. First one is to locate the surface corresponding to a user-specified value and create triangles. Then, to ensure a quality image of the surface, calculate the normal to the surface at each vertex of each triangle.

2.13 Implementation of the Fly Path and Navigational Environment of virtual camera

I developed a GUI in which 2D slice views of the transverse, sagittal and coronal images are available. The 3D volumetric rendered view is also available.

Navigation through the entire colon lumen in the large intestine can be achieved by either surface- or volume-based rendering computer graphics techniques. The surface-based navigation is efficient (i.e., in real time), but lacks rendering quality in terms of the surface smoothness, and most importantly, it lacks information beyond the surface. We used the perspective projection for the visualization. In the Perspective projection three things are required for the virtual camera. First one is the location of the virtual camera, second one is the location of target point and third one is the direction of camera.

3 RESULTS

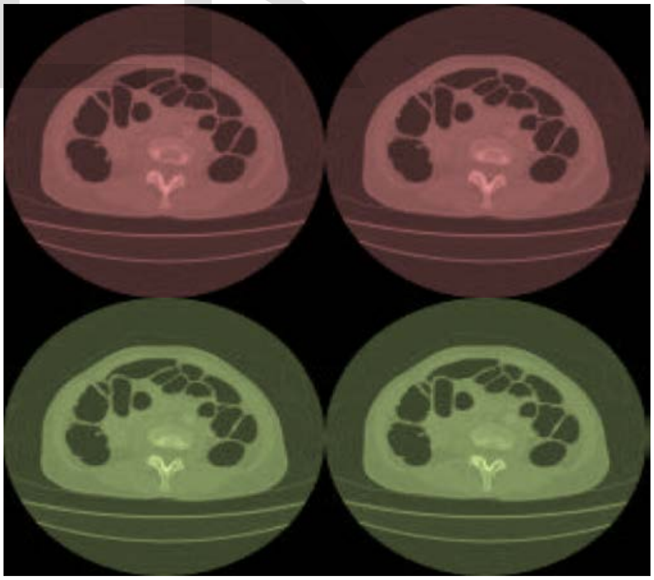

Fig.2. Original CT Images

Fig.3. Image after Thresholding

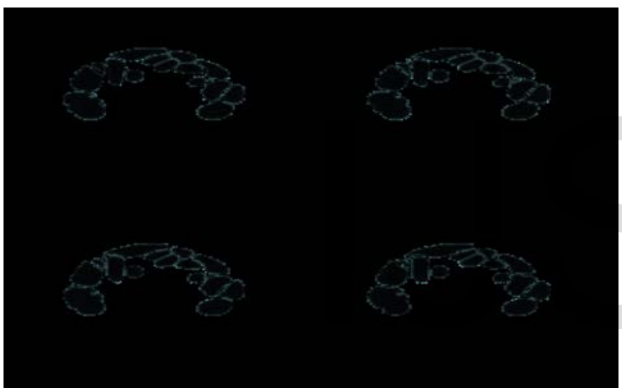

Fig.4. Image by 3D connected component labelling

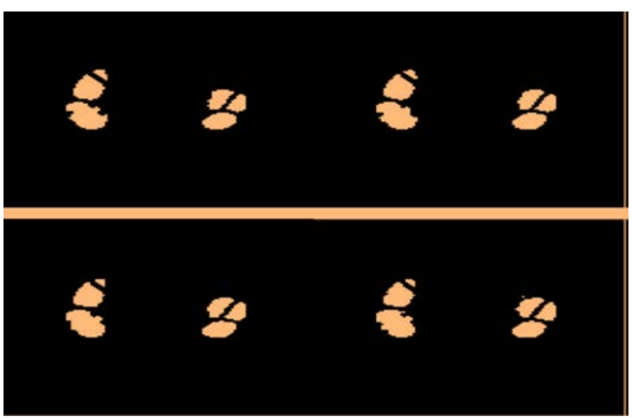

Fig.5. Image by 3D Region Growing

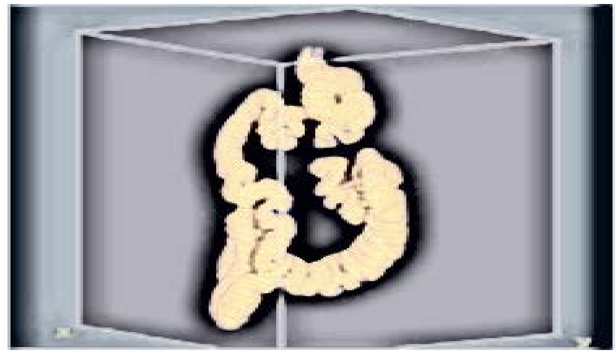

Fig.6. 3D view of Hollow Colon

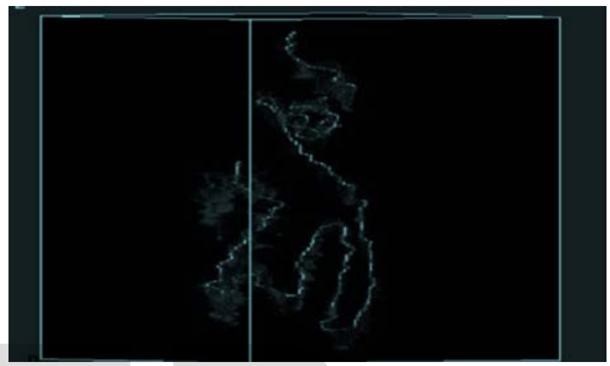

Fig.7. 3D view of center line by Ma and Sonka Algorithm

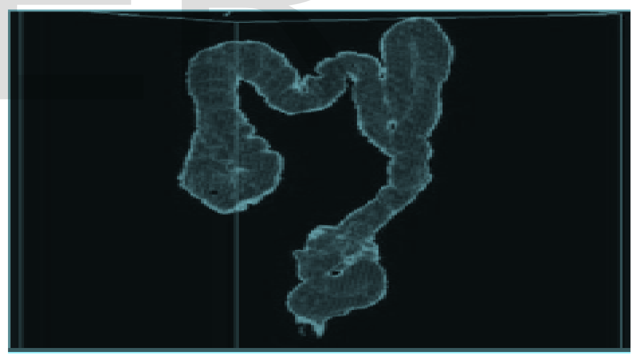

Fig.8. 3D view of Region Growing

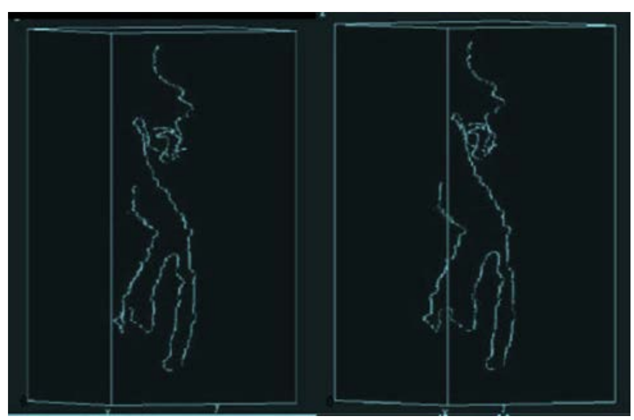

Fig.9. Different 3D view of centre line after modified Ma and Sonka's and two pass tracking algorithm

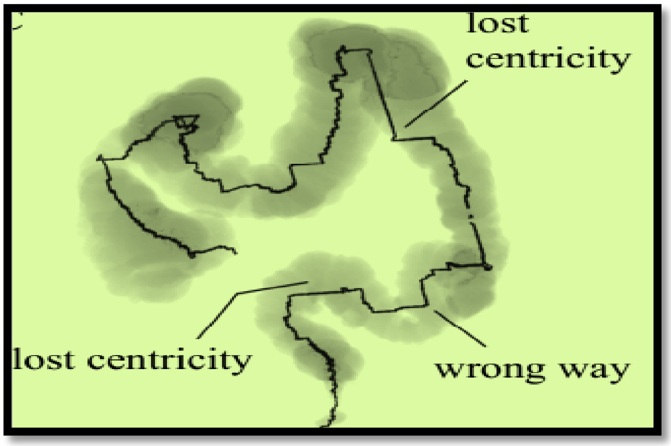

Fig.10. Centerline Obtained from Voxel Coding Algorithm

4 Conclusion

Thus an effort is put to bring forth a simple working model for virtual colonoscopy we have seen that segmentation and center line detection are of utmost importance as the generated view of the colon very much depends on these two. Extensive research is proposed for center line detection as that gives flexibility to camera fly (movement).

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