FlowHead: Fluid Optimisation Workflows for Highly Effective Automotive Development Processes

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Industrial design optimisation for fluids: requirements, challenges

- Large number of design variables
- Acceptable run times
- Able to deal with complex geometry
- Integration into the complete design process
- Robust minima

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How to satisfy these requirements

- Large number of design variables, acceptable run times
- Able to deal with complex geometry
- Integration into the complete design process
- Robust minima in deterministic optimisation
  - Response surface methods
  - Computation of the Hessian: moment methods
  - Multi-objective optimisation

How to satisfy these requirements

- Large number of design variables, acceptable run times
  - Gradient-based optimisation
  - Adjoint solvers
  - Complete differentiation of metrics and parametrisation
  - Fully coupled KKT solvers, 'one-shot'
  - Multi-level methods, including the design
- Able to deal with complex geometry
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How to satisfy these requirements

- Large number of design variables, acceptable run times
- Able to deal with complex geometry
    - Automatic parametrisation
    - Node-based parametrisations
    - Morphing-based parametrisation
    - CAD-based parametrisation
    - Robust mesh deformation algorithms
- Integration into the complete design process
- Robust minima in deterministic optimisation
    - Response surface methods
    - Computation of the Hessian, moment methods
    - Multi-objective optimisation

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How to satisfy these requirements

- Large number of design variables, acceptable run times
- Able to deal with complex geometry
- Integration into the complete design process
    - Complete sensitivity computation, $\frac{\partial J}{\partial \alpha}$
    - Integration into the design chain:
    - CAD return
    - Integration into the product development process
    - Use of low-fidelity models in the early design phase
- Robust minima in deterministic optimisation
    - Response surface methods
    - Computation of the Hessian, moment methods
    - Multi-objective optimisation

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FlowHead: Fluid Optimisation Workflows for Highly Effective workflows in Automotive Design processes

- Funded by the EC, FP-7, SMSFRP (small to medium scale research project), Tansport programme: "competitive product development",
- Budget: €3.2M
- Duration: Feb 2009 - Jan 2012
- 11 Partners, 9 Countries
- coordinated by JDM at QMUL

FlowHead partner organisations

- 2 Car manufacturers:
- 4 Software companies (2 SMEs):
- 5 Universities:

FlowHead partner organisations

- 2 Car manufacturers:
  - Renault (F): industrial application, robust optimisation
  - VW (D): industrial application, topology optimisation
- 4 Software companies (2 SMEs):
- 5 Universities:

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- 2 Car manufacturers:
- 4 Software companies (2 SMEs):
  - ESI (F): commercial solvers, continuous and AD adjoints
  - ICON (UK): open-source continuous adjoint solver OpenFOAM
  - FE-Design (D): design chain integration into workbench software
  - CD-Adapco (F): robust design via RSM methods
- 5 Universities:

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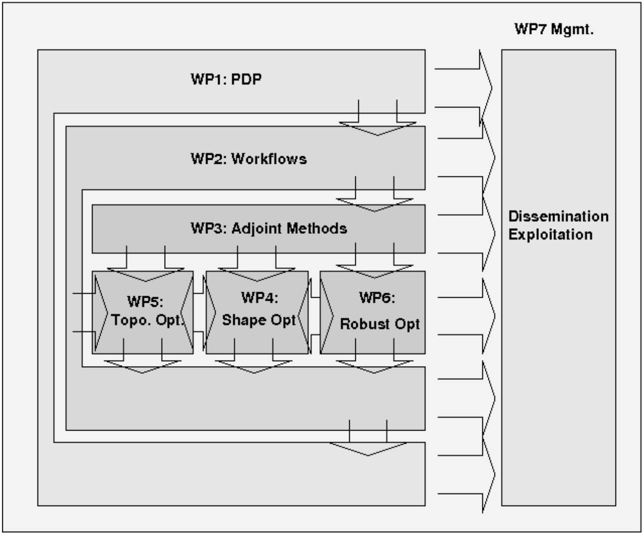
  - TU Sofia (BG): integration into PDP management software
  - TU Munich (D): shape optimisation, regularisation
  - TU Denmark (DK): topology optimisation
  - TU Warsaw (PL): robust optimisation with RSM, adjoint-driven mesh adaptation
  - QMUL (UK): CAD-based optimisation, application of AD to commercial solvers, robust design with approximate Hessians.

Aims of FlowHead

- Reduction of lead development time [..] via integration of CFD optimisation workflows into the PDP [..]
- To establish a robust, user-friendly and modular workflow of CFD optimisations [..]
- Development of sensitivity analysis methods for CFD based on discrete and continuous adjoint methods [..].
- Development and implementation of gradient-based shape optimisation techniques using a) a mesh-based approach and b) a CAD-based approach for automotive CFD applications.
- Development of topology optimisation methods for CFD and their integration into the CFD optimisation workflows.
- Development of robust optimisation methods that exploit efficient adjoint sensitivities

Structure of FlowHead



Core Structure of FlowHead

- WP 3: Development of new adjoint solvers
- WP 4: Shape optimisation
- WP 5: Topology optimisation
- WP 6: Robust optimisation

Core Structure of FlowHead

- WP 3: Development of new adjoint solvers
  - Enhancement of an existing open-source continous adjoint flow solver (OpenFOAM)
  - Evaluation of using arbitrary solver combinations: continuous FE-based adjoint flow solver with commercial flow solvers Fluent, STAR-CD
  - Development of a new commercial flow solver, written in F90, using AD Tools (Tapenade)
- WP 4: Shape optimisation
- WP 5: Topology optimisation
- WP 6: Robust optimisation

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Core Structure of FlowHead

- WP 3: Development of new adjoint solvers
- WP 4: Shape optimisation
  - Development of complete sensitivity chains including parametrisation, ready for integration into the design loop (workbench)
  - Node-based parametrisation, regularisation,
  - Morphing-based parametrisation,
  - CAD-based parametrisation.
- WP 5: Topology optimisation
- WP 6: Robust optimisation

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Core Structure of FlowHead

- WP 3: Development of new adjoint solvers
- WP 4: Shape optimisation
- WP 5: Topology optimisation
  - Extension to realistic problems
  - Evaluation of application toward Reynolds numbers
- WP 6: Robust optimisation

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- WP 6: Robust optimisation
    - Development of adjoint-enable response surface methods for Hessian approximation
    - Development of AD-derived Hessian computation
    - Development of fast multi-level methods, adaptive grids for primal, dual and design, fully coupled with coarse grid Hessian evaluation.

Aims of FlowHead

- Advance with robust general-purpose ajoint solvers
- Develop automatic parametrisation methods for shape optimisation
- Enlarge the scope and capability of topology optimisation in fluid flow
- Integrate shape and topology optimisation into the industrial design workflow

Acknowledgements

FLOWHEAD

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

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University of London

SEVENTH FRAMEWORK PROGRAMME