Computer-based Design in Engineering through Simulation using Cloud Computing

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***Abstract* - Cloud computing offers features such as resource pooling, comprehensive network access, rapid elasticity, on-demand self-service, and measured services that result in new business trade. Computer-based design provides foresights that can be converted into methods, which can then be used to implement a product design idea by integrating capabilities for intelligent information support and group decision, thereby exploiting a common enterprise network model and knowledge interface through shared technologies. The processing power that is needed to simulate designs in real world is one of the challenges in computer-based design. Cloud-based simulators offer new possibilities to control "network effect" by depending on access to large groups of computational resources that are available in "cloud" to overcome challenges such as limited processing power and information storage capability. In this study, we focus on computer-based design in engineering through simulation using cloud computing.**

***Keywords*— Cloud computing, computer-based design, simulation, prototype, technology.**

I. INTRODUCTION

Cloud computing has proven to be a disruptive technology in information technology (IT) application field that clouts existing technologies such as utility and parallel computing [1]. It increases demand on engineering systems with new market trends. With rapid development of Internet technologies within an Internet-based environment, computer-based design appears to be a multi paradigm for sharing information, hardware, and software [2]. Adapted from original cloud computing paradigm and introduced into computer-aided product development fields, cloud-based design is gaining attention from academia to industry. It refers to a service-oriented networked product development model wherein service consumers are permitted to configure, select, and use customized product realization resources and services that range from computer-aided engineering (CAE) software to reconfigurable manufacturing systems, which is achieved via several service synergetic multidisciplinary integration components such as infrastructure-, platform-, software-, storage-, database-, hardware-, process-, and integration-as-a-service [3]. To understand cloud-based design and manufacturing breadth, depth, and opportunities as a development paradigm for distributed and collaborative product development [4–6], two counterparts, i.e., cloud-based design (CBD) and cloud-based manufacturing (CBM), need to be discussed.

In distributed and collaborative environments, CBD implies a networked design model that controls cloud computing, service-oriented architecture, Web 2.0, and semantic web technologies to maintain cloud-based engineering design services [7, 4]. A CBD system must include the following prerequisites: it must be cloud-based computing, universally quantifiable from mobile devices, and manage complex information flow. Nonetheless, even though an ideal CBD system does not exist, some companies develop and provide certain essential components for CBD systems such as Autodesk offers a cloud-based platform, namely Autodesk 123D [8], which lets users to convert photographs of artifacts into three-dimensional (3D) models, create or edit 3D models, and generate related prototypes with remote 3D printers accessed via the Internet. Autodesk also offers a cloud-based mobile application, i.e., AutoCAD 360 [9], which lets design engineers to view, edit, and share AutoCAD digital files via smartphones. A social networking site, i.e., 100kGarages.com [10], allows a customer to search for proficient and competent design service providers by providing consumers with each alternative service provider's profile page, which includes information such as a service provider's specialties and sample designs.

In modern engineering computer-based design based on cloud computing, scope is not only restricted to regular cloud computing but also goes beyond infrastructures such as design, manufacturing, and supervision where users can configure, select, and use customized information,

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resources, and services for systems' achievement and product operation [11]. In addition, an end user is aware about physical resource location and accessible devices. Furthermore, it facilitates users to develop, deploy, and manage their designs and applications.

Global engineering software market has been subdivided as follows:

Engineering software market based on software type

- Computer-aided design (CAD) software
- Computer-aided engineering (CAE) software
- Computer-aided manufacturing (CAM) software
- Architecture, engineering, and construction (AEC) software
- Electronic design automation (EDA) software

Engineering software market based on applications

- Design automation
- Plant design
- Product design and testing
- Drafting and 3D modeling
- Others (i.e., 3D printing, enterprise resource planning, project management, and knowledge management).

II. EXISTING SYSTEM

According to the National Institute of Standards and Technology [12], cloud computing model comprises five indispensable characteristics, i.e., resource pooling, comprehensive network access, rapid elasticity, on-demand self-service, and measured services, and three service models, i.e., software-as-a-service (SaaS), platform-as-a-service (PaaS), and infrastructure-as-a-service (IaaS). Moreover, there are three main deployment models, i.e., private, public, and community clouds. Hybrid cloud—the fourth deployment model—consist of at least two distinct deployment models. According to literature, the characteristics of cloud computing are

- On-demand self-service: A consumer can separately provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider.

- Comprehensive network access: Proficiencies are available over the network and accessed via standard mechanisms that promote the use of thin or thick client platforms such as mobile phones, tablets, laptops, and workstations.

- Resource pooling: A provider's computing resources are combined to serve multiple consumers using a multitenant model with different physical and virtual resources dynamically allocated and reallocated as per consumer demands. There is an intellect of location independence given that a customer has no knowledge about the exact location of the provided resources but can specify the exact location at a higher abstraction level (e.g., country, state, or datacenter). Storage, processing, memory, and network bandwidth are some of the examples of resources.

- Rapid elasticity: Capabilities can be provisioned elastically and released to scale rapidly internally and externally corresponding with demand. To a consumer, capabilities available for provisioning appear to be unlimited and can be quantitatively usurped at any time.

- Measured services: Cloud systems inevitably control as well as optimize resource use by controlling a metering capability at some abstraction level appropriate to a service type. Resource use can be monitored, controlled, and reported, which provides transparency for a provider as well as consumer.

Cloud has been used for ages in engineering to epitomize networks. Lately, the term has been used for describing innovative applications that rely on web. Considering all cloud features, application developers began vast development by implementing this technology.

III. ENGINEERING THROUGH SIMULATION

Simulation is defined as the imitation of a real-world process over time [13]. First, the act of simulating something requires a model development that signifies the key characteristics of selected physical or abstract systems. The model represents the system itself, whereas simulation represents system operation over time. Simulation is used in many contexts such as simulation of technology for performance optimization, safety engineering, testing, training, education, and video games. Computer experiments are used to study simulation models over and over again. In addition, simulation is used with scientific modeling of natural or human systems to obtain insights into their functioning [14]. Simulation can be used to demonstrate real effects of alternative conditions and course of actions. It is also used when a real system cannot be affianced because it may be inaccessible, dangerous, or intolerable to engage; designed but not yet built; or simply not exist [15]. A computer simulation is an attempt to model a hypothetical situation on a computer to see how a system

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works. By changing simulation variables, predictions can be made about a system behavior. Simulation is a tool to investigate a system behavior that is under study [13].

In civilian and military personnel training, simulation is regularly used because it is extremely dangerous to let trainees use real tools, thereby teaching them important lessons in a "safe" virtual environment. The advantage of using simulation is it allows errors during training leading to no damage or injury, and so, it is widely used for educational purpose.

The disadvantages of simulation include valid source information attainment concerning a pertinent key characteristic and behavior selection, shortening calculations and expectations inside simulation, and reliability and rationality of simulation outcomes. Processes and conventions for model verification and validation are an ongoing field of academic study, modification, and research and development in simulations technology, especially in computer simulation.

A given model prototype is desired owing to complex parameters even it is time consuming and pricey. Taking into consideration cost and time factor, simulators are a good choice for research scholars and engineers and are the best tool for computer-based design. Simulators that use massive database and arithmetical process require gigaflop or teraflop processing power, which is not easy to obtain from standard computers. The solution to this problem is super or cluster computers that use parallel computing essentials. A cluster-based super computer is simple to build but requires proper planning and testing. Lack of skills and training makes it difficult to build a super computer. Considering an average load during a super computer's lifespan, organizations are disinterested to invest. Therefore, simulators, which are an important tool for computer-based design for academicians, researchers, designers, and manufacturers, need to be dependent on third-party solution providers, which provide opportunities in cloud technology to use its scalability and elasticity for developing cloud-based simulators. 24 × 7 availability and pay-per-use model are the center of attraction, which attract many customers to use cloud-based simulators.

Middle market manufacturers could design products better in terms of quality and faster in terms of speed if they had access to process more simulations in their design cycle.

Assume a bicycle manufacturer who wants to assess frame stress on multiple geometries or a consulting shop that is leased to simulate complex hydrodynamics on a marine vessel. Such users need access to a simulation environment that is of a million dollar but for only a short time period.

Simulation can enhance manufacturing and engineering companies' competitive position by reducing their costs and providing well-organized development, production, procurement, and logistics.

Even though simulation solutions are used in engineering and manufacturing extensively, small- and medium-sized enterprises (SMEs) face difficulties to use advanced tools. To use simulation software, engineering and manufacturing SMEs need to

- Purchase simulation software licenses
- Purchase cutting-edge hardware to run simulations
- Require system engineering to establish and operate hardware, operating systems (OS), and simulation software
- Require competent staff to use simulation software.

The grouping of prerequisites as indicated above makes simulation software extensive to use and expensive too. Therefore, many SMEs fail to use simulations, and so, cloud computing provides a solution. Clouds are described by on-demand self-service, comprehensive network access, resource pooling, rapid elasticity, and measured services. However, pure cloud infrastructure services solve hardware capital expenditure problem, whereas other problems still persist. Our cloud solution is based on a one-stop-shop setup that helps to solve all problems. Thus, SMEs can completely concentrate on their businesses rather than spending comprehensive efforts on IT-related aspects.

Administering simulation applications can be performed at different levels that are complementary and directed at different types of use cases. As end user requirements differ, there are numerous ways to access various services. The respective service pillars are summarized below:

- IaaS provides hardware and OS building blocks such as virtual machines, storage, and network. Since simulations require basic computer infrastructure, they may require services out of cloud. The cloud can also provide huge computing and data resources on demand that could accelerate complex simulation tasks that require high performance computing capabilities.
- PaaS provides countless programming and deployment frameworks. Moreover, supplementary features, such as distribution, messaging, monitoring, databases, and workflows, are provided.
- SaaS provides cloud services at the application level (i.e., simulation applications), which can be applied to any software.

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IV. CASE STUDY

A) Dezineforce: An engineering design optimization service

Electronic wind tunnel simulations permit designers to analyze a component's performance without building a prototype. Computers let designers to perform the abovementioned activity but involve the use of expensive supercomputers, which require experts for maintenance. For example, the Renault Sport Formula One Team invested £350m in a computational aerodynamics research center to run race simulations on car designs.

Placing computational processing power in cloud reduces operating cost. A hosted engineering design optimization service was developed by Southampton start-up dezineforce that provides users access to an integrated suite of tools for analyzing design behaviour and performing methodical search. The company revealed the power of SaaS in engineering. Of late, it demonstrated a wind farm optimization simulation with Intelligent Fluid Solutions Ltd. that uses dezineforce service to simulate optimal position for wind turbines on a wind farm. The service allowed Intelligent Fluid Solutions Ltd. to run the simulation as a cloud service, without any investment needed in a high-performance computing cluster.

An in-house high-performance computing cluster will mostly be idle during discreet periods. High-performance computing in cloud is a better alternative because users pay for a computational resource only when they need. Furthermore, the company says its IT infrastructure has been established to run, schedule, and secure multiple engineering simulations in cloud [16].

B) CloudSME: A cloud-based simulation platform for manufacturing and engineering

CloudSME develops a cloud-based, one-stop-shop solution that provides a scalable platform for small- and large-scale simulations and enables wider response of simulation technologies. CloudSME simulation platform will support end user SMEs to use customized simulation applications in the form of SaaS-based provision. Moreover, simulation software service providers and consulting companies will be able to access a PaaS solution to rapidly assemble custom simulation solutions in cloud for their clients. CloudSME simulation platform will be built on current and established technologies that will help to deliver quick results.

In the one-stop-shop setup targeted by CloudSME, it is considered that end users would simply enjoy running a simulation, and they have no demand for competency on underlying infrastructure and platform services. These users normally use a front-end application with a graphical user interface (GUI). CloudSME end users will use GUI and front-end applications or a web service employing SaaS [17].

Fig. 1 CloudSME

C) Ciespace: A new cloud-based computational fluid dynamics simulation toolkit

Ciespace (2007) was established by Dr. Kenji Shimada—Professor of Mechanical Engineering at Carnegie Mellon University—to offer mesh generation technology to market, and the company has now introduced its first commercial cloud-based simulation that provides computational fluid dynamics (CFD) space, leading to a variety of benefits such as access to virtually unrestrained CPU capability, cash-in-hand pricing, and supreme parallel processing providing shorter product design cycles. Ciespace has developed an engineering simulation workflow engine that exemplifies the usual product lifecycle management or product data management logic for partnership and frivolous project management.

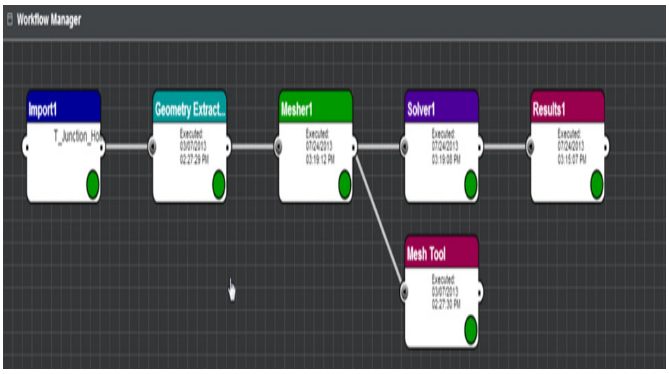

Fig. 2 Snapshot of workflow manager in Ciespace

Ciespace aims to leverage the partnership environment a platform for other simulation tools (i.e., commercial and open source). To make such a platform useful to attract

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users and developers from inception, they needed to build their own simulation tool, i.e., OpenFOAM.

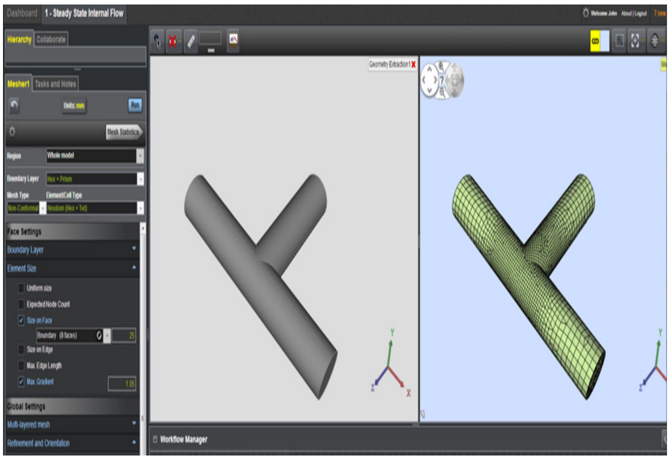

Fig. 3 Snapshot of steady-state internal flow in Ciespace

OpenFOAM provides adequate value to meet many engineering use case requirements. However, it is not the best simulation tool. There are certain limitations such as its collaboration workflow and other aspects related to cloud-based architecture [18].

V. CONCLUSION

This paper presented CBD and the importance of cloud computing for supporting CBD. From thorough examination, it was recognized that simulators are one of the best tools for academicians, researchers, and manufactures for their project designs and analysis rather than physical prototype development for testing. It also highlighted the importance of cloud computing-based simulators by taking into account its characteristics, which is one of the methods in engineering to design and analyze without huge investment.

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