A Novel Federated Cloud Simulation Framework and its Key Techniques

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Abstract— **In increasingly saturated markets, innovation and product development are essential conditions for the sale of products. Adopting collaborative product development makes full use of several independent systems, and enhances their abilities at the same time. But as a matter of fact, collaborative product development (CPD) systems are complicated and comprise various systems for collaborative design, simulation, and optimization. It involves processes like CAD modeling, simulation and optimization, requires data and information like CAD digital models, CAE analysis and optimization results from distributed sources.**

When simulation is added into a collaborative product development environment, there always exist several subsystems in the same environment with independent design goals. These subsystems may follow different design or management rules in their respective engineering fields.

As a well-known modeling and integration standard of distributed simulation, HLA (High level Architecture) has been successfully adopted in various simulation systems, and been extended to some other research areas. HLA defines a federation as a named set of federate applications and a common Federation Object Model (FOM) that are used as a whole to achieve some specific objectives. Federates exist within a federation in the form of data abstraction, and federated integration keeps well the independency of its participants. This kind of integration is more suitable for and is widely used in distributed and loosely coupled simulation integration. The owner of each participant does not need to worry about exposing too much private information. The federation only defines the interesting domains for given objectives and the rules of their interoperations. It is a real loosely coupled integration solution. Within a federation, subsystems collaborate in an indirect way so that the context of interoperation can be taken into consideration.

At the same time, due to their distributed and multi-participant nature of CPD systems, web services are widely used to provide interoperation functions and cloud computing is a reasonable architecture choice. As one kind of cloud computing, cloud simulation is a model for enabling convenient, on-demand network access to a shared pool of configurable simulation resources (e.g. computers, simulators, physical equipment, simulation tools, platforms, open-resource code, models and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability in which simulation resources, including hardware, software, and different kind of models, are available to provide as services. However, architecture of cloud simulation varies according to different application objectives.

This paper proposes a novel federated cloud simulation framework, in which cloud computing technique is adopted to extend HLA. This framework extends HLA into two levels: resource management federation level and application federation level. Concerned key techniques are presented, including HLA compatible access, virtual resources management and simulation task automatic generation. This framework has great potential to improve the efficiency and availability of distributed collaborative simulations, and enhance the applicability and flexibility of collaborative product development systems (Figure 1).

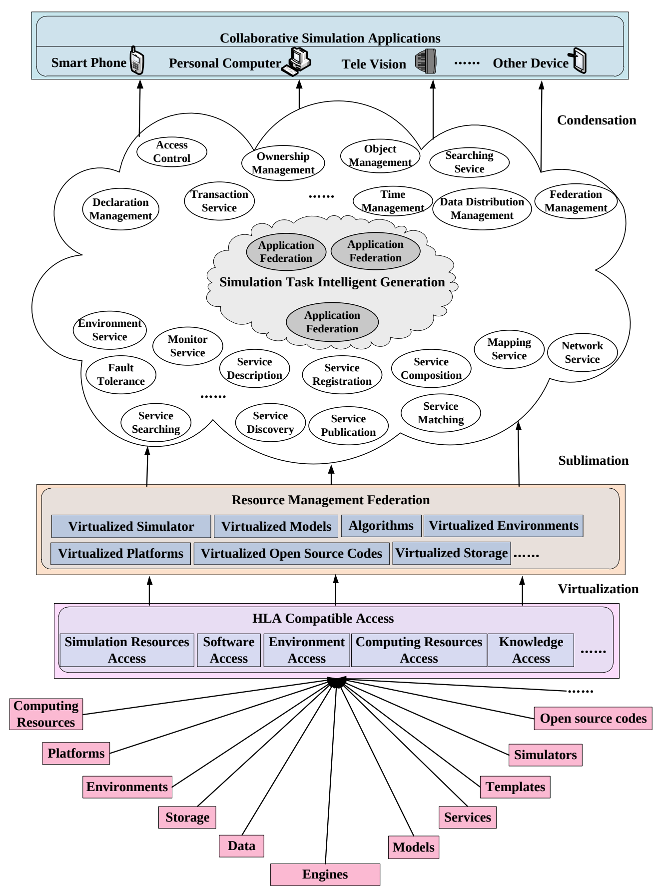

Figure1 **Federated framework for cloud simulation**

In this framework, there are three processes related to this federated framework: virtualization turns related simulation resources into virtualized resources; sublimation organizes virtualized simulation resources in a *cloud* manner; and condensation maps services in federation based cloud into application scenarios.

Before virtualization, an HLA compatible access system collects simulation related resources to supporting future applications. These resources include computing resources, platforms, environments, storage, data, engines, models, services, templates simulators and open source codes. Computing resources reflects computation execution and supporting capability, such as CPU power. Engines are basic software supporting some given operations, such as searching engine supports service searching. Services are simulation related services, which can be divided into two categories, basic services and value-added services. Basic simulation services are indispensable services for a successful simulation application, such as time advance service, data distribution service, and ownership service. Value-added services goes with basic services and improves the quality of basic services, such as service searching, service discovery, service composition, and service matching. Environments reflects different platforms on which applications run, such as Windows, Linux, Symbian, Windows Mobile, Android, Palm OS, BlackBerry and Snow Leopard. Data gives history records to evaluate coming simulation transactions. Data templates describe regulated registration or publication formats, and sometimes service composition needs process templates to introduce some basic skeletons. Models are essential abstractions of some entities or processes.

As a virtual resources pool, resource management federation saves information and access methods of resources gathered by HLA compatible access system. The virtualized resources include virtualized simulator, virtualized models, algorithms, virtualized environments, virtualized platforms, virtualized open source codes, and virtualized storage.

Federated framework for cloud simulation is composed of a set of well-organized services and one kernel, simulation task intelligent generation system. The services include resources related services and application related services. Resources related services searching, organizing, manipulating and access virtualized resources in the form of services, such as environment service, monitor service, fault tolerance service, mapping service, network service, service description, service searching, service discovery, service registration, service publication, service composition and service matching. Application related services serves simulation applications in a more direct manner, which include declaration management service, user access control, transaction service, ownership management service, object management service, content searching service, time management service, data distribution management service and federation management service. The simulation task intelligent generation system provides (semi)automatic simulation task creation functions to support different kinds of simulation tasks.

Collaborative simulation applications can be performed on any device that can access network. These applications include collaborative design evaluation, collaborative simulation based optimization and collaborative training.

The key techniques of proposed federated framework for cloud simulation include HLA compatible access technique, virtual resource management technique, simulation task automatic generation technique, simulation task dynamic adjustment technique and ubiquitous computing.

As an HLA compatible access technique HLA enabled template is designed to facilitate transform actions of commercial simulation models. In this HLA enabled template, DiyModel class, which is user defined model class, is a kernel part. DiyModel encapsulated the virtual variable and event objects so that user program can exchange data with other distributed models without concerning about the data mapping process.

As a virtual resource management technique, resource management federation (RMF) organizes, manipulates and stores simulation related resources in a layered federation manner. Its main ides is that every computer (node) that joins collaborative simulation and every node's resource are declared as the members of "resource pool", and RMF is responsible for the management of simulation resources.

Application federation is the result of simulation task automatic generation technique and simulation task dynamic adjustment technique. It fulfills different kinds of simulation requirements in a flexible manner. This paper chooses a FCA like method to construct SOM ontology from scratches, and proposes a deterministic finite state automaton is built to automatically transform SOM file into an ontology based SOM. Compared with existing ontology construction method, this method is easier to apply in HLA based CPD systems. It also maximally reuses existing knowledge. For ontology based FOM auto generation, this paper introduces ontology fusion method, which includes three basic steps. Ontology mapping employs a top-down mechanism to explore all bridge relations between two terms from different ontologies on the base of bridge axioms and deduction rules. Ontology alignment adopts a bottom-up mechanism to discover implicit bridge relations between two terms from different domain ontologies on the base of equivalent inference. And ontology merging generates new ontology from founded equivalent bridge relation. It adopts an axiom-based reasoning ontology fusion strategy, and takes heavy-weighted ontologies into consideration. It can find all the explicit and derived inter-ontology relations. As to collaboration task dynamic adjustment, this paper employs ontology maintenance to dynamically adjust ontology based FOMs.

Ubiquitous computing enables end users access federated framework for cloud simulation on any device that can access Internet. To be brief, this part is not included in this paper.

The proposed federation-based cloud simulation framework extends HLA into two levels: resource management federation level and application federation level. The OMT of an application federation in HLA can be configured dynamically by RMF, the share and maintenance of distributed and heterogeneous simulation models and physical nodes can be implemented as services. It aims particularly in short-term-stable multi-objective collaboration under incomplete coverage condition of control domain and trust domain for heterogeneous simulation systems.

The further work includes some management functions of the framework, such as fault tolerance, intelligent update, consistent sustainment, and so on.