Implementing Analytical Target Cascading Optimization Architecture Into NASA's OpenMDAO Software

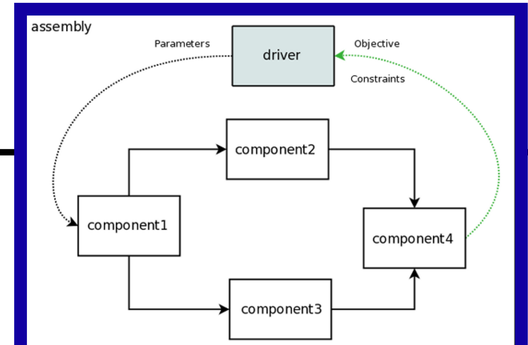
Joseph Carr with Prof. Kokkolaras Department of Mechanical Engineering, McGill

How to Read This Poster

This poster is meant to be read in a similar manner to how a computer solves an optimization problem. Here the objective is maximize the reader's understanding of optimization (or minimize confusion), which is done by reading through the sections of this poster (or evaluating this poster's components), until a sufficient level of knowlege is reached (or converged to an understanding).

What is MDAO

- Multidisciplinary design analysis optimization (MDAO)
- Study of the application of numerical optimization techniques to the design of engineering systems involving multiple disciplines or components.
- There exist many different architectures (methods) for arriving at optimal solutions, effectiveness and computational cost is problem dependant.
- This project focuses on the Analytical Target Cascading (ATC) architecture and its implementation into OpenMDAO, an environment made by NASA.



Math

Programming

Mathematical Forumulation

An optimization problem is made up of

- A cost function, f(x)
- A vector of design variables, x
- A set of disciplines, R(x)
- A set of inequality constraints, c(x)
- Methods for solving generally involve fixed point iterations

Mathematical Formulation Examples

All In One (AIO)

$$\begin{aligned} & R_i(x_i) = 0 \\ \min_{x_i} \quad & f(x) \\ \text{subject to} \quad & c_i(x_i) \geq 0 \end{aligned}$$

ATC

$$\begin{aligned} & R_i(x_i) = 0 \\ \min_{x_i, T_i} \quad & f(x) + \Phi(T_i - R_i) \\ & \Phi_i(T_i - R_i) \\ \text{subject to} \quad & c_i(x_i) \geq 0 \end{aligned}$$

What is OpenMDAO

- Open-source environment made by NASA,
- Setup takes a Components files and an Assembly file
- Components file contains disciplines, R, as functions
- Assembly file containts architecture is set up
- Minimizers, called drivers, are used with their associated variables, x, constraints, c, and objective functions, f, declared.
- Drivers perform fixed-point iteration methods to solve the problem

ATC

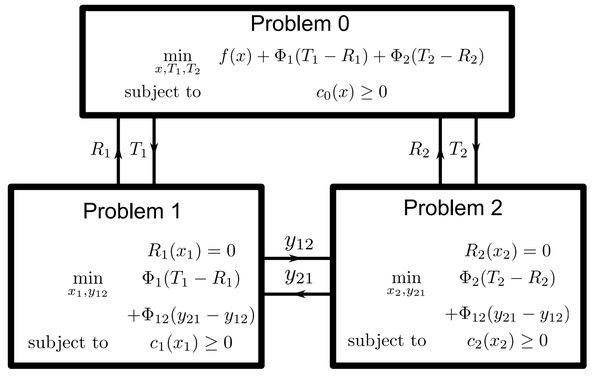
Visualization

Outcome

ATC Formulation

- Decomposes the problem into several sub problems,
- Shared variables are handled by having the sub problems sending target and response values
- Lagrangian-like penalty weights are used to create penalty functions to minimize the difference between the targets and responses.

ATC Visualized



Results

- AIO, AIO with eliminated equality constraints, IDF and MDF architectures sucessfully implemented in OpenMDAO
- OpenMDAO's Automatic Architectures successfully set up, running IDF, MDF and CO, returning the same results as hard coded implementations
- OpenMDAO does not seem as amenable to ATC implementations as other platforms, e.g. MATLAB

Conclusion

Acknowlegements

Thank you to all the people whom without this project would not have been possible

- Prof. Kokkolaras
- Creators of OpenMDAO and maintainers of the help forum
- The McGill Faculty of Engineering
- NSERC

Finallly, if the reader has not converged to an understanding, reiterate.

Reiterate