Visualization Transfer from 2D Image to 3D Volume

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Abstract

Traditional visualization work focuses on collaborative visualization and 2-D data analysis, which is limited when analyzing complex 3-D data. In 3-D volume data analysis, visualization transforms the invisible phenomena in volume data into visible, revealing the rich connotations contained in volume data. It enhances domain experts' awareness of three-dimensional space. However, it is complicated for experts to mark target objects in 3-D images, because it is very difficult to select the target point in the 3-D image accurately. If all seed points can be automatically recommended to the 2-D image, and after manual selection, the required structure can be marked in the 3-D image by the seed point tracking algorithm, then domain experts will be able to greatly improve the efficiency of data interpretation. In this paper, we propose an interactive visualization system based on client-server seed point recommendation and tracking, which consists of a 3-D volume explorer and a 2-D slice analyzer, to help domain experts fully utilize their background domain knowledge to illustrate different parts of the data. The system realizes multi-user interaction and can run on multi-terminal devices because the client-side calculation is very small. It allows taking full advantage of the hardware resources because all the computation-intensive tasks especially for the whole data rendering can be allocated to the powerful server while the light-weight tasks can be allocated to the portable clients. For example, the brain surgeon expert, pulmonologist, and cardiologist can visualize and analyze the different subsets of the volumetric scientific data, that is, the corresponding subvolumes of the brain, heart, lungs, and blood vessels. We calculate the image entropy of all slices on the server side, and select the slice with the largest entropy, and then recommend all seed points according to the seed point recommendation algorithm based on meanshift. In addition, we also design a seed point tracking algorithm based on continuous scale space theory, which realizes the migration from 2-D to 3-D.

1 Introduction

2-D data usually enables domain experts to understand the characteristics of the data. And it has some certain advantages when presenting details of certain parts. Slice interpretation is an important way that extract local 2-D data from the original datasets and present it distinctly for more detailed analysis. It can help domain experts focus on a certain piece of data, thus having less distraction from unrelated parts [2] .

The analysis of 3-D data can better display the overall structure of the data. In the 3-D volume data analysis, interactive direct volume rendering is one of the most effective methods to visualize and reveal the significant features presented. It enables domain experts to intuitively discover scientifically meaningful features and get a better spatial perception of the data.

However, it is complicated for experts to mark a series of structure in a 3-D image. Because it is difficult to select a point in a 3-D image. If all the seed points can be automatically recommended regarding the 2-D image, and after manual selection, we can mark the required structure in the 3-D image through the seed point tracking algorithm, then domain experts will be able to explore the data globally to grasp general context information like spatial relationship.

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In our work, we propose a server-client based interactive visualization system, which consists of a 3-D volume data explorer and a 2-D slice analyzer. It can make full use of the hardware performance, because computation intensive tasks are assigned to the server for completion while the light-weight tasks can be assigned to the clients. We use the concept of image entropy to recommend the slice with the largest entropy. After importing the slice, the user can use the seed point recommendation algorithm to recommend all the appropriate seed points, and then select the appropriate seed points to form a 3-D image through the seed point tracking algorithm. Users can also adjust the color of seed points, which will directly change the color of the corresponding structure in the 3-D image.

2 Our Method

In this paper, we propose an interactive visualization system for seed point recommendation and tracking based on a client-server framework.

In this system, the server provides powerful computing and rendering performance, and the client mainly completes user interaction functions. The 3-D volume explorer rendering the whole volume data is mainly run on the server, while the 2-D slice analyzer, subvolume renderer, and interaction processing are on the client. The system realizes multi-user interaction and can run on multi-terminal devices, because the client's calculation is very small. The 3-D volume browser can present an overall structure that is invisible in 2-D. We allow the algorithm in 2-D slices recommending the selection of seed points (seed point recommendation) and track the entire 3-D object whose seed points are located in 3-D space.

Fig. 1 is a flowchart of the system. First, we preprocess the original data into volume data. Second, each user (client) connected to the system server has 50 slices of volume data in the X-direction. Third, each expert selects points according to the depth value of the image and targets the tissues that they want to understand in-depth. Finally, according to the seed point selected by the expert, the entire 3-D object in the 3-D space is tracked.

2.1 Analysis of Recommended Slice Seed Points

The seed point recommendation function of slices is done on the server. After calculating the image entropy of each slice, the server selects the slice with the largest entropy and recommends seed points for it. Finally, the recommended slice is sent to the client. We improved the MeanShift algorithm on the client to implement seed point recommendation to allow domain experts to select only one seed point in the slice and track the entire 3-D object whose seed point is located in 3-D space to better allow different experts to view the relevant medical tissue structure. In our system, the input is the slice data of human tissue. We regard it as a pixel matrix, and the pixels are evenly distributed on the image. The process of our seed point tracking algorithm is as follows: first, we use the mean shift algorithm to drift all the pixels in the pixel matrix for the first round, which can get the corresponding offset mean points of all the pixels; then, we use the 2-D floodfill algorithm to automatically select the areas connected with these mean points and mark them differently. Then randomly select a point from the labeled regions for secondary drift, which will make the point drift to the position with the highest density in the region. This kind of point in each region is the final recommended seed point. The user can filter the seed points according to the image depth value (seed point recommendation), or use the mouse to select and fine-tune the recommended seed points (you can add or delete the recommended seed points). For different medical tissues, different colors and transparency can be used for tracking.

2.2 Server Terminal Seed Tracking

The seed point tracking algorithm is based on the continuous spatial scale theory. Specifically, the corresponding tracking algorithm is selected intelligently according to the number of the same substances or density around

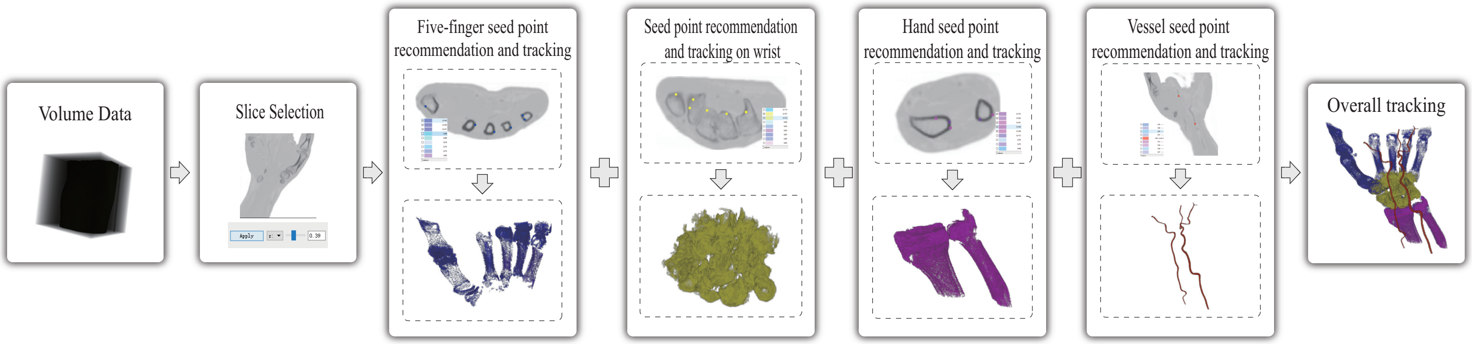

Figure 1: Pipeline of system. This flowchart details the transition from 2-D to 3-D. After the user extracts the partial 2-D data, using the mouse to pick it up according to needs to determine the seed point. Users can choose to use different colors to track different medical tissue. From left to right, the data of five fingers, palms, wrists and blood vessels will be tracked. The last part of the flowchart shows the overall effect of tracking different parts of the tissue.

the candidate seed points. In 2-D space, there are eight other pixels around one pixel point. We have used the density difference between the eight density mean and seed point. If the difference is less than a given value, it can be understood that the scale space is continuous. At this time, we follow the idea of DBSCAN cluster extension module Firstly, each seed point is selected in order, and the distance from other seed points to the point is calculated. Then, the cluster is established according to the given threshold of neighborhood radius and neighborhood object number. Then, the neighborhood sample points of each seed point in the cluster are calculated respectively. The seed point with the most sample points is determined as the center point of the cluster. At this time, other points in the cluster are the points with direct density from the center point. Thus, the image is divided into clusters of blocks, and then transferred from the center point to the boundary of the cluster and filled with color.

If the density difference is greater than the given value, we need to use the algorithm based on the flood fill algorithm to realize the migration function. The specific method is to automatically select the area connected with the seed point, and achieve the specified filling effect by setting the upper and lower limits of the connectable pixels and the connection method in advance. When the adjacent pixel is within a given range or within the range of the original seed pixel, the point will automatically colored. When all the colors of the points are painted, the tracking algorithm is completed.

Our tracking algorithm makes users only need to interpret some 2-D slices with obvious features, and then the algorithm will automatically migrate the interpretation from these 2-D slices to the whole human structure. In other words, the tracking algorithm enables users to interpret 3-D slices through 2-D slice interpretation.

3 Results, Discussion and Conclusion

In this article, we propose an interactive visualization system based on client-server seed point recommendation and tracking. The system allows experts to select seed points in the slice, and visualize the entire 3-D object and the tracked seed point in 3-D space, realizing automatic migration from 2-D to 3-D.

The system selects the slice with the largest entropy by calculating the image entropy, and then uses the seed point recommendation algorithm based on the improved mean shift algorithm to recommend all the seed points, and then realizes the 2-D to 3-D migration through the seed point tracking algorithm based on the continuous scale space theory

Users can also use the pre rendering function of some certain section. Real-time interpretation is performed on the client according to the currently selected slice. After that, the corresponding seed points will be generated according to the interpretation results, and the final 3-D imaging results are consistent with the pre rendering results. It is worth noticing that the server only uses some colors provided by the client, not all colors are used, which depends on the user's own choice.

The final visualization will be integrated and displayed in real-time on the server side because the rendering for the whole data is often computertation-intensive. The overall illustration result will rendered on the server side. Any changes performed on the data from any clients would be updated on the server in real-time.

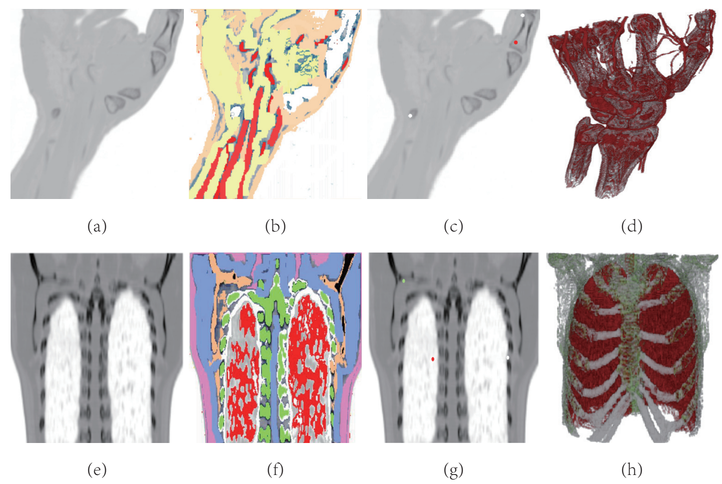

Figure 2: Migration algorithm from 2-D to 3-D with pre rendering function. (a) Hand slice selected by user. (b) Pre rendered results. (c) The seed points selected by users according to the rendering results (d) Hand data results of 3-D imaging. (e) Chest slice selected by user. (f) Pre rendered results. (g) The seed points selected by users according to the rendering results. (h) Chest data results of 3-D imaging.

There are still some limitations in our work at present. For example, the current system can not run on multiple devices, but can only run on PC using windows or Linux. We expect the system to run on tablets and even mobile phones. Moreover, the current interactive function is incomplete. Not every expected function can interact. In the future, we will further implement these functions and strive to achieve our expectations as soon as possible.

Because of these certain limitations, we plan to continue our work to improve the system. First, we plan to develop some new features for the system, and we will develop more smart tools to improve the user experience. Second, we will increase the multithreading capability of the server to improve the performance of the program. Third, the server needs to be further optimized to increase the rendering speed of the machine so that it can be used for low-end graphics cards.

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