# Unsteady adjoint optimization with grid adaptation

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## Personal Information

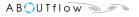
#### Background

- 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 Szumbarski







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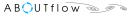
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#### **Current Position**

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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-gird





## Work Plan

#### **Preliminaries**

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

Unsteady Euler/NS solver (Residual Distribution Scheme)

- 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

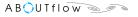
#### Prerequisites

• Unsteady Euler/NS solver (Residual Distribution Scheme)

- Implementation of unsteady adjoint in the NS solver
- Implementation of moving geometry
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## Work Plan

#### **Preliminaries**

- Unsteady adjoint for a simple ODE with checkpointing
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## Prerequisites

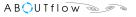
• Unsteady Euler/NS solver (Residual Distribution Scheme)

#### Primary Task

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







## Work Plan - continued

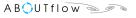
#### Testing and evaluation

- 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



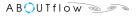


## **Progress**

#### **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

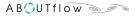
#### **RWTH**

- 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:

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

(1)

Tangent Linear:

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

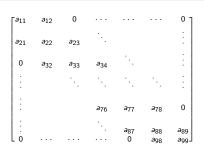
(2)

Adjoint Equation:

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



# Advantage of Finite Difference to Develop Jacobian



(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







# 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

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