Multiscale Interactive Visualization of Biomedical Data: Concrete Achievements

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ABSTRACT

Integrative research, involving the modeling of living systems at different scales, is becoming more extensively used in the biomedical community. For this reason, an open-source library, called MSVTK, is being implemented to fill the gap in software visualization solutions handling multiscale data. The library adopts state-of-the-art visualization and interaction techniques to solve the various challenges. The efficacy of the proposed software solutions is being demonstrated on exemplary problems collected from current biomedical research studies.

Keywords: Interactive visualization, multiscale data, open-source library.

Index Terms: [Biomedical and Medical Visualization], [Data Fusion and Integration], [Multi-field, Multi-modal and Multivariate Data], [Multidimensional Data]

1. INTRODUCTION

In living organisms, system processes are the result of interactions between multiple sub-systems, each of which is very complex to model. Recently, the biomedical community has started to develop integrative approaches to these problems, as a result of which a range of multiscale datasets is now becoming available. However, a review of the state of the art has made it evident that there are, as yet, few tools for visualizing and exploring biomedical data defined across a broad range of spatial and/or temporal scales [1]. Multiscale visualization has long been investigated in other scientific contexts, notably in geographical data visualization. While these approaches are extremely effective within their own specific context, not all of them can be generalized to other domains. This applies particularly to the biomedical area owing to its specific challenges and the nature of its datasets [2]. The essential problem of multiscale visualization is to enable users to visualize data and information of different types and origins that exist across a range of scales, possibly in both space and time. Typical data will be 3D+t data consisting of multiple instances, over time, and at different scales. At a minimum, these data must be displayed together, and often they need to be combined with related heterogeneous data of different dimensionality (0D, 1D or 2D).

The MSV project [3], funded by the European Commission, is focused on resolving some of the challenges associated with the multiscale visualization of biomedical data, and some of the early results achieved are presented below.

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2. THE EXEMPLARY PROBLEMS

To enable us to define the best interaction and visualization approaches and to test the solutions developed on an appropriate set of scenarios, a review was undertaken of the data collections available in different biomedical domains. Further, a data collection was created consisting of data that are: publicly available, present one or more multiscale challenges, have evident potential usefulness for the scientific community in the near future or have ostensible clinical value. These data examples have been grouped by biomedical domain and associated with brief descriptions, one or more snapshots, and links to enable them to be downloaded (when authorization has been given) [4].

3. BEST PRACTICE

Our analysis showed that, for most applications, multiscale visualization does not involve the development of specific new techniques, but the complexity of the interaction demands a unified and carefully planned approach to design. Currently, it takes considerable effort to create a multiscale visualization paradigm for a specific biomedical application. A review of the state of the art identified a set of guidelines, which provide a suitable infrastructure for designing a multiscale data visualization library [5]. When selecting the multiscale techniques to be used for the visualization, the features of the data should be considered carefully. Based on analysis of the exemplary problems, 10 factors were identified, and some formal analysis techniques were suggested for quantifying them. Forms of best practice were grouped into 8 functional components; a multiscale visualization system can now be designed by choosing appropriate techniques for the functions needed, for example, selecting from zooming, lensing, or other possibilities to view data at a smaller scale.

4. THE MSVTK SOFTWARE LIBRARY

To address the challenges mentioned above, an open-source library, MSVTK, is being implemented, based on the best practice guidelines. MSVTK implements the click-and-zoom interaction paradigm: visual cues are provided for the positions of lower scale data with respect to the whole scene, which leads to an intuitive interface for data navigation. Meaningful information about the data represented is conveyed by the shape and color of the icon, with the aim of optimizing the user experience. At the same time, to help the user to understand the relative positions of the various data, some of which may be invisible at the current scale, a data tree allowing selection, or a small map of the view, are provided. The implementation has been designed to be as general as possible. The software library is being developed as an extension of VTK [6] and provides software elements, such as widgets, that might be used later in other software development projects to add support to the multiscale visualization.

In particular, MSVTK has extended the use of vtkButtons, which are used to provide a visual cue on the data available, and for data navigation. The button is divided into two regions: the texture and the shoulder. The points in both regions are assigned texture coordinates. The texture region has texture coordinates consistent with the image to be placed on it, while all points in the shoulder one are assigned a texture coordinate specified by the user. At all scales, some datasets may have a size that makes it impossible to deal with them on the hardware available. Proper management of these data during the interaction has been included in MSVTK; this relies on previous work to manage out-of-core data using a multi-resolution and bricking approach [7]. Further, an extension to the basic VTK functionalities is being added to deal better with time-varying data. The core language is C++, chosen for its flexibility and performance. Particular attention is also being paid to cross-platform issues.

5. The Demonstrators

The MSVTK components are being used in the development of prototypes addressing the exemplary problems to check the efficacy of the proposed approach. Two demonstrators that are at an advanced stage of development are presented here.

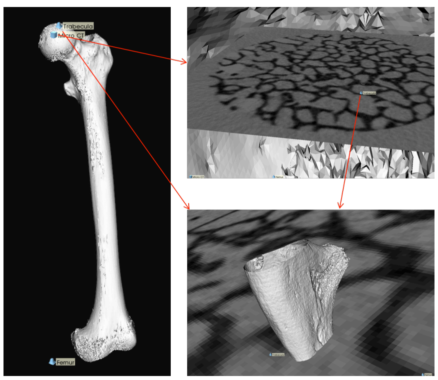

Figure 1: MSVTK application example: click and zoom interactions (red arrows) with volume and surface data (all three data on the left, and micro and nano datasets on the right)

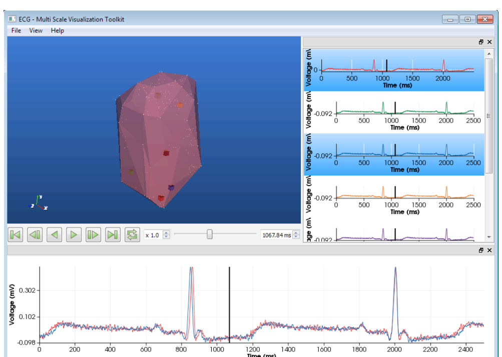

Figure 2: MSVTK ECG demo. Points and ECGs are linked using vtkButtons and time is controlled via a Qt/VTK toolbar

The aim of the first prototype is to verify the efficient and effective behavior of the chosen click-and-zoom interaction paradigm by visualizing multiple datasets at different spatial scales inside an application. The solution is to use vtkButtons as an interactive tool placed in a rendering view. The user is allowed to navigate 2D/3D image datasets at different spatial scales (i.e. CT scan at organ level, microCT scan, and nanoscan), making use of the vtkButtons to move from one scale to another and also to zoom back to the whole system scale, within both slice and 3D rendering views. To allow easy testing of different configurations, some features of the vtkButtons' behavior are exposed in the GUI, such as visibility, position with respect to the bounding box, and interaction style (zoom or fly to), and more properties can be added in the future (Figure 1).

The second prototype is an application demonstrating how MSVTK can be used in a cardiological problem. The heterogeneous and sparse input data is acquired over a short time period (2.5 s): 210 3D points acquired on a heart surface along with six electrocardiograms (ECG) sampled over two cardiac cycles (Figure 2). The challenge of time management and synchronization between data is tackled by implementing a reusable time Qt/VTK toolbar containing a time slider and a collection of buttons to play, pause, etc. Such widget can be connected with any VTK filter to expose an API for time within the filter pipeline and it can be observed and called by any other widgets. Data heterogeneity is handled using a different representation for each data type and bidirectional data communication is controlled via a specialized vtkButtons manager: a click on a 3D vtkButton selects the associated ECG and vice-versa. To further improve the user experience, several visualization techniques are applied: color-coding emphasizes the link between heterogeneous data (e.g. red 3D button corresponds to red ECG); a convex hull surface improves the 3D representation of the point cloud.

6. Conclusions

MSVTK is providing support for an important aspect of interactive visualization, which is missing from the available software frameworks that deal with biomedical data (such as VTK itself): to efficiently interact with multiscale data. The interaction approach is based on exemplary problems, which were collected worldwide, analyzed, and made public. These data have allowed the challenges that must be addressed to be identified; along with an extensive review of the state of the art, this has supported the specification of best practice. The MSVTK library is being tested by the implementation of prototypes, which aim to demonstrate the efficacy of the proposed solution in different biomedical contexts. Even if different aspects of multiscale interaction are presented in separate applications for clarity, nothing will prevent future software interfaces from combining them to address specific biomedical issues. The MSV project results are publicly available to the biomedical community – the first components of the MSVTK library are already released in open source (www.msvtk.org); the final release is planned by the end of 2012.

Acknowledgement

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