الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري
Arab Academy for Science, Technology & Maritime Transport

CFD: Model Quality Assessment

PROSPECTS AND CHALLENGES

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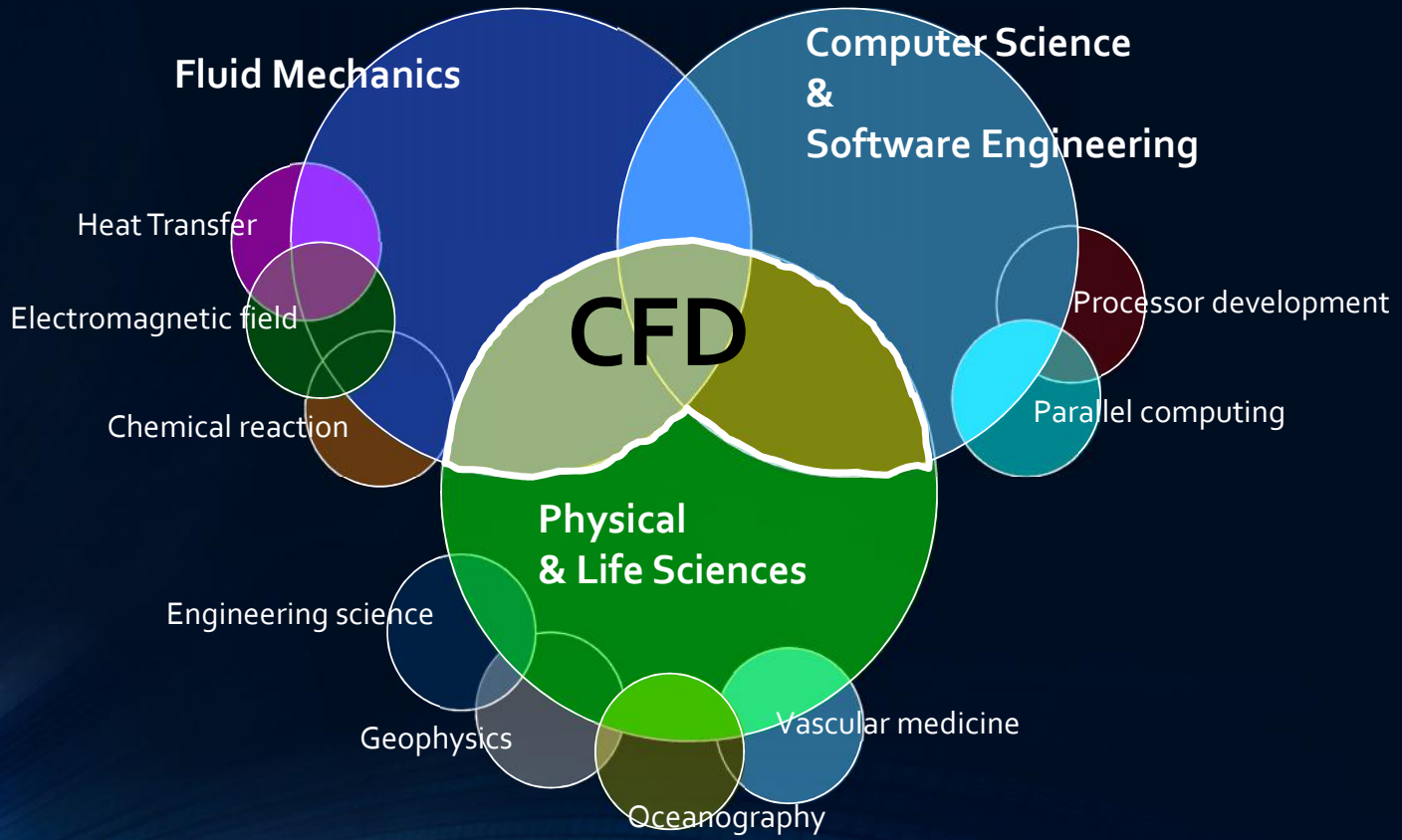
CFD Today: Research Areas

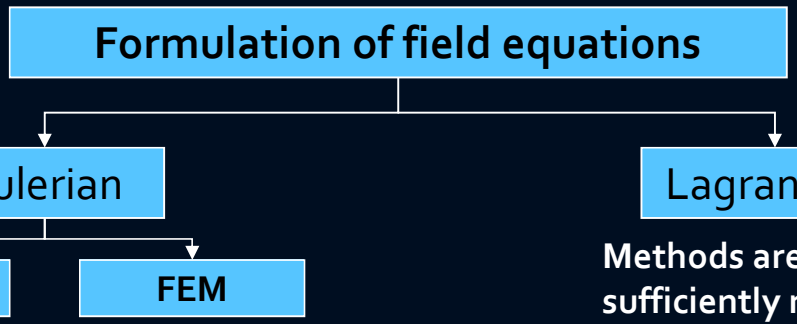


CFD Today: Frames of Reference

Theories of matter:	**Continuum hypothesis**	**Molecular / Kinetic theory**	Quantum theory
Mechanics:	**Newtonian**	Relativistic	
Chaos theory:	**Deterministic chaos**	Random chaos	

Engineering CFD

CFD Today: The Codes



Commercial codes:
-Fluent
-CFX
-CFD++
-FLACS
-FloTHERM
-EFDLab
-FlowVision
-PHOENIX
-… many more !

Open-Source:
-OpenFOAM
-Code_Saturne
-FDS

Commercial codes:

-COMSOL

-ADINA

Open-Source:

-Elmer

Methods are not sufficiently mature for engineering applications.

-Lattice Boltzmann Method

-DSMC

-SPH

No commercial codes.

Only "experimental" Open-Source codes !

CFD Today: Code Structure

Building Blocks

- Geometry & grid generation module
- Problem settings module
- Solution module
- Visualization module

What to :

Assume

- Boundary / initial conditions
- Physical models

and what to :

Neglect

- Physical phenomena (i.e. heat transfer, chemical reaction...etc)
- Properties (i.e. compressibility, real gas...etc)

and what to :

Calculate

- Unknowns
- Relationships between field variables

Solution methods and algorithms

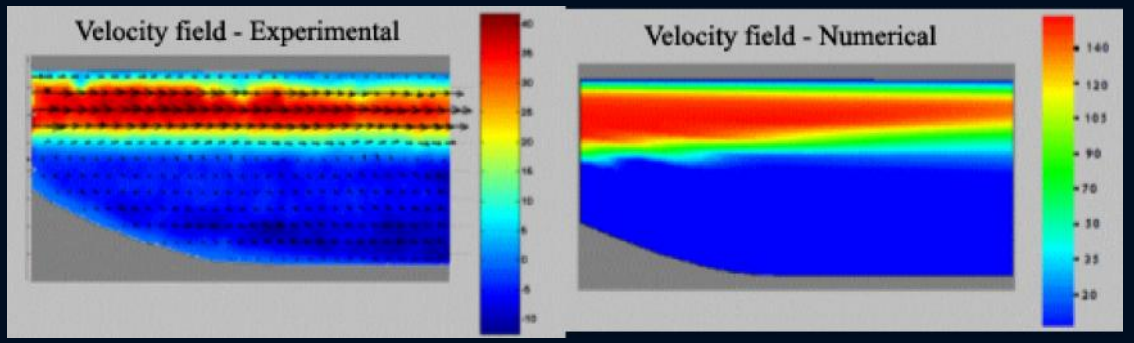
- Spatial / temporal descritization schemes
- Convergence criterion
- Interpolation methods
- ...etc.

CFD Today: Commercial vs. Open Source

Feature	Open-source	Commercial
Customization of physical models	Excellent	Good
Customization of numerical schemes	Excellent	Poor
Authenticity of physical models	Excellent	Good
User friendliness	Poor	Excellent
Free technical support	Poor	Good
Paid technical support	Excellent	Excellent
Academic use	Excellent	Poor ~ Good
Industrial use	Poor	Excellent

CFD Model Quality: Basic Measures

Colorful Fluid Dynamics (CFD)

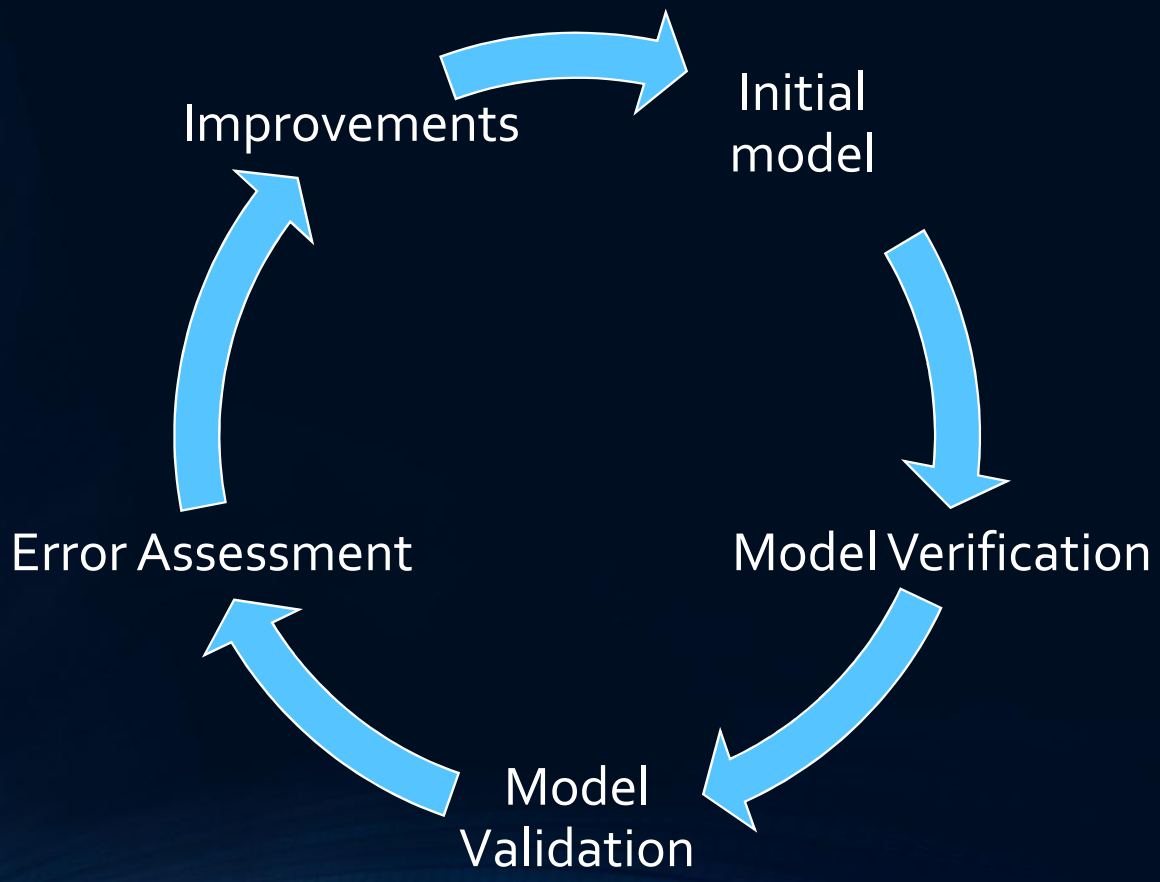


Computational Fluid Dynamics (CFD)

There are two basic measures for CFD model quality:

1. Does the mathematical model (i.e. equations) describe the physical phenomena accurately ?
2. Does the CFD model solves these equation accurately ?

CFD Model Quality Assessment



Building the initial model

- Assumptions regarding the boundary conditions must be taken from literature
- Grid size guidelines might be taken from the numerical scheme properties:
  - Courant number criteria from maximum grid size and time step
  - Peclet number criteria for the discretization scheme

Model Verification

1. • Grid independence test
2. • Time step test
   • Start by courant condition of 30, and reduce
3. • Numerical scheme test
   • Start by 2nd Order accurate scheme and not less
4. • Convergence test
   Start by residuals of the order of $1x10^{-4}$ and reduce

The verification procedure aims at assessing the numerical error produced in the solution due to:

1. Spatial discretization
2. Time discretization
3. Interpolation between cell and face values
4. Number of iterations

Model Validation

Define a representative location for the solution

↓

Compare the solution at the representative location with experimental measurements

↓

Estimate the error qualitatively and quantitatively

- A representative location is a location where the solution of the CFD model represent sound physical importance to the study (i.e. pipe radius, building height…etc)
- The comparison with experimental results must be firm, takes into account the problem scale and dimensions
- Error estimate must take into account the solution trend (quality) and statistical error (quantity). This can be done by very simple statistical tools such as the goodness of fit method.

Error Assessment

- A generalized error assessment framework must be developed to enable good quality assurance of the CFD Model
  - This could be done by integrating the error assessed at each stage of the model life cycle
- The error assessment framework must consider the model limitations (Reynolds number, temperature drop, chemical reaction mechanism…etc)

Model Improvements

- Model improvements must start with the attempting to reduce the numerical error before jumping to the model improvements → Every additional equation represent a great burdon on the solution time