Load Balancing and Patch-Based Parallel Adaptive Mesh Refinement for Tsunami Simulation on Heterogeneous Platforms using Xeon Phi Coprocessors

PASC 2017

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Technical University of Munich

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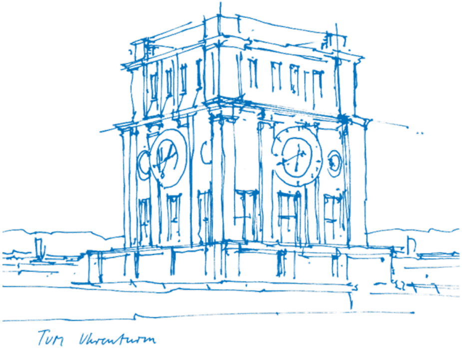
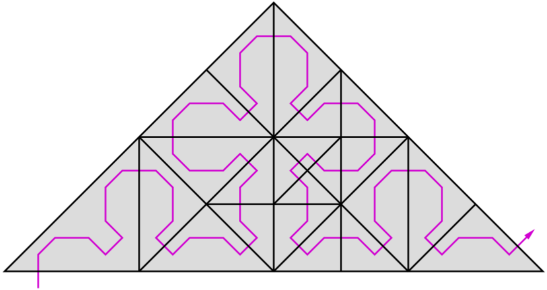


* Supported by CNPq/Brazil

sam(oa)^2 framework

- sam(oa)^2 - Space-filling curves and Adaptive Meshes for Oceanic And Other Applications
- A parallel framework for solving 2D PDEs
- Dynamically adaptive triangular meshes
- Data storage and traversals based on the Sierpinski curve
- Hybrid MPI+OpenMP parallelization also based on the curve



Tsunami simulations – Tohoku 2011

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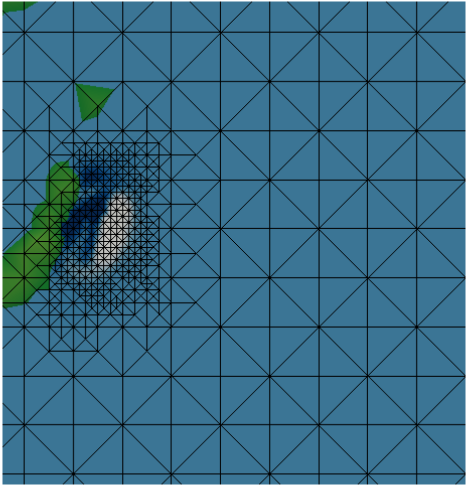
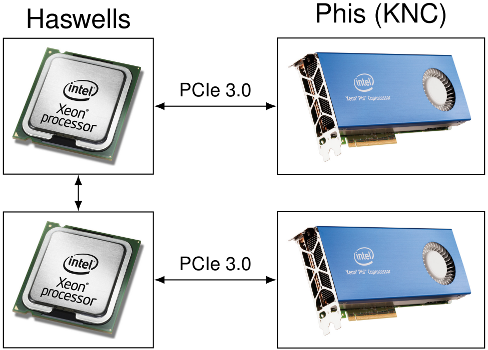
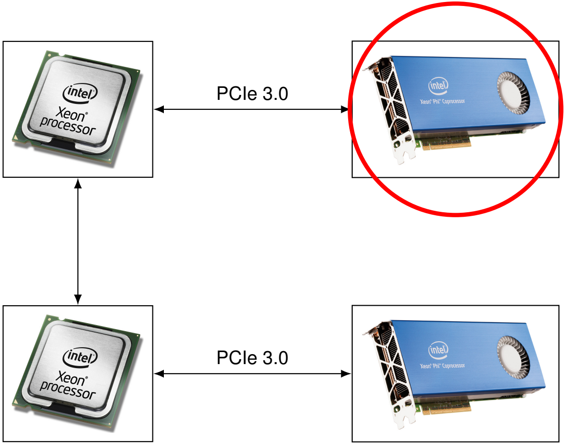


Salomon supercomputer

- Hosted by the IT4Innovations National Supercomputing Centre, Czech Republic
- Nodes with a dual-socket Haswell system and two Xeon Phi coprocessors



Part 1: Native mode



Intel® Xeon Phi™ coprocessors

Intel® Xeon Phi™ 7120P (KNC)	
Cores (max threads)	61 (244)
Clock rate	1.24 GHz
SIMD vector length	512-bit
Peak perform. (DP)	1.21 TFlops/s
Peak bandwidth	352 GB/s
Memory	16 GB

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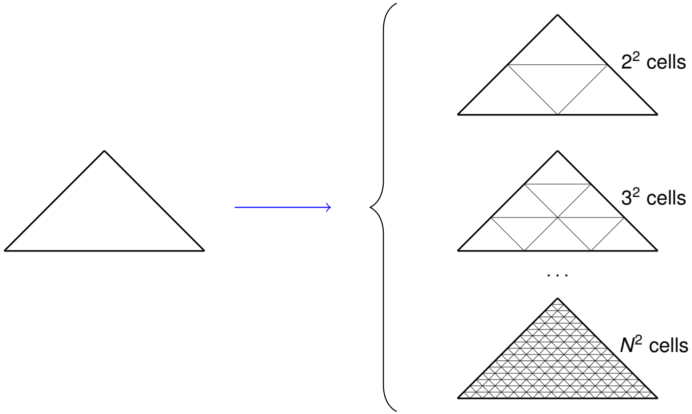
- Proposed solution: add a static refinement layer where it is possible to add vectorization.

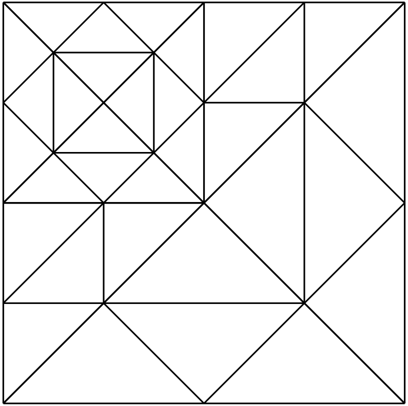
Replacing cells with regular patches

- Each cell becomes a patch of regularly refined cells



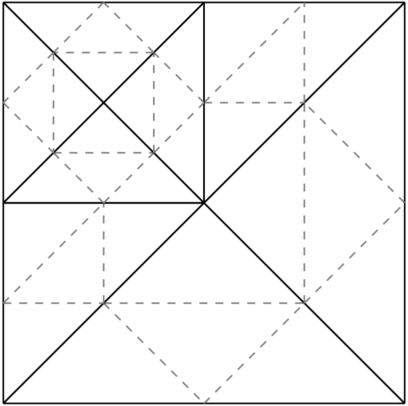
Replacing cells with regular patches

- Example mesh - 32 cells



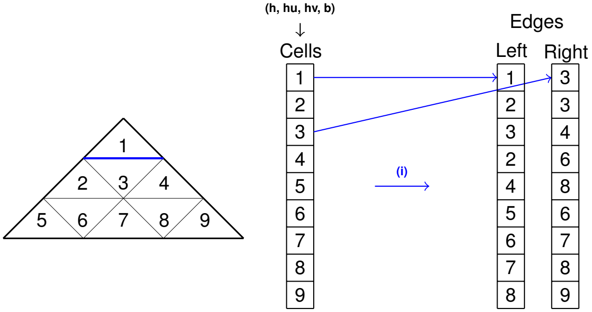
Replacing cells with regular patches

- Example mesh - 32 cells (8 patches with 2^2 cells)



Applying vectorization to the patches

- All edges in a patch can be processed using SIMD vector instructions.
  (i) Cell data is copied to temporary arrays that represent the edges



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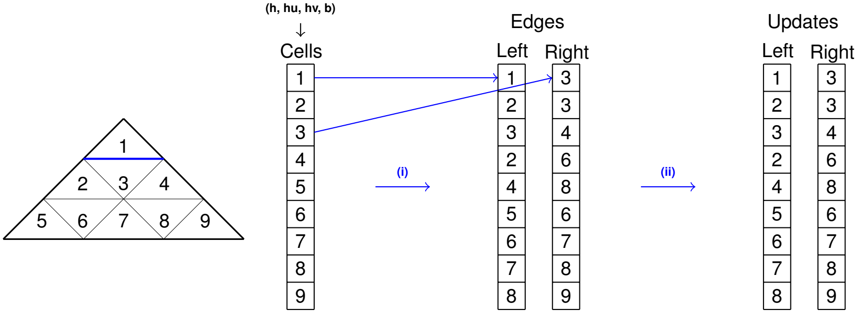

Applying vectorization to the patches

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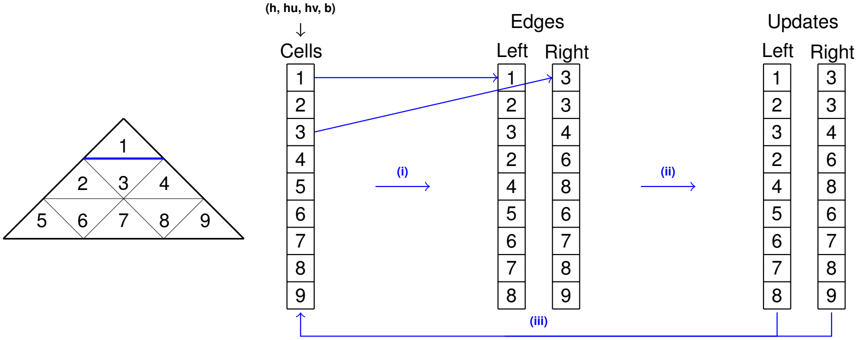
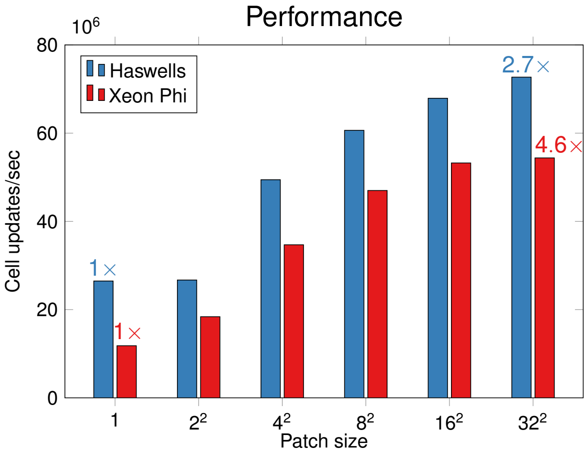
  - **(ii)** Then all edges are processed by a vectorized solver
  - **(iii)** Finally, the computed updates are used to update the cell data



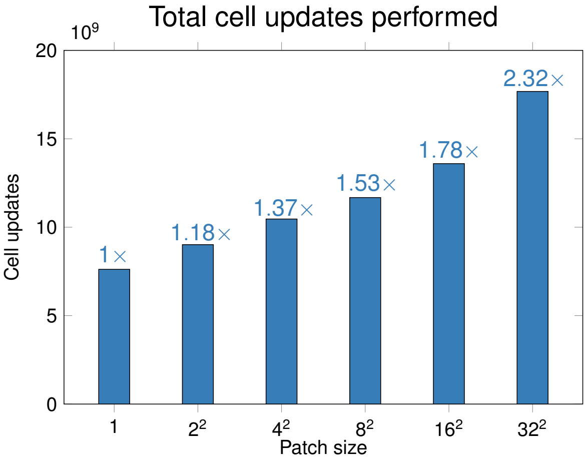
Native mode: Performance results

- Using two Haswells vs. a single Xeon Phi:



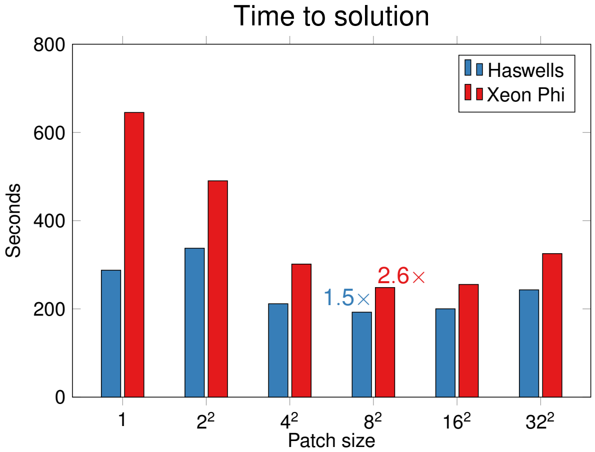
Native mode: Performance results

- However, using large patches increases the number of cells in the mesh.



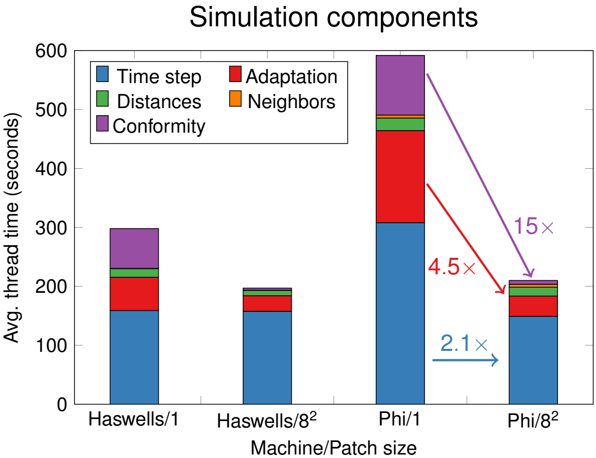
Native mode: Performance results

- Time to solution is a better metric in this case.

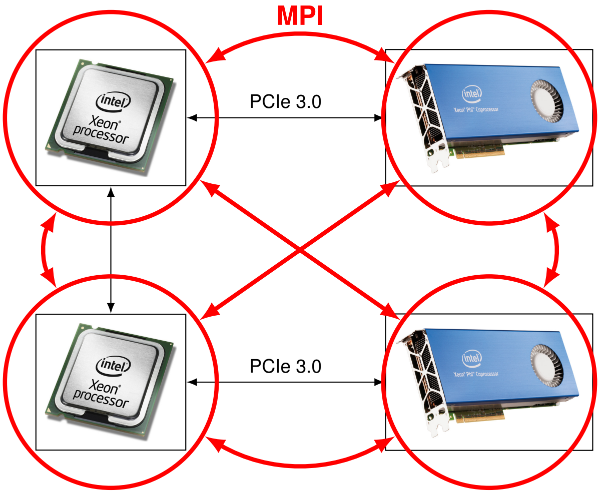


Native mode: Performance results

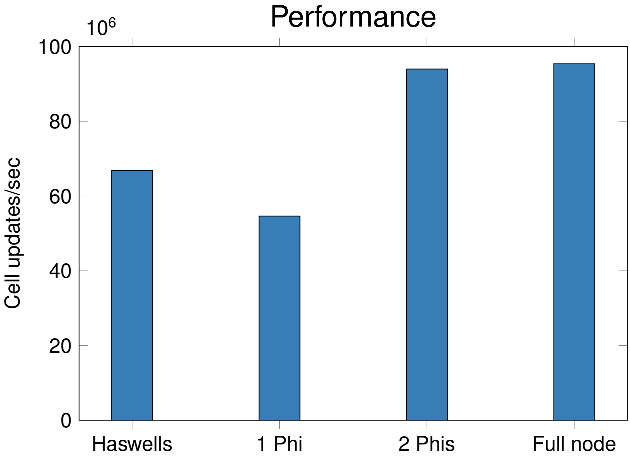
- Reduction of the mesh complexity contributes greatly to the speedups:



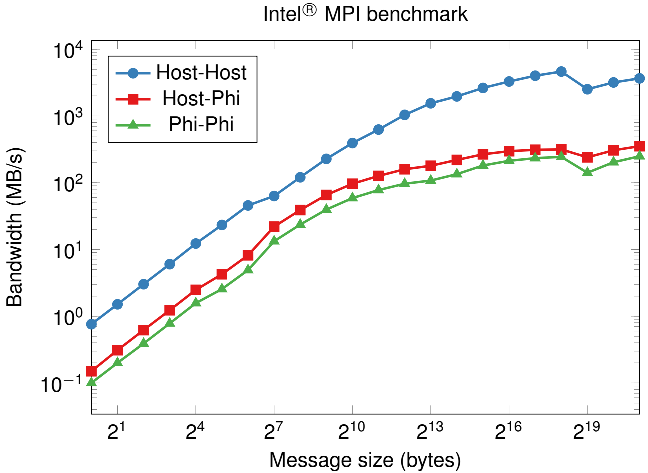
Part 2: Symmetric mode



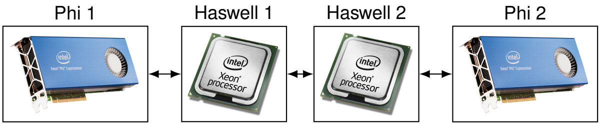
Symmetric mode: Initial results

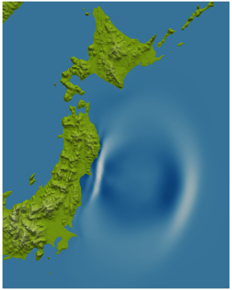


First problem: slow MPI communication with Phis



Second problem: homogeneous load balancing





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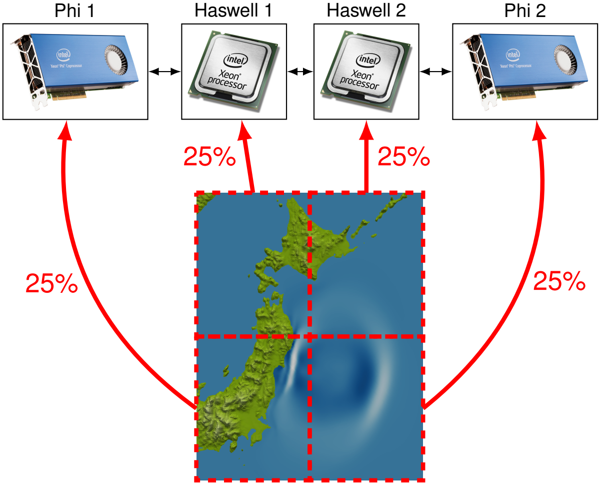

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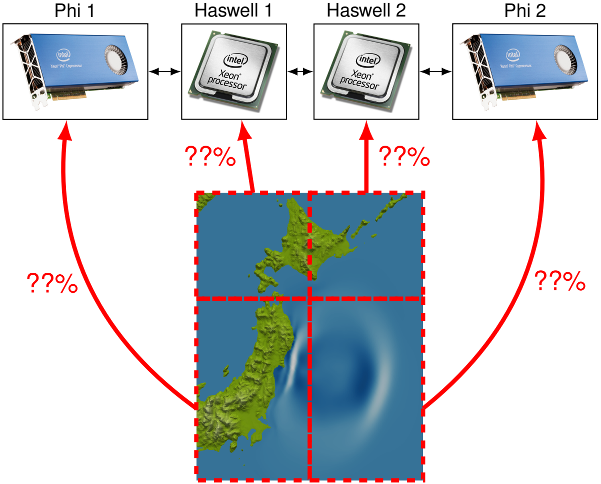

Heterogeneous load balancing

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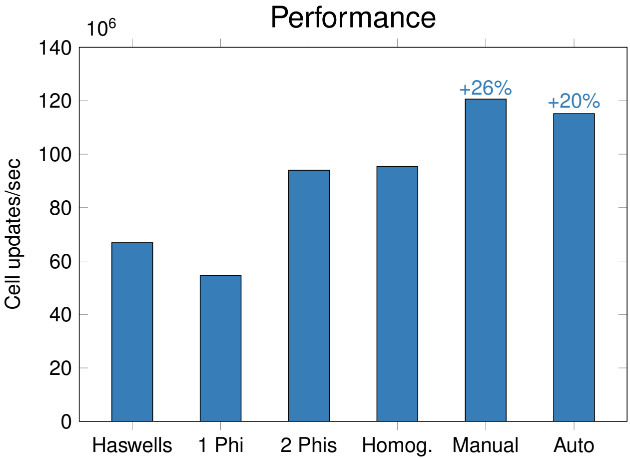
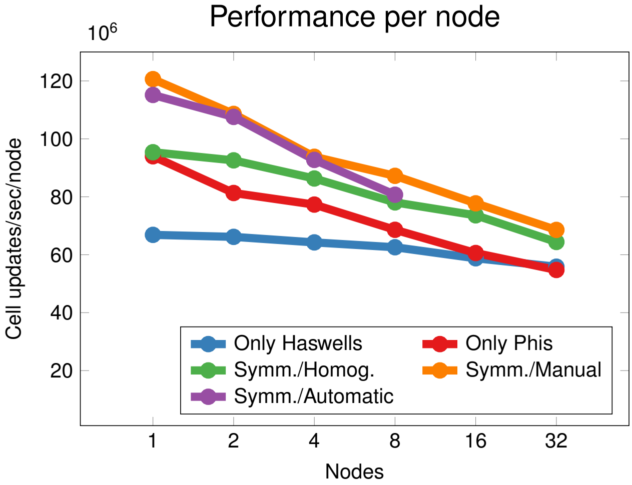
- But what about other systems? And other simulations?
  $\Rightarrow$ We also implemented a “auto-tuning” approach, where the simulation code iteratively chooses the distribution based on statistics from previous time steps.
  $\Rightarrow$ For that we defined the efficiency of each processor as: $Eff = load/time$.

Symmetric mode: Single node



Symmetric mode: Multiple nodes (weak scaling)



Final remarks

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- But its benefits are restricted to a small number of nodes, because MPI communication with the Xeon Phis is considerably slow.

- Heterogeneous HPC systems containing accelerator-type devices are becoming increasingly common.
- Thus, many HPC applications will require heterogeneous load balancing for keeping up with the modern hardwares.

References

1. Meister et al. “*Parallel memory-efficient adaptive mesh refinement on structured triangular meshes with billions of grid cells*”. ACM Transactions on Mathematical Software (TOMS), 2016.
2. Ferreira et al. “*Load Balancing and Patch-Based Parallel Adaptive Mesh Refinement for Tsunami Simulation on Heterogeneous Platforms using Xeon Phi Coprocessors*”. Platform for Advanced Scientific Computing (PASC), 2017. (Being published with Open Access)

Acknowledgements

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