Cgmp: A Multi-Physics Multi-Domain Solver User Guide and Reference Manual

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Abstract:
This document describes **Cgmp**, a solver written using the **Overture** framework to solve multi-physics multi-domain problems. The solver can be used, for example, to solve thermal hydraulics problems where fluid flow in one domain is coupled to heat transfer in another *solid* domain.

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1 Introduction

This document is currently under development.

Cgmp solves problmes on overlapping grids and is built upon the **Overture** framework [**?**],[**?**],[**?**].

2 The Equations

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5 Convergence results

This section details the results of various convergence tests. Convergence results are run using the **twilight-zone** option, also known less formally as the **method of analytic solutions**. In this case the equations are forced so the the solution will be a known analytic function.

The tables show the maximum errors in the solution components. The rate shown is estimated convergence rate, σ, assuming error $\propto h^{\sigma}$. The rate is estimated by a least squares fit to the data.

The 2D trigonometric solution used as a twilight zone function is

$$
\begin{aligned}
u &= \frac{1}{2}\cos(\pi\omega_0 x)\cos(\pi\omega_1 y)\cos(\omega_3\pi t) + \frac{1}{2} \\
v &= \frac{1}{2}\sin(\pi\omega_0 x)\sin(\pi\omega_1 y)\cos(\omega_3\pi t) + \frac{1}{2} \\
p &= \cos(\pi\omega_0 x)\cos(\pi\omega_1 y)\cos(\omega_3\pi t) + \frac{1}{2}
\end{aligned}
$$

The 3D trigonometric solution is

$$
\begin{aligned}
u &= \cos(\pi\omega_0 x)\cos(\pi\omega_1 y)\cos(\pi\omega_2 z)\cos(\omega_3\pi t) \\
v &= \frac{1}{2}\sin(\pi\omega_0 x)\sin(\pi\omega_1 y)\cos(\pi\omega_2 z)\cos(\omega_3\pi t) \\
w &= \frac{1}{2}\sin(\pi\omega_0 x)\sin(\pi\omega_1 y)\sin(\pi\omega_2 z)\cos(\omega_3\pi t) \\
p &= \frac{1}{2}\sin(\pi\omega_0 x)\cos(\pi\omega_1 y)\cos(\pi\omega_2 z)\sin(\omega_3\pi t)
\end{aligned}
$$

When $\omega_0 = \omega_1 = \omega_2$ it follows that $\nabla \cdot \mathbf{u} = 0$. There are also algebraic polynomial solutions of different orders.

grid	N	p	u	v	T	$\nabla \cdot \mathbf{u}$	T_s
innerOuter1	20	1.32e-02	3.69e-03	2.74e-03	8.37e-04	2.68e-02	1.75e-03
innerOuter2	40	2.17e-03	4.03e-04	3.26e-04	1.85e-04	5.01e-03	4.33e-04
innerOuter4	80	4.20e-04	5.31e-05	3.89e-05	4.55e-05	1.71e-03	1.09e-04

Table 1: Inner-outer. Maximum errors, polynomial, $t = 1.$, $\nu = .1$, $k_T = \nu/P_r$, $k_s = .01$ (?).

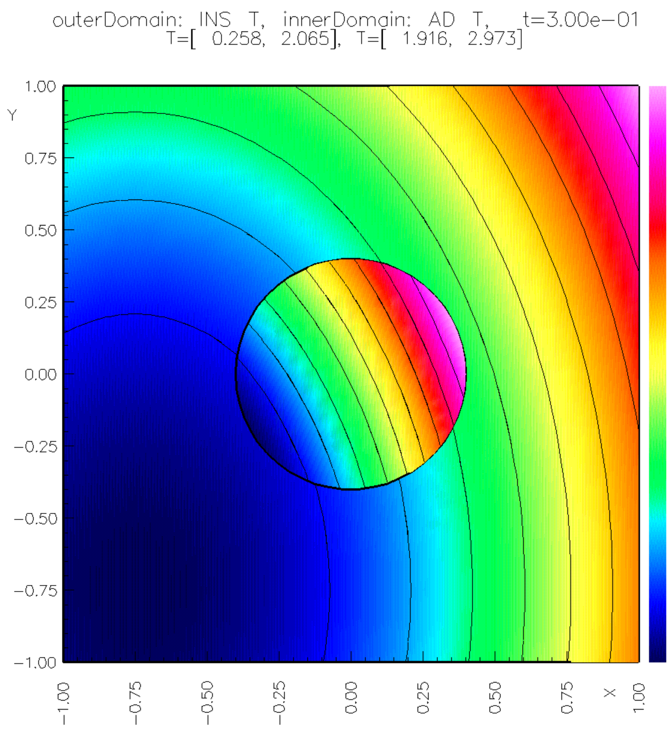

Figure 1: INS outside, AD inside, TZ.

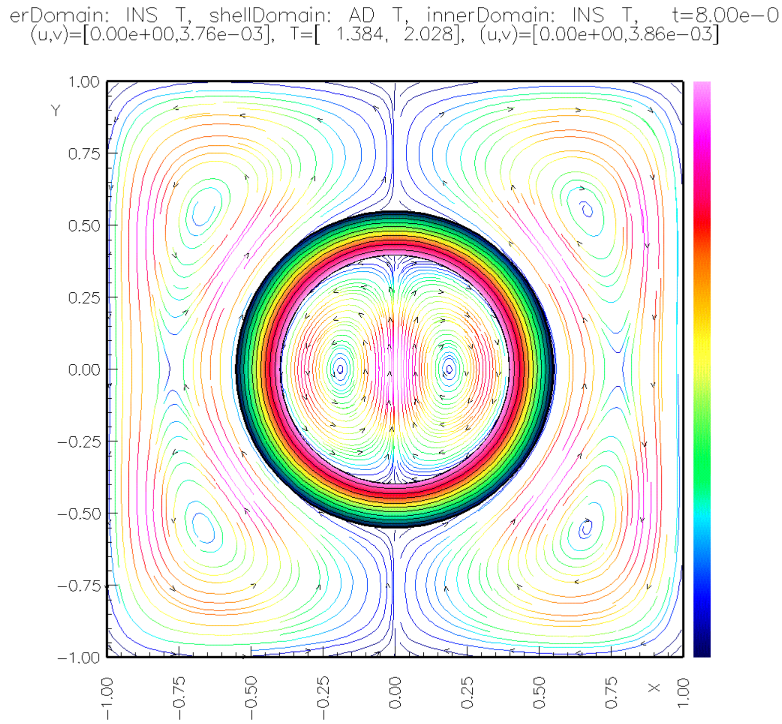

Figure 2: INS outside, AD in shell, INS inside.

6 Some interesting examples

Here is a collection of interesting examples computed with Cgmp.

6.1 A Hot cylindrical shell separating two incompressible fluids

Figure 2 shows a solid ”hot” shell separating two incompressible (Boussinesq) fluids

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