Animation and Exploration for Intervention Planning

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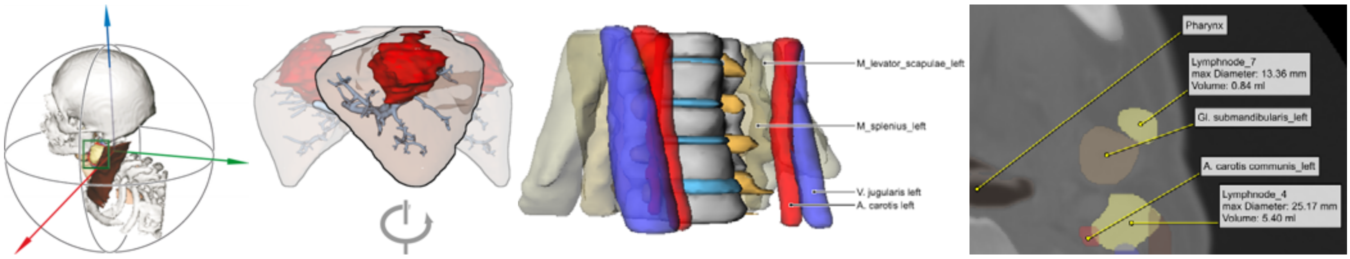

1 Introduction

3D intervention planning enters more and more the clinical routine. Beside the 2D slice visualization of CT or MRI images, 3D models of derived segmentation data are used. In the past years, great progress was achieved in image processing, image analysis and segmentation techniques. However, the support of the interaction with the 3D data is only available for highly specialized applications such as guided navigation in virtual colonoscopy. Mostly, the user gets the data presented in a 3D viewer and must explore them manually. Techniques to support the reproducible generation of standardized 3D images and animations for documentation and presentation are a neglected field of research.

In my PhD thesis, I aim at the investigation of general techniques to support the exploration of 3D medical volume data as well as the standardized documentation and descriptive presentation. The techniques shall support the whole workflow of collaborative intervention planning, such as in tumor boards and interdisciplinary discussions of complex cases. In particular, I develop an animation framework to generate reproducible animations in an effective way. Furthermore, I develop new approaches for selecting 'good' viewpoints for medical visualizations and for annotating 3D and 2D scenes.

2 Medical Intervention Planning

For complex intervention planning tasks, high-resolution medical image data (CT or MRI) are acquired. The relevant structures, e.g., pathologies and crucial anatomic structures such as vasculature are segmented. The segmentation information is employed for generating interactive 3D visualizations to support treatment decisions such as operability and the specification of a surgical strategy. Interactive 3D visualizations are primarily used for individual intervention planning as well as for collaborative intervention planning and discussions of radiologists, surgeons and other medical doctors. As an example for collaborative intervention planning, tumor board discussions are considered, where a complex case is presented by one medical doctor to initiate an interdisciplinary discussion to finally come to treatment decisions. This discussion as well as the individual intervention planning process may be strongly supported by carefully prepared animations and other exploration techniques.

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3 Methodology

In-depth interviews with medical doctors along with evaluations of existing applications and exploration techniques and detailed workflow analyses provided a base to identify the lacks in intervention planning processes using 3D visualizations. Major requirements were detected in techniques to support the exploration of 3D data for intervention planning, techniques to create case presentations for interdisciplinary discussions and techniques to document decisions made in the intervention planning process.

Due to the immense number of cases in clinical routine, the utilization of 3D visualizations should be as extensive as possible and run automatically on each patient dataset. Concerning the differences between the patients and their individual anatomy, this implies a high adaptivity. Besides the automation, a large amount of standardization is desirable. The same structures shall be visualized in the same style and similar pathologies shall be shown from similar viewpoints. Due to the individuality of each intervention planning process, the medical doctor shall have the opportunity to change each parameter of the visualization, like visible structures or viewpoints on his or her own.

For intervention planning mostly a pre-segmentation of structures is performed. Hence, I focus on isosurface visualization.

4 Progress to Date

Suitable animations may efficiently support the exploration of 3D visualizations and the scene understanding, by showing overview animations of the scene, emphasizing structures of interest or moving the camera to good viewpoints on well established camera paths through the scene. Animations as well as pre-rendered videos, are also beneficial for interdisciplinary discussions of doctors, for presentations, and for documentation. The work of [Wohlfart and Hauser, 2007] gives a first insight on how animation and interaction can be integrated carefully, supporting the user with animations on the one hand and leave him or her the full capability of individual interactions on the other hand. To fulfill the requirements of automation, I developed an animation framework [Mühler et al., 2006]. Using a specially designed script language, the behavior of objects can be described independently from concrete patient data. Since the approach of scripted animations is not new, I introduced a method to reuse one script for many similar but certainly new or unknown cases. The script language is based on a multi-level concept that provides very abstract descriptions of behavior with high-level instructions like `sceneOverview` and full control of every parameter of each structure with low-level instructions like `setColor` simultaneously. Besides the automation, the script language enables the generation of standardized visualizations (videos and screenshots) that can be used for routine documentation. As the script language is still only really usable for system developers (e.g. to integrate predefined behaviors in an application) continuing work of my thesis will focus on bridging the usability gap to the medical doctors.

For the automatic generation of animations that adapt to new cases as well as for the interactive support of the user in orientation and navigation in the scene, I developed a new viewpoint selection technique that computes 'good' viewpoints for a single structure [Mühler et al., 2007]. Most work on viewpoint selection focus on volume rendering visualizations ([Bordoloi and Shen, 2005], [Takahashi et al., 2005]) and finding viewpoints using an information measure like viewpoint entropy [Vazquez et al., 2001]. However, domain knowledge is mostly ignored. Thus, I integrated for the first time domain knowledge in a viewpoint selection technique. The domain knowledge is represented by several parameters, that are specific and important for medical applications, like preferred view region, visible surface, stability of viewpoint, distance to current viewpoint, and many more. The influence of these parameters may be flexibly adjusted by weights. Parameter maps indicate the influence of the current parameter settings on the viewpoints. Thus, different presets of parameter weights can be used for different applications or medical tasks and questions.

To improve the recognition and finding of structures during exploration annotations of single structures are essential. Therefore I investigated annotation techniques especially for the intervention planning process. Structures need to be labeled in 2D as well as in 3D. Besides the annotation of structures with their name or affiliation, the annotation with measurements and additional information like comments of radiologists are important to support the medical doctor. For the 3D annotations, I adapted an approach of [Ali et al., 2005] and extend it with special features for medical visualizations, such as labeling of hidden structures, that yield in a faster recognition and selection of structures, or automatic grouping of labels. For the labeling of segmented structures in 2D, I develop a new technique, that considers the specialty of slicing through a stack of slices and avoid 'jumping' of labels but preserve frame coherency.

The annotations as well as the animation techniques and the viewpoint selection are integrated in the MEDICALEXPLORATIONTOOLKIT (METK)[1], an open source toolkit for developing medical applications. The METK is based on MEVISLAB [Bitter et al., 2007], a development environment for medical solutions. By integrating my current and future research results in an open-source toolkit, I hope to reach a broader audience.

Furthermore, the techniques I developed (and plan to develop) for my thesis, are deployed in several surgical applications. For example, the animations are used for educational purposes in the LIVERSURGERYTRAINER, a comprehensive training system for abdominal surgery [Bade et al., 2006]. The system was evaluated by 12 surgeons with positive results [Cordes et al., 2007]. Besides the animations, the viewpoint selection and annotation techniques are integrated in a surgical application for planning neck dissections [Tietjen et al., 2006], that is currently tested in clinical routine.

5 PLAN OF RESEARCH

To complete my thesis, I plan to investigate two major aspects: Usable authoring of animations and evaluation of the generated animations.

First, I want to develop techniques that enable a medical doctor to author animations and standardized views without having to learn the underlying script language. The user should create whole animations by defining single key states for only one representative dataset. Those key states must be interpreted in an intelligent manner to generate scripts, which can be applied to other, similar datasets. One difficulty is to find similar views to the one chosen by the user and to deviate an implicit scene description. These processes need to be hidden from the user and integrated in a user friendly authoring environment (e.g. as part of a surgical application).

Since the parameterization for the viewpoint selection is determined manually (albeit evaluated as good) so far, it is preferable to investigate the relationship of the parameters in detail to detect possible dependencies. I also plan to develop an approach to calculate parameterization for good viewpoints from many viewpoints that were manually selected as good or bad by medical experts.

The second major aspect of my future plans is the carefully evaluation of medical animations. The evaluation of animation in general is a largely unexplored field of research. I intend to use eye tracking systems to explore the user's focus on several areas and structures in an animation to compare different animation and visualization techniques by regarding their convenience. Combining the inspection of animations with the solving of given tasks to test the user's comprehension of the animation is a second approach to evaluate medical animations.

[1] A first short report can be found in [Tietjen et al., 2008]. A larger report was proposed for submission to *IEEE Transactions on Visualization and Computer Graphics* and is currently being prepared.

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