SHORT COURSE ON ADVANCED NUMERICAL METHODS FOR HYPERBOLIC EQUATIONS

www.unitn.it/nm2025

Lecturers

Prof. Dr.-Ing. Michael Dumbser and Dr. Firas Dhaouadi
Two special lectures given by Prof. Dr. Dr. hc. E.F. Toro, OBE
Department of Civil and Environmental Engineering
Laboratory of Applied Mathematics
University of Trento, Italy

Dates

From Monday 3rd February to Friday 7th February 2025

Onsite and online venue

University of Trento, Via Mesiano, 77, I-38123 Trento, ITALY
The course is held **onsite**, but is also available **online** via ZOOM

SUMMARY

The short course on advanced numerical methods consists of a structured intensive one-week programme of 40 hours of theoretical lectures and computer laboratory exercises on advanced numerical methods for hyperbolic partial differential equations with applications in engineering and science. The course covers finite volume methods, the exact and approximate solution of the Riemann problem, second order TVD methods, higher order ENO, WENO and discontinuous Galerkin methods, as well as the discretization of non-conservative problems. Special emphasis is put also on numerical methods that are able to handle complex geometries. In particular, unstructured Finite Volume and discontinuous Galerkin schemes as well as mesh-free particle methods are presented. The course is primarily designed for PhD students and post-doctoral researchers in applied mathematics, engineering, physics, computer science and other scientific disciplines. The course may also be of interest to senior researchers in industry and research laboratories, as well as to senior academics. The lectures on the theory will be supplemented with laboratory-based computer exercises to provide hands-on experience to all participants on the practical aspects of numerical methods for hyperbolic problems and applications using MATLAB programs specially designed for the course.

CONTENTS

Review of basic theoretical aspects of hyperbolic conservation laws and numerical concepts for hyperbolic equations. Finite volume methods for one-dimensional systems. Godunov's method. The Riemann problem. Approximate Riemann solvers. Godunov-type finite volume methods for non-linear systems. Construction of higher order non-oscillatory methods via non-linear schemes: TVD, ENO and WENO reconstruction procedures. Discontinuous Galerkin Finite Element methods for one-dimensional problems. The well-balanced property and numerical methods for non-conservative hyperbolic systems. Extension to multiple space dimensions on Cartesian grids.

Complex geometries using unstructured triangular meshes in two space dimensions and using mesh-free approaches.
Mesh-based algorithms: Finite volume schemes on unstructured meshes for two-dimensional geometries. Second-order reconstruction and slope limiting on unstructured meshes. Applications to the shallow water equations and the Euler equations of compressible gas dynamics. High order discontinuous Galerkin finite element methods on unstructured meshes.
Mesh-free algorithms: Introduction to Lagrangian particle methods. Guidelines for implementation of smooth particle hydrodynamics (SPH) based on approximate Riemann solvers.

On the last day, the course is rounded-off by advanced seminar-style lectures with outlooks to the following topics: better than second order schemes on unstructured meshes, high order methods on space-time adaptive grids (AMR), time-accurate local time stepping (LTS), high order Lagrangian schemes on moving unstructured meshes, applications to compressible multi-phase flows and nonlinear elasto-plasticity. Numerical methods for all Mach number flows.

ABOUT TRENTO AND THE DOLOMITES

The historical city of Trento is situated in the autonomous Italian region of Trentino - Südtirol, close to the world-famous mountains called *Dolomites*. Trento is very easy to reach by car or train from Austria (150 km south of Innsbruck) and from Verona (90 km north of Verona). The nearest and most convenient airport is Verona Airport, 15 minutes from the Verona train station. The region around Trento is of extraordinary beauty, with its unique mountains and lakes that offer the participants many exciting outdoor activities like skiing, hiking or climbing.

COST

Onsite participation fee: Students and post-docs: **€500**; Senior academics and others: **€1000**; (free of "VAT tax" as art. 10 DPR 633/72). Fees cover lectures, laboratory exercises, lecturing material and MATLAB sample programs.

Online participation fee: **€250.** The fee covers lectures, laboratory exercises, lecturing material and MATLAB programs. Lectures and exercises are transmitted in live streaming via ZOOM and are also recorded. ZOOM recordings will be made available to all participants.

REGISTRATION AND ADMINISTRATIVE INFORMATION

All participants (**onsite** and **online**) must **register** online at www.unitn.it/nm2025.

Registration **deadline** is **27th January 2025**.

For further information on registration and payment, please e-mail to:
Prof. Dr.-Ing. Michael Dumbser (michael.dumbser@unitn.it)
Tel. +39 0461 28 2659

Once the payment has been made please send a copy of the receipt via e-mail to the address indicated above. **Onsite** participants must bring their **own laptops** with MATLAB installed. Online participants will receive the ZOOM link of the course only after payment of the course fee.

Payment of the **course fee** must be made **only after registration** and **after January 1st 2025**, but **before 31st January 2025** by **bank transfer** or **credit card**.

Full details for payment of the course fee will be sent individually to each participant after **registration** on the website www.unitn.it/nm2025.