Simulation-Visualization Complexes as Generic Exploration Environment

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Abstract. Simulation-visualization complexes combine tools for numerical simulation and data visual representation. They facilitate together the research process of investigating a phenomenon by decreasing necessary time and cost resources. The paper is devoted to the process of design and development of such kind of complexes. It introduces the approach that permits to combine simulation and visualization compounds together and represents at the same time a minimum of user discomfort related with the increasing functionality of a final complex. This goal can be achieved if the interface of the exploration complex will be designed and developed in accordance with such usability criterions as consistency, informative feedback and design simplicity.

1. Introduction

Today's existing simulation tools can not always satisfy researchers if, for instance, output data is too vast to be analyzed in numerical form. If it happens, the best approach for conducting effective analysis is to visualize the numerical data and then deal with the graphical interpretation of the obtained results.

The paper represents the approach of how to combine the features of simulation and visualization software in the framework of one generic exploration environment that can be obtained by the linkage of computational processes and the processes concerned with the graphical interpretation and interaction.

The introduction to numerical simulation and scientific visualization is provided in section 2 of the following paper. Section 3 is devoted to the integration of simulation and visualization compounds and shows what kind of feedback exists between them. Section 4 represents a view to the complex interface solution in generic exploration environment. Such interface usability criterions as feedback, consistency, visual and task simplicity are explained.

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2. Introduction to Exploration Complexes

Supercomputer systems of different architectures have become very popular for solution of various mathematical and physical problems demanding large data volumes. The choice of this modern and powerful equipment is caused by the requirement to decrease the time interval necessary for simulation process and/or visualization of obtained results.

Generic simulation-visualization complexes are exploration complexes that contain both tools for numerical simulation, data visual representation and interaction capabilities that facilitate together the process of phenomenon investigating by shorten necessary time and cost resources.

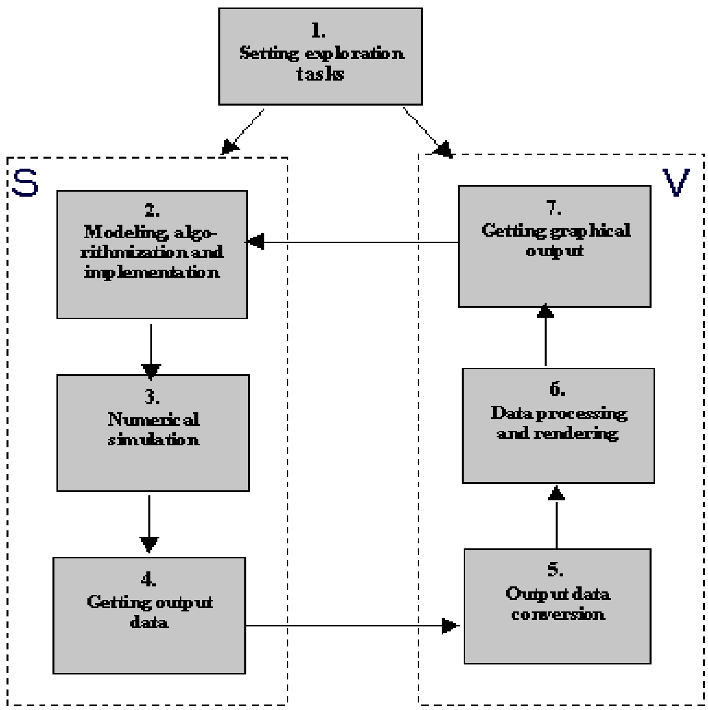

Fig. 1. Numerical Simulation ->Visualisation

Fig. 1 represents the main functional compounds of simulation-visualization process as a whole.

Three preparation stages usually precede numerical simulation: modeling, algorithmization and development of simulation software [11].

The stage of modeling is the most complicated as it covers the elaboration of mathematical models, development of numerical schemes for effective simulation, definition of the investigated zones and fields, selection of scales and criterions. [8]

Algorithmization stage [4] includes algorithm development, selection of hardware and software for further implementation of this algorithm, algorithm adaptation in accordance with selected hardware, if it is necessary. If it is a supercomputer of parallel architecture, then parallel algorithm should be developed.

As for the implementation stage, it means the cycle of scripting, testing and validation.

Supercomputer applications aimed to numerical simulation usually have command-line or zero-dimensional (0-D) user interface. Command line here is as usual a typical interface solution [7]. User may only vary simulation parameters, i.e. initial conditions, criterions, scale, etc. using a keyboard. Sometimes it is not effective and comfortable, especially when the computational processes are based on the complicated mathematical logic.

Only people participated in the development of this software or specially pre-trained persons can effectively interact with the computational processes and analyze output data.

If data generated by numerical simulation software is large and complicated, then the best way to analyze it is to present this data visually. The parameters of many physical and chemical processes are better observed in graphical form. Moreover, there are special information systems based on numerical simulation methods, where visualization can be considered as the only solution of representing output results, such as weather forecasting, medical diagnostics and different types of monitoring.

The problems concerned with data visual presentation are very urgent today because of the fast increasing of data volumes processed by different computer systems including supercomputers. The progress of visualization hardware and software is caused by continuous rising of requirements addressed to them. In the sphere of science and engineering these requirements include clear visual presentation and efficient real-time control of huge data volumes obtained through calculations based on complicated multidimensional models.

So today visualization software developers focus their efforts on the implementation of integrated interactive systems that consist of information management compounds, data structuring tools and visualization toolkits.

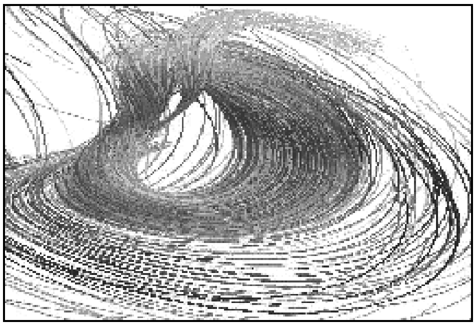

Fig. 2. Example of 3D visualization of electromagnetic flow

Output data volumes obtained as a result of numerical simulation are always represented in a special format. If this format is different from those that can be supported by visualization software, it is necessary to convert obtained data to one of

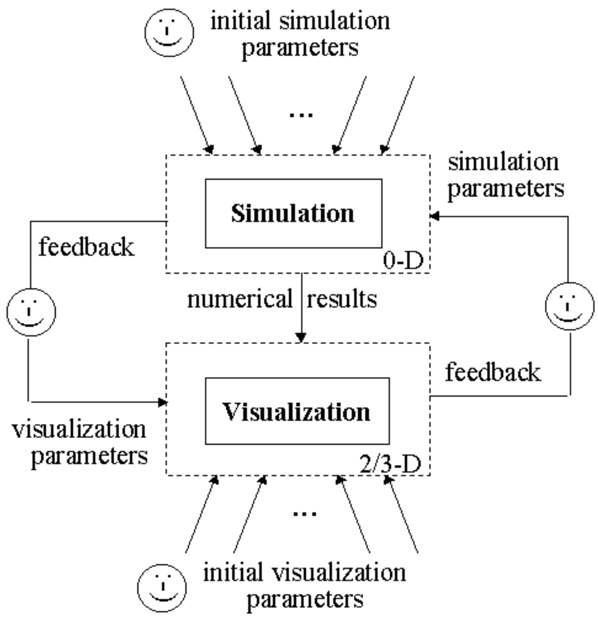

Fig. 3. Traditional feedback scheme between simulation and visualization software

the available visualization formats. For this purpose a special data format converter should be included into simulation-visualization scheme.

There are many software applications to work with video, graphics and animation that can be used for the visualization of static and/or dynamic objects either existing or being simulated. In ideal case this software includes integrated systems of analyses, processing and data imaging based on the classical representation as graphs with the complicated data visualizations as 2D surfaces or 3D objects (Fig.2). With the help of the following systems users can obtain information from various databases, conduct mathematical and logical operations, edit or analyze them visually, and finally reproduce high-quality copies of images. The following functionality is available by so called 2D or 3D (2/3-D) graphical user interfaces [9].

Creating the Virtual Reality environment is the highest level of 3D visualization when the stereo virtual objects can be interacted during the presentation process. Virtual Reality technologies permit the real-time interaction with the models of 3D objects, including the effect of full presence in the real medium through the audio, video and even tactile components.

Virtual Reality is the modern concept that is widely used today not only in entertainment and education as it was several years ago but also in different science domains, such as biology, medicine diagnostics, molecular modeling, aerospace industry, electrostatics, etc.

3. Interaction between Simulation and Visualization Compounds

The main advantage of combination of simulation and visualization features in the framework of one exploration complex is the significant decrease of time resources necessary for the conduction of the experimental cycle. [3]

The experimental cycle can be shorten, first of all, by minimization of feedback processes, number of people involved in each process and their effort aimed to the maintenance of interaction–adaptation features. Fig. 3 and 4 illustrate how the situation changes when separate simulation and visualization software systems (Fig.3) are combined into one generic complex of the same purpose (Fig. 4).

Simulation-visualization complexes can be static or dynamic [1]. The static complexes deal with time independent data. Generated once, the following data does not change. Only visualization parameters can be varied for better observing the reproduced image.

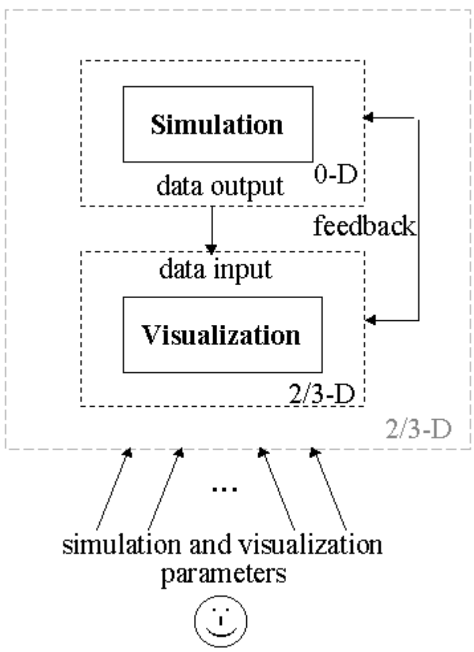

Fig. 4. Feedback scheme in generic simulation-visualization environment

As for dynamic complexes, the interaction between simulation and visualization compounds here is very complicated. Numerical data is generated by simulation software periodically and the visualization results are also updated with the same frequency. So the visualization reproduced currently is the graphical interpretation of numerical data generated at some moment. Visualization results are also can be modified by available visualization parameters.

Thus a common static complex can be interpreted as a special case of a dynamic complex. Ideal variant is when a dynamic exploration complex maintains all the features of static one.

IntelliSuite™ CAD for MEMS can be considered as an example of static simulation-visualization complex implemented as a standalone application. MEMS is an acronym of Micro Electro Mechanical Systems and is a microfabrication technology which exploits the existing microelectronics infrastructure to create complex machines with micron feature sizes. IntelliSuite is an integrated software complex which assists designers in optimizing MEMS devices by providing them access to manufacturing databases and by allowing them to model the entire device manufacturing sequence, to simulate behavior and to see obtained results visually without having to enter a manufacturing facility. [5]

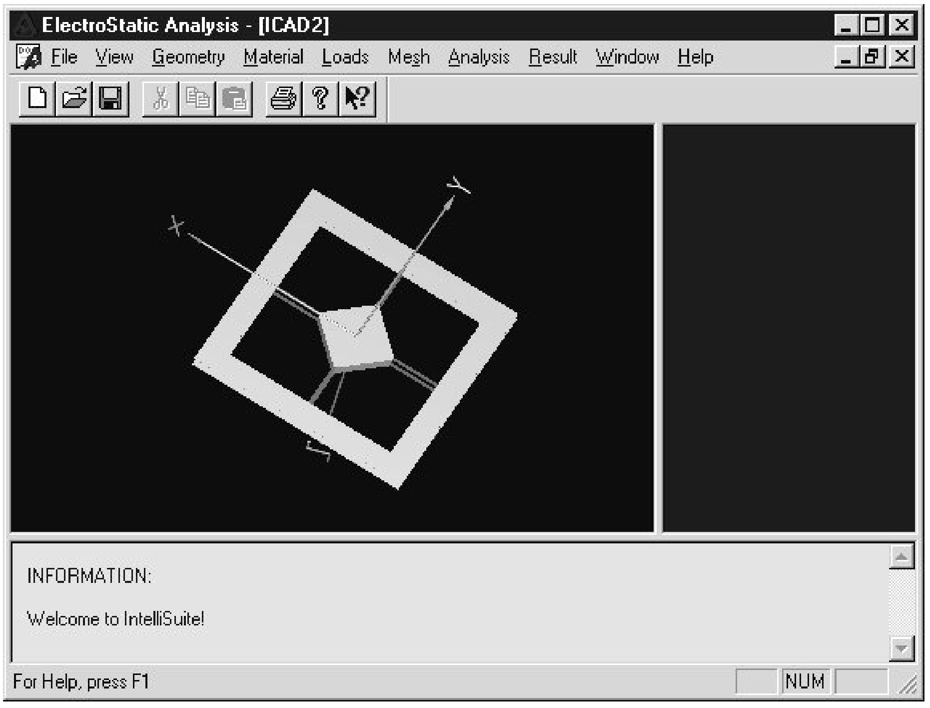

Fig. 5. IntelliSuite results: 3D visualization of an accelerometer

It provides the ability to simulate with high accuracy different classes of MEMS devices induced mechanically, electrostatically and electromagnetically and then to obtain the graphical presentation of the appearance of each simulated device. ACIS 3D Visualization Toolkit is used for the implementation for new visualization engine of IntelliSuite CAD for MEMS. Fig. 5 represents the prototype version of 3D interface of the Electrostatic Analysis Component of the following exploration complex.

There are also two different variants of implementation of generic exploration complexes. A simulation-visualization complex can be implemented as distributed software complex where numerical simulation is conducted on a separate computer system (or even systems) and visualization process is generated on a separate graphical server or workstation. There is another approach when it is implemented as standalone generic simulation-visualization software located on the same computer system possessing necessary computational and visualization resources. The solution about the implementation form is defined both by the complexity of the task to be simulated and the desired visualization features.

Sometimes UNIX workstation or even a simple PC is enough for obtaining sufficient results (simple CAD/CAM applications). But there are several situations when expected results can be provided only by means of distributed exploration complex, where, for instance, the numerical simulation is organized on supercomputer of Cray, HP Convex or Parsytec series and the visualization process is conducted on SGI Onix2 or Origin 2000 supercomputer (complicated run-time tasks). [2]

4. Complex Interface Solution

Integration of two interrelated software compounds of different purposes in a generic complex leads to necessity of design and development of a generic graphical interface that provides a user the ability to interact with each component and to influence on feedback between them. This interface permits to minimize the exploration cycle as a whole, as the features of each compound are now available to user via the same environment. And, moreover, the user interaction with the simulation compound becomes more friendly as 0-D interface of the simulation part is replaced by the graphical 2/3-D user interface of the entire generic simulation-visualization complex (see Fig. 3, 4).

User interface structures optimize access to application data and features. The human-computer interaction becomes highly efficient and productive by mapping the tasks to user goals.

The effective interface design starts from the structure of the product and integrates navigation, information design, visual design and technology. Complex interface solution for a generic simulation-visualization complex should be based on at least three main usability criterions: [6]

1. Consistency at all levels

If actions are executed in a specific way on one screen, users expect the action to be performed in the same way throughout the other screens. They expect certain features of the interface behavior in certain ways no matter with what compound of the exploration complex they work: with simulation or with visualization.

2. Informative feedback

Feedback closes the communication loop between the computer and the user, telling the user how their actions were processed and what the results of those actions are. In the absence of error messages, normal feedback lets the user know that the system is behaving in the expected manner.

3. Design simplicity:

Several types of simplicity contribute to a well-designed user interface:

- Visual simplicity is achieved by showing only the most important objects and controls.
- Verbal simplicity means usage of direct, active, positive language.
- Task simplicity is achieved when related tasks are grouped together, and only a few choices are offered at any one time.
- Conceptual simplicity is accomplished by using natural mappings and semantics, and by using progressive disclosure.

The main aim of the generic interface is to facilitate the work of users so that increasing functionality of simulation-visualization complex does not lead to rapid increasing of user discomfort while working with it.

5. Conclusion

The paper presents the approach of building the generic environment for numerical simulation and scientific visualization. Both tasks that are going to be linked are rather complicated. The paper provides a view of how it can be done with a minimum of user feeling that system complexity has been increased.

The main idea is to combine simulation and visualization features into the generic environment with a common graphical user interface through what a user will be able to manipulate simulation and visualization parameters wherever it is necessary with a minimal effort and in accordance with his expertise. This environment will combine both simulation, visualization and feedback capabilities between two these compounds that permits to deal with the results of numerical simulation in visualized form and to change the circumstances of conducting simulation processes.

Such usability criterions of interface design as: consistency, informative feedback and design simplicity permit to minimize demands on human memory. That will help to provide the success of the exploration complex among its further users. The ideal variant is even to provide the generic environment with adaptive user interface that permits a concrete user to have at the top level the most frequently used features [6].

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