MultiScale exemplary problems

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Objectives

The Virtual Physiological Human (VPH) [1] is a framework that focuses on the investigation of the human body as a single complex system, integrating the efforts of different biomedical disciplines, ranging from bioinformatics to medical imaging. This requires the interconnection of different computational models and data used by each discipline at different spatial and temporal scales.

One of the challenging issues of this interconnection is the interactive visualization of multiscale biomedical data as a single system, in which the user can navigate through the patient-specific data using an approach similar to Google Earth [2]: starting from the whole body and zooming into a cell scale of, for example, the heart and zooming out to the whole body to focus again on a different organ. Despite the growing demand from areas such as biomedicine and bioengineering, among others, this topic has received very limited attention so far.

A project, called MSV [3] (Multiscale Spatiotemporal Visualisation), has been funded by the EC, to develop an open-source library for interactive visualization of multiscale biomedical data. The consortium is composed of international leading partners in the development of visualization software tools for biomedical applications.

In order to understand and focus on the real needs of the different VPH projects, various exemplary problems and datasets have been collected. This is now driving the development process of the open source library, MSVTK, which will be continued during the final year of the project (2012).

Material and methods

During the first year of the project (2010), an assessment exercise was carried out to identify the challenges and problems of the VPH community on multiscale visualization. During this, different representatives from European, US and New Zealand projects working on multiscale modelling were asked about their approaches, the nature of the models used, and the kind of data used/produced. A detailed description of a representative problem for each project explains the different multiscale data and models that are used; from this, a set of high priority challenges was identified on which the project would focus initially.

During the second year (2011), a collection of exemplary problems with example datasets was created; this is now publicly available [4]. These exemplary problems are representative of the challenges identified by the assessment exercise and will be used for the development period of the MSVTK library.

Some exemplary problems have been selected to develop early prototypes to assist the long-term development of the library. These are focused on specific challenges and will allow the new proposed concepts to be demonstrated.

Results

As a result of the assessment exercise, a document summarising the output obtained from the most relevant VPH projects in the fields of orthopaedics, vascular and cardiac modelling was created

summarising, for each project, the data and models used at each scale [5]. The temporal scales considered are months (follow-up studies), hours (continuous EEG-fMRI scan), seconds and milliseconds (electro-mechanical simulation of the heart). The spatial scales considered are genetics, cell level, tissue level, organ level and body level. An example diagram can be seen in Figure 1.

Analyzing the information provided by the different projects, the eight most relevant challenges in multiscale visualization were identified by consensus among the consortium members; their detailed description can be found in [6]. These challenges can be summarised as: integration of information in different spatial and temporal scales, from metres to nanometres; integration of data in the same reference system, that will require the use of registration algorithms; very large volumes of data in each scale, such as 4 GB of data for a microCT image or 7 GB of data for the electrical simulation of the heart that might be larger than the available computer memory; gaps between the different scales, because sometimes not all scales are available but the navigation should be continuous across the scales; heterogeneous data types, like for example different image modalities, surface meshes, volumetric meshes or signals; heterogeneous dimensionality of data (1D, 2D, 3D, 3D+t); high dimensionality data sets, like time-varying vector fields (6D+t); interactive visualization, where the real-time user interaction is considered and finally, time varying issues, where the time scale can range from years to nanoseconds.

During the second year of the project, the collection of exemplary problems and datasets mentioned above was made publicly available. It is composed of 31 exemplary problems that can be accessed through the Biomed Town [4] website, grouping the data by the following biomedical fields/domains: cardiology, cerebral aneurysm, musculoskeletal modelling, neuroimaging, oncology, virtual colonoscopy, human anatomy, mouse Atlas, zebrafish embryo, genetics, and clotting. For each exemplary problem, one or more challenges are addressed, while the majority of them have a clear clinical focus. All datasets are related to the human body, except the atlas mouse and zebrafish embryo. These animal examples are included because they exhibit specific features that are not possible to retrieve for humans. For the mouse, the linkage between anatomical and genetic data is interesting, while the zebrafish embryo dataset is interesting for its use of 4D confocal microscopy, which is not usual in humans.

The available data for each exemplary problem includes the contact person, a representative snapshot, a general introductory description of the problem, the identification of the challenges addressed, and the download links for the data.

Finally, two prototypes are being developed using the exemplary problems collected. The first focuses on the click-and-zoom interaction paradigm when dealing with spatial multiscale data. The user can visualize multiple datasets at different spatial scales and navigate from one scale to another. Three datasets at different spatial scales have been selected: CT scan at organ level of a bone, micro CT scan, and nano CT scan. Regarding the strategy, a *vtkButtons* approach has been developed to zoom from one scale to another and to zoom back to the previous scale.

The second prototype demonstrates the visualization of sparse data in time: electro-physiological CARTO points are visualized in synchronization with ECG signals. Sparse points acquired on the patient's heart surface are visualized in time during the heart cycle. For each point, the corresponding ECG signal is visualized in another view. For this prototype, a new Qt widget has been developed that allows the time range to be configured at two different scales: large-scale movement and fine-scale selections.

Conclusion

The feedback from the community was comprehensive and, in general, a very positive response to the objectives of the MSV project was perceived. The assessment exercise helped to identify and profile the different challenges that need to be faced when approaching the visualization of multiscale spatio-temporal data.

As a result of collecting the human-related datasets, we have moved one step forward in the visualization of the Virtual Physiological Human, where the human body is seen as a single complex system. Data from different parts of the body are available: brain, lungs, breast, heart, thorax, spine, prostate or femur. The datasets collected also belong to different spatial and time scales: from genetics to the whole body and from milliseconds to several months.

Despite the fact that it is extremely difficult to make medical imaging data available due to permission restrictions when patients' data are involved, a set of significant datasets has been assembled. These exemplary problems will be used to drive the development of the biomedical multiscale visualization library (MSVTK) and to validate its implementation with concrete use cases. Furthermore, the datasets can be used beyond the scope of the MSV project and provide exemplary cases and introductory samples for engaging people with the VPH framework.

Visualizing datasets from different fields into a single framework can open the door to hidden collaborations between different disciplines. The advances in bioinformatics, like next-generation of genome sequencing are progressing in parallel with advances in the field of medical imaging, like ventricular tachycardia treatment planning using patient specific pre-computed models of the heart and visualizing them during the intervention. Another example is the research studies that focus on the connection between mutations of specific genes and the effects on the ionic conduction of the heart cells. Using the information from different disciplines and putting the patient on the centre, can definitively benefit the patient's treatment.

The two prototypes developed using the collected exemplary problems enabled a demonstration to be performed of the approaches proposed for solving some of the challenges identified. These prototypes are a proof of concept and will be used as a reference for the next development period. While the prototypes are focusing on specific datasets and custom applications, the approaches employed will be generalized for the development of MSVTK library, focusing on generic designs that allow them to be applied in different contexts. The experience obtained from these developments will also reveal any necessity for improvements of new features to be added to VTK to match with MSV needs.

During the last year of the project, MSVTK library will be developed as an extension to the Visualization Toolkit (VTK) [7] and integrated into Slicer [8], OpenMAF [9], GIMIAS [10], CTK [11] and other open-source biomedical applications in order to provide a set of common multiscale visualization techniques that will cover the needs of the VPH community [12].

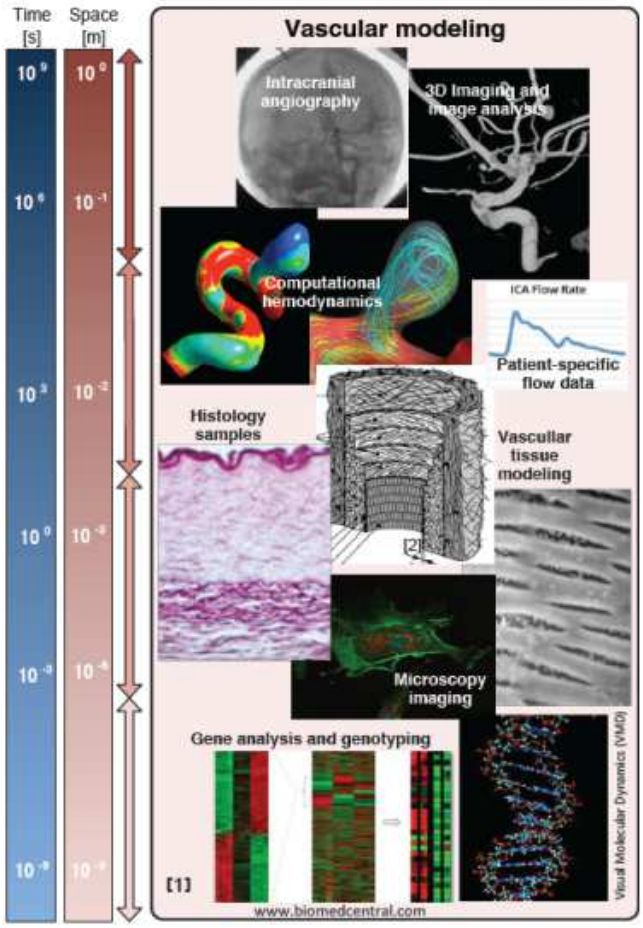

Figure 1: Vascular modelling for intracranial aneurysms.

Acknowledgement

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