Development of a Web-based MDO Framework for Design and Analysis Integration

Chang-Kyu Park, Member, KIMICS

Abstract—The rapid progress of the Internet and network is affecting the engineering design environment as well as business that use Web technologies to enhance their competitive edge. In product development, experts and organization who take part in the design process are often geographically dispersed. Furthermore, different divisions and business often have heterogeneous CAD/CAE systems and methods for expressing product data, and addressing this heterogeneity creates additional costs and increases development time. Managing distributed CAD, CAE and other related systems in an organic and holistic manner from the initial stages of product development is imperative to ensure successful collaboration in the design process. Therefore, this study suggests a Web-based MDO framework to support interfacing and collective use of design and analysis tools.

Index Terms—Web technology, MDO (Multidisciplinary Design Optimization), CAD/CAE systems, Design process, CAE process

I. INTRODUCTION

Research on design optimization [1] has progressed significantly since its introduction to the design field. Due to the limited practical value of research outcomes, however, research has not been fully applied in industries either at home or abroad. Optimization is traditionally performed by binding mathematical expressions that define objective function, design variables, and boundary conditions into a comprehensive expression, and connecting the result with analytical software. Multidisciplinary Design Optimization (MDO) is a method that efficiently designs large-scale systems and deliverables that require multiple functions. This design technique, which was vigorously developed by the aviation industry of the U.S., has been based on a single optimization algorithm since the early 1990s, and its usefulness has been widely recognized of late. MDO is a group-oriented technique that creates effective outcomes when experts from multiple disciplines come together to conduct organic and systematic research by combining integrated design, optimization design, and CAD/CAE interface technology. Unlike the case of optimization of a single field, MDO involves analyses of various areas that interface in a complex manner. The enhancement of MDO’s efficiency requires cooperation among experts in the fields of design optimization, engineering analysis, CAD/CAE interface technology, and computing infrastructure. To facilitate efficient composition of optimization issues and generate results in engineering design, it is essential to have information technology or computing infrastructure in place. However, the existing research on MDO has centered on algorithms and analyses, which have problems of their own.

In product development, experts and organizations who take part in the design process are often geographically dispersed. Furthermore, different divisions and businesses often have heterogeneous CAD/CAE systems and methods for expressing product data, and addressing this heterogeneity creates additional costs and lengthens development time. Organic and holistic management of distributed CAD [2], CAE, and other related systems from the initial stages of product development is imperative to ensure successful collaboration in the design process. At the same time, communication between each site must also be facilitated.

This study integrates design (CAD) and analysis (CAE) information to manage MDO more effectively and to support interfacing and the collective use of design and analysis tools. We use the workflow [3, 4 and 5] concept (one of the most important elements of today’s e-business) to integrate, automate, and manage product development processes and we verify the effectiveness of a system by examining an example of engineering design. Because product design and development are conducted through collaboration or the division of labor between multiple departments or organizations (rather than by a single department or organization), a web-based environment is deployed to enable the practical use of advanced optimization techniques that can maximize the autonomy of individual departments or corporations and enhance the entire design performance. This ensures that design, analysis, and optimization processes can be performed at any time and in any place using standard communication protocols available through web services and web browsers, which are global open protocols.

Manuscript received August 12, 2010; revised September 7, 2010; accepted September 10, 2010.

Chang-Kyu Park is with the Department of Ship and Ocean, VISION University of Jeonju, Jeombuk, 560-760, Korea (Email: ckpark@jvision.ac.kr)
II. RELATED TECHNOLOGIES

2.1 Workflow and Workflow Management System

The corporate environment has experienced many recent changes due to the dramatic development of network and computing environments. In particular, the Internet has enjoyed explosive popularity as networks have expanded, giving rise to the term “e-business” and facilitating active internal and external interactions among corporations and customers. Increasing attention is being given to workflow, which is a core element of the technology behind e-business. According to the Workflow Management Coalition (WFMC, http://www.wfmc.org), a non-profit organization established in 1993 to set workflow standards, the term refers to work processes that are executed and managed automatically by a computer. The WFMC also defines a workflow management system (WFMS) as a software system that specifies a workflow, while defining, executing, and managing a work process accordingly [4]. In other words, the conceptual definition of workflow is a business operating system of a corporation that improves processes and manages three key components of an organization: people, resources, and processes. A WFMS is also the latest information technology that ensures the automation and integration of work processes within and between businesses.

2.2 Distributed Design

From a computing perspective, a distributed system collectively refers to a group that is connected by a network in which hardware, software, data, and users join together to accomplish a particular goal [6]. Many research outcomes in the general engineering field are published on distributed design, particularly by the Georgia Institute of Technology. Choi et al. define distributed design as a framework that helps geographically dispersed engineers who have different objectives, knowledge, experiences, tools, and resources, to make decisions simultaneously [7]. Zhiqiang et al. define it as a tool that allows design specialists, whose information, data, and models are dispersed over a network, to maximize the use of all available resources, whether those resources are local or remote [8]. Panchal defines it as a tool to integrate and mobilize geographically dispersed designers and assets with intrinsically heterogeneous software characteristics at the design stage [9]. In the engineering field, distributed design can be defined as a design paradigm that enables all engineers and managers of each company and department involved in physically and geographically dispersed design to share information and knowledge, thereby enabling them to make efficient and rapid decisions.

2.3 Web Services

Web services are a standard technology of next-generation web applications that enable data sharing between applications by going through firewalls regardless of platform, development language, and communication protocol. Web services use standardization technologies including HTTP, XML, SOAP, and WSDL to provide distributed services as recommended by the World Wide Web Consortium (W3C). Existing services offered through the web provide users with their required information by finding it on the web according to interactions between web browsers and users. In contrast, web services allow applications to provide services to and share data with one another. Existing distributed systems lack interoperability due to the use of different platforms, development languages, and communication protocols, whereas web services can be developed and executed independent of the platform and development language. This ensures interoperability among heterogeneous systems.

III. SYSTEM OVERVIEW

The system introduced in this study is developed from an enterprise perspective to allow those inside and outside of a company, or anyone accessing a company’s server, to collaborate and share distributed design information with each other on a real-time basis. This is done through the use of a central web-based distributed design framework (WDF) execution server, which ensures sharing of various processes of a business via the Internet in Fig. 1.

![Fig. 1. WDF (Web-based Distributed Design Framework).](image-url)

Using this system, the manager first defines the processes of a project and draws up the flow of each task that involves CAD, CAE, and optimization. The manager then conducts process modeling to select
workers responsible for each task. A process is a concept that diagrams the flow of tasks for automation. The flow of tasks shows the details of each step of the task to help viewers understand what a task entails.

Fig. 2. Process modeling.

A process modeler is a form that is used to represent a process. A process consists of a Process Map that contains a complete picture of the process, Tasks or Activities that define tasks on that process map, Transitions that show the connection flow between tasks or activities, Operators that represent the combinative or divergent relationship between tasks or activities, and sub-processes. A process modeler is a tool that integrates all of the above elements and draws up processes in an organic manner.

When process modeling is complete, the manager then launches the project and informs the first worker of the defined process that the project has started. Each worker completes his or her assigned task consecutively based on the workflow specified by the manager in the process modeling stage in Fig. 2.

4.1 Problem definition

To validate the proposed method, stiffened plate example is taken as an example. It is found that the proposed method could overcome the bottleneck of CAD and CAE such as transferability of data, though CATIA is used at the moment. Besides, carrying out an optimization process during the CAE process is another essential part for the structural optimization process.

The objective in this design example is to minimize the volume of a stiffened plate that is 4000 mm long and 4000 mm wide, as shown in Fig. 3. The boundary condition of the stiffened plate is that of simple support, and a normal distributed load (P) of 0.09 Mpa is applied vertically to the plate. The design variables are Lw and Tw, which are the dimension of the stiffened material and the thickness of the plate, respectively. Formulas for optimization are given in Expressions (1) through (3) below.

\[
\begin{align*}
\text{Minimize} & \quad \text{Volume (Lw, Tw, Tp)} \\
\text{Find} & \quad \text{Lw, Tw, Tp} \\
\text{Subject to} & \quad g = \sigma - \sigma_a \leq 0; \text{ Stress} \\
\text{Where} & \quad 350 \leq \text{Lw} \leq 550, 10 \leq \text{Tw} \leq 20, 10 \leq \text{Tp} \leq 20
\end{align*}
\]

4.2 Process modeling

Prior to conducting the above example, process modeling, project (process) launch, CAD, CAE, and optimization are carried out. The manager first performs process modeling to define processes, as shown in Fig. 4. When process modeling is complete, the manager selects the workers responsible for each task. Next, the workers perform each task – CAD, CAE, and design optimization – as specified in the process modeling as shown in Fig. 5.
variables and then defines attributes to associate the configuration of the CATIA V5 model with the design variables. Finally, the worker specifies the initial values, types, and scales of the variables. After performing the task and selecting a CAD file stored on a database, the worker in charge of design enters data – element type, material property, boundary condition, and mesh – for the ANSYS analysis. Because many cases may occur for the method of data entry used for analysis, the system is configured to allow two types – UI and text – for user convenience. For a worker who handles optimization to perform his or her work in the same manner as in previous tasks, the worker needs to access a web portal server and carry out tasks to configure optimization.

Fig. 5. CAD, CAE and Optimization tasks for stiffened plate.

### 4.3 CAD, CAE and Optimization tasks

For CAD, the worker opens a CATIA V5 model. To perform design optimization, each worker defines design variables and then defines attributes to associate the configuration of the CATIA V5 model with the design variables. Finally, the worker specifies the initial values, types, and scales of the variables. After performing the task and selecting a CAD file stored on a database, the worker in charge of design enters data – element type, material property, boundary condition, and mesh – for the ANSYS analysis. Because many cases may occur for the method of data entry used for analysis, the system is configured to allow two types – UI and text – for user convenience. For a worker who handles optimization to perform his or her work in the same manner as in previous tasks, the worker needs to access a web portal server and carry out tasks to configure optimization.

Fig. 6. CAD task for stiffened plate.

Fig. 7. CAE task for stiffened plate.

First, the worker responsible for design and analysis selects the file stored on the database and chooses issues on which to perform optimization. The worker enters the objective function, design variables, and boundary conditions into the database. The system is set up to enable selection of the ANSYS version from ANSYS 7.0, ANSYS 7.1, ANSYS 8.1, and ANSYS 9.0. The final optimization results can be checked using either a graphic or text view.

![Graphic of optimization task](image)

Fig. 8. Optimization task for stiffened plate.

**V. CONCLUSIONS**

The design of multi-function, high-performance, multi-purpose, and valuable products requires multidisciplinary analysis and design that involve multiple engineering phenomena. In other words, it requires MDO technology, a systematic design automation technology that determines an optimal design in a balanced and organic manner by simultaneously accounting for various engineering principles, knowledge, and technology.
Although MDO technology has made significant progress since the early 1990s, its focus has been on analysis through algorithms and it has failed to properly reflect multidisciplinary analysis and design technologies that are bound to arise during product development. Thus, this study presents a MDO technique to integrate design, analysis, and optimization of the entire product development process based on workflow technology, which is the core technology of today's e-business. CAD, CAE, and optimization are implemented through web services that allow data to be shared between applications by going through firewalls regardless of platform, development language, and communication protocol.

The implementation also ensures that outcomes from all related processes are stored on the database. Stiffened plates are used as an example to verify the validity of the technique suggested in this study. This example shows that the challenges of data conversion between CAD and CAE can be overcome by using CATIA. While performing the optimization process, the study also confirms that CAE processes are an essential part of structural optimization. This study affirms that a process automation technique based on workflow can apply information technology to existing structural design and improve it in product development and design.

REFERENCES


---

**Chang-Kyu Park** received the Ph. D. degrees in Department of Naval Architecture and Ocean Engineering from Soul National University, Seoul, Korea, in 2007. From March, 2009, he has been the faculty of Department of Ship and Ocean, VISION University of Jeonju, Jeonbuk, Korea. His research interests include Web-based Network, CAD/CAE and Structural Design. He is a Member of the KIMICS, SNAK, COSEIK, KOSMEE, KOSME, KSOE and KSME.