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GECEM: A portal-based Grid application for computational electromagnetics

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Abstract

The Grid-Enabled Computational Electromagnetics (GECEM) portal is a problem-solving environment that uses grid technologies to support scientists in accessing distributed resources for the solution of computational electromagnetics (CEM) problems. These resources include input files specifying the system geometry, and proprietary software and hardware for mesh generation and CEM simulation. Through interacting with a web-based grid portal, a user can access these resources, submit jobs, monitor and execute distributed grid applications, and collaboratively visualize the results of the CEM simulation. Thus, the portal allows users to use Grid infrastructure to share resources among geographically distributed partners in order to execute large-scale computational electromagnetics simulations, and to collaboratively analyze and visualize the results.

This paper describes a secure, web-based portal, built on the GridSphere framework, composed of a number of JSR-168 compliant portlets that deploy services at the back end for discovery and management of distributed resources, and for invoking services for mesh generation and CEM simulation. The paper also describes how security is achieved through the Grid Security Infrastructure and single sign-on.

Keywords: Computational electromagnetics; Portals; Portlets; Web services

1. Introduction

Grid-based portals are an increasingly popular way of allowing computational scientists to perform collaborative research and share geographically-dispersed resources [1]. Scientific simulations are often both data- and compute-intensive, and may involve heterogeneous resources running under different operating environments. Such simulations typically involve complex interactions between a number of systems. The Open Grid Service Architecture (OGSA) [2] describes an infrastructure which is suitable for collaborative resource sharing via the Grid. However, the installation and use of this grid infrastructure is generally complex and difficult for all but trained experts. Grid middleware provides mechanisms for performing low-level grid tasks such as transferring files, executing processes and monitoring process output. However, in general, scientific end users do not have the expertise, or the desire, to directly perform these low-level tasks themselves. Web-based grid portals provide an integrated user interface that not only provides a single point of access to heterogeneous resources, but also hides the complexities associated with their use. Scientists can work in terms of application domain concepts, and can concentrate on their research without worrying about the complexities of using the Grid.

Computational electromagnetics (CEM) is of increasing importance to the civil and defence sectors, and is central to important problems such as predicting the electromagnetic compatibility between complex electronic systems, and the response of systems to lightning strikes and electromagnetic pulses. Large-scale CEM simulations are computationally intensive, and can involve access to resources that are intrinsically distributed. For example, in the case of an "extended enterprise" in which multiple partners from industry and academia are cooperating to design and build a complex system that requires CEM simulations, the geometry of a component may be created at one location, a mesh conforming

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to this geometry may be generated at a second location, and a CEM simulation based on the mesh may be performed at a third location. Finally, the output from the simulation may be analyzed and visualized at one or more other locations. Thus, CEM simulations are suitable candidates for use of the Grid.

This paper describes the Grid-Enabled Computational Electromagnetics (GECEM) project, focusing in particular on how it makes use of grid technologies to support collaborative research through the design and implementation of a portal based on portlets and services. The portal enables remote mesh generation, and the migration of the CEM solver code to be executed at a remote location. The portal supports collaborative simulation and access to distributed resources among the different project partners in a user-friendly approach. To this end, the GECEM portal has been designed to support the generation of computational meshes using meshing services at the University of Wales, Swansea, the solution of a CEM problem on this mesh on a supercomputer at the Singapore Institute of High Performance Computing, and the collaborative visualization of the results by participants at Cardiff University and BAE SYSTEMS in Bristol [3].

The remainder of this paper is organized as follows. Section 2 discusses the design of the GECEM portal, and describes the design requirements and key features of the portal. Section 3 presents the architecture of the GECEM portal, and discusses the portal and portlet technologies on which it is based. Implementation aspects are considered in Section 4. Related work is discussed in Section 5, and conclusions and directions for future work are presented in Section 6.

2. Design of the GECEM portal

The GECEM project involved both industrial and academic partners, the former being BAE SYSTEMS and Hewlett-Packard, and the latter Cardiff University and the University of Wales, Swansea. The other project partner was the Singapore Institute of High Performance Computing, which is an industry-focused research organization. The design of the GECEM portal was a collaborative and iterative process involving project partners that sought to match end user requirements to technical solutions within the budget and two-year time span of the project. This section discusses the most important outcomes of this design process.

2.1. Requirements

The GECEM portal must satisfy requirements in the following areas:

User access. The portal should provide users with a single point of access, without the need to login to multiple different machines. The portal should also support simultaneous access by multiple users.

Job workflow. A GECEM workflow takes as input a geometry file, and uses this to evaluate conforming surface and volume meshes by executing two distinct codes. A third executable takes the surface and volume mesh files as input and performs a CEM simulation. A GECEM job consists of running all or part of such a workflow, and the portal should support the configuration, submission, and monitoring of GECEM jobs.

Visualization. Once a CEM simulation is complete, users should be able to collaboratively visualize the result within the portal.

Job management. Users should be able to submit multiple jobs at the same time. Users should be able to log out of the portal and the job should still continue to run. Subsequently users should be able to login to the portal to check on the progress of their jobs.

Legacy code. The portal should be able to transparently access legacy codes to perform the numerical tasks in a GECEM workflow.

CEM simulation migration. High quality CEM solver codes often represent significant investments of time and money, and may give a business a competitive edge that would be lost if their codes were accessible to others. Thus, the owner of such a CEM solver code may not want to install it permanently on multiple computers outside of their organization. The portal should support the secure migration of the CEM simulation executable code to a selected target machine, together with any necessary input data sets. The code should then execute, its output stored in a user-specified location, and the code on the target machine deleted, along with any related data sets.

Service discovery. The services accessible from the portal for computation and visualization must be registered with a resource registry, and be discoverable from within the portal.

Resource selection. Users should be able to browse multiple machines to select input files, and be able to specify where the output files are stored. When the service discovery mechanism discovers multiple services capable of performing the same task, users should be able to select which one they wish to use.

Security. The portal must allow users single sign-on access to resources through their security credential, such as a UK e-Science certificate. Single sign-on refers to the ability of a user to perform a single action of authentication (such as entering a password) to access the distributed resources that he or she is authorized to use. In addition, delegation of credentials must be supported so that tasks such as file access and job execution can be preformed on a user's behalf, and any files generated are owned by the user. Delegation is a mechanism whereby a user or service can delegate a subset of their access rights to another service.

2.2. Features of the GECEM portal

The GECEM portal satisfies all the requirements listed in Section 2.1. The legacy codes for surface and volume mesh generation are exposed as Grid services, and the CEM migration process is also controlled by a Grid service. Of course, the execution of the CEM simulation code on the remote host is not entirely secure, but the approach adopted reduces the risk of an organization's valuable software being accessed by unauthorized parties. The mesh generation and solver migration