AEROSPACE COMPUTATIONAL ENGINEEERING – 3ème année cycle ingénieur Estia

Second diplôme : Master of science « Aerospace Computational Engineering » de l'Université de Cranfield

Course details : MODULES*

MODULE C++ PROGRAMMING

Module Leader
Dr Irene Moulitsas

Aim
Object oriented programming (OOP) is the standard programming methodology used in nearly all fields of major software construction today, including engineering and science and C++ is one of the most heavily employed languages. This module aims to answer the question 'what is OOP' and to provide the student with the understanding and skills necessary to write well designed and robust OO programs in C++. Students will learn how to write C++ code that solves problems in the field of computational engineering, particularly focusing on techniques for constructing and solving linear systems and differential equations. Hands-on programming sessions and assignment series of exercises form an essential part of the course.
An introduction to the Python language is also provided.

Syllabus
The OOP methodology and method, Classes, abstraction and encapsulation;
Destructors and memory management, Function and operator overloading, Inheritance and aggregation, Polymorphism and virtual functions, Stream input and output;
Templates, Exception handling, The C++ Standard Library and STL.

MODULE COMPUTATIONAL METHODS

Module Leader
Dr Irene Moulitsas

Aim
The module aims to provide an understanding of a variety of computational methods for integration, solution of differential equations and solution of linear systems of equations.

Syllabus
The module explores numerical integration methods; the numerical solution of differential equations using finite difference approximations including formulation, accuracy and stability; matrices and types of linear systems, direct elimination methods, conditioning and stability of solutions, iterative methods for the solution of linear systems.

MODULE NUMERICAL MODELLING FOR INCOMPRESSIBLE FLOWS

Module Leader
Dr Laszlo Konozsy

Aim
To understand the state-of-the-art CFD methods used for computing incompressible flows in science and engineering.

Syllabus

- Overview of various formulations of the governing equations and numerical methods for incompressible flows (linear & high-resolution methods)
- Solution approaches: pressure Poisson, projection (approximate and exact), artificial compressibility
- Centred schemes
- TVD and Riemann solvers for incompressible methods
- Second and high-order methods (time and spatial discretise)

MODULE NUMERICAL MODELLING FOR COMPRESSIBLE FLOWS

Module Leader
Dr Panagiotis Tsoutsanis

Aim
To introduce basic concepts in the discretisation and numerical solution of the hyperbolic systems of partial differential equations describing the flow of compressible fluids.

Syllabus

- Mathematical properties of hyperbolic systems
- Conservation Laws
- Non-linearities and shock formation
- WENO schemes
- MUSCL schemes Introduction to the Riemann problem
- Lax-Wendroff scheme
- Introduction to Godunov's method
- Flux vector splitting methods
- Approximate Riemann solvers
- Explicit and implicit time-stepping schemes

ANALYSIS AND VISUALISATION OF BIG DATA SYSTEM AND HIGH PERFORMANCE COMPUTING

Module Leader
Dr Zeeshan Rana

Aim
To provide an introduction into the use of visualisation, data mining, and interactive human-computer interfaces for the analysis and interpretation of CFD simulations. Visualisation can be a critical component in helping an engineer gain insight into the typically complex optimization problems that arise in design. Through the combination of visualisation and user interaction in computer tools, the engineer's insight can help guide the computer in the process of identifying better, more effective designs. Visualisation can also be combined with automated data mining techniques to improve optimization procedures.

Syllabus

- Data interchange formats
- Interpretation of data
- Graphical representation of data
- Parallel data visualisation
- Data mining, reduced order modelling, model identification and surrogate models
- Data fusion
- Virtual reality visualisation
- Desktop versus supercomputing
- Parallel computing issues
- Parallellisation approaches for distributed and shared memory systems. MPI & OpenMP.
- Current CFD Process Bottlenecks
- Whole Product Applications

MODELLING APPROACHES FOR AEROSPACE APPLICATION

Module Leader
Dr Laszlo Konozsy

Aim
To understand the key features of mathematical modelling approaches and computational methods used for simulating flows relevant in aeronautical and aerospace applications.

Syllabus
- Overview of the governing equations of fluid dynamics applicable to external flows including classical and advanced turbulence modelling approaches for aeronautical and aerospace applications ;
- CFD methods for low- and high-speed flows used for advanced aerospace applications ;
- CFD methods for digital wind tunnel applications ;
- State-of-the-art case studies and application examples.

CAE ADVANCED APPLICATIONS

Module Leader
Dr Laszlo Konozsy

Aim
This course covers more advanced aspects of CAE, the aim being to introduce students to key concepts and techniques in the use of CAE application software tools. Use is made of structured computer based workshops which employ industry standard systems for CAD through to Engineering Analysis.

Syllabus
- Introduction to I-DEAS CAE Finite Element Analysis (FEA) Simulation software,
- CAE FEA Pre- and Post-Processing, Free mesh and Mapped mesh techniques,
- Quality checks on nodes and elements, Finite element and geometry based
- boundary conditions, Utilising solids based modelling geometry for downstream
- CAE FEA, CAE linear statics analysis using the I-DEAS CAE FEA Simulation
- software, Case Studies.

VALIDATION AND VERIFICATION FOR AEROSPACE APPLICATIONS

Module Leader
Dr Zeeshan Rana

Aim
To introduce the concepts of validation and verification methods including the management of computational errors and uncertainties related to simulation of external flows for aeronautical and aerospace applications.

Syllabus
Mathematical foundations of uncertainty quantification methods and related theories including the definition of consistency, stability and convergence
Taxonomies of numerical errors and uncertainties
Principles of code verification for external flows
Introduction to the method of manufactured solutions
Principles of solution verification
Principles of the generalized Richardson extrapolation including a method how to report numerical errors in a unified way based a proper grid convergence study
Principles of mathematical model validation
Statistical approaches to epistemic uncertainty
Construction of validation and verification hierarchies.