

Review of Open-Source Software Based on DG Method for Simulation of Ideal Gas Flows on Unstructured Meshes

Korchagova V.N.^{1,2}, Sautkina S.M.², Fufayev I.N.³

¹*Ivannikov Institute for System Programming of the RAS*

²*Bauman Moscow State Technical University*

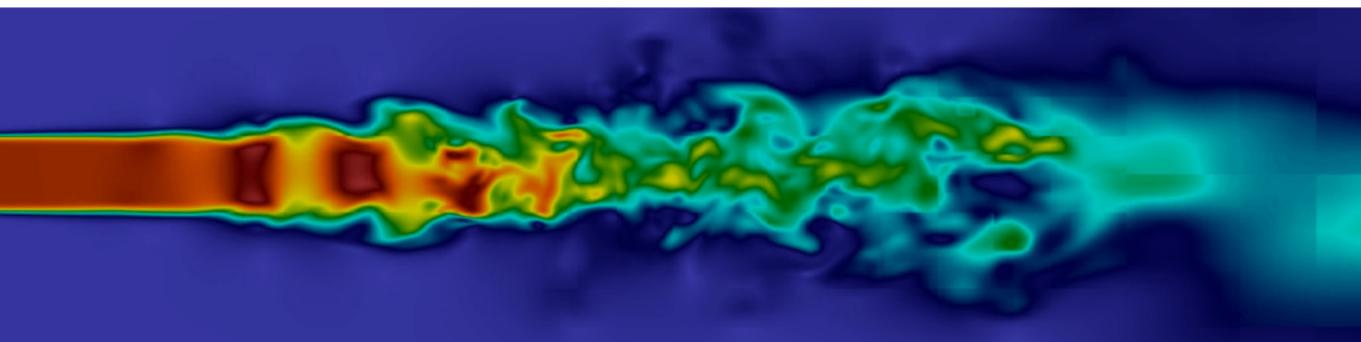
³*Keldysh Institute of Applied Mathematics of the RAS*

Moscow
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Introduction

Gas dynamics specifics

- Discontinuity of solution
- Hydro- and gas dynamic instabilities (Rayleigh–Taylor, Kelvin–Helmholtz, *etc.*)
- Different directions of disturbances propagation in subsonic and supersonic flows



Discontinuous Galerkin method

$$\text{FEM} + \text{FVM} = \text{DG}$$

Advantages

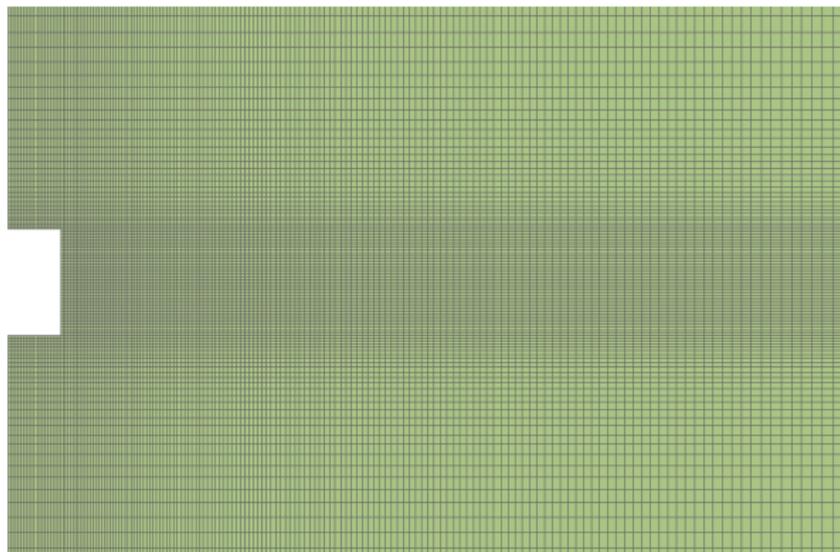
- Compact stencil
- Easy to increase the order of accuracy
- Strong theory of numerical fluxes (Lax–Friedrichs, HLL, HLLC, *etc.*)

Main difficulties

- Monotonization of solution is required nearby strong discontinuities
- Complexity of implementation

Ladenburg underexpanded jet, 2D formulation¹

$t^* = 7.6 \cdot 10^{-4}$ s; $Co = 0.5$; HLL flux

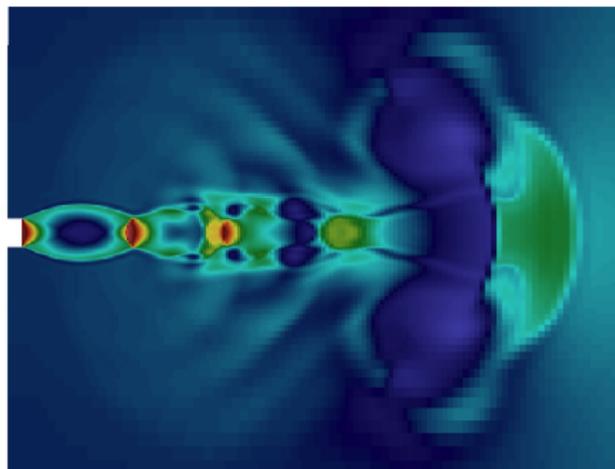


Part of mesh, 40 cells per diameter (built with SALOME)

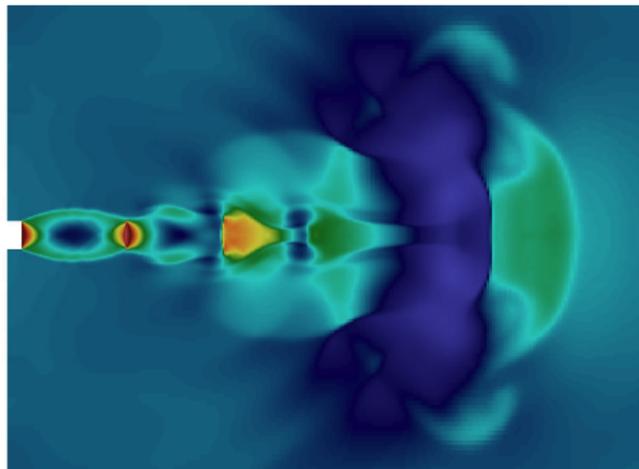
¹<https://journals.aps.org/pr/abstract/10.1103/PhysRev.76.662>

Ladenburg underexpanded jet, 2D formulation

$t^* = 7.6 \cdot 10^{-4}$ s; $Co = 0.5$; HLL flux



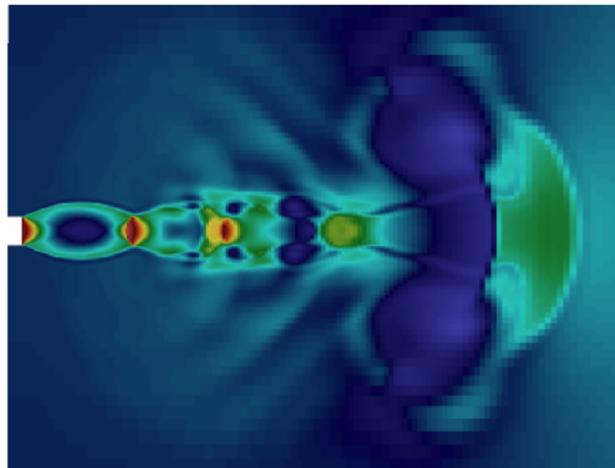
RKDG (in-house code), 40 cpd



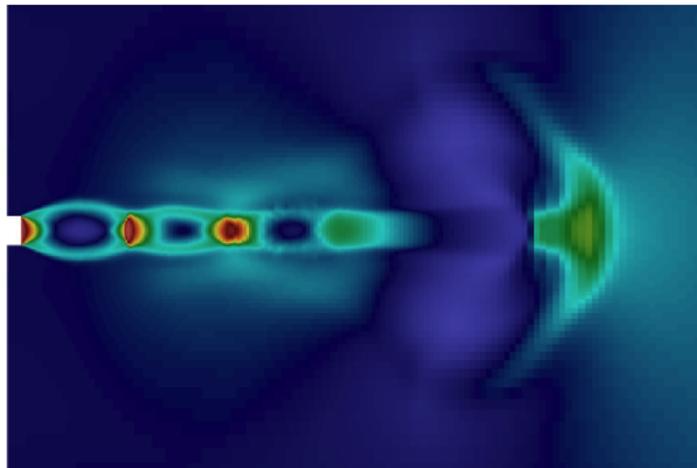
rhoPimpleCentralFoam, 80 cpd

Ladenburg underexpanded jet, 2D formulation

$t^* = 7.6 \cdot 10^{-4}$ s; $Co = 0.5$; HLL flux



RKDG (in-house code)



OpenFOAM (rhoPimpleCentralFoam)

Density field, 40 cells per diameter

GitHub statistics

 Why GitHub? Enterprise Explore Marketplace Pricing discontinuous galerkin 7 Sign in Sign up

Repositories 144

[Code](#) ?

[Commits](#) 247

[Issues](#) 112

[Packages](#) 0

[Marketplace](#) 0

[Topics](#) 2

[Wikis](#) 32

[Users](#) 6

Languages

C++	43
Python	28
Fortran	12
MATLAB	12
C	11
Julia	5
Jupyter Notebook	5
Java	3
Objective-C	2
PostScript	2

144 repository results

Sort: **Most stars**

flexi-framework/flexi Fortran ★ 55

Open Source High-Order Unstructured
Discontinuous Galerkin Fluid Dynamics Solver

GPL-3.0 license Updated on 9 Oct

ABAtanasov/GalerkinSparseGrids.jl Julia ★ 25

Sparse Grid Discretization with the *Discontinuous Galerkin* Method for solving PDEs

[sparse-grids](#) [discretization](#) [interpolation](#)

Updated on 24 Sep

inducer/hedge Python ★ 25

Hybrid-and-Easy *Discontinuous Galerkin* Environment

Updated on 6 Aug 2018

cpraveen/dflo C++ ★ 24

Discontinuous Galerkin solver for compressible flows

[compressible-flows](#) [c-plus-plus](#) [mpi](#)

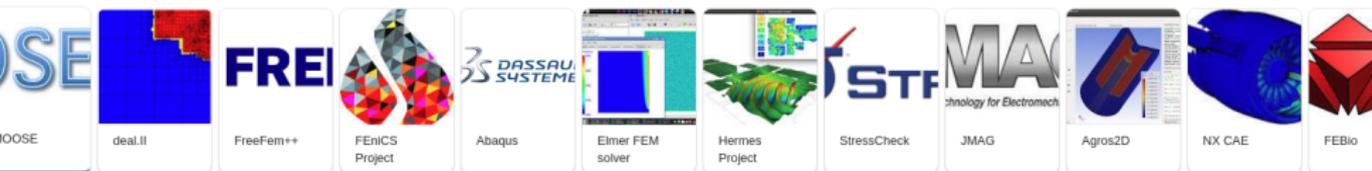
06.12.2019 7 / 16

What about big codes?

"Is there any software or source code of Discontinuous Galerkin method?"^a

^aResearchGate, 2014

- Last answer: 03.11.2019
- **11** codes are proposed
- **8** codes are alive now



How to choose the code?

View of a scientific user

Code “at a glance”:

- contains needed features;
- documentation;
- set of tutorials;
- community (workshops, feedbacks, seminars...);
- compatibility with other formats.

First experience:

- fast and comfortable installation;
- running of tutorials;
- verification with own tests;
- readability and flexibility of code.

Large set of features

Diversity of features

- DG as one of the FEM-based approaches
 - different solvers for various problems
 - unstructured meshes and adaptive mesh refinement
 - massive parallelism
-
- Common structure of codes: FEM libraries + DG support + some addons
 - First steps in DG: solvers for advection equation
 - Most of packages: **DG only for problems with continuous solutions**
 - Compressible flow solvers are rare

Codes with compressible flow solver



- C++
- Imperial College London and University of Utah
- 2015
- DG, Spectral Element Galerkin, Flux Reconstruction
- Numerical fluxes: Lax–Friedrichs, HLL, HLLC, AUSM, Roe, Toro
- Artificial viscosity in troubled cells; author's indicator
- High compatibility (gmsh, Star-CCM, VTK...)

Flexi

- Fortran
- Universitat Stuttgart
- 2019
- Pure DG
- Numerical fluxes: Lax–Friedrichs, HLL, HLLC, Roe
- Subcell FVM in troubled cells; indicators – Pierson, Jameson, Ducros
- Own pre- and postprocessor HOPR + conversion to different formats (gmsh, VTK...)

Test cases

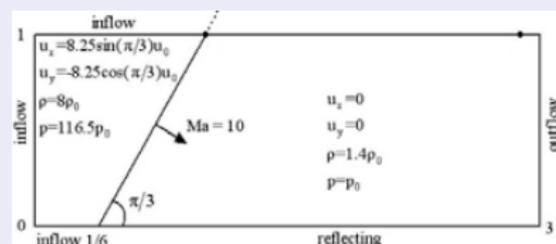
Sod problem (quasi-1D)

$$(\rho, u, v, w, p) = \begin{cases} (1, 0, 0, 0, 1), & x \leq 0.5, \\ (0.125, 0, 0, 0, 0.1), & x > 0.5. \end{cases}$$

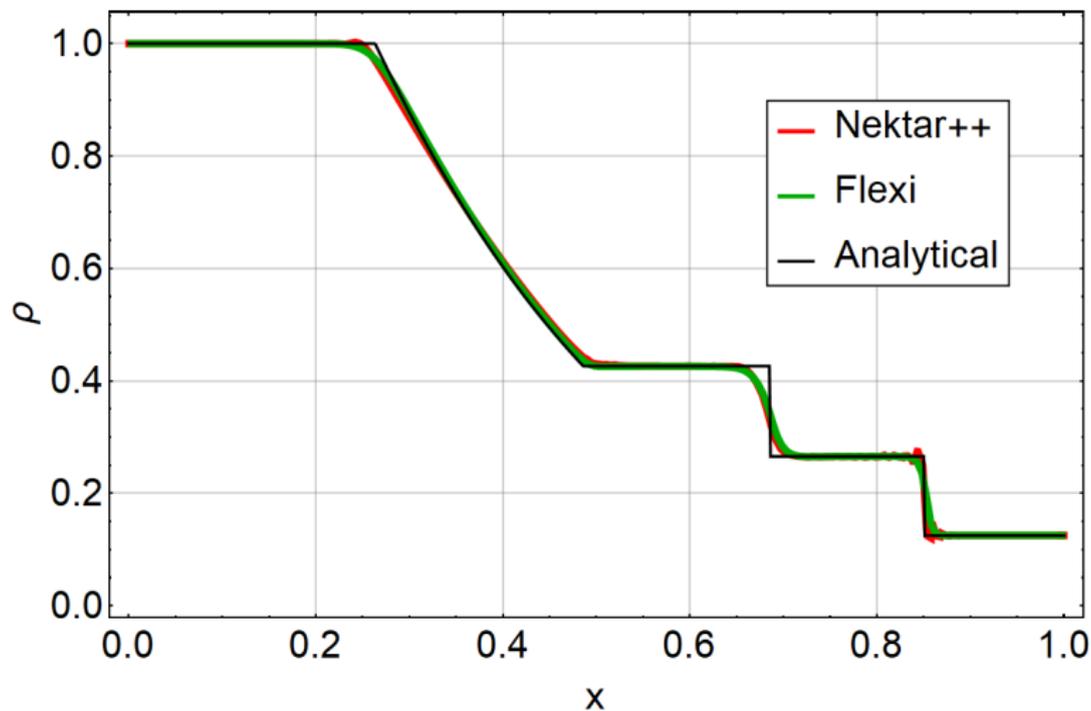
Forward step



Double Mach reflection



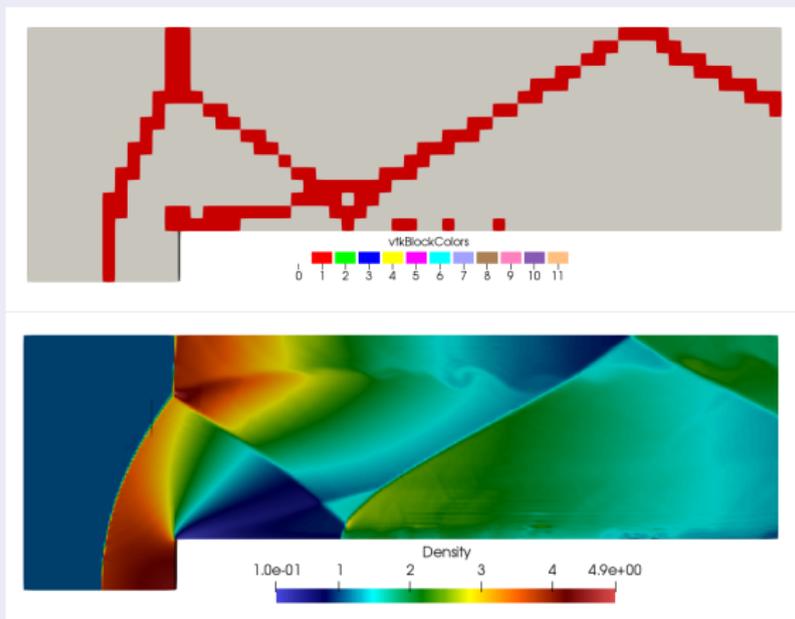
Sod problem (quasi-1D)



Forward Step problem

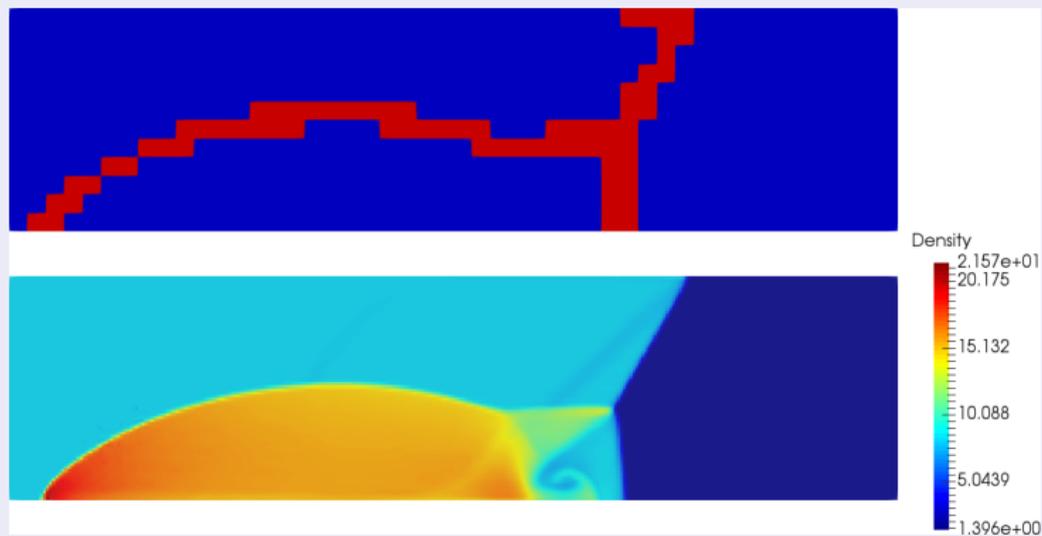
Nektar++: unstable computation

Flexi



Double Mach Reflection problem

Flexi



Summary

- Large set of codes implies DG approach
- Too much difficulties in using apart from developers:
 - ▶ installation problems: compatibility of versions of shared libraries;
 - ▶ difficulties of setup;
 - ▶ holes in documentation
- Seems promisingly for modification and improvement

Thank you for your attention!