Bidirectional Coupling - From 3D Field Simulation to Immersive Visualization Systems

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***Abstract*—The interactive exploration of complex simulation data have spurred a renewed interest in visualization techniques, because of their ability to give an intuitively clue for the interpretation of electromagnetic phenomena. This paper presents a methodology for a bidirectional coupling of VTK-based visualization systems to interactive and immersive visualization systems which are specially adopted for the handing and processing of large and transient simulation data. In this work, the coupling is demonstrated by the flexible virtual reality (VR) software framework VISTA which is used by many national and international research groups.**

I. Introduction

Together with the development of computers, simulation software has attained nowadays a rather high level of sophistication. In many real-life engineering situations, the problem is no longer to be able to simulate, but rather to be able to interpret correctly and efficiently the huge amount of numerical information generated by the simulation. Visualization was regarded so far as an auxiliary task in finite element (FE) modeling that was limited to the servile representation of simulation results. But together with the increase in the complexity of simulation data, the interest in appropriate visualization systems is renewing nowadays. The general requirement for such systems is to enable a fast or even sub-real-time graphical representation of transient simulation data, irrespective of its data volume. For such scenario, specially adapted software concepts are required to fulfill such criteria. This paper presents the idea and the technical background of a bidirectional coupling of the VTK-based electromagnetic visualization tool Trinity.IVR and the VR-framework ViSTA.

II. Related Work

In many research projects the coupling of different software frameworks and software tools are an important issue. In [1] Schopfer et. al. present an integration platform (CHEOPS) for chemical process modeling and simulation. In this approach an overall integration framework is provided in which all simulation and visualization tools are integrated. Riedel et al. present a network-based coupling of the visualization tool VISIT and existing simulation algorithms running on an HPC System. Within the CONV project [2] the VISIT internal client - server architecture is used for handling the coupling process. In addition to these approaches for coupling different software tools there are also solutions for coupling algorithms to enhancing the capabilities of an existing software framework. In [3] Raffinn et. al. describe the coupling of algorithms for mass-spring systems and deformable objects with an existing VR Software framework to process distributed physical based simulations. Our approach builds upon the ideas of the presented papers and on our prior work presented in the section III.

III. Previous Work

Since 2001 the institute of electrical machines (IEM) developed the command line based software tool iMoose.trinity [4] which provided a liberty of visualization algorithms for the electromagnetic field problems. The commands were realized in Python [5], so that users could assemble static visualization scenes in an individual Python script. Within the scope of [6] its enhancement iMoose.trinity.VR [7], [8] has been developed, which applied the Open-Source Visualization Tool KIT (VTK) [9]. In 2009 the IEM started the development of iMoose.trinity.IVR [10] and new electromagnetic visualization methods [11], [12]. This software tool combined the advantages of both former packages and is integrated in the daily use for visualization of FE data. Its concept is designed to add FE post-processing and processing facilities as long term research goals.

Beside the development of VR capabilities focusing on electromagnetics, the virtual toolkit ViSTA [13] and the extension for flow phenomena ViSTA Flowlib [14] have been developed in the course of many research projects. ViSTA is a flexible and extensible software framework which is already productively used by many national and international research groups [15]. ViSTA has a scalable interface that allows its deployment in desktop workstations, small and large VR systems, like the 3D workplaces or CAVE-like systems. Hence, new modules and concepts are easily integrated and can be used on a wide range of different systems. Another important feature of ViSTA is its focus on advanced interaction techniques for full and semi-immersive environments like Cave or 3D workplaces.

IV. Goals and Methodology

The main goal of this work is to provide a framework for a flexible coupling between ViSTA and iMOOSE-Trinity, which is not regulated by the restrictions of certain middleware software, e.g. like CORBA [16]. The coupling methodology presented here, is only focusing on the VTK layer for realizing the coupling strategy, which generally allows a interconnection to any VTK-based visualization environment. Regarding the fact that ViSTA and iMOOSE-Trinity are both using VTK pipelines, new functionality can easily be integrated in both software tools during the coupling process.

A direct integration of ViSTA into iMOOSE-Trinity is not suitable because both pieces of software have their own data structure and different purposes. Both systems are expert systems with their own internal logic. The coupling must be regarded, not as a mere integration, but rather as an enhancement of functionality. Therefore, a bidirectional network-based coupling is preferred. The purpose of this coupling is to offer the possibility to link a simulation package with the whole range of immersive visualization systems, from 3D office systems up to cave-like systems. Bi-directional coupling is required to trigger new post-processing actions from within the VR environment. Techniques like making interactive cuts or seeding particles for flow (or flux line) representation are common in both systems and must be mirrored in a consistent way in the two environments to achieve a seamless coupling. For instance, in the case of leakage flux visualization, the interaction entails a back-and-forth communication between VISTA and iMOOSE.Trinity. This mirroring of functionalities is far from being trivial and represents a major task of the project.

The coupling mechanism consists of a six layer state handling process, see Fig.1. First and last layer represent the application layers of both participating programs. Each layer in between is part of the state transcription. The arrows associated with each layer represent the type of communication, whereas its communication direction between layer one and six can be reversed to ensure a bidirectional coupling interface. To guarantee a further single usage of ViSTA and iMOOSE-Trinity the code changes are restricted to a minimum, so that all required transcription knowledge is hosted in the communication layers. The synchronization of the iMOOSE-Trinity application and its runtime state is realized by so called the RemoteObjects. Main task of such objects is the serialization for network communication, which is a mechanism to identify object entities in both applications, and the encapsulation of the underlying network protocol itself. The network protocol is optimized for bidirectional synchronization states and considers the problem of parallel state manipulation on the level of single objects by semaphore access control. The translation of logical equivalent objects, like procedure calls and visualization states, e.g. rendering-primitives, is used for the coupling of the internal logic. The exchange of the visualization content is achieved by the VTK-Legacy format. The coupling destination (ViSTA) requires in this description only a minor extension allowing an interactive receiving and handling of the state updates from the coupling source platform (iMOOSE-Trinity).

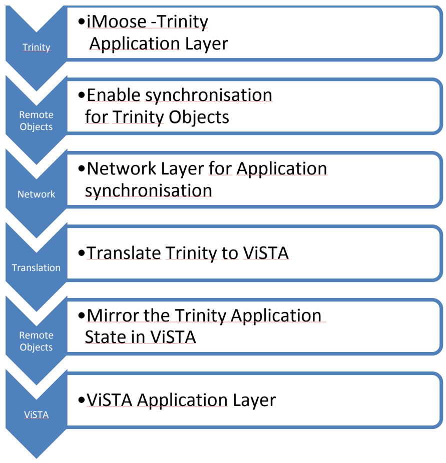

Fig. 1. State handling between iMOOSE-Trinity and ViSTA.

V. Conclusion

Efficient methods for the visualization of finite element solutions are essential for the evaluation of electromagnetic devices under research and development. This paper presents a generalized software architecture for the coupling of VTK-based graphical representations to full and scalable immersive visualization systems. The full paper will describe the object state handling in detail which is crucial for a seamless interconnection between both systems. The required software interface will be exemplified by a standard interactions. Finally performance issues of the proposed concept are evaluated and discussed, concluding with possible further improvements.

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