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ULF - Universal Laminar Flame Solver

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General Facts

Overview

- A flexible, robust framework for homogeneous and heterogeneous reactive systems
- Object-oriented C/C++ code with multiple compiler/platform support
- Run-time configurable and adaptable (models, solvers, libraries, etc.)
- Convenient interface for user defined equations (similar as written on paper)
- Standardized UML-type format for setup files
- Interfaces to third party software available:
  - Solvers: BzzMath [1], SUNDIALS [2], RADAU [3], Seulex [3], ...
  - Chemistry/Transport: Cantera [4], EGlib [5], ...
  - Math: Blaze [6], Eigen [7], Lapack [3], ...
- Test driven development (nightly unit and integration testing)
- Monitoring of testing framework via CDash [15] and Jenkins [16]

Available Models:

- Extensive libarary of 0D and 1D problems related to combustion
  - Reactors
  - Flames in physical and composition space
  - Multi-component droplet combustion
  - Coal particle combustion
  - Soot model coupling (QMOM-methods)
  - Heterogeneous catalysis
- 2D combustion problems (WIP)
- Variety of diffusion models available
  - Const. Lewis numbers
  - Mixture-average approach
  - Full multi-component

Numerical details:

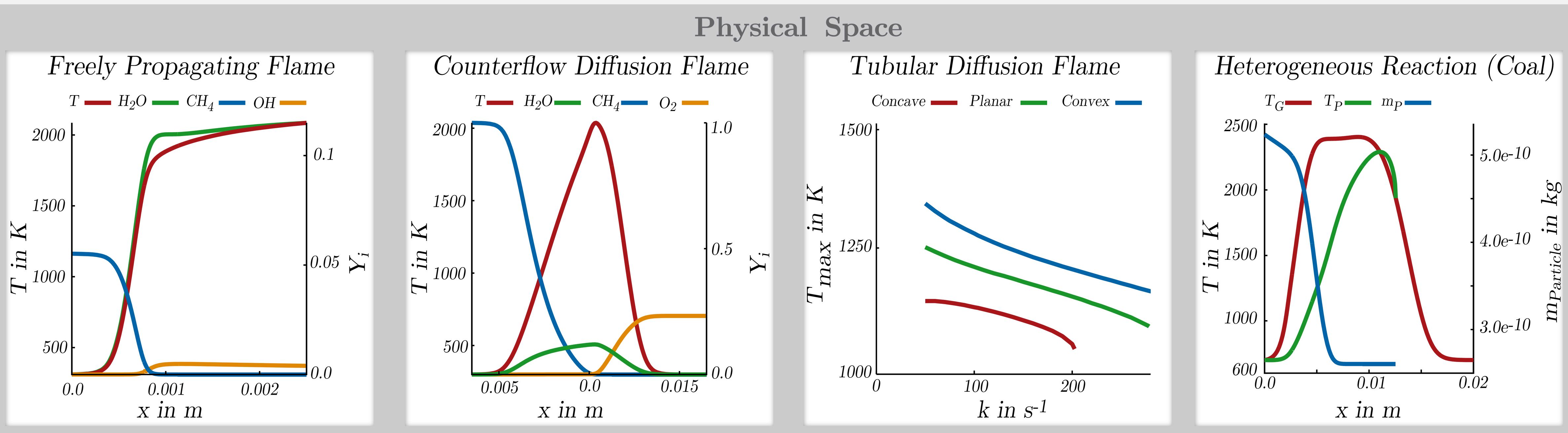
- Stationary and transient solvers (ODE and DAE systems)
- Optional operator splitting techniques
- Finite-Difference and Finite-Volume discretization
- Higher order discretization schemes in space and time
- Adaptive mesh refinement

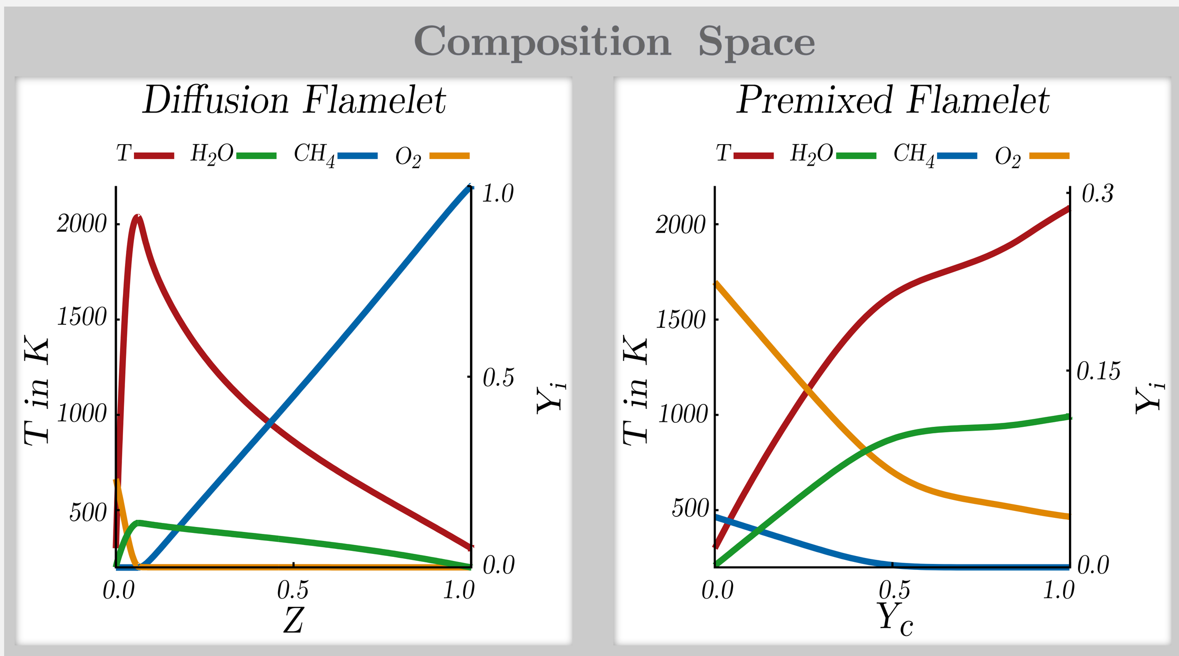
Convenience features:

- Dynamic file I/O with support for different formats: hdf5 [8], vtk [9], plain ASCII
- Text based configuration allows efficient scripting and automatization
- Template files for standard problems simplify usage for beginners or frequent users
- Python interface (WIP)

Exemplary 1D Flame Models

This is an overview of exemplary 1D flame models in physical and in composition space. All models are validated against other scientific codes and experimental results.





Tabulation Interface

Generation of multi-dimensional flamelet lookup tables (FLUT):

- Tabulation of physical and composition space flamelet solutions including thermo-chemical quantities
- ULF Python wrapper with tools for automatic table generation and post processing
- Efficient processing and interfacing of flamelet tables through separate tool **flameletConfig [10]**

Available interfaces to CFD-codes:

- OpenFOAM [11]
- ANSYS CFX and Fluent [12]
- DNS-code DINO [13]

Direct Coupling

Usage as library:

- Evaluation of thermo-chemical quantities during runtime of third party codes, such as:
  - Chemical source terms and transport coefficients
  - Eulerian transport modeling for particles and sprays (QMOM)
  - Heterogeneous reaction systems for catalysts and coal
  - Solution of additional differential equation systems

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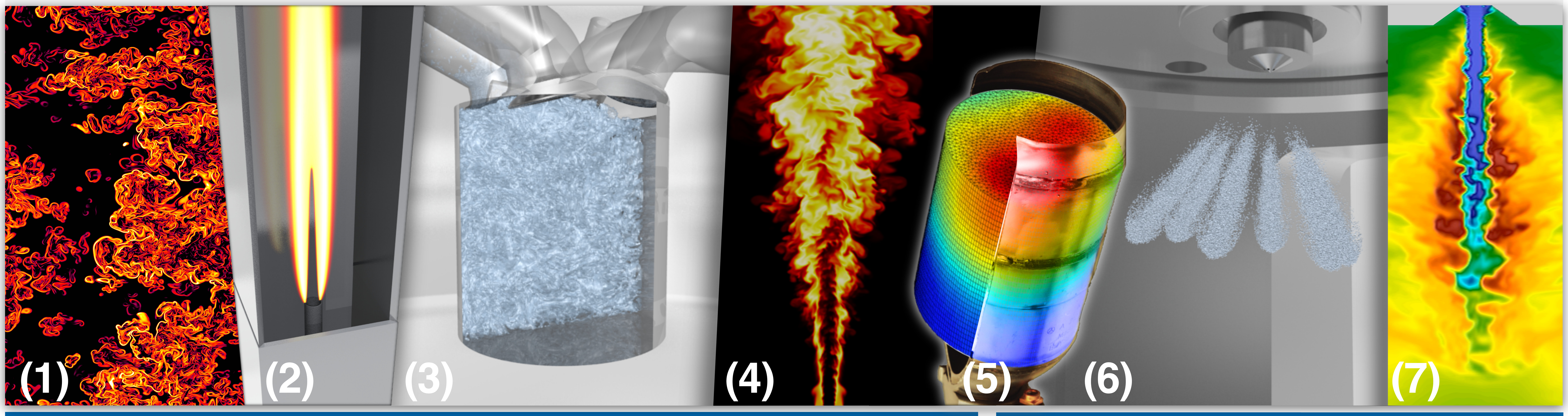
Applications

(1) DNS of shear-layer (DINO),
(2) laminar DME flame (OpenFOAM),
(3) LES of DISI engine (ANSYS CFX),
(4) LES of turbulent DME flame (OpenFOAM),
(5) Three-way catalyst heterogeneous reaction (Matlab [14]/CARMA)
(6) Spray injection and evaporation (OpenFOAM),
(7) LES of coal gasifier (ANSYS Fluent)



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