Design of a user-oriented application for the exploration of medical datasets

T. Ropinski, J. Meyer-Spradow, F. Steinicke, K. Hinrichs

In this paper we describe the experiences we have made when designing a user-oriented software system allowing the interactive visual analysis of medical datasets. We give an overview of the work in progress regarding the system and explain how data handling as well as interactive exploration of medical datasets of different modalities is supported. All design decisions made within the development process of the proposed system have been made in cooperation with health professionals from the domains of radiology as well as nuclear medicine.

Keywords: medical visualization; user interface; 3D exploration, DICOM

Entwurf eines benutzerzentrierten Softwaresystems zur Exploration medizinischer Daten.

In diesem Artikel beschreiben die Autoren ihre Erfahrungen beim Entwurf eines benutzerzentrierten Softwaresystems zur interaktiven visuellen Analyse medizinischer Volumendaten. Es wird ein Überblick über den derzeitigen Stand des Systems gegeben, wobei auf die Verwaltung medizinischer Daten verschiedener Modalitäten sowie auf deren interaktive Exploration eingegangen wird. Das Design und die Entwicklung des vorgestellten Softwaresystems wurde in enger Kooperation mit Medizinern aus den Bereichen Radiologie und der Nuklearmedizin durchgeführt.

Schlüsselwörter: medizinische Visualisierung; Benutzerschnittstelle; 3D Exploration; DICOM

1. Introduction

Today the usage of medical scanners for the acquisition of imaging data, e.g., CT, MRI and PET, is an everyday task in medical departments all over the world. With the decreasing costs and the rising availability of these scanners, health professionals are able to perform studies by using an enormous amount of high resolution data which is potentially valuable. However, due to the rapid development of high precision medical imaging techniques and their high spatial resolution the amount and complexity of data makes performing diagnostic examinations a challenging task. Whereas in the past the acquired images have been developed on film, this method is not contemporary in many cases. This is mainly because of two reasons, the high expenses of film developing which would be necessary to deal with the large amount of datasets, and the required space for aligning all images acquired in a single scan for performing a diagnosis. Thus, there is a high demand for solutions allowing an inexpensive and efficient exploration of large medical datasets. Interactive visualization of medical volume datasets provides such a diagnosis tool for medical applications. In this paper we describe our experiences in designing such an interactive user-oriented application which supports health professional when visually exploring medical datasets (see Fig. 1). The described application is currently under development in cooperation with health professionals from nuclear medicine as well as radiology within the collaborative research center SFB 656. This paper describes our current work in progress regarding the application. During our work we have identified certain features, which are necessary to support the analysis of medical datasets in both research as well as clinical diagnosis. First of all, it is important to provide a selection process which gives the user the ability to select a so called *working set* of datasets to be analyzed. Since the set of all datasets is usually very large, an efficient method is required to easily find, identify and select datasets to further work with. The way how to identify the working set and how to access it later on is described in the following section. After the working set has been identified it needs to be accessible from within the program to allow further processing. In our application the user has the ability to visually explore the working set, by the usage of different visual representations. In Section 3 we describe the interaction with a conventional 2D slice viewer, a 3D visualization and how these are integrated into a user interface, to support comparisons between different datasets. The paper concludes in Section 4 by giving an overview of features which will be incorporated in the future.

2. Handling data

As mentioned above health professionals have to deal with an enormous amount of medical datasets of different modalities. This amount requires an appropriate way to store and index the datasets, which is usually done by exploiting the DICOM data exchange format. Within our prototype application we have decided to support data handling by using a working set of datasets. This working set contains a variety of items, which can be 3D or 2D datasets as well as reports stored on a DICOM server. This section describes how to select a working set and how the items contained in a working set can be accessed by the user.

2.1 Selecting a working set

To identify datasets to work with an intuitive user interface is necessary to reduce the complexity inherent to searching through large databases. The DICOM data format already supports the integration of metadata, e.g., patient name, identifier of series, imaging mod-

Ropinski, Timo, Dr., Meyer-Spradow, Jennis, Steinicke, Frank, Hinrichs, Klaus, Prof. Dr., Westfälische Wilhelms Universitat Münster, Institut für Informatik, Einsteinstraße 62, 48149 Münster, Germany (E-Mail: ropinski@math.uni-muenster.de)

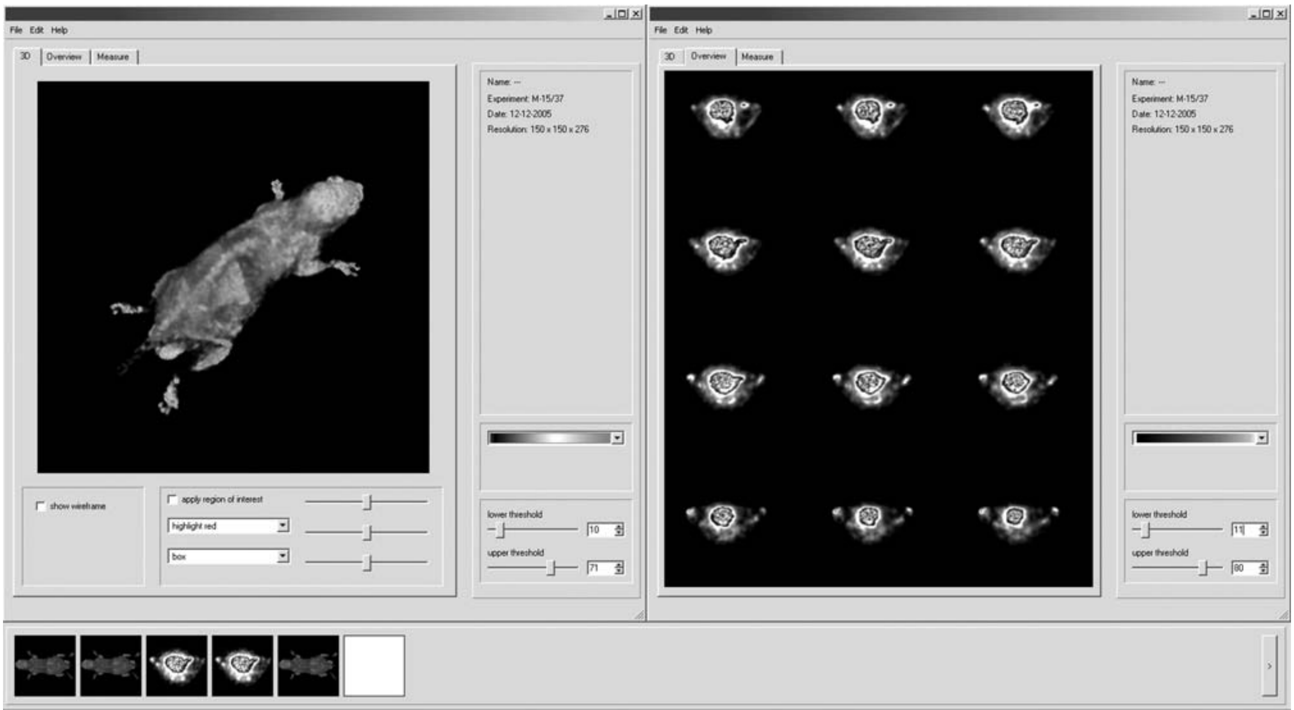

Fig. 1. Integration of different visual representations into the user interface

ality, which can be exploited when searching for datasets. In our prototype application we provide a user interface which allows an easy identification of the datasets the user wants to add to the working set (see Fig. 2 (left)). Thus, the user is able to perform a search by patient name, modality or injected tracer. Furthermore, these search criteria may be combined by using the *and* respectively *or* operation. A hierarchical search allows to interactively choose the way search results are classified. Hence, it is possible to search for all datasets belonging to a certain study or acquired on a specific scanner. Furthermore, relations can be switched and it is possible to search, for instance, for all studies incorporating a specific patient as well as all patients examined within a study. To browse through this hierarchy, the *arrow menu metaphor* may be applied (*u.s. patent no. 6,928,433 (2005)*).

The results, which can be either displayed in a list view or as icons of a search – usually given by a topogram – can be incrementally refined by using them as the input for a successive searching process. In the future we also plan to integrate the support for visually querying, as it is described by Ahlberg and Shneiderman in (*Ahlberg, Shneiderman, 1994*).

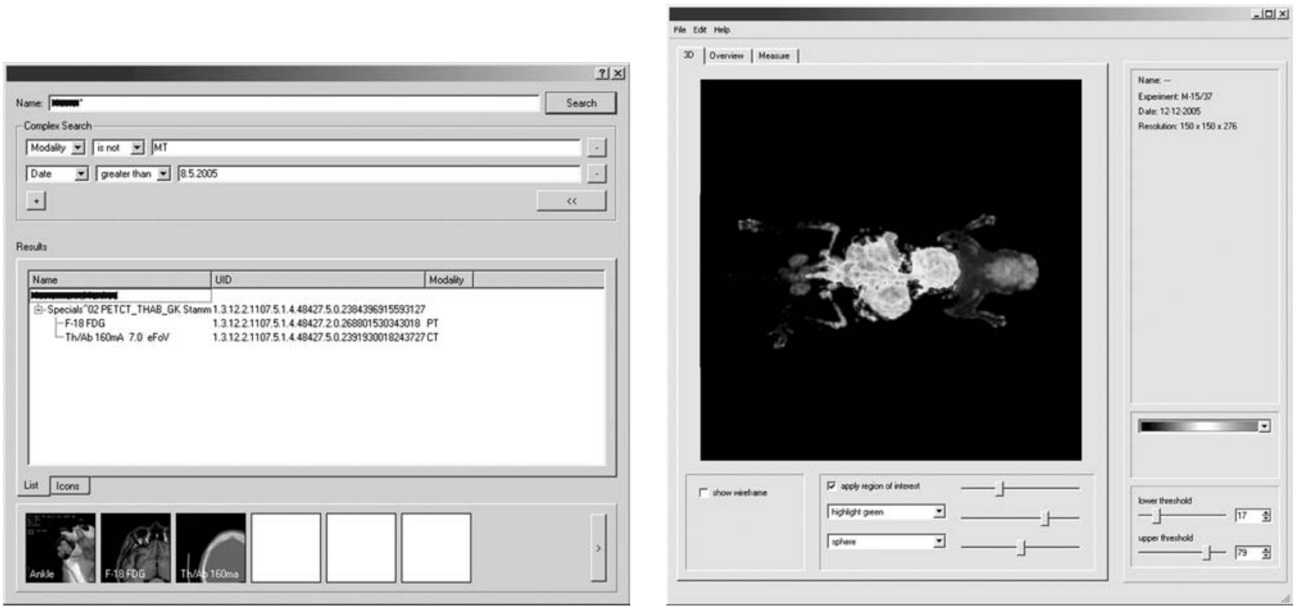

Fig. 2. User interface for adding datasets to the working set (left), more advanced visualization metaphors can be applied within the 3D representation (right)

2.2 Accessing items of the working set

Once datasets have been chosen to be contained in the working set an appropriate mechanism is required to access them. We have chosen to support this organization by using the *drawer metaphor*, which is shown in the bottom of Fig. 1. This container widget shows an iconic representation of all datasets contained within the working set and is able to contain 3D datasets as well as 2D images. Since frequent access of the working set is common, it is desirable to have this widget easily accessible in the entire application. However, since it takes a lot of screen space, the user can show or hide it as desired. To select a dataset contained in the working set for further processing it can be dragged onto one of the visual representations described below.

3. Interactive visual analysis

The main goal for designing the user interface of the presented program was to organize the components in a way, which is adapted to the work flow, usually performed by a health professional when analyzing imaging data. The usage of 2D images is still the most common way to interpret medical imaging data. Since, when dealing with x-ray images – the first optical imaging technique applied in medicine – there is usually no third dimension and thus 2D images have been the only source for performing a diagnosis. With the rise of other medical scanners supporting a third dimension, health professionals were already accustomed to interpret the data visualized as a series of 2D images and the way of processing them was standardized so, that they retained this form of analysis. But even more important the information contained in a 2D image is not cognitively overwhelming and it is easy to comprehend. Therefore, health professionals are very well trained in getting information out of 2D images and thus we have decided to use a 2D slice viewer as the main component of the application. In addition we provide an interface for exploring 3D visualizations, which may incorporate more information than 2D images. However, the spatial comprehension of a 3D visualization is generally considered to require a higher cognitive effort. Moreover to visually explore a single dataset, in many scenarios it is important to compare two or more datasets. In the presented applications we support this task by allowing simultaneously displaying different datasets.

All the different visualizations supported by our application are linked together such, that when the user has selected a dataset to work with, this dataset can be visualized in all possible representations. Furthermore, the visualization parameters, which can be interactively specified apply to all visual representations. For instance, when the user defines a certain threshold it is applied to the 2D as well as the 3D representation of the current dataset if desired. Although, usually just one representation is displayed on the screen, we have implemented all representations as floating windows, which can therefore be arranged as a single window build up out of different components (see Fig. 1). To allow the arrangement of the representation we provide a set of buttons, where each button represents a certain arrangement, e.g., simultaneously viewing 2D images and a 3D visualization. Thus, the user is able to combine the representations as needed.

Within all visual representations, the user is able to perform a set of standard interactions. It is possible to change the current transfer function by using a combo box, which allows to select from a set of preloaded transfer functions. Also the thresholding can be changed by using two sliders allowing to alter the lower and the upper threshold independently. Once an appropriate threshold interval is specified the user can interactively alter the interval by using the middle mouse button. When pressing the button and moving the mouse, the threshold interval is shifted accordingly or stretched respectively shrinked. This technique has proven good usability since it allows an easy adaption of lower as well as upper threshold values by providing rapid visual feedback. Furthermore, the adaption can be performed directly on top of the graphics canvas and the user does not need to concentrate on other widgets which may distract the users attention.

3.1 Analysis of 2D images

The analysis of 2D images is supported by our application by providing an intuitive user interface for browsing through 2D images similar to some methods described by Holzinger et al. (*Holzinger et al., 2005*). Initially, an overview of all slices of a dataset is displayed in a way such that the slices are displayed together with the associated metadata (see Fig. 1). Furthermore, a set of interactions is supported. To allow a better navigation through the usually large amount of slices, a zoomable interface (*Bederson, 2001*) assist the user by supplying a seamless integration of the focus region given by the currently viewed slice and the context given by the adjacent slices. By performing a double click on one slice, the selected slice is maximized to be displayed in fullscreen mode.

Although, health professionals usually have a lot of practice in interpreting 2D images, this task might get more difficult when 2D slices are visualized, which are not perpendicular to one of the main object planes. Especially when the user is able to define arbitrary cutting planes, which should be used as reference plane for visualizing the slices, it is harder to spatially comprehend the displayed slices. To reduce this cognitive overload, we exploit a topogram. This topogram – which is comparable to a preview scan when using a flatbed scanner – is usually acquired by medical scanners in advance, before the actual scan is started. It is a low-resolution overview image aligned with the coronal plane. In our application we visualize the topogram next to the slices and overlay it with a 2D line showing the orientation of the displayed slices in appropriate cases. The user can interactively change the reference plane for the visualized slices by changing the endpoints of the overlayed lines.

3.2 Interactive 3D exploration

In addition to the 2D viewing components our application supports interactive 3D exploration by allowing standard interaction techniques as, for instance, zooming and moving the object. However, in this section we concentrate on the more advanced exploration techniques which can be applied within the 3D representation. Since within our project the simultaneous exploration of PET and CT datasets is required, we have integrated a focus and context technique, which allows to visualize registered datasets in parallel. Usually this visualization is done side by side or by applying a blending factor to merge the datasets within one representation.

Since in most medical applications the region of interest, e.g., tumors or arterial structures, is small in comparison to the overall dataset, mechanisms are required to support health professionals to focus on these regions. Furthermore, certain features and properties of anatomical tissues are essential for the diagnosis and need to be preserved, e.g., size and shape of pathologies as well as their spatial position and vicinity to other anatomical structures. Therefore it is important that visualization techniques consider these demands and aid comprehension by visualizing contextual structures and object relations. With our additionally provided technique the user is able to apply a region of interest, which seamlessly integrates a different visual appearance as described in (*Ropinski, Steinicke, Hinrichs, 2005a*) (see Fig. 2 (right)). The region of interest can be moved and resized interactively and the visual appearance applied can be selected out of a preset of appearances. We distinguish two kinds or appearances, *graphical appearances* and *data-based appearances*. By using a graphical appearance, the user is able to apply different visualization parameters to the region of interest of a dataset, e.g., a different transfer function or the use of illustrative visualization techniques (*Ropinski, Steinicke, Hinrichs, 2005b*). In contrast with data-based appearances it is possible to exchange the dataset represented within the region of interest. Thus, it is possible to simultaneously visualize a CT dataset to apply spatial details with a high resolution as context and a PET dataset to give clue about metabolism activity in the region of interest. In the future quantitative analysis methods are going to be incorporated, e.g., averaging the metabolism activity within the region of interest.

3.3 Comparison of datasets

Especially when performing studies incorporating many datasets it is desirable to be able to compare different datasets. In the comparison mode the user is able to select several datasets, which can be visualized simultaneously. We have chosen the *stack metaphor* to allow the user to navigate to adjacent slices. By clicking on the *dog ears* visualized on the upper right corner of each stack, the user is able to navigate through the stack. The navigation is either performed only for the stack the user interacts with, or for all linked stacks. The number of slices which are located behind the currently displayed slice is visualized by altering the thickness of the upper border of the stack accordingly.

4. Conclusion and future work

In this paper we have described our ongoing work towards a user-oriented application for the interactive exploration of medical datasets of different modalities. We have presented intuitive mechanisms for uniformly handling medical datasets of different categories. Furthermore, our current prototype supports interactive 2D and 3D analysis combined within one user interface.

After the basic application layout as well as the data handling is completely realized we will focus on the integration of advanced 2D as well as 3D interactions. We are working for instance on an integration of widgets supporting an easy definition of transfer functions and on a intuitive mechanism to define 3D clipping planes with 6 degrees of freedom. As additional feature we will develop a reporting tool to support recording the results of an analysis. Furthermore, we will perform a usability study to evaluate the usability of the presented application according to the aspects described in (*Holzinger, 2005*).

Acknowledgements

The authors would like to thank Klaus Schäfers for providing insights into the visual analysis of medical datasets. This work was partly supported by grants from the Deutsche Forschungsgemeinschaft (DFG), SFB 656 MoBil Münster, Germany (project Z1).

References

Ahlberg, C., Shneiderman, B. (1994): Visual information seeking: Tight coupling of dynamic query filters with starfield displays. In: Human Factors in Computing Systems (CHI94): 313–317.

Automatic hierarchical categorization of music by metadata (u.s. patent no. 6,928,433), 2005.

Bederson, B. (2001): PhotoMesa: A zoomable image browser using quantum treemaps and bubblemaps. In: ACM Symposium on User Interface Software and Technology (UIST01): 71–80.

Holzinger, A. (2005): Usability engineering for software developers. In: Communications of the ACM: 71–74.

Holzinger, A., Geierhofer, R., Ackerl, S., Searle, G. (2005): Cardiac at view: The user centered development of a new medical image viewer. In: Central European Multimedia and Virtual Reality Conference (CEMVRC2005): 63–68.

Ropinski, T., Steinicke, F., Hinrichs, K. (2005a): Interactive importance-driven visualization techniques for medical volume data. In: Proc. of the 10th Int. Fall Workshop on Vision, Modeling, and Visualization (VMV05): 273–280.

Ropinski, T., Steinicke, F., Hinrichs, K. (2005b): Tentative results in focus-based medical volume visualization. In: Proc. of the Int. Symposium on Smart Graphics 2005: 218–221. Springer LNCS 3638.