

THE WORKFLOW CONSTRUCTION AND MANAGEMENT IN AERONAUTICAL MULTIDISCIPLINARY OPTIMIZATION

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Abstract

This paper introduces a workflow construction method in aeronautical multidisciplinary optimization running on Service-Oriented Architecture computing platform. It includes three steps: creating Computation Independent Model, transforming it into Platform Independent Model and building up Platform Specific Model. Using this method, several workflows running on the heterogeneous SOA platform have been established and managed efficiently and scientifically.

1 Introduction

With the increasing request of aircraft precisely design, the traditional optimization method based on single discipline and small scale of design variables can hardly fill the growing requirements of advanced aircraft, which leads attention to the aeronautical multidisciplinary optimization method with large scale of design variables. This kind of complex optimization process usually depends on a specialized platform and so that a Service-oriented Aeronautical Multidisciplinary Optimization System (SAMOS) for aircraft design is developed.

The SAMOS organizes the optimization process by integrating many applications and services in different scientific fields, which cooperate and interact to achieve the optimization object together. This complex

system of optimization has large information need to exchange while it is running, including control information, parameter information, data files, model information, dispatch information, etc. These information exchanging operations need to be well organized and managed to make the system into an entirety, which can automatically run without artificial intervention. To meet the requirements above, this paper introduces the concept of workflow into the SAMOS. The workflow can integrate various services and applications, and make sure that the aeronautical multidisciplinary optimization system is well controlled under a heterogeneous running environment that distributed in different locations.

2 Heterogeneous Environment of SAMOS

The SAMOS runs in a tri-layer heterogeneous environment for computing resource share and one of its typical architecture for noise and lift optimization is shown as the follow chart.

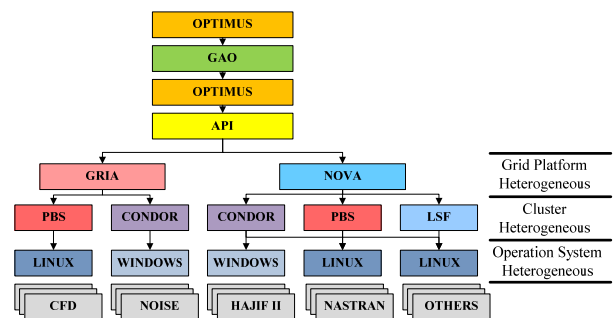


Fig. 1. SAMOS Heterogeneous Architecture

Such heterogeneous running environment is common in aviation enterprise's optimization applications, especially during the cooperation of many companies. For example, some enterprises run software on Windows but some run it on Linux; some enterprises use Condor[1] as the computing cluster management software, as well as LSF, OpenPBS, BOINC, etc. Moreover, when the cooperative enterprises are in different places, their computing resources are perhaps in different grid platforms. Generally, the heterogeneous environment contains three levels, including OS heterogeneity, cluster management software heterogeneity and grid platform heterogeneity, shown as Figure 2.

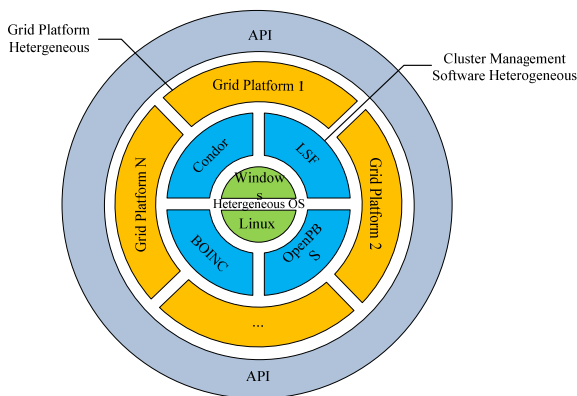


Fig. 2. Three Levels of Heterogeneity Environment in Resources Sharing Platform

There are different ways of shielding heterogeneous environment to adapt various situations. As following: shield heterogeneous OS by means of cluster management software; shield different cluster management software through Grid platform; shield heterogeneous Grid platforms by API.

To control and manage the optimization system running in heterogeneous environment, a workflow is also needed as a dispatcher of all information and data. It implements computing resource share through the instruction stream and the data flow witch dispatched by the workflow engine. The script files and parameter

files are used as the carrier of instructions. The engine sends instructions to each layer of the platform and then waits for the accomplishment of the applications and services with the block way. The carrier of data is the files such as finite element model files, result files, intermediate files and job packages, etc. Meanwhile, the instructions sent by workflow engine are received by relevant layers of SAMOS, altered and forwarded according to the special requirements to make them can fit the heterogeneous running environment.

3 Workflow Construction

“Workflow” comes from manufacturing industry and office automation domain. It can execute and manage enterprise's production process automatically with the help of computer technology. The first international organization for standardization of workflow, Workflow Management Coalition, has defined workflow as the computerized facilitation or automation of a business process, in whole or part [2].

3.1 Workflow Construction Steps in SAMOS

Particularly in SAMOS, the workflow mainly describes the optimization execution process, including the operation stages, input and output data, instructions exchanging, files transferring, optimization parameters and flow controlling, etc.

During the workflow construction, the key problem concerned is how to transform the optimization schemes, which formulated by designers, into a workflow that can be executed by the workflow engine automatically and efficiently. Generally, there are three steps to establish an aeronautical multidisciplinary optimization workflow: 1) design a process scheme of optimization; 2) transform the process scheme into a logical model; 3) build up the practical workflow with the guide of the

logical model. The order relationship of these three steps is shown as Figure 3.

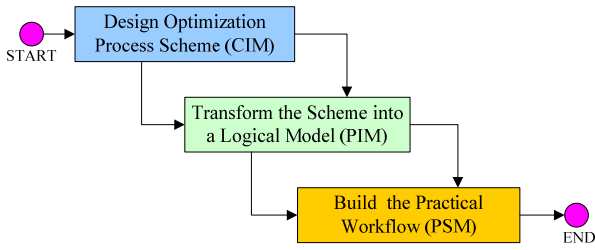


Fig. 3. Generally Steps to Establish a Workflow

3.2 Step1: Computation Independent Model

As Figure 3, the starting point to build up a workflow is the optimization process scheme. This scheme is a description about the optimization process designed by professional people from the aircraft design viewpoint and should include following contents: the object of optimization, some constraints and boundary conditions, selected design variables in different disciplines, the optimization steps and loops, the applications and services need to be invoked, etc. This optimization scheme can be provided as a chart with brief words to describe the operations of the optimization system. This step is to create a Computation Independent Model (CIM).

As an example, the following figure shows a Computation Independent Model definition of the subsonic flutter optimization.

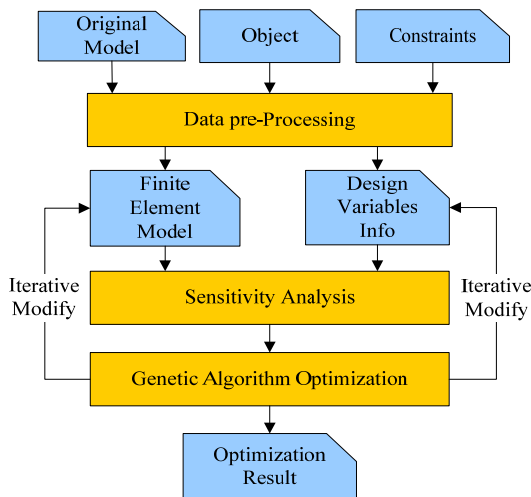


Fig. 4. Optimization Process Scheme (CIM Level)

From Figure 4, we know that this flutter optimization has three mainly operations: data pre-processing, sensitivity analysis and Genetic Algorithm optimization [3]. Besides, it also needs to modify finite element model and design variables information iteratively. But at this level, we don't care about how to get the design variables sensitivity and how to compute the flutter speed. The Computation Independent Model is the top level of the workflow which describes major operations.

3.3 Step2: Platform Independent Model

The second step of workflow construction is transforming the scheme into a logical model to describe the details of optimization. The main task to establish the logical model includes: design the specific flow of the phases in the system, define necessary instructions and data files while invoking applications and services, unify I/O format of the files, etc. This step is to build up a Platform Independent Model (PIM).

As the further model of Computation Independent Model, PIM provides more details about the workflow. The PIM chart of the optimization scheme is following.

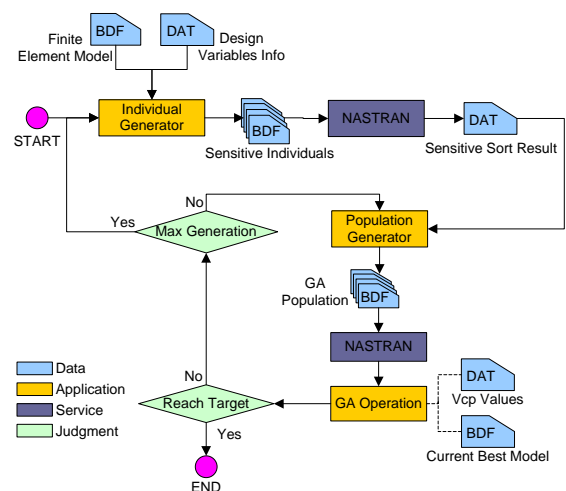


Fig. 5. Workflow Logical Model (PIM Level)

As shown in Figure 5, the input of the system includes original model, optimization object, design variables and constraints. Genetic

Algorithm is chosen for optimization, and sensitive analysis method of design variables is applied in order to reduce the computation time. Besides, this optimization obtains flutter speed (object value) by using MSC.NASTRAN as solver. The PIM chart also determines that this optimization is nested loop architecture: the outer loop finish the sensitivity analysis and the inner loop in charge of GA optimization.

The workflow logical model (PIM) is independent of computing platform; designers can realize the logical model on Windows or Linux, or perhaps on distributed operation system. The characteristic of platform independent make the PIM chart easily to be modified and updated, without thinking about the concrete implementation.

3.4 Step3: Platform Specific Model

After building up a PIM chart, the next step is set up a practical computation platform workflow. The main job of this step is finding the relationship between the parts of the logical model and components of the workflow engine. This step is to implement a Platform Specific Model (PSM).

In this example case, OPTIMUS has been chosen as the workflow engine. The practical workflow has been created based on OPTIMUS engine according to the logical model with a pattern of double loops.

OPTIMUS can build up a practical workflow using various kinds of components. The common components are Input variable, Input variable array, File, Action, Connection, Output variable and Output variable array. Further, the Input/Output variables are used to set running environment parameters or exchange control information; Files are used to store optimization results and intermediate results; Actions are in charge of integrating applications or solvers into workflow; as well as

connections are used to set up the right order and establish connect among other components.

According to Platform Independent Model, suitable executable components are selected to represent different parts of the workflow logical model, and they are integrated together with connections. The practical executable workflow in OPTIMUS is shown as following.

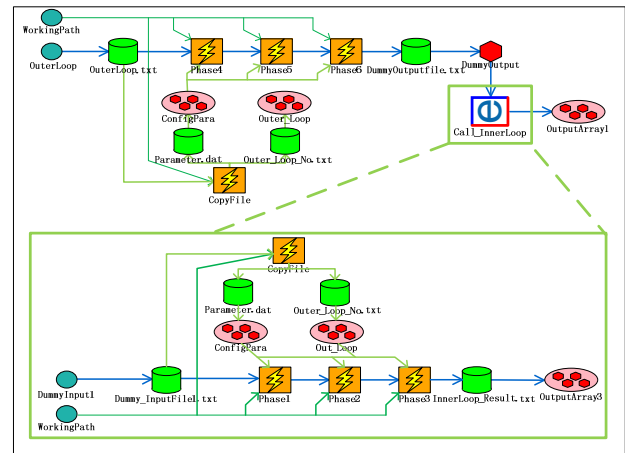


Fig. 6. Workflow in OPTIMUS (PSM Level)

Now the optimization workflow can be executed automatically by computer. And the example workflow of flutter optimization has been carried out many times successfully.

The workflow construct method introduced in this paper has already implemented and validated in lots of aviation optimization projects. A typical one is the optimization for the subsonic flutter of a composite tail-wing showed above. This optimization's object is to increase the subsonic critical flutter speed of the tail-wing by adjusting composite laminations of its skin. The optimization has obtained good results.

4 Workflow Management

During the runtime of SAMOS, the workflow engine manages the optimization process dynamically by means of the predetermined parameters. The management operations include: a) Manage the clusters by monitoring the

computing resources and workload status, feedback the health status of the cluster; b) Watch the services and applications' running status, make judgments of timeout and if so then try again or search for new available resources; c) Manage the data files by operations of files such as package, unpack, dispatch, retrieve, backup, archive, clear; d) Detect the timeout events and resubmit jobs, etc.

There are different ways to get system status while SAMOS is running, including sending check requests through APIs, visiting internal variables, reading parameter files and querying databases. The workflow engine uses this status information to control the process of workflow. Besides, the software which has ability to manage itself, such as condor, can adjust constantly changing computing resources and workload automatically.

These checking and management operations are necessary parts of the workflow to ensure that the SAMOS always runs well and provides an effective way to watch and control the workflow.

5 Typical Application Using Workflow

The method to construct and manage the workflow raised by this paper has been used in the construction of 6~7 workflows successfully in the aeronautic multidisciplinary optimization projects. These workflows have integrated multiple services and applications, including NASTRAN, DesParO[4], HAJIF II, Genetic Algorithm and Neural Network, etc. The BRIDGE project in which the workflow construction and management method was used gained very highly evaluated by European Commission.

BRIDGE project aims at demonstrating the benefits of GRID technology for international cooperation, between Europe and China. An intercontinental workflow had been set up for multidisciplinary optimization of lift and noise.

The brief architecture model of the workflow in BRIDGE is shown as follow.

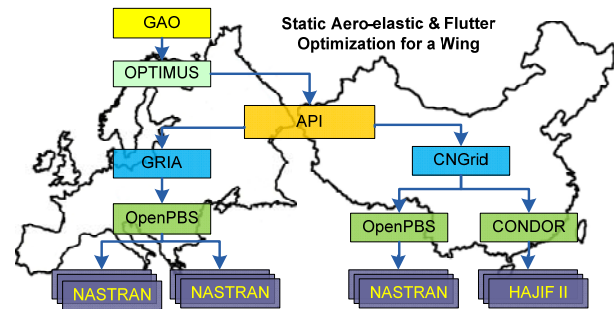


Fig. 7. Intercontinental Workflow in BRIDGE Project

During the project, each run of this workflow requires 140 thousands inner loops and takes about 14 days to complete. It exhibits good performance and is quite robust while running. The final review report gives BRIDGE the following remark: “The project was very successful and achieved all its goals” [5].

6 Conclusion

The following conclusions can be obtained according to the construction method and the experience of workflow implementation for the aeronautic multidisciplinary optimization:

1. Multidisciplinary optimization in aeronautical area is quite complex. Building up the workflow efficiently is a critical process to realize the requirement of such optimization.

2. There are three steps to build the workflow: design a top process scheme of optimization, transform it into a logic model, and establish the practical workflow. This method can integrate several services to set up a complicated workflow quickly and scientifically.

3. The service-oriented aeronautical multidisciplinary optimization workflow built by OPTIMUS can be operated under the heterogeneous running environment in different locations, which can realize the large-scale optimization computation utilizing the shared resource.

4. The construction and management method of the workflow has been verified in many aeronautical optimization projects and has proved that it is very easy and efficient to establish a new workflow.

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