

# Unsteady adjoint optimization with grid adaptation

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# Personal Information

## Background

- Born in Khulna, Bangladesh
- B.Sc. in Mechanical Engineering from Bangladesh University of Engineering & Technology
- M.Sc. in Computational Mechanics from University of Duisburg-Essen, Germany

- Joined WUT as ESR 14 on October, 2013
- Supervised by Prof. Jacek Szumbariski



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## Current Position

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# 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-grid



# Work Plan

## Preliminaries

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

## Phase 1

- Unsteady Euler/NS solver (Residual Distribution Scheme)

## Phase 2

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



# Work Plan

## Preliminaries

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

## Prerequisites

- Unsteady Euler/NS solver (Residual Distribution Scheme)

## Project Tasks

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



# 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

- 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:

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

Tangent Linear:

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

Adjoint Equation:

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



# Advantage of Finite Difference to Develop Jacobian

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

- 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



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

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