

Geodise Application: Solving CFD-based Shape Optimisation Problems on the Grid

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Contact: Wenbin Song (w.song@soton.ac.uk)
 Southampton Regional e-Science Centre
 School of Engineering Sciences
 University of Southampton
 Highfield, Southampton
 SO17 1BJ

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UTP for design

for engineering product development. Using high-fidelity analysis models earlier in the design chain will provide enormous benefits, but it also presents significant challenges for all aspects of current design practice.

Geodise (Grid Enabled Optimisation and Design Search for Engineering) project is one of a new breed of EPSRC funded research programmes involving multi disciplinary teams working to build a state of the art design tool demonstrator. The GEODISE demonstrator is intended to carry out engineering design search and optimisation involving fluid dynamics, and is bringing together the collective skills of engineers and computer scientists.

Design Automation

Computation-based collaboration not only needs raw computing and storage power, but also an infrastructure for effective, efficient, and secure collaboration. Ad-hoc integration based on shell scripts is neither reliable nor scalable. Geodise (Grid-enabled optimisation and design search for engineering) aims to provide toolkits and a GUI environment to aid engineers in solving computation-based optimisation problems more efficiently. Automation of design process from CAD through analysis to manufacturing is the key to success for delivering improved quality, reduced cost, and increased reliability

Optimisation as Services

Up to now, callbacks are used in most optimisation packages to provide evaluations of objective functions and constraints, while the optimisation algorithm provides the logic as the main driving factor behind search for improved designs. However, it should be the designers, rather than the search algorithms that make decisions in this process. The optimisers, as services, become essentially valuable aids for designers in the process of improving products. The implementation of optimisation methods as services enables users to drag and link different optimiser components to the required analysis codes, and the communication between the two is realised using light weight SOAP messages. This message based model for optimisation implements loose

coupling between the optimisation logic and the analysis codes. The main difference of this approach to conventional strong coupling approach can be seen in the Figure 2. It is also makes it easier for users to plug in customised computing job scheduling tools and monitoring and steering capabilities.

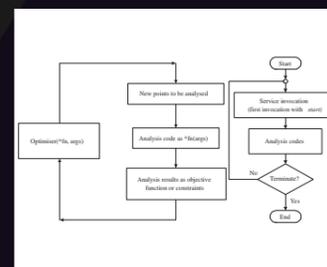


Figure 2: Conventional and Service-oriented Optimisation Workflows

Models with meta-data

Design optimisation is a data intensive process, where huge amount of unstructured, related data will be produced, including plain text files and proprietary binary data. Managing these unstructured engineering data is a challenging task. In our work, a Geodise Database toolkit is developed based on the concept of metadata. The use of metadata enables data to be more effectively used and managed. Files and structured data are augmented with metadata which describes the data in a way that is both human and machine friendly. Metadata are archived in a metadata database which is built on a commercial relational database. The files are archived in a separate Globus server using GridFTP. Based on the basic functionalities provided by the Geodise database toolkits, related concepts and data can be grouped together to form logical groups for particular tasks. For example, for a CAD-based shape optimisation

problem, the CAD model, related meshing and solver tools are grouped and archived to improve the efficiency and reliability in the use of these models when the number of models grow. Another use of Grid-enabled databases is in the remote monitoring of optimisation processes given the job handle. As results are dumped into the database during the process of optimisation, the user can monitor the progress of the search from a convenient place, even on a 3G mobile phone.

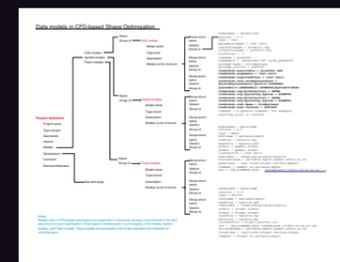


Figure 3: Metadata-assisted Data Model

Scripting Search Sequences

The flexibility and functionality offered by the Matlab scripting environment enable users to build complicated optimisation workflows as well as making use of a large number of post-processing plotting tools. With the support for accessing Java object from within Matlab, Grid support tools are imported into Matlab environment, make it possible for engineers to access Grid-enabled resources from Matlab. Two scripts are shown in Figure 4, one is concerned with Design of Experiments and parallel evaluation of different geometries and CFD simulations. The results from this script are archived in the database. The second script involves building a response

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surface model based on data archived from the first script and then a Genetic Algorithms search is carried out on the resulting response surface model.

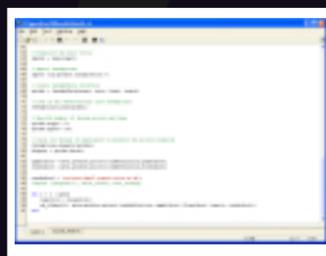


Figure 4a: Matlab scripts for the Design of Experiments

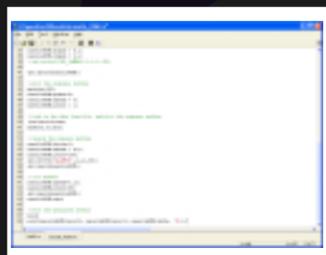


Figure 4b: Matlab scripts Genetic Algorithm search on the RSM

Workflow Composition GUI

The ability to compose different search sequences in a GUI environment using well-defined components is also important to improve the usability of optimisation tools for designers. The workflow construction environment built by the Geodise project provides functionalities to create component instances, define properties of each component and link components based on the input/output properties of each component. The graphically composed workflow can then be converted into Matlab script for execution on local or Grid-enabled remote Matlab servers. A typical workflow is shown to illustrate a search process with data archived in metadata database during each loop.

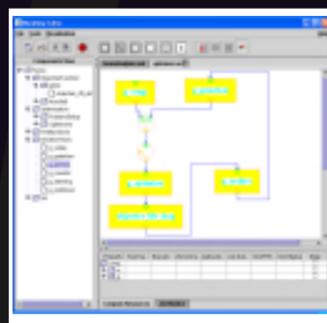


Figure 5: Workflow Construction Environment

Behind the workflow construction GUI is the execution environment which executes the scripts generated from the GUI. Matlab is used in the current work which supports free form scripting capabilities. It also provides rich numeric algorithms and visualisation functions.

Delivering Better Designs, Faster

In the current work, CFD-based shape optimisation problems are used to illustrate the use of the tools presented in previous sections. Parametric geometries have been generated using a feature-based solid modelling (FBSM) system (ProEngineer). The automation is achieved via the use of a standard data exchange format (STEP). An automatic mesh generation process is achieved by relying only on the top-level topologies (surfaces) in the geometry definition. Appropriate mesh control parameters are determined based on the relative values of geometry parameters. This approach therefore leads to a robust mesh generation for a wide range of geometry changes. To overcome the issue of high computational cost associated with CFD solutions, a Design of Experiments approach and Response Surface Modelling is used to improve the efficiency of the search.

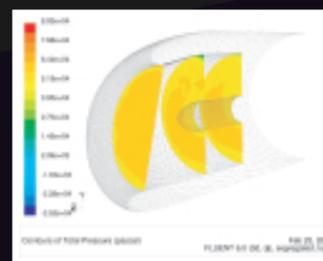


Figure 6: Total pressure distribution for throat, fanface and fanexit planes.

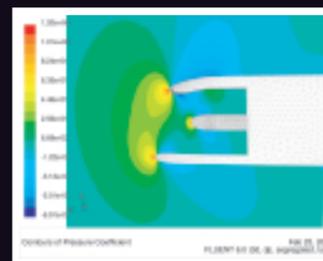


Figure 7: Pressure coefficients for the nacelle symmetry plane.

Geodise Team Members

Liming Chen, Sergio Campobasso, Mihai Duta, Hakki Eres, Zhuoan Jiao, Graeme Pound, Colin Puleston, Wenbin Song, Barry Tao, Jasmin Wason, Fenglian Xu

Investigators:

Simon Cox, Mike Giles, Carole Goble, Andy Keane, Nigel Shadbolt

Industry Partners:

BAE Systems, Compusys, Condor, Epistemics, Fluent, Intel, Microsoft, Rolls-Royce

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