Integrating the Zoltan parallel partitioning and data distribution library into Fluidity

Paul Woodhams
NAG Ltd
Jon Hill
AMCG, Imperial College London

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nag®
Experts in numerical algorithms and HPC services

Overview

- Project
- Fluidity
- Adaptivity
- Parallel Adaptivity
- Zoltan
  - Usage
  - Difficulties
  - Benefits
- Conclusion

Project

- Collaboration between AMCG, Imperial College London and NAG Ltd
- 1 year of effort split over 2 years
- Aim to replace the current mesh re-partitioning solution with one using Zoltan
  - More general purpose (element types, particles)
  - Access to more partitioning libraries
  - Easier to extend

Fluidity

- Computational Fluid Dynamics code
- Finite Element
- Unstructured Mesh
- Adaptive Mesh
- Parallel

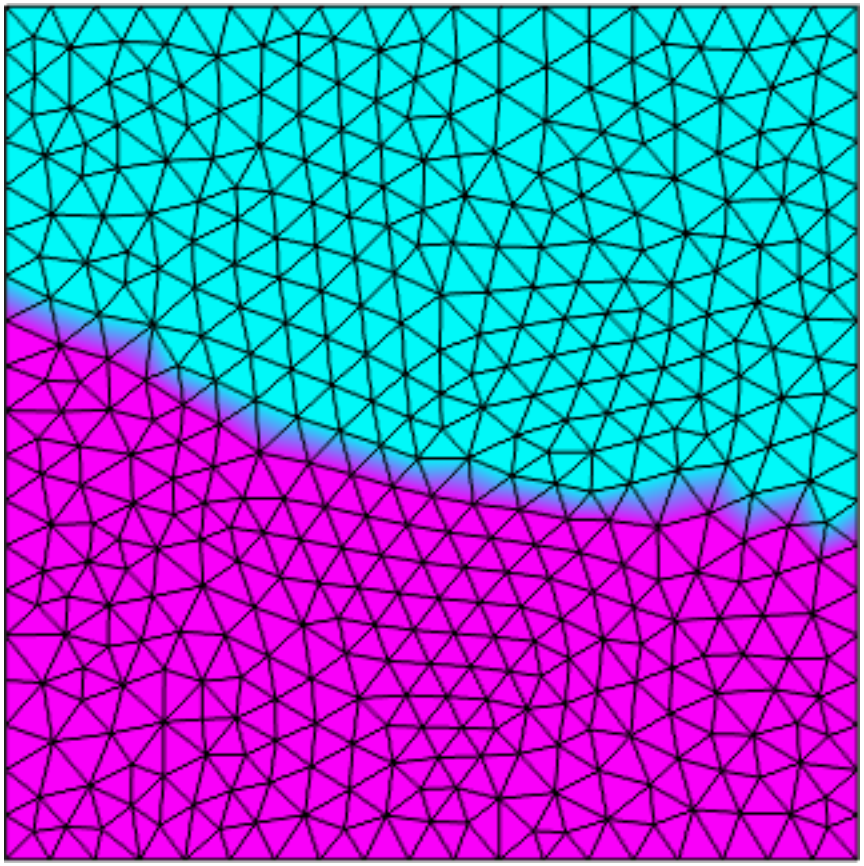
Adaptivity

- Adaptivity is a serial process
- Involves mesh refining/coarsening
- Form error metric from the solution fields
- Adapt mesh to minimize this error metric
- Benefits
  - Improves accuracy of solutions
  - Captures the behaviour of physical phenomena
  - Reduces computation by coarsening when possible

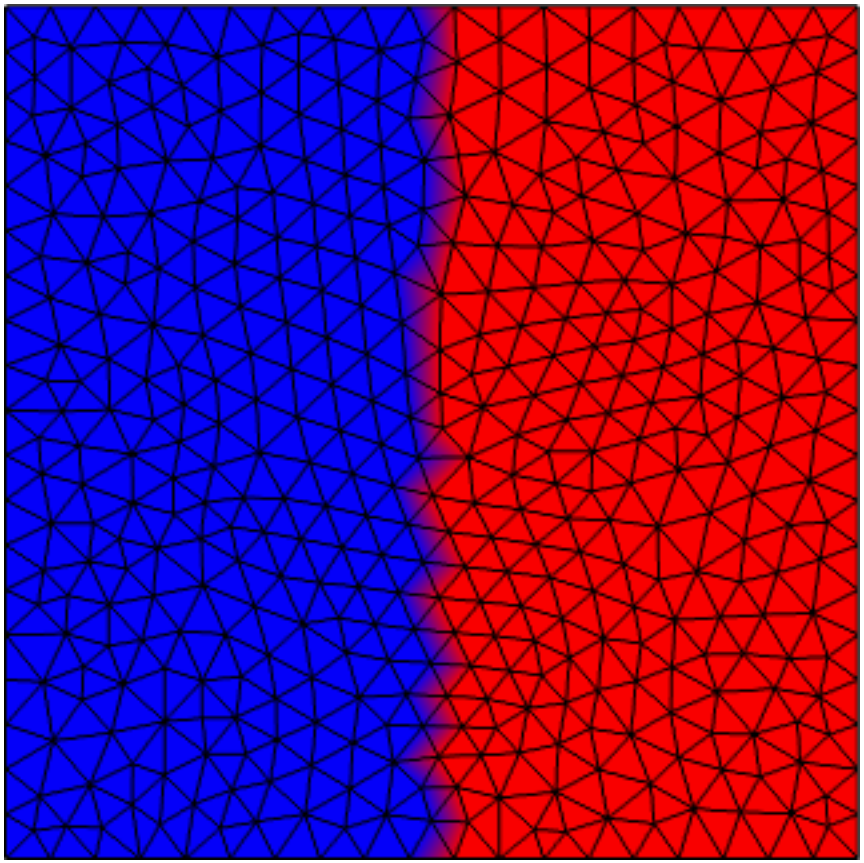
Parallel Adaptivity Approach

- Adapt mesh locally
  - Lock halo elements
- Re-partition mesh
  - High edge-weights applied to poor quality elements
  - Load balance using partitioning library
  - Migrate the nodes, elements and fields
  - Reconstruct data structures
- Repeat above steps
- Final partitioning with no edge-weights

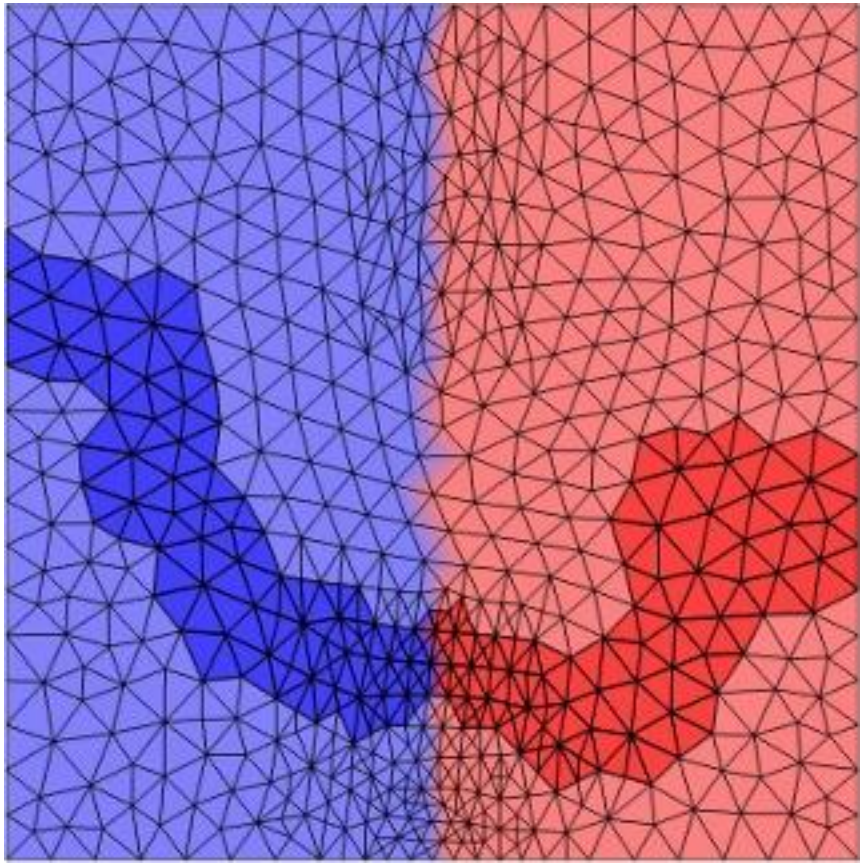
Parallel Adaptivity



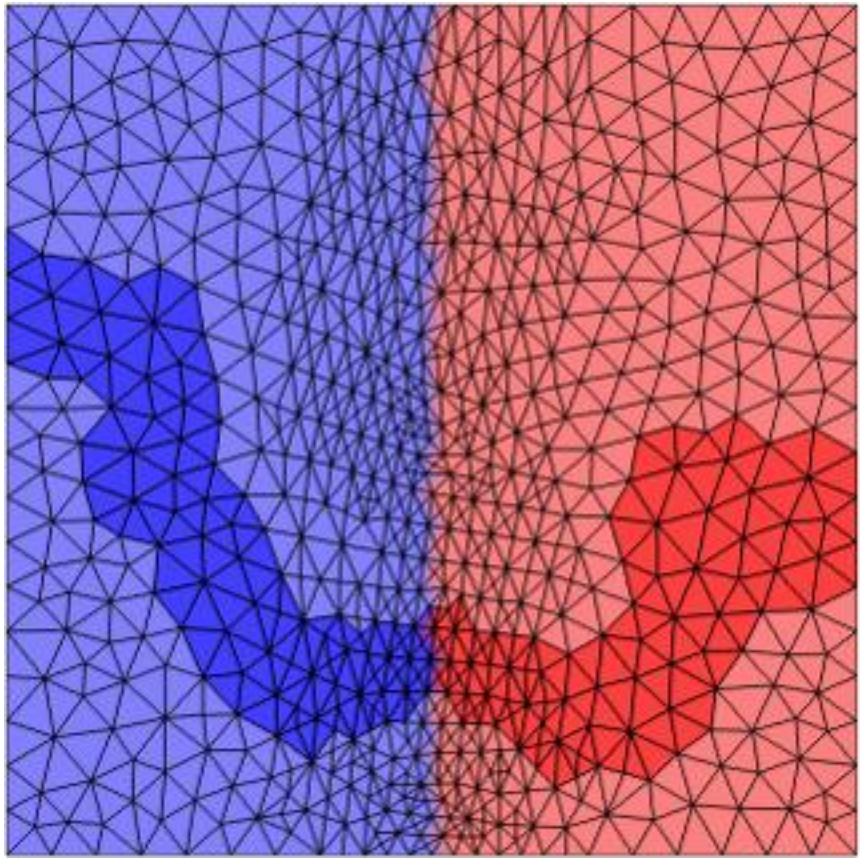
Parallel Adaptivity



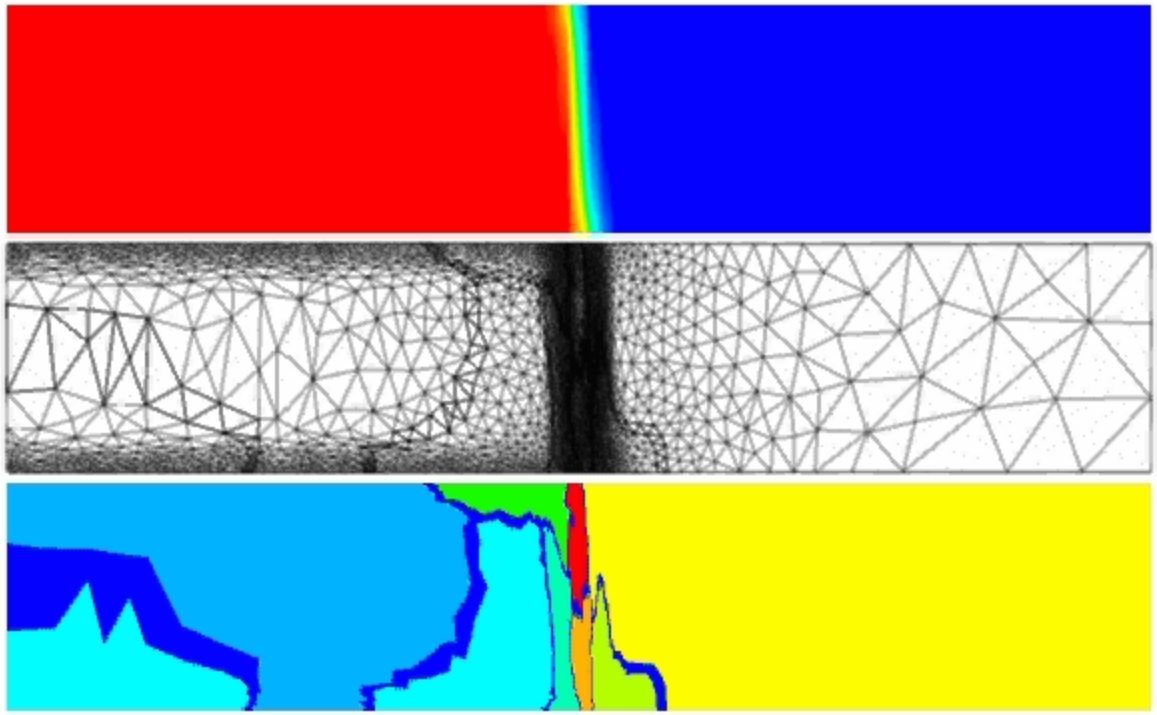
Parallel Adaptivity



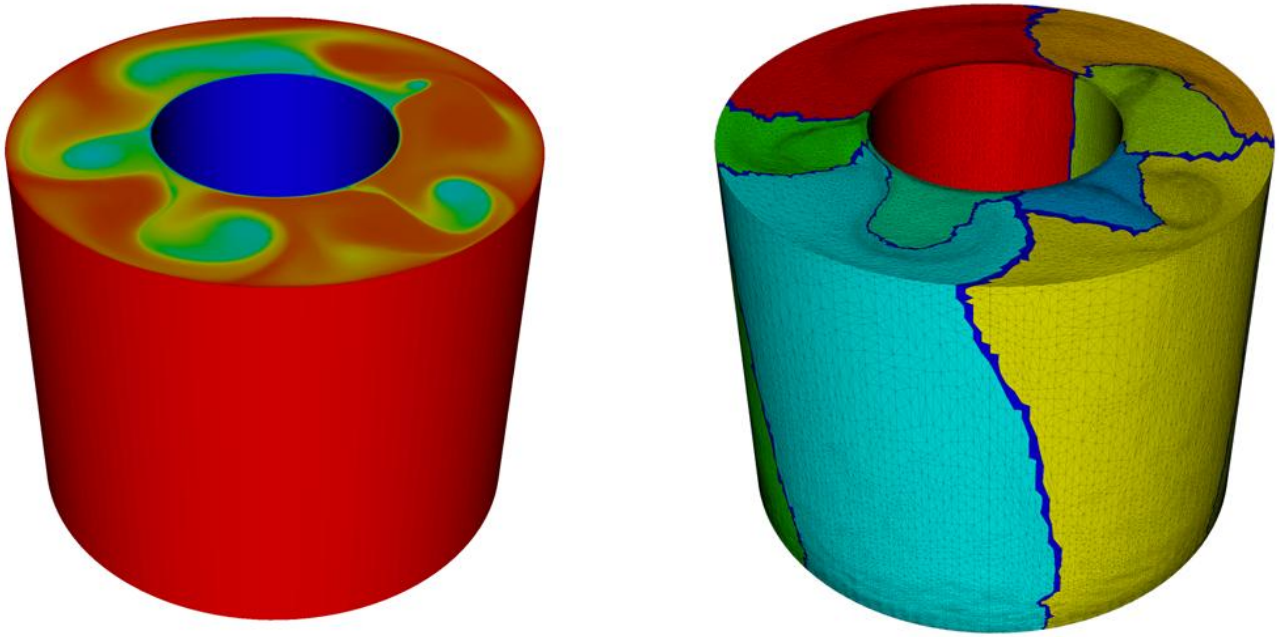
Parallel Adaptivity



Parallel Adaptivity



Parallel Adaptivity



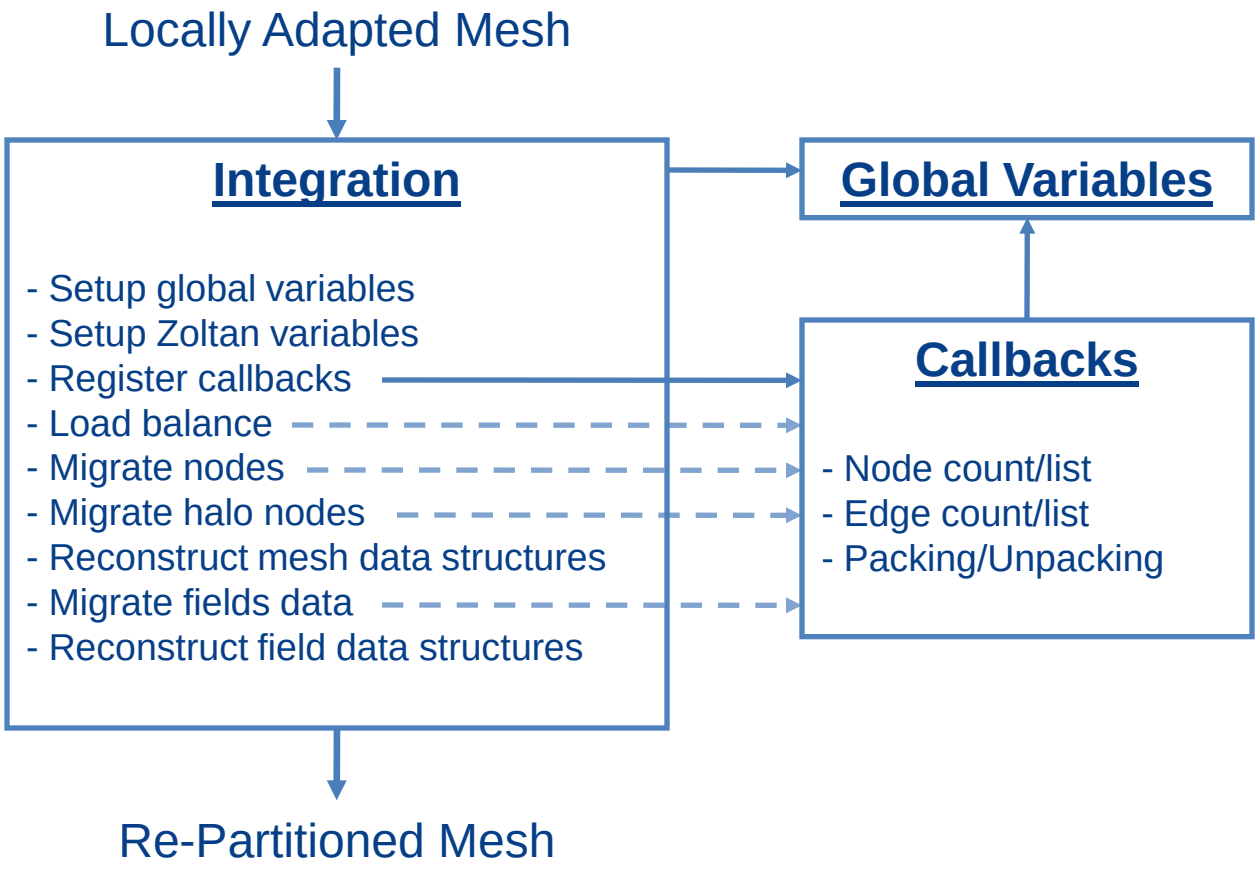
Zoltan

- Library of tools for parallel, unstructured and adaptive applications
  - Load Balancing and Parallel Reparitioning
  - Data Migration
  - Graph Colouring
  - Memory Management
- Sandia National Laboratories
  - http://www.cs.sandia.gov/zoltan/Zoltan.html

Zoltan Usage

- Provide callback functions
  - Node and edge lists
  - Node and edge weights
  - Packing/Unpacking data
- Call Zoltan library routines
  - Zoltan_LB_Balance
  - Zoltan_Migrate

Zoltan Usage in Fluidity



Difficulties

- Working with a black box
  - Edge-weighting sometimes ignored
  - Solution was to loosen the load imbalance tolerance
  - Caused other problems...

Difficulties

- Empty partitions
  - Fluidity assumes non-empty partitions
  - Zoltan does not guarantee non-empty partitions
  - Added checks for empty-partitions
    - After the load balance calculation
    - Before any data is migrated
  - If an empty partition is found we load balance again
    - Tightened load imbalance tolerance
    - Edge-weighting switched off as last resort

Benefits

- General purpose solution
  - Element types
  - Detectors/Particles
  - Periodic meshes
- Access to different partitioners
  - ParMETIS
  - PT-Scotch
  - Zoltan Graph and Hypergraph

Conclusion

- Zoltan is the default in Fluidity
- All partitioners available through Fluidity options
- Passes all Fluidity tests in buildbot
- Early performance results are promising

Acknowledgements

- All the developers at AMCG
- UK Research Councils
- NAG Ltd

Questions?