Ani3D расширение параллельной платформы INMOST для CFD приложений

В. К. Крамаренко[1,3] И. Н. Коньшин[1,2] Ю. В. Василевский[1,3]

[1]ИВМ РАН

[2]ФИЦ ИУ РАН (ВЦ РАН)

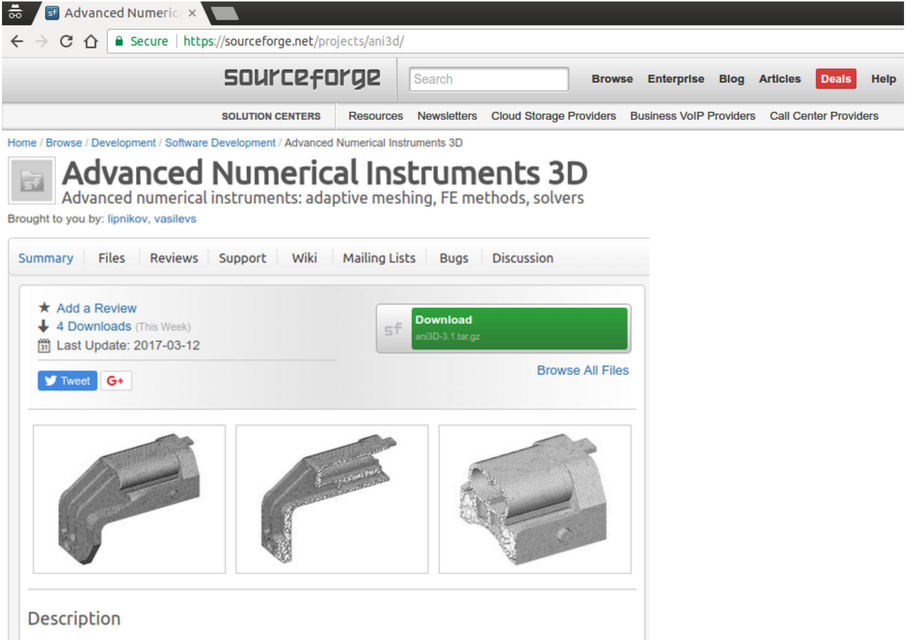
[3]МФТИ

CFD-Weekend, 2017

План

- Последовательный пакет Ani3D
- Параллельная платформа INMOST
- Интеграция Ani3D–INMOST
- Модельные CFD задачи

Ani3D


Advanced Numeric
Secure
https://sourceforge.net/projects/ani3d/
sourceforge
Search
Browse
Enterprise
Blog
Articles
Deals
Help
SOLUTION CENTERS
Resources
Newsletters
Cloud Storage Providers
Business VoIP Providers
Call Center Providers
Home / Browse / Development / Software Development / Advanced Numerical Instruments 3D
Advanced Numerical Instruments 3D
Advanced numerical instruments: adaptive meshing, FE methods, solvers
Brought to you by: lipnikov, vasilevs
Summary
Files
Reviews
Support
Wiki
Mailing Lists
Bugs
Discussion
Add a Review
4 Downloads (This Week)
Last Update: 2017-03-12
Tweet
G+
Download
ani3D-3.1.tar.gz
Browse All Files
Description

Ani3D software package

- Generation of tetrahedral meshes
- Mesh adaptation
- FEM discretization on tetrahedral meshes
- Solution of linear and nonlinear systems
- *Serial* code in Fortran and C

Open source code: `http://sourceforge.net/projects/ani3d`

Ani3D libraries

Ani-MBA library

- generation of quasi-uniform meshes in a user-defined metric
- uniform refinement of tetrahedral meshes

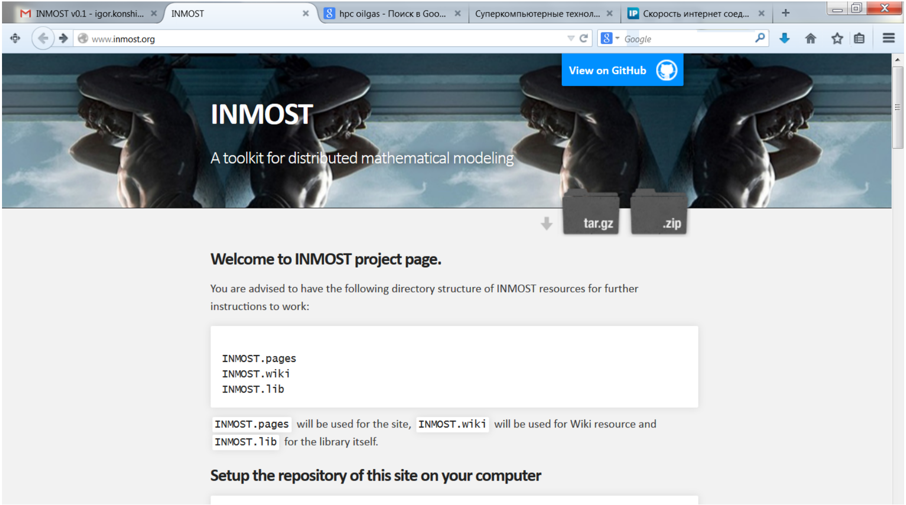
Ani-FEM library

- local finite element discretization on tetrahedron
- assembling the local discretizations into a global linear system

the rest of libraries...

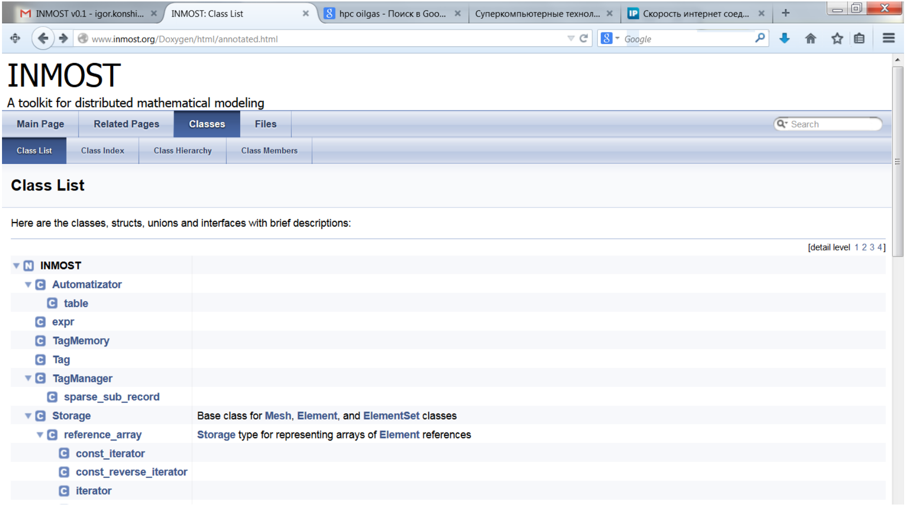
- Ani-C2F, Ani-INB, Ani-LMR, Ani-PRJ, Ani-RCB
- Ani-ILU, Ani-LU

INMOST: www.inmost.org



INMOST: wiki.inmost.org

INMOST: doxygen.inmost.org



INMOST

- **I**ntegrated
- **N**umerical
- **M**odelling and
- **O**bject-oriented
- **S**upercomputing
- **T**echnologies

INMOST is the software platform for developing parallel numerical models on general meshes.

INMOST is a tool for supercomputer simulations characterized by a maximum generality of supported computational meshes, distributed data structure flexibility, cost-effectiveness, cross platform portability.

INMOST: Mesh

- Mesh data are distributed
- Conformal meshes with Tetrahedra, Hexahedra, Prisms, Pyramids, Polyhedra etc.
- Mesh elements hierarchy: Vertex, Edge, Face, Cell
- Mesh element can contain some data (tags)
- Specification of “ghost” elements (“hallo”)
- Exchange tag data for ghost elements
- Save/Load mesh data in a parallel format file (.pmf, .pvtk, ...)

INMOST: Solver

- Assemble the distributed matrix and right-hand side of the linear system
- Parallel solution of the distributed linear system
- A set of internal linear solvers
- A set of external solvers: PETSc, Trilinos, SuperLU, ...

Parallelization Technology

Mesh

- read and partition
- refine on each processor *preserving conformity*
- merge

Init

- enumerate respective elements
- create tags for DOFs numbers
- synchronize tags

Assemble

- generate local matrix for each tetrahedron
- assemble them into a global matrix

Stokes problem

Formulation

$$
\begin{array}{rcccll}
-\Delta \boldsymbol{u} & + & \nabla p & = & 0 & \text{in} \quad \Omega \\
\nabla \cdot \boldsymbol{u} & & & = & 0 & \text{in} \quad \Omega \\
 & & \boldsymbol{u} & = & \boldsymbol{u}_0 & \text{on} \quad \partial\Omega_1 \\
 & & \boldsymbol{u} & = & 0 & \text{on} \quad \partial\Omega_2 \\
\frac{\partial \boldsymbol{u}}{\partial \boldsymbol{n}} & - & p & = & 0 & \text{on} \quad \partial\Omega_3
\end{array}
$$

$$
\boldsymbol{u}_0 = (64 \cdot (y - 0.5) \cdot (1 - y) \cdot z \cdot (1 - z), 0, 0)
$$

Stokes problem

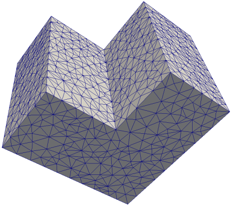


Figure : The coarsest mesh S0

Table : The problems parameters

Problem name	S0	S1	S2
Number of nodes	5187	36824	279903
Number of edges	31637	243079	1908542
Number of tetrahedra	25113	200904	1607232
Matrix size	115659	876533	6845238
Number of nonzeros	10751851	84374191	668849086

Numerical results

Table : The solution of S1 problem on $p = 1, ..., 32$ processors

p	T_{ini}	T_{ass}	T_{prec}	T_{iter}	N_{iter}	Dens	PM	T_{sol}	S
1	0.38	69.07	31.41	97.20	242	0.85	0	128.61	1.00
2	0.28	40.97	20.30	76.88	322	0.93	0	97.18	1.32
4	0.21	25.31	12.76	47.88	332	1.03	0	60.64	2.12
8	0.14	13.76	7.83	28.68	332	1.15	1	36.51	3.52
16	0.10	8.37	4.77	18.46	362	1.37	3	23.23	5.53
32	0.06	5.09	4.12	12.70	402	1.65	8	16.82	7.64

Table : The solution of S2 problem on $p = 4, ..., 32$ processors

p	T_{ini}	T_{ass}	T_{prec}	T_{iter}	N_{iter}	Dens	PM	T_{sol}	S
4	1.48	181.05	142.29	1484.02	722	0.97	0	1626.31	1.00
8	0.90	94.03	76.01	847.62	802	1.03	0	923.63	1.76
16	0.58	52.03	72.70	481.50	802	1.10	2	554.20	2.93
32	0.37	29.23	26.88	288.73	802	1.21	2	315.61	5.15

Unsteady convection-diffusion problem

Formulation

$$
\begin{aligned}
\frac{\partial c}{\partial t} \quad - \quad \nabla\left(D\nabla c\right) \quad + \quad \mathbf{v}\cdot\nabla c \quad &= \quad 0 \quad \text{in} \quad \Omega \\
c \quad &= \quad g \quad \text{on} \quad \partial\Omega
\end{aligned}
$$

$$
D = \begin{pmatrix} 0.001 & 0 & 0 \\ 0 & 0.001 & 0 \\ 0 & 0 & 0.001 \end{pmatrix}
$$

$$
\mathbf{v} = (1, 0, 0)
$$

Unsteady convection-diffusion problem

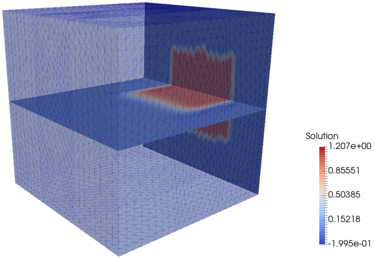


Figure : The concentration at time $t = 0.5$

Table : The problems parameters

Problem name	L0	L1	L2
Number of nodes	20417	155905	1218561
Number of tetrahedra	111616	892928	7143424
Matrix size	20417	155905	1218561
Number of nonzeros	291393	2281217	18053121

Numerical results

Table : The solution of problem on mesh L1 on $p = 1, ..., 32$ processors

p	T_{ini}	T_{ass}	T_{sol}	T_{Σ}	S
1	26.16	552.87	33.86	612.89	1.00
2	16.48	327.93	21.31	365.72	1.67
4	9.83	197.89	12.19	219.91	2.78
8	5.75	114.81	7.28	127.84	4.79
16	3.56	73.57	4.03	81.16	7.55
32	2.31	47.28	2.45	52.04	11.77

Table : The solution of problem on mesh L2 on $p = 1, ..., 32$ processors

p	T_{ini}	T_{ass}	T_{sol}	T_{Σ}	S
1	436.82	5692.31	723.23	6852.36	1.00
2	169.17	2628.09	258.71	3055.97	2.24
4	94.33	1461.24	147.30	1702.87	4.02
8	53.62	874.21	91.24	1019.07	6.72
16	31.52	522.99	53.28	607.79	11.27
32	17.6	308.84	29.61	356.05	19.24

Выводы

- Представлено Ani3D-расширение параллельной программной платформы INMOST.
- Функциональность INMOST расширена за счет КЭ и сеточной библиотек пакета Ani3D.
- Численные эксперименты продемонстрировали параллельную эффективность подхода.
- Примеры могут быть загружены с:

https://github.com/INMOST-DEV/INMOST/tree/master/Examples/Ani_Inmost

Динамическое управление параметрами линейных решателей для нестационарной задачи фильтрации

Д. В. Багаев[1,3] И. Н. Коньшин[1,2] К. Д. Никитин[1]

[1]ИВМ РАН

[2]ФИЦ ИУ РАН (ВЦ РАН)

[3]МГУ

CFD-Weekend, 2017

Linear systems and linear solvers

- Solution of linear systems
- Linear systems are differ
- A lot of linear solvers
- A lot of parameters for each linear solver
- How to choose the linear solver
- How to choose the linear solver parameters

Goal

- Time optimization of $A_k x = b_k$
- INMOST
- BIILU2 linear solver
- τ – threshold parameter p
- q – overlap parameter

N14 sample problem

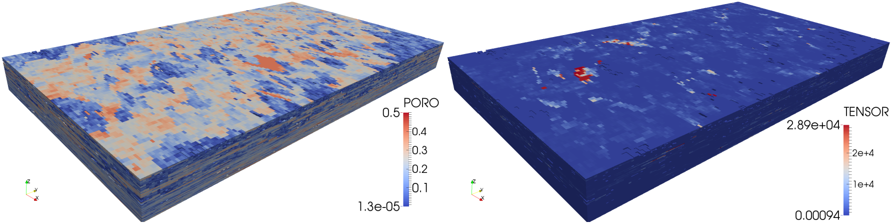


Figure : The porosity and permeability distributions for SPE-10 problem

Black-Oil Simulator for Scholars (BOSS) for SPE-10 problem.
The size of the model mesh is $60 \times 220 \times 85$ cells ($1.122 \cdot 10^6$ cells).
The porosity varies from $1.3 \cdot 10^{-5}$ to 0.5 (see Fig. left).
The permeability varies from 10^{-3} to $3 \cdot 10^4$ (see Fig. right).
The model has 5 vertical wells completed throughout formation.
The dimension of the linear system N14 is 3 896 013 unknowns.

Unsteady black-oil simulation – fixed parameters (τ, q)

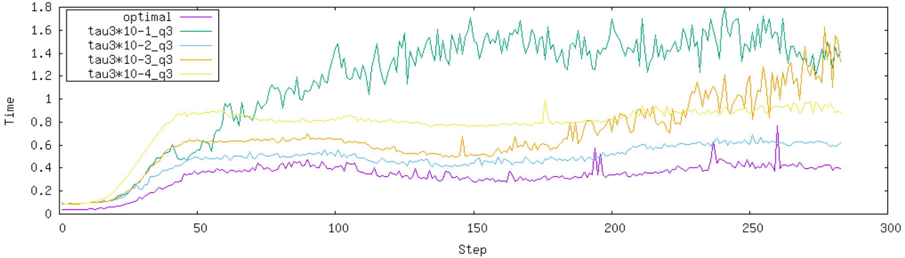


Figure : Unsteady black-oil simulation solution times depending on time step k

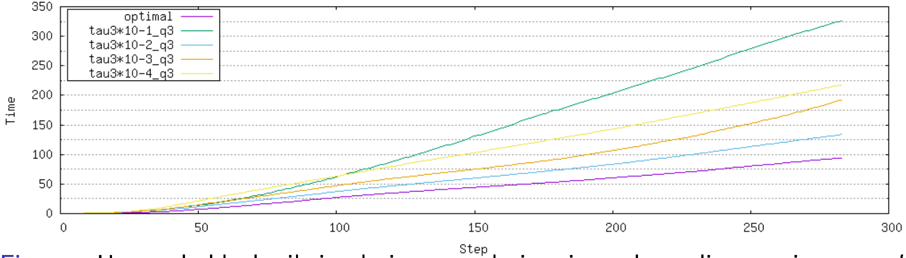


Figure : Unsteady black-oil simulation cumulative times depending on time step k

Unsteady black-oil simulation – parameters optimization

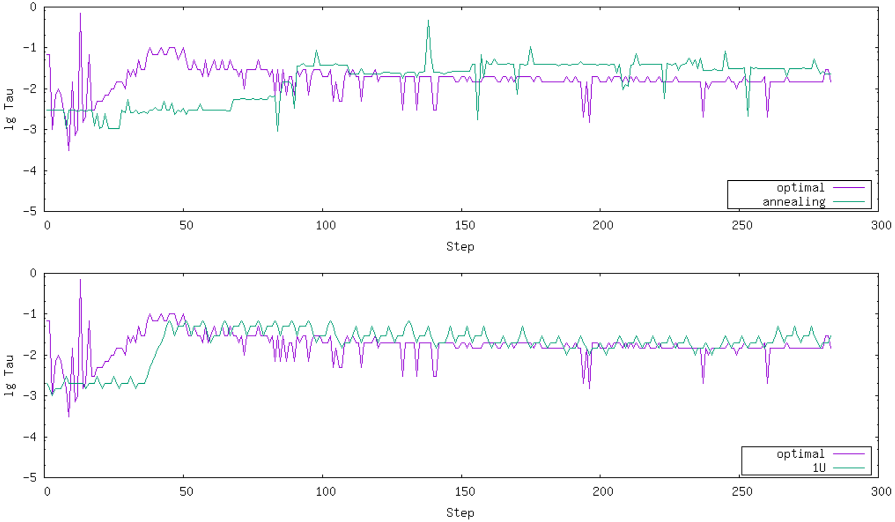


Figure : Optimizing τ for black-oil simulator

Unsteady black-oil simulation – parameters optimization

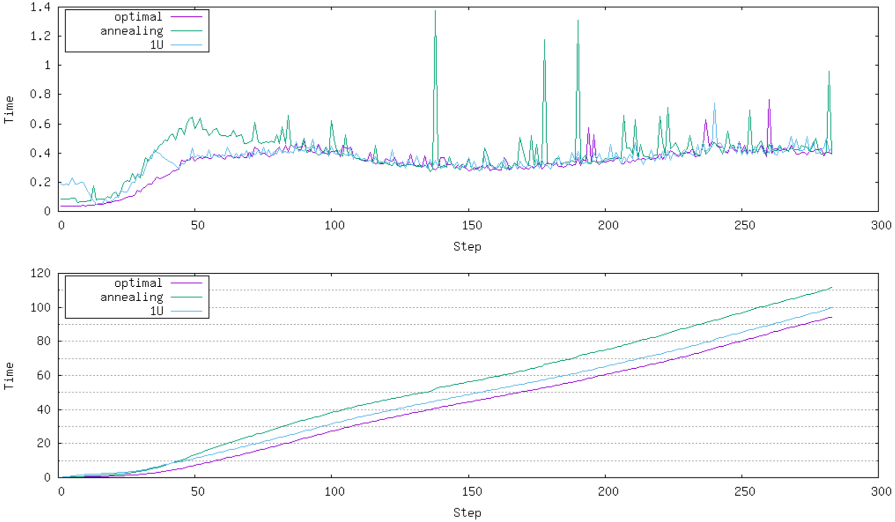


Figure : Local and cumulative times depending on time step k

Unsteady black-oil simulation – parameters optimization

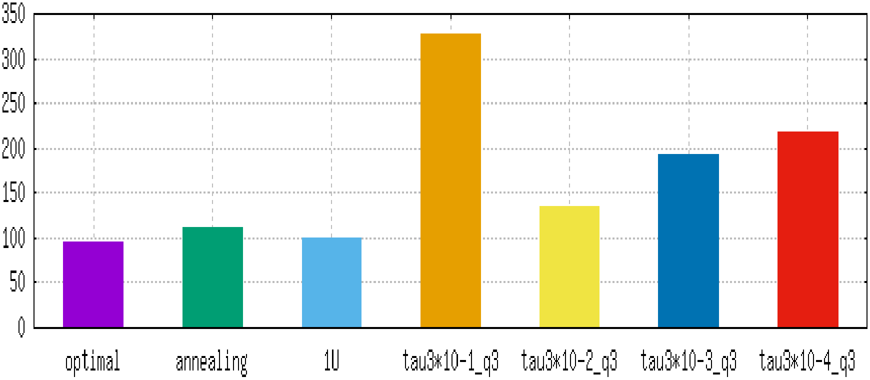


Figure : Cumulative times bar chart for default sets of parameters and for proposed algorithms compared with the optimal one

Выводы

- Предложены несколько алгоритмов оптимизации порога фильтрации τ
- Время решения близко ($\approx$10%) к оптимальному
- Лучше чем любой фиксированный набор параметров
  - В 2-3-4 раз лучше чем “обычные” наборы параметров
  - В 1.5 раза лучше чем “наилучший” набор

- Может быть применено к:
  - другим линейным решателям типа PETSc AS(q)+ILU(k)
  - другим нестационарным приложениям, например, гемодинамике