KEY ISSUES IN CLOUD SIMULATION PLATFORM BASED ON CLOUD COMPUTING

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ABSTRACT
Networked modeling & simulation platform can provide important support for collaborative simulation applications by integrating simulation resources over networks. Facing the increasing rich simulation resources over networks, the new challenge is that users need to get simulation services on demand simply and use simulation resources in a more efficient, transparent, and ubiquitous way. This paper presents Cloud Simulation Platform (CSP) that introduces the idea of Cloud Computing into networked modeling & simulation platform. We discusses the key issues in CSP including the operating principle of Cloud Simulation model, CSP architecture and components, and the key technologies in CSP. CSP provides a promising solution to the problems that networked modeling & simulation platform is facing, and this paper presents a map for future research on CSP.

Keywords: cloud simulation, cloud computing, cloud manufacturing, high performance simulation, networked modeling and simulation platform

1. INTRODUCTION

The rapid development of Modeling & Simulation (M&S) technology has profound influence on understanding the complicated world in recent years. M & S platform technology provides effective support for modeling, computing, analyzing, evaluating, verifying, and forecasting in many application domains such as simulation in military training, industry, and economics. To deal with the large amount of simulation resources distributing over networks, networked M&S platform technology has become one of the most powerful tools to support sharing and collaboration of distributed simulation resources (Zhang and Chen 2006), especially in large-scale simulation applications such as virtual prototyping of space shuttle. With the rapid development of distributed computing technology, more and more types of simulation resources can be connected into networks and take part in collaborative simulation process. This has resulted in a sharp increase in complexity of networked simulation systems, as well as increasing difficulty in making use of distributed and heterogeneous simulation resources (Bohu 2007). Despite the increasingly rich simulation resources over networks, it is even more difficult for users to find what they just need to complete their simulation tasks. Now networked M&S platform technology is facing new challenges from a user-centric viewpoint.

One of the great challenges is that simulation users need to take full advantage of a variety of simulation resources in distributed and heterogeneous environments efficiently and transparently (Lei and Lin 2010). Simulation resources are the basis for modeling and simulation, and they include models, computing devices, storage, data, knowledge, software, and simulator needed by simulation systems. The simulation resources usually distribute in dispersed locations across different organizations over networks. To leverage the required simulation resource, users need to check its location, and then negotiate with the owner before they can access to it. This is a very inefficient operation mode for resources sharing. In addition, the distributed simulation resources often run in heterogeneous environments. Diverse hardware platform, operating system, and programming environment set up obstacles for users to integrate them together to support collaborative simulation applications. So the key problem is how to shield distribution and heterogeneity of simulation resources to provide a transparent access mechanism and build an efficient resources sharing environment.

Moreover, users need to get on-demand simulation services according to their personalized requirements and use them ubiquitously. Currently the networked M&S technology has shifted the focus from computing-centric angle to user-centric. However, current complex simulation systems always bring about a heavy burden caused by the deployment and configuration work. Users have to spend much time installing hardware drivers, operating systems, and software tools to establish a specific simulation application. The system development process is cumbersome and cannot meet user's need of customizing a simulation system simply and rapidly. In addition, there is a growing demand for using mobile network terminals (e.g., pad computer, smart phone, etc.) to participate simulation anywhere anytime. Users don't want to know too many technical details about how to call a simulation function remotely, as well as how to integrate diverse simulation resources to implement a specific function. Thus users can pay more attention to simulation applications themselves instead of technical details. Therefore, the networked M&S technology had better provide a new paradigm by which simulation resources could be integrated to construct a simulation system according to the needs of users flexibly and dynamically. And the simulation system can be accessed and used through ubiquitous terminals anytime anywhere.

To address these issues, the idea of Cloud Computing (Buyya *et al.* 2009) may provide an opportunity to give impetus to the development of networked M&S technology. Cloud Computing refers to a pattern of IT service delivery and utilization. In Cloud Computing, users may access the scalable IT resources on demand via networks by using a computer, smart phone and other interactive terminals, and they don't need to download and install applications on their own devices because all IT resources (computing and storage) are maintained by cloud servers. In this paper we introduce the idea of Cloud Computing into networked M&S technology and present Cloud Simulation Platform (CSP). The paper firstly presents the operating principle of Cloud Simulation model. Then the CSP architecture and the components are illustrated, and the key technologies in CSP are discussed to indicate the future research areas. The key issues discussed in this paper can contribute to the future research on CSP.

2. RELATED WORK

There are many different definitions for Cloud Computing. For example, it refers to a large-scale distributed computing paradigm that is driven by economies of scale, in which a pool of abstracted, virtualized, dynamically-scalable, managed computing power, storage, platforms, and services are delivered on demand to external customers over the Internet (Foster et al. 2008). Cloud Computing is considered as a new business paradigm describing supplement, consumption and delivery model for IT services by Utility Computing (Mladen 2008) based on the Internet. The typical examples of public Utility Computing include Google AppEngine, Amazon Web Services, Microsoft Azure, IBM Blue Cloud, Salesforce. So far, Cloud Computing is regarded as the sum of IaaS (Infrastructure as a Service), PaaS (Platform as a Service), and SaaS (Software as a Service). Cloud Computing providers can deliver on-demand services covering IT infrastructure, platform, and software vie virtualization and service encapsulation technology. Thus, it can meet the needs of ever-rising scale of computing and storage of consumers and lead to decrease in IT investment cost at the same time. Cloud Computing introduces a promising model and technical approach to the problems networked M&S platform facing. For example, virtualization technology (Thomas *et al.* 2005) can support deep encapsulation of a logic entity of IT infrastructure (e.g., CPU, memory, disk, and I/O) and software into a pool of virtual machines, thus it can achieve high efficient and transparent utilization of resources.

3. CLOUD SIMULATION MODEL

Figure 1 illustrates the operating principle of Cloud Simulation model. A simulation cloud refers to a cluster of virtualized simulation resources and services. The physical simulation resources can be mapped into virtualized resource templates by virtualization technology (Lei and Lin 2010). For example, package ANSYS software, Window XP, 4 CPUs, 1G memory, and etc. into a virtual machine template. And the functions of a simulation resource can be encapsulated into standard services that are loosely coupled and interoperable. The simulation clouds can shield the complexity caused by the distribution and heterogeneity of resources, and accomplish unified management of the standard services.

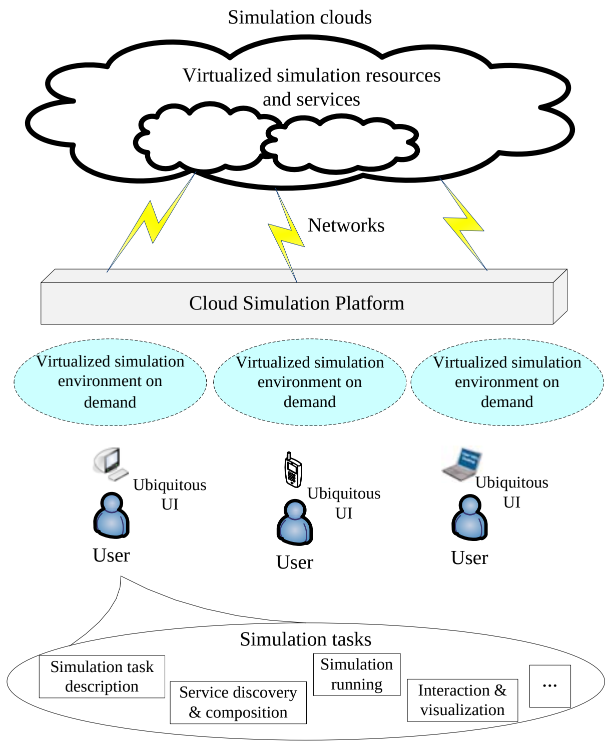

Figure 1: Cloud Simulation Model

Users don't need to deploy their own simulation environments involving hardware and software meeting specific needs. A user can submit a request of simulation tasks to CSP by using ubiquitous interactive terminals (e.g., smart phone, pad computer, etc.), and the request will be parsed by CSP to generate formal requirements of simulation resources. CSP launches a search to match the needed resources in the simulation clouds according to the resource requirements. The selected resources then will be accumulated to establish a virtualized simulation environment, and CSP can complete the deployment of the resources automatically by the way of instantiating the virtualized resource templates. In the virtualized simulation environment, users feel like facing a real system designed for his specific needs, and the simulation functions can be acquired in a unified form of service, e.g., web service (Papazoglou *et al.* 2007), to support collaborative simulation. In run-time simulation process, CSP can assemble services and schedule resources dynamically over networks, and users can interact with the virtualized system as well as monitor the visual feedback remotely. Once a crash or unrecoverable error occurred in some simulation resource, CSP can carry out live migration (Christopher *et al.* 2005) from the trouble resource to another healthy one. This ability of fault tolerance can achieve a high reliable collaborative simulation, and the whole process is transparent to users.

4. CLOUD SIMULATION PLATFORM ARCHITECTURE

Figure 2 shows the layered architecture of CSP. It consists of four layers: *Virtualized Resource Layer*, *Middleware Layer*, *Simulation Service Layer*, and *Ubiquitous Portal Layer*. CSP can integrate a broad range of simulation resources as Figure 2 illustrates, and provide support for simulation applications such as military training, product development, and conceptual prototype verification.

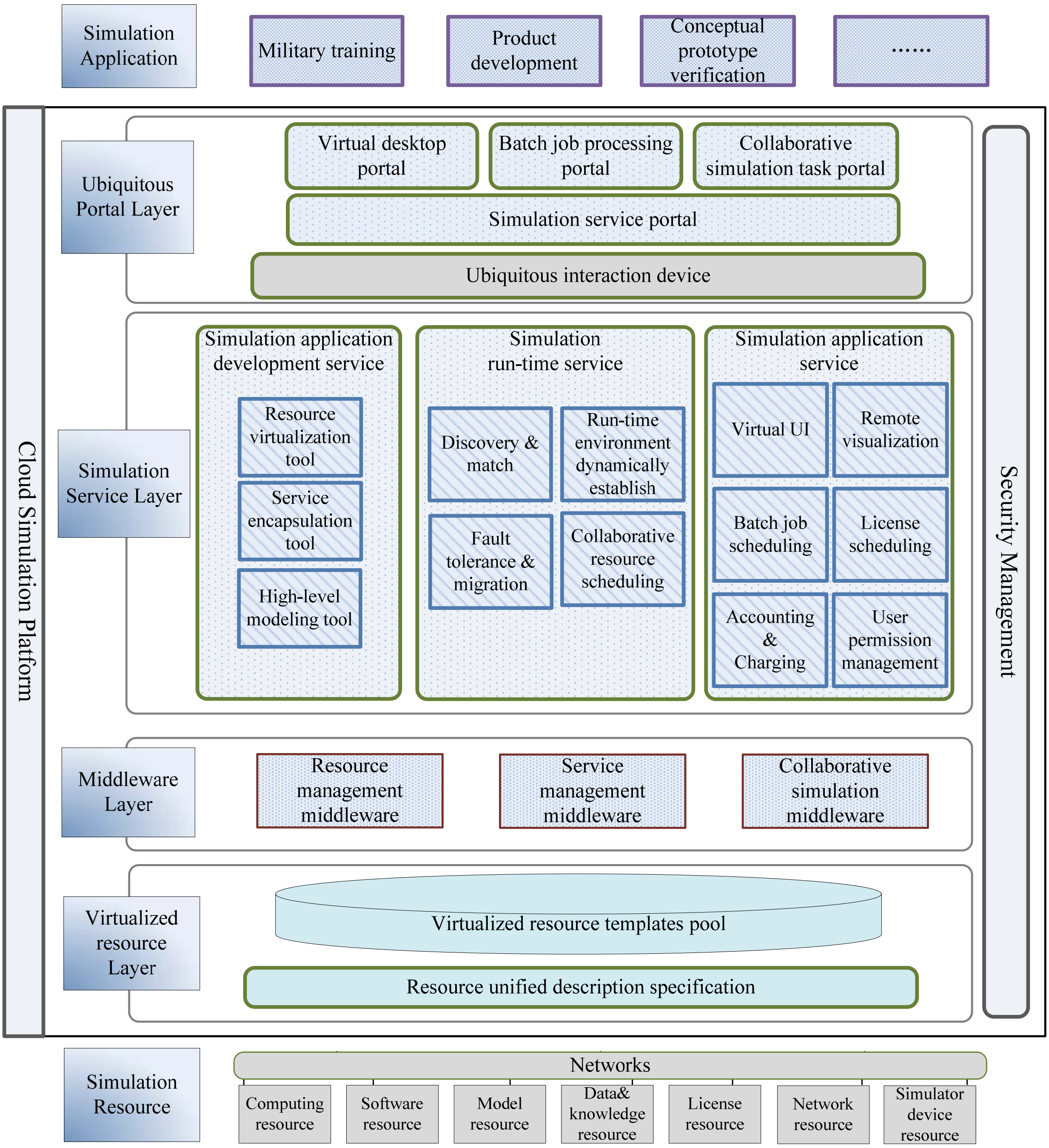

Figure 2: Cloud Simulation Platform architecture

4.1. Virtualized Resource Layer

The *Virtualization Resource Layer* is responsible for connecting a variety of simulation resources over networks and mapping them to virtualized templates according to a unified description specification. The simulation resources consist of computing resource, software resource, model resource, data resource, knowledge resource, license resource, network resource, and simulator device resource.

The physical resources such as computing resource, software resource, and model resource can be mapped to virtual machine templates where the fine-grained resources (e.g., CPU, memory, etc.) can be regrouped to create new virtualized resources. These virtualized resources are logical partition and the abstract composition of the real ones, and the templates should be described according to the unified description specification. The provider of the resources can register the templates in the registration center of CSP to establish a virtualized resource pool. The pool seems like a cloud where the raindrops of simulation resources aggregate and move.

4.2. Middleware Layer

The *Middleware Layer* serves as middleware with the common functions that links the *Virtualization Resource Layer* with the *Simulation Service Layer*. This layer includes three types of middleware to implement resource management, service management, and collaborative simulation, respectively.

The resource management middleware is used to manage the virtualized resource templates pool as well as the physical resources. It takes charge of allocating resources dynamically according to the scheduling commands issued from the upper layer. The distributed and heterogeneous resources are under control of this middleware and the real-time running status can be monitored.

The service management middleware acts as a service container to support unified service description, registration, discovery, match, composition, and remote call. This middleware shields the complexity caused by distribution and heterogeneity, and makes the functions of the resources independent from specific infrastructure.

The collaborative simulation middleware offers support for run-time simulation process management. This middleware serves as a special service-oriented RTI that is responsible for maintaining simulation run-time status, allocating data in federations and controlling the synchronization of multiple tasks.

4.3. Simulation Service Layer

The *Simulation Service Layer* is the core functional component to provide frequently-used services supporting simulation applications. The services are divided into three categories: simulation application development service, simulation run-time service, and simulation application service.

The simulation application development service is used to design and customize simulation applications with three tools. The resource virtualization tool is used to encapsulate simulation resources into virtualized templates, thus the corresponding physical resources can be managed through the exposed interfaces. The service encapsulation tool is used to package the functional interfaces of the simulation resources into standard services, and this tool provides a development environment for users to customize the domain-specific services. The high-level modeling tools gives support for users to complete high-level modeling work of simulation tasks with interactive visual tools.

The simulation run-time service is responsible for the run-time process management. There are four types of services supporting run-time simulation. The discovery & match module is used to search the suitable services and resources in response to simulation requests. Another module is responsible for establishing the virtualized simulation environment dynamically meeting the needs of simulation tasks, and deploying the resources automatically. The collaborative resource scheduling module is used to parse the description of coordinated tasks, manage the time steps of concurrent tasks, and dispatch the services and resources to complete the simulation tasks.

The simulation application service provides the support of common functions that simulation applications need. The module of virtual UI is used to generate personalized virtual desktop interfaces. Users can access CSP and interact with applications through virtual UI by network browsers. The remote visualization module is responsible for rendering visual graphics that show the live image of simulation task progress. The module of batch job scheduling is used to manage the task queue and schedule the tasks. The license scheduling module is used to manage the licenses of commercial software, including license reservation, dispatch and recovery. The accounting & charging module is used to account the simulation resource usage according to the rate set by the resource provider and charge the users. The module of user permission management provides mechanism for user management, such as account maintenance, identity authentication, role assignment, and access control.

4.4. Ubiquitous Portal Layer

The *Ubiquitous Portal Layer* provides interfaces supporting ubiquitous UI for users to access CSP services. This layer offers interface adapter for interactive terminal devices including PC, pad computer, and smart mobile phone, so users can acquire simulation services without time and space constrains.

The CSP portals include simulation service portal, virtual desktop portal, batch job processing portal, and collaborative simulation task portal. The simulation service portal is the homepage where users can search for simulation services and customize their own simulation applications. To better support typical simulation application patterns, three kinds of portal mentioned above are offered on the homepage.

In the virtual desktop portal, users can customize preferred system environment including hardware and software, then CSP find the matched virtualized templates and instantiate the virtual machines. Finally CSP returns the remote virtual UI to users for interaction.

In the batch job processing portal, users submit batch job files to CSP, then CSP parses the file and find the needed simulation services and resources to deploy simulation environment. Once the environment is ready, the tasks are uploaded to the virtual machines, and CSP returns result to users when the job is done.

In the collaborative simulation task portal, users can establish the high-level model of simulation tasks. The formal description of the model is parsed by CSP, then CSP discover the needed services and resources to create simulation federation. In the simulation process, users can monitor the run-time status through the portal. In addition, users can start, pause, continue, and stop the simulation progress in the portal.

5. KEY TECHNOLOGIES IN CLOUD SIMULATION PLATFORM

5.1. Simulation Resource Virtualization and On-demand Use

To support high efficient sharing and flexible use of large-scale simulation resources, virtualization is one of the key techniques (Lei *et al.* 2011). Virtualization technology can decouple simulation applications from needed simulation resources, thereby allowing the fine-grained resources to integrate on demand flexibly.

The key issues in simulation resource virtualization include simulation resource taxonomy, unified formal description of simulation resource, virtualized simulation resource template, composition verification, management of large-scale virtualized resource pool, mapping approach from physical simulation resource to virtualized resource, and remote management of simulation resource status.

5.2. Service-oriented Simulation Resource Publication and Intelligent Match

Service computing technology plays a important role in CSP. The unified service encapsulation of simulation resource make it possible to shield the complexity derived from the distributed and heterogeneous resources. Moreover, standard service interfaces can implement effective inter-operability in collaborative simulation based on standard protocols. To realize efficient and intelligent search for simulation resources, semantics-based service match technique (Martin *et al.* 2007) is essential to CSP.

The key issues include formal description of service of simulation resource, semantics description of simulation service, semantic service encapsulation approach, simulation service publication, Ontology-based service match method, and semantic composition of simulation service.

5.3. Simulation System Dynamically Construction and Deployment

One of the advantages of CSP is the capability of constructing a simulation environment on demand dynamically and rapidly. This technique facilitates the time-consuming deployment work for complex simulation system to a large degree. In addition, it can optimize the utilization of simulation resources in run-time simulation along with the fluctuating resource needs.

The key issues include formal description of simulation task requirement, automatic parsing of resource requirement, intelligent match of virtualized resource template, virtualized resource composition optimization, automatic deployment of simulation resource, and virtualized simulation resource instantiation and run-time management.

5.4. Fault Tolerance and Migration in Run-time Simulation

One of the most important targets of CSP is to achieve high reliability, because a variety of failures and errors are inevitable in collaborative simulation progress over unstable networks. CSP should have the ability of fault tolerance to ensure the simulation tasks proceed at the lowest cost once failures occurred. Migration technique offers a mechanism that enables fault tolerance in run-time simulation.

The key issues include run-time simulation monitoring, risk evaluation and fault prediction, run-time simulation failure detection, optimal selection for migration target, migration cost evaluation, live migration in run-time simulation, and post-migration simulation tasks synchronization.

5.5. Utilization Accounting

The distinguishing characteristic of CSP different from other networked M&S platform, such as Grid simulation platform, is that CSP gives support for business transaction between simulation resource consumers and providers. And the transaction billing accords with the actual usage of simulation resources, just like electricity utility charging. The simulation resource utilization accounting technology is the key to accomplish the target.

The key issues include multiple-level accounting model of simulation resource utilization, fine-grained simulation resource utilization statistics, transaction and rate standard management, and user account security management.

5.6. Ubiquitous UI and Remote Virtual Interface

User operating environment is no longer confined to PC desktop in CSP. CSP provides more powerful support for simulation in mobile environments relying on ubiquitous computing and virtualization technology. Users can access CSP by using mobile terminals such as pad computer and smart phone, and customize their virtual UIs to implement remote interaction.

The key issues include ubiquitous terminal adapter standard, interaction context perception and processing, adaptive visualization in small UIs, personalized portal customization, virtual desktop customization and automatic building, and remote interaction and visualization in virtual UIs.

6. CONCLUSION

Networked M&S platform gives powerful support for collaborative simulation applications by means of integrating simulation resources over networks. Facing the new challenge of increasing difficulty in making use of massive simulation resources in distributed and heterogeneous network environment, users need a way to leverage the rich simulation resources to build complex simulation applications rapidly and simply. This paper introduced the idea of Cloud Computing into networked M&S platform and discussed the key issues in Cloud Simulation Platform. We discussed the operating principle of Cloud Simulation model, CSP architecture, and the key technologies in CSP. The proposed CSP provides a promising approach that users can get simulation services on demand and use simulation resources in a more efficient, transparent, and ubiquitous way. And this paper provides a research map for future research on CSP. We are developing a CSP prototype now and we plan to establish a M&S application of aircraft design on CSP in the future.

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