Peano Geometry Sophisticated Interface (PeGSI)

BGCE Honours Project

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ABSTRACT

" The increasing accuracy requirements in many of today's simulation tasks in science and engineering more and more often entail the need to take into account more than one physical effort. Among the most important and, with respect to both modelling and computational issues, most challenging of such 'multiphysics' problems are Fluid-Structure Interactions (FSI), i.e. interactions of some movable or deformable elastic structure with an internal or surrounding fluid flow" ([3], p. V). In order to be able to tackle such problems, effective and efficient simulation programs are needed. Here we present the Peano Geometry Sophisticated Interface (PeGSI), which acts as a geometry interface and a decoupling layer between a fluid and a structure solver. The final objective is to be able to simulate the drift ratchet phenomenon described in [4]. PeGSI is a BGCE honours project: The Bavarian Graduate School of Computational Engineering offers an honours program funded by the Elite Network of Bavaria to promote highly qualified students. Part of the program's curriculum is extensive project work. These honours projects are usually run by small groups of students and last six up to eight months (http://www.bgce.de).

1 Introduction

1.1 Peano

- A fluid solver developed at the Chair of Scientific Computing in Computer Science, TUM [5, 2].
- **Goal**: Tackle sophisticated Fluid-Structure Interaction challenges.
- Based on spacetrees, space-filling curves, and stack-based data management with an efficient implementation (low memory requirements and a good cache behavior) [2].
- It supports 2D and 3D scenarios, adaptive cartesian grids, multi-level algorithms, and a domain decomposition.
- Supports parallel execution.

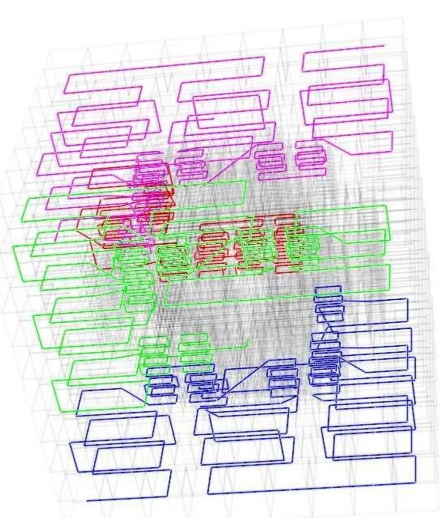

Figure 1: Domain decomposition in Peano

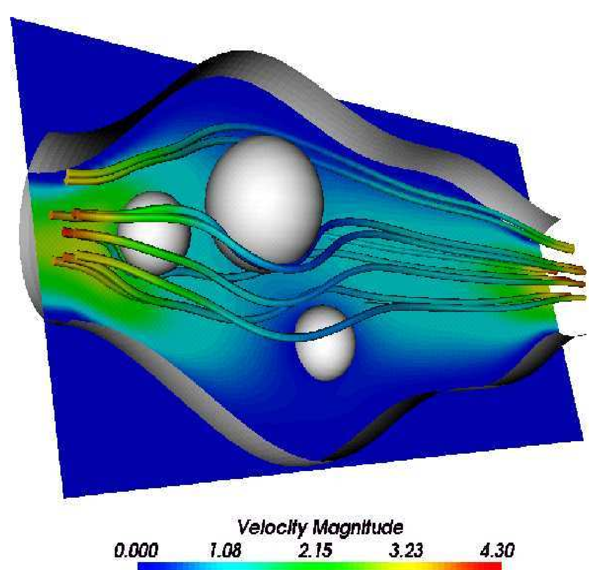

Figure 2: Example for a drift ratchet FSI problem [4] computed via F3F

1.2 PeGSI

Right now, geometry information is hand-coded inside Peano.

⇒ **Goal**: Develop a geometry interface for Peano (Peano Geometry Sophisticated Interface - PeGSI).

- Remove the coupling between the geometry information and the fluid solver code.
- Act as an abstraction layer between the Peano fluid solver and any structure solver.
- Support another fluid solver called F3F developed at the chair.
- Provide import filters for different geometry representations (e.g. IGES and STEP files formats).
- Thus, enable FSI simulations using Peano.
- Experience software engineering by practicing it through simulating a real software company.

2 Design

PeGSI consists of two main parts:

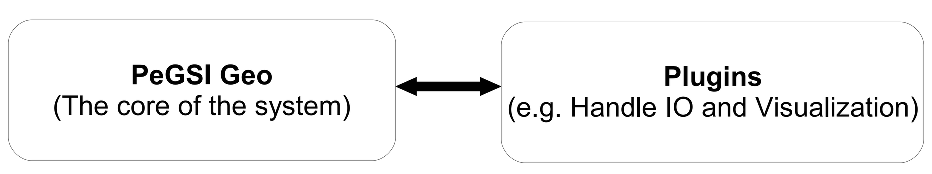

Figure 3: PeGSI components

⇒ Implementation was split into **three** releases. Each release addresses a specific issue and they are built up on each other subsequently.

✓ **Release 1**: Establish the spacetree processing kernel and establish Peano interface.

✓ **Release 2**: The mapping layer between the fluid solver and the structure solver.

✓ **Release 3**: Build a simple structure solver which will be deployed with PeGSI and Peano to simulate the drift ratchet problem [4] (Proof of concept).

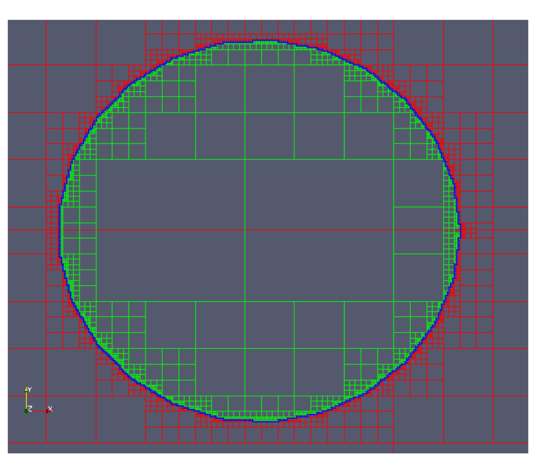

Figure 4: Simple 2D geometry representation using PeGSI

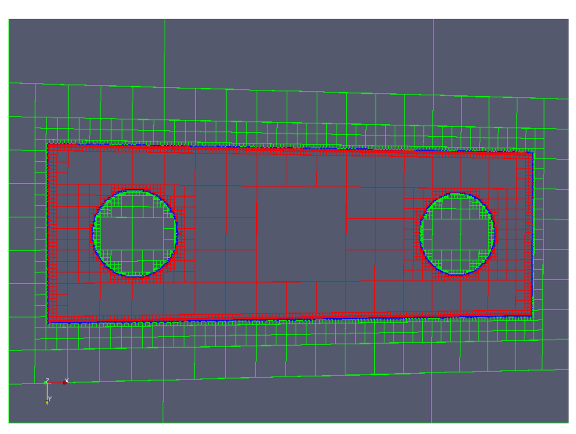

Figure 5: 2D channel using PeGSI

3 System Architecture

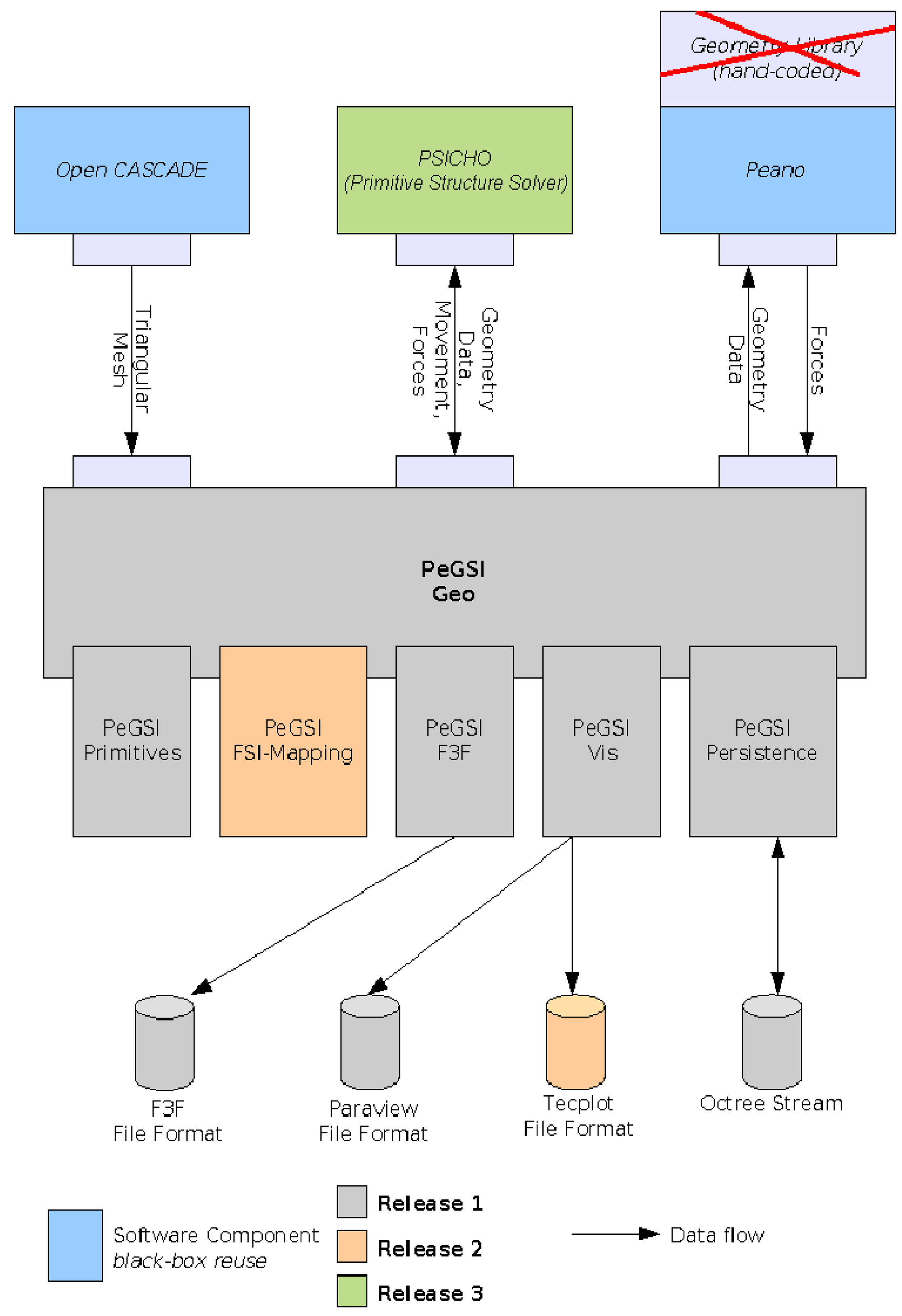

Figure 6: PeGSI architecture

4 Results

The following figures show some of the scenarios which were generated using PeGSI. It is worth noting that the space-tree used in PeGSI is **completely independent** from the grid used by Peano or any other fluid or structure solver. Moreover, the space-tree creation and modification is done at **runtime**, so there is no need for any preprocessor step. 2D and 3D are supported, and PeGSI is able to do a nearest neighbourhood search, force mapping and handle moving geometries.

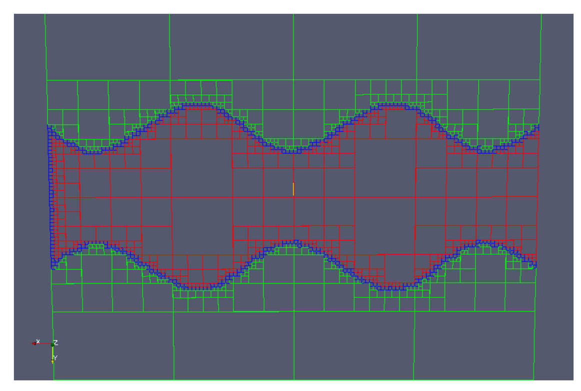

Figure 7: Driftratchet in 2D using Octrees

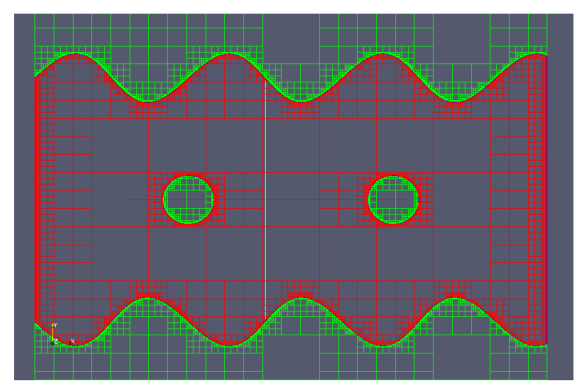

Figure 8: Driftratchet in 2D using Peano trees (a space-tree based upon tri-partitioning)

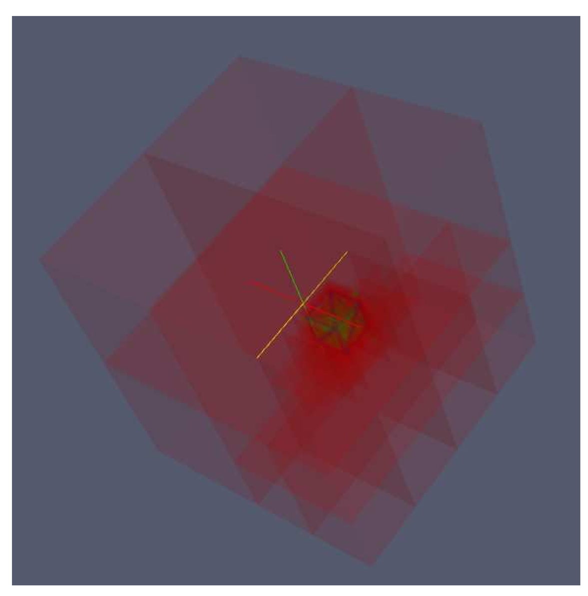

Figure 9: Cube representation in 3D using Octrees

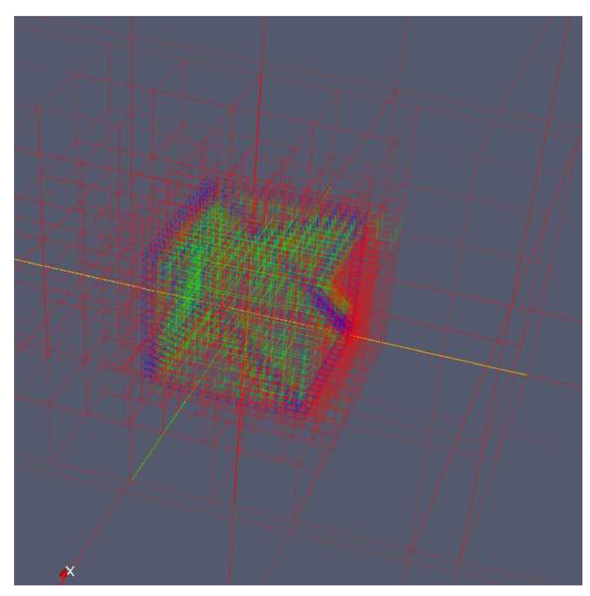

Figure 10: Cube representation in 3D using Peano trees

References

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[3] Hans-Joachim Bungartz and Michael Schäfer, editors. *Fluid-Structure Interaction - Modelling, Simulation, Optimisation*, volume 53 of *Lecture Notes in Computational Science and Engineering*. Springer-Verlag, Berlin, August 2006.

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