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Performing Three Dimensional Interactive Operations of CT Medical Images

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Abstract: Three-dimensional medical image visualization becomes a research area in medical field, including computer-aided diagnosis, surgery planning and simulation, artificial limb surgery, radiotherapy planning and teaching etc. Three dimensional visualization is a series of theories, methods and techniques which applies computer graphics, image processing and human computer interacting techniques. In most cases, 3-D images are represented as a sequence of two-dimensional (2-D) parallel image slices. Three-dimensional of human medical images for a sequence of two-dimensional image slices. Furthermore, more complex interaction methods including interaction clipping, extraction of any angle virtual slice with translation on 3-D medical images can be realized. Segmentation refers to the process of partitioning a digital image into multiple segments. The goal of segmentation is to simplify and/or change the representation of an image into something that is easier to analyze. Image segmentation is used to locate objects and boundaries in images

Key words: 3D Visualization · Segmentation · Clipping

INTRODUCTION

Virtual environments are becoming more and more important for the volumetric medical data reconstructed from slices of images coming from Magnetic Resonance Imaging (MRI), Computer Tomography (CT) instrumentations. The possibility to visualize and interact with three-dimensional reconstructed organs while being immersed into a virtual environment provides doctors a very naturalistic way to investigate patient's anatomy [1]. However, most 3D user interfaces for immersive and semi-immersive virtual reality applications lack in usability or make not possible a user-friendly interaction.3D medical images, facilitating diagnosis, surgical planning, therapy evaluation and remote 3D examination. It improves understanding of complex anatomies by providing an interactive three-dimensional environment with simple Web-based user interface. GPU based ray casting algorithm is adapted for clipping, slicing and translation of the 3-D images for the medical image. Volume segmentation is an important part of computer based medical applications for diagnosis and analysis of anatomical data. The computer based tools allow scientists and physicians to understand and diagnose anatomical structures by virtually interacting with them [2].

Volume segmentation plays a critical role by facilitating automatic or semi-Automatic extraction of the anatomical organ or region-of-interest. Medical imaging is the technique and process used to create images of the human body [3-7].

Volume visualization examines a set of techniques that allows viewing an object without mathematical representing the other surface. Many volume visualization algorithms are computationally expensive and demand large data storage. Various techniques in hardware and software are generalizing volume visualization as well as real time performances. Rendering is the process of generating an image from a model, by means of computer programs. The model is a description of three dimensional objects. It would contain geometry, viewpoint, texture, lighting and shading information. The image is a digital image or raster graphics image [8-11].

Volume rendering is a technique used to display a 2D projection of a 3D discretely sampled data set. A typical 3D data set is a group of 2D slice images acquired by a CT

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or MRI scanner. Usually these are acquired in a regular pattern (e.g., one slice every millimeter) and usually have a regular number of image pixels in a regular pattern [12-15].

Volume segmentation is an important part of computer based medical applications for diagnosis and analysis of anatomical data. With rapid advances in medical imaging modalities and volume visualization techniques, computer based diagnosis is fast becoming a reality. Volume segmentation plays a critical role by facilitating automatic or semi-Automatic extraction of the anatomical organ or region-of-interest. These methods can assist doctors to make better and more accurate diagnosis and we intend to further refine this technique and potential clinical applications in future work

A real time volume clipping method which is capable of using several analytical planes for virtual clipping in order to display internal anatomical structures with in volumetric data sets. A single proxy plane is used for computation of the direction of ray i.e., cast from view point. The intersection between the rays and plane are computed on GPU. The start and end points are determined by analyzing relationship with the ray direction, intersections and normal of planes. Volume integral is computed along the ray from start to end point. To obtain visual feedback of clipping, we implement translation to interactively change the shape of clip object.

Slicing is extension of Clipping. Once the clipping plane identified, the sliced image will be displayed. Due to clipping point and direction of virtual clipping plane was determined, it can establish a central axis. Using of the virtual clipping plane identified along this central axis of cutting three-dimensional objects, in the mean while the virtual slice images are displayed.

Segmentation refers to the process of partitioning a digital image into multiple segments. The goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. The functional we propose provides a measure of similarity of the intensity characteristics of the bone and tissue regions through a comparison of their cumulative distribution functions; minimizing this similarity measure therefore yields the maximal separation between the two regions.

In a recent survey, the existing segmentation technique has four categories: intensitybased, edge-based, region-based and deformable. In this work, we define a functional that can serve as the core functional for any variational approach to bone segmentation in CT images. The proposed functional can be easily augmented to include a priori information on region shape, region texture, or other characteristics, should they be available. Incorporating further a priori information can only improve the quality of these segmentations.

Intensity-based approaches refer to the simplest segmentation techniques that are based on local or global intensity thresholding.

In region-based techniques the global region information which guides the segmentation and the goal is to partition the image into regions based on some given homogeneity condition. Initialized seeds grow by incorporating similar pixels, where similarity is defined by a set of statistical tests. Since the initial introduction of active contours. variational methods have played a key role in image segmentation, as they allow the design of segmentation algorithms that incorporate both the local features of edge-based algorithms and the global features of region-based algorithms. In the variational approach, the desired segmentation is formulated as the solution of a functional minimization problem. The functional to be minimized is a mapping from a set containing all allowed segmentations to the real line; that set varies depending on the assumptions that are made on the desired segmentation. Such an advantage is not negligible in the context of bone and soft tissue segmentation in CT images, where the location of a given scan is often a good predictor of the geometry of the segmentation obtained.

Previous Research: Three-Dimensional Reconstruction of Medical CAD modelling explored the bioengineering application of reverse engineering in converting CT/MRI based images to CAD models [14], the interactive process of refining the surface may need to take place since mesh generation can fail in certain cases depending on the complexity of the outer surface.

Knowledge-Based 3D Segmentation and Reconstruction of Coronary Arteries Using CT Images (2004) deals about an approach for segmenting human left coronary arteries using computerized tomography (CT) images. First a knowledge-based segmentation algorithm is used, analogous to what has been used to segment

SAR data and MRI brain images, based on Bayes' rule to classify the volumetric data into three homogeneous regions and find the region that filled with blood.

Accelerating 3D Medical Image Segmentation with High Performance Computing (2008) was based on a solution called the Topological Active Volumes. The potency of this solution arises from their ability to segment, match and track images of anatomic structures by exploiting constraints derivedfrom the image data together with a priori knowledge about the location, size and shape of these structures. Deformable models are capabl1e of accommodating the often significant variability of biological structures over time and across different individuals. Furthermore, deformable models support interaction mechanisms that allow medical scientists and practitioners to bring their expertise to bear on the model based image interpretation task when necessary. The Topological Active Volumes solution includes a different idea for the shape representation than the original one of the deformable models. As a result the entire segmentation process is performed in a slightly different manner. It assumed that instead of evolving a contour, the image would be covered with a discrete mesh. The nodes of this mesh would be incorporating the whole image and each node would have the ability to move in a predefined neighbourhood, thus evolving the shape of the whole mesh. The Topological Active Volumes extended this solution to operate in 3D environment, using a set of slice images combined to form one 3D model [15].

3D Brain Segmentation Using Active Appearance Models and Local Regressors (2008) describes a system which uses volumetric Active Appearance Models (AAMs) to locate the shape and positions of each structure, then refines the segmentation with a set of local regressors which estimate the probability that voxels near the boundary belong to the structure. One of the most effective methods of segmentation of subcortical structures in the brain. Given a set of labeled training images, a new image can be segmented by registering each of a subset of the training images to the new image, transferring the labels and using these to vote for the most likely label for each voxel. By selecting the subset to be those training images with similar properties to the target image, state of the art performance can be achieved. This approach is effective, but relatively time-consuming, due to the number of full 3D registrations required. The method described below is inspired by this classifier fusion approach, but is much more efficient. Rather than perform many individual registrations, we use a combination of AAMs to locate the structures.

Hypotheses

Clipping:

- Computation of ray direction
- Computation of ray-plane interaction

Slicing

Segmentation:

- Initialization of Contour
- Compute energy of the contour
- Minimizing energy of the contour
- Segmented images

MATERIALS AND METHODS

The system deals with the interactive operations in medical images using ray casting algorithm. We propose a real time visualization method based on GPU ray casting, which is capable of using multiple planes for convex volume clipping. In the GPU ray casting algorithm proposed, only a single proxy plane is used to compute ray equations and ray-plane intersections are computed by analytical geometry on GPU, instead of the two-pass rendering [16]. We extend six planes of the bounding box to an arbitrary number of planes and these planes are not required to be parallel to one of xy, yz and xz coordinate planes. Therefore, our method is more flexible and more useful for volume clipping. Manual segmentation of bone regions in CT images is tedious, time consuming and subject to observer variability; as a result, there is a strong demand for automating the segmentation procedure.

Hypotheses Testing

Clipping: Clipping is cutting away sections of a model at one or more selected slices. On one side of each selected slice, the model is removed, revealing the image of each selected slice and the rest of the visible model. Following steps are involved in the clipping of 3D image using GPU based ray-casting algorithm.

- Computation of ray direction
- Computation of ray-plane interaction

Computation of Ray Direction: A ray direction must be given before computing intersections of planes. A plane specified and rendered to generate a ray direction. GPU based ray-casting algorithm allows users to specify arbitrary orientation and number of planes by adding some actual clip planes. The point Pe is the fragment vector in the proxy plane. This can be used to generate the normalized direction of the ray. The ray direction De can be computed by De = normalize (Pe.xyz).

Computation of Ray-Plane Interaction: According to the analytic geometry, the parameterized equation of a ray is defined as

$$Pw.xyz = Peye.xyz + Dw.\, t$$

Where Pw is the 4D homogeneous coordinates (x, y, z, 1), Peye is the eye position (viewpoint), t is the distance from the eye position. Positive t stands for points having the distance t along the ray direction Dw. And negative t denotes points with the distance t along the contrary ray direction-Dw. A plane is usually defined as Ax+By+Cz+D=S.P=0 where (A, B, C) is the normalized normal of the plane, S = (A, B, C, D) and Pw = (x, y, z, 1) are homogeneous coordinates. Combining the above equations, the intersection of ray and plane will be obtained. When the denominator of combined equation becomes zero, the t become infinite and there will be no intersection between plane and ray or ray is parallel to plane.

Slicing: Slicing is extension of Clipping. Once the clipping plane identified, the sliced image will be displayed. Due to clipping point and direction of virtual clipping plane was determined, it can establish a central axis. Using of the virtual clipping plane identified along this central axis of cutting three-dimensional objects, in the mean while the virtual slice images are displayed.

Segmentation: Segmentation refers to the process of partitioning a digital image into multiple segments (sets of pixels, also known as super pixels) [17], the goal of segmentation is to simplify and/or change the representation of an image into something that is more meaningful and easier to analyze. Image segmentation is typically used to locate objects and boundaries (lines, curves, etc.) in images. More precisely, image segmentation is the process of assigning a label to every pixel in an image such that pixels with the same label share certain visual characteristics. The result of image segmentation is a set of segments that collectively cover the entire image, or a set of contours extracted from the image. Each of the pixels in a region is similar with respect to some characteristic or computed property, such as color, intensity, or texture. Adjacent regions are significantly different with respect to the same characteristic. The segmentation process is as follows:

- Initialization of Contour
- Compute energy of the contour
- Minimizing energy of the contour
- Segmented images

Initialization: The initialization procedure is divided into three steps. In the first step, the region of interest containing all the soft tissue and bone is determined. This is a relatively simple task that can be done with a global thresholding algorithm. Subsequently, the region containing the bones is roughly determined by classifying pixels by their intensity. The brightest 10% of the pixels are designated as bone; this figure is a safe upper bound, based on empirical observations, on the relative cortical bone area in a typical CT scan. The last step of the initialization procedure is based on the contour reconstruction technique. An initialization could certainly be done manually, however in order to have a fully automatic segmentation procedure, it is essential to have a fully automatic initialization procedure as well. In what follows, we detail a fully automatic initialization technique which determines the region of interest and initial contour so as to both ensure an accurate segmentation and reduce the execution time of the algorithm. Let S denote the set of bone pixels designated and consider the curve evolution equations

$$\frac{\partial \vec{\gamma}}{\partial t} = -\left(\vec{\nabla} d\left(x,S\right).\vec{N}\right)\vec{N}$$

The stationary point of this curve evolution will be a curve which traces the outer most pixels in S with a linear interpolation between distinct bone structures. We dilate the contour obtained in this way by 5 pixels for a safety margin and use the resulting contour as the initialization for our algorithm.

Compute Energy: Segmentation of an image I via active contours, also referred to as snakes, operates through an energy functional controlling the deformation of an initial contour curve under the influence of internal and external forces achieving a minimum energy state at high gradient locations.

Minimizing Energy: Minimizing the energy is equivalent to solving the corresponding Euler-Lagrange equation,

$$a.v^{"} - \beta.v^{(4)} = -\nabla p(v, f)$$

which simply means that the internal forces shall balance the image force. In practice one does not study the contour at all points. Instead, the contour v is represented by a vector of control points vj. The control points must not be separated by more than a few pixels to prevent the contour from bypassing attractive but small areas in the image. It is the purpose of the elasticity force to keep the control points equidistant.

The Contour Fitting Process

Step 1: Suggesting an Initial Contour: To make the contour attract to the shape in the image to which one wants to fit the contour, an initial suggestion should be given. “Representation”, this can also include determining the representation of the contour. When segmenting a 2D image, the representation is straightforward; a vector of control points.

Step 2: Calculating the Attractor Image: The original image has to be filtered to create the attractor image. The attractor Image is then preferably filtered with gradient filters to create the image force. The image from Figure is filtered with two edge detecting filters (detecting edges in different directions) and in two scales. The results are added, normalized and squared, resulting in the attractor image.

CONCLUSION

Proposed clipping method based on GPU ray casting is capable of using multiple planes for convex volume clipping. One proxy plane is used and ray-plane intersections are computed on GPU. Fragment coordinates encode the direction of a ray that is cast from the viewpoint. Presented an approach to compute intersections between the ray and clip planes to perform the interactive operations

The present position of clipping plane can be translated to any angle and the sliced image can be obtained in any position and any angle.

The bone segmentation from the sliced image can be performed by level set method. The sliced image from the above procedure can be used for the segmentation. The main purpose of active contours in three dimensions is probably visualization, which was not treated in this thesis (the AVS environment did this work). However, some aspects could be studied further. For example, how should a contour passing empty spaces in the attractor image is visualized? Suggestions are that it should either be flattened out, or that it should be transparent, depending on the application.

A key to successful use of the active contour model is to have a good initial suggestion. Also, new internal forces could be added, keeping the contour from diverting too much from the suggested model. It is also possible to define the internal forces differently in different parts of the contour. For example, when visualizing ventricles of the heart in time-sequences, some parts are known-in advance-to move more than others and those parts should then be less rigid in the time-dimension. “Experiments” (the “heart” volume) is actually a volume sequence, i.e., a four dimensional image. An extension of the active contour concept to four dimensions could be useful, for example to measure the variation of the volume of a ventricle in time [18-20].

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