Development of a Web-based Analysis Tool: A Preliminary Component for a Multidisciplinary Optimization Framework

K.F. Hulme and C. L. Bloebaum
Multidisciplinary Optimization and Design Engineering Laboratory (MODEL)
Department of Mechanical and Aerospace Engineering
State University of New York at Buffalo

ABSTRACT

It is desired to achieve a systematic approach to the integrated, concurrent design of products and their related processes, including manufacture and support. Many of the method development efforts in the field of Multidisciplinary Design Optimization (MDO) attempt to simplify the design of a large complex system by dividing the system into a series of smaller, simpler, and coupled subsystems[1]. Once the large system is decomposed, researchers are presently attempting to find methods for simplifying the analysis of the system, thus reducing the time and cost required to attain a converged design.

An MDO issue that is the focus of much research today is the concept of sequencing the coupled subsystems. Sequencing is a methodology that reorders the design tasks in a given system, to allow for maximum efficiency in the execution of the design. The efficiency of a system can be increased if certain problem-dependent parameters are minimized, such as CPU time, feedbacks, or crossovers. Another area of current research within the field of MDO is the concept of system reduction, through coupling suspension and elimination. The decomposition of a large system results in a series of smaller subsystems that are interrelated through couplings. Researchers are looking for means to identify couplings that are weak relative to others. These such weak couplings could be suspended for a portion of the system analysis, or eliminated outright[2].

From the previous paragraph, it is clear that a representative and efficient means of determining the feasibility and robustness of MDO methods is crucial. To this end, the authors have developed a computer tool, coded in Fortran, called CASCADE. CASCADE is an acronym which stands for Complex Application Simulator for the Creation of Analytical Design Equations[3]. CASCADE can be used to generate an analytical representation of a complex system. This representation consists of coupled algebraic equations of user-specified size. Thereafter, CASCADE employs a system analysis to iteratively converge the generated system representation. To add realism to the simulation, the process can be made to take place in a distributed environment, using Parallel Virtual Machine (PVM). After the "system" has converged, CASCADE employs a sensitivity analysis by using the Global Sensitivity Equations (GSE)[4] to compute the total derivatives of the output responses (behavior variables) with respect to the inputs (design variables). This sensitivity information could potentially be used to analyze coupling strengths for possible suspension/elimination, or in an optimization sensitivity analysis. CASCADE writes each converged behavior variable to a separate subroutine. Researchers could potentially experiment with these output-subroutines to further investigate coupling strength, sequencing issues, or convergence strategies. Lastly, CASCADE generates a complex optimization problem, whose variables are the design variables and behavior variables of the just-converged set of complex equations. The

optimization problem is then solved, using the GSE-computed derivatives, and the CONMIN optimizer. With the new converged design point, the cycle of system analysis, sensitivity analysis, and optimization repeats until a converged overall design is attained. Thereafter, the objective function and each constraint function of the randomly generated optimization problem are written to separate subroutines. Researchers could potentially experiment with alternate optimization strategies, using these subroutines along with a perturbation of the design variables.

A realistic Multidisciplinary analysis might include disciplinary members who are not collocated, or who have widely-varying computational resources. To expand CASCADE to address these issues, a user-friendly Graphical User Interface (GUI) has been developed. The interface was developed using Java, the "language of the Web". Rather than assign input options by answering to a text-based Fortran program, the user can generate a system (and related features) by assigning options using choice buttons and menus. As of March 5, 1997, the Java-based version of CASCADE is available via the MDO Test Suite at the NASA Langley Research Center. The URL is as follows:

http://fmad-www.larc.nasa.gov:80/mdob/mdo.test/

To reiterate, the CASCADE program has been developed as a tool for simulating the construction and convergence of an analytical representation of a complex system. A system representation of this form can be used to verify the feasibility of other MDO research concepts, including task sequencing (with the aid of De-MAID/GA[5]), and coupling suspension and elimination. In addition to these established research areas, other MDO-based research areas that are in preliminary design stages include optimal design visualization using Virtual Reality (VR) techniques, and the use of Response Surfaces as an alternative to total derivative computation. Although all of these compartments of MDO research are related, most have been developed independently by different researchers. Clearly, a computational platform is required to bond these concepts into one all-encompassing *MDO Framework*. Such a computer tool could be used to simulate a large portion of a product design cycle. Eventually, such a tool could be used by a design team in the hopes of both providing greater insight to the dynamics of a complex design problem, and reducing the time and cost of the entire design cycle.

First and foremost, such a framework should be heterogeneous in nature: usage should be possible on any computational platform. The Java programming language will hence by used, for the design of the users front-end (GUI). Ultra-fast transmission of data is required - the use of Asynchronous Transfer Mode (ATM) networking as an alternative to the standard Ethernet connection will be investigated. This framework should be distributed - usage is anticipated by members of design teams who may not be collocated, and who may have access to varying computers architectures. Hence, distributed computing via PVM will be further investigated.

The functionality of this framework will first be tested using a well-established "test bed" design problem and will later be extended to handle "real-world" multidisciplinary design problem. An MDO framework could be a vital tool for extending MDO-related system improvement strategies to new engineering fields. With the guidance of this framework, the authors hope to extend the concepts of MDO to aid in the design process of Roller Coasters.

REFERENCES

1. Sobieszczanski-Sobieski, J., "A Linear Decomposition Method for Optimization Problems - A Blueprint for Development." NASA Technical Memorandum 83248, 1982.

2. Bloebaum, C.L., "An Intelligent Decomposition Approach for Coupled Engineering Systems." Forth AIAA/USAF/NASA/OAI Symposium of Multidisciplinary Analysis and Optimization, Cleveland, OH September, 1992.

3. Hulme, K.F. and Bloebaum, C.L., "Development of a Multidisciplinary Design Optimization Test Simulator." Sixth AIAA/NASA/ISSMO Symposium on Multidisciplinary Analysis and Optimization, Bellevue, WA, September 1996.

4. Sobieszczanski-Sobieski, J., "The Sensitivity of Complex, Internally Coupled Systems." AIAA Journal, Volume 28, No. 2, pp. 153-160.

5. Rogers, J.L., "DeMAID/GA - An Enhanced Design Manager's Aid for Intelligent Decomposition." Sixth AIAA/NASA/ISSMO Symposium on Multidisciplinary Analysis and Optimization, Bellevue, WA, September, 1996.