Unsteady adjoint optimization
with grid adaptation

Sheikh Razibul Islam

Institute of Aeronautics and Applied Mechanics
Warsaw University of Technology

srislam@meil.pw.edu.pl

August 18, 2014

Objectives

- Adjoint solver for unsteady Navier-Stokes (including check pointing)
- Usage of adjoint calculation for shape optimization and optionally for optimal control
- Optimize the performance with grid adaptation and optionally multi-gird

Work Plan

Preliminaries

- Unsteady adjoint for a simple ODE with checkpointing
- optimal control for simple ODE

Prerequisites

- Unsteady Euler/NS solver (Residual Distribution Scheme)

Primary Task

- Implementation of unsteady adjoint in the NS solver
- Implementation of moving geometry
- Gradient-based shape optimization

Work Plan - continued

Testing and evaluation

- Testing of the Euler/NS code on non-stationary cases
- Testing of the obtained gradients against finite difference
- Testing of a complete optimization

Performance improvements

- Hessian-of-solution based mesh refinement
- Goal-oriented based mesh refinement

Progress

Progress

- Literature review
- Training on adjoint-based mesh adaptation and optimization
- Training on AD tools
- Training on Open MPI
- Development of Adjoint implementation on Euler solver is underway.

Secondments

RWTH

- Familiarization in parallelization of adjoint solvers
- Review of AD tools for parallel application
- Implementation of operator overloading based AD to develop Adjoint solver

RR

- Investigation of turbo-machinery problem using the developed adjoint solver
- Application of grid adaptation tool chain available in WUT for turbo-machinery test cases

Duality Formulation For Adjoint Design

Primal:

$$Q^{n+1} = F(Q^n) \tag{1}$$

Tangent Linear:

$$\frac{\partial Q^{n+1}}{\partial \alpha} = \frac{\partial F}{\partial Q}\frac{\partial Q}{\partial \alpha} + \frac{\partial I}{\partial \alpha} \tag{2}$$

Adjoint Equation:

$$v^n = \left(\frac{\partial F}{\partial Q}\right)^T v^{n+1} + \frac{\partial I}{\partial Q} \tag{3}$$

Advantage of Finite Difference to Develop Jacobian

$$
\begin{bmatrix}
a_{11} & a_{12} & 0 & \cdots & \cdots & \cdots & 0 \\
a_{21} & a_{22} & a_{23} & \ddots & & & \vdots \\
0 & a_{32} & a_{33} & a_{34} & \ddots & & \vdots \\
\vdots & & \ddots & \ddots & \ddots & \ddots & \vdots \\
\vdots & & & a_{76} & a_{77} & a_{78} & 0 \\
\vdots & & & \ddots & a_{87} & a_{88} & a_{89} \\
0 & \cdots & \cdots & \cdots & 0 & a_{98} & a_{99}
\end{bmatrix}
\tag{4}
$$

- Developed Jacobian is a complete sparse matrix which can be calculated locally
- It is conveniently scalable
- Options to implement higher order FDM, if more accurate jacobian is required
- Tested for stationary problems with sufficient accuracy

ABOUTflow

Acknowledgements

This work has been conducted within the **About Flow** project on "Adjoint-based optimization of industrial and unsteady flows".

http://aboutflow.sems.qmul.ac.uk

About Flow has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under Grant Agreement No. 317006.