SWIFT: Fast algorithms for SPH on multi-core architectures

Fast neighbour-finding and task-based parallelism

Pedro Gonnet, Matthieu Schaller, Tom Theuns, Aidan Chalk
ECS/ICC, Durham University
8th International SPHERIC Workshop, June 5th, 2013

Take-home messages

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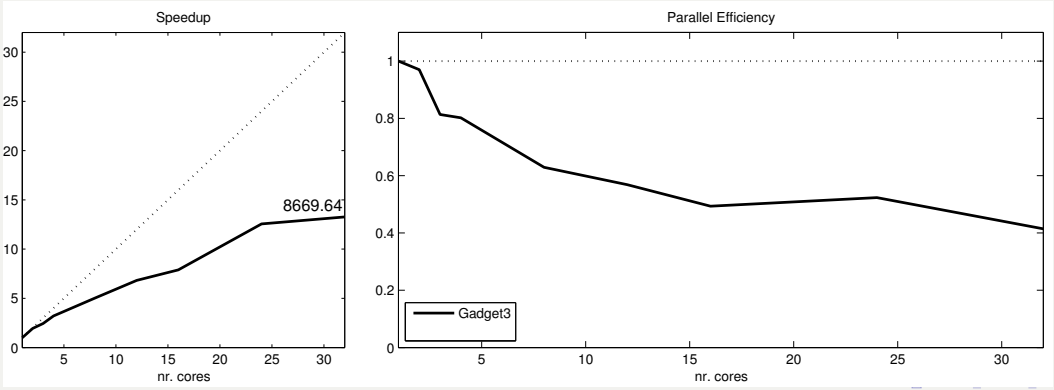

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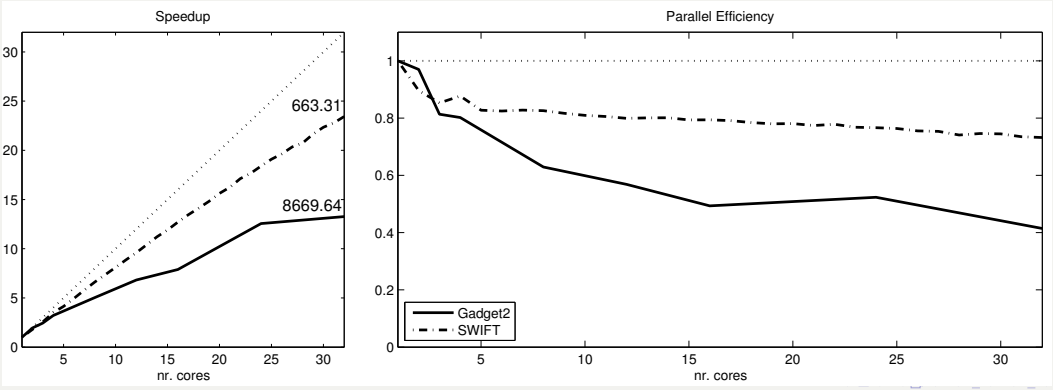

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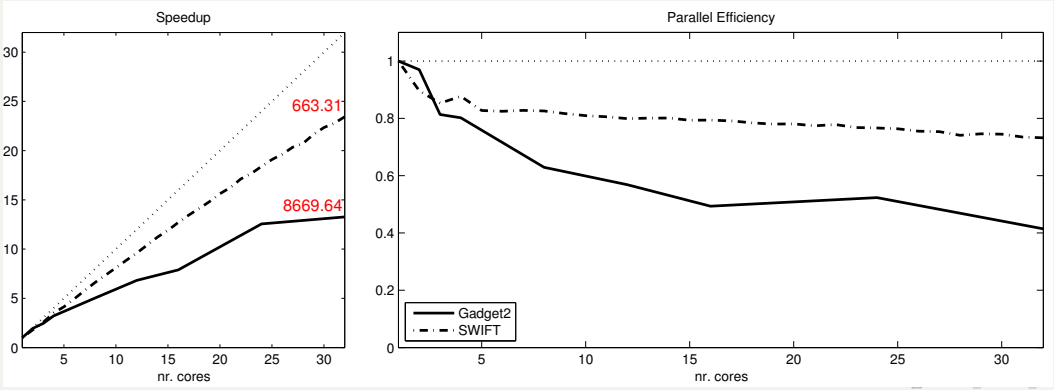

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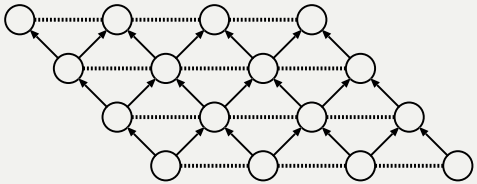

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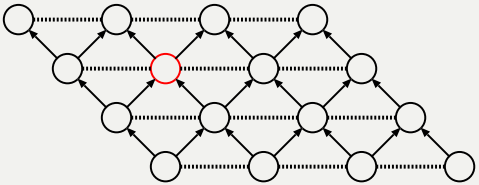

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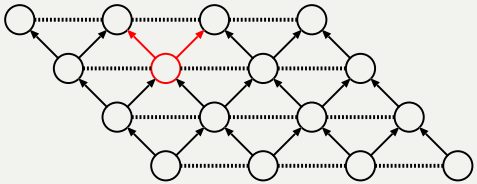

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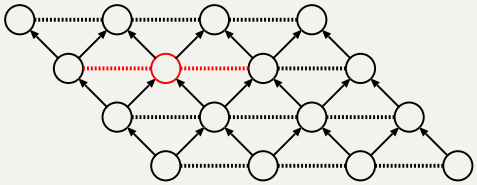

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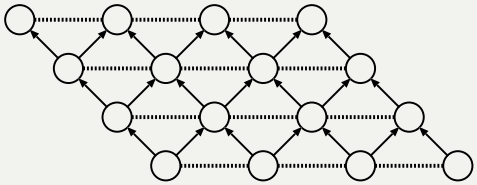

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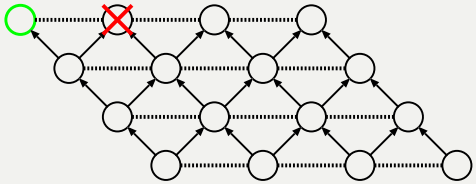

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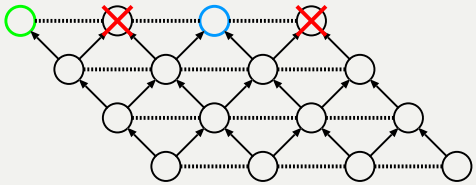

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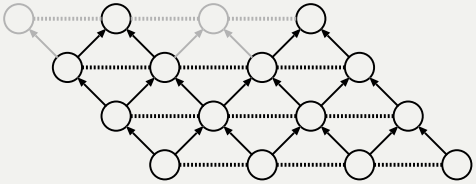

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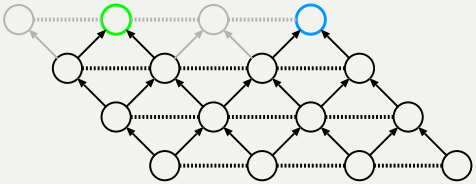

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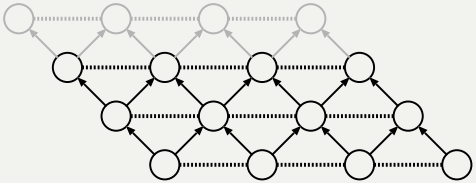

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- However, this usually means that we have to re-think our entire computation, e.g. redesign it from scratch to make it task-based.

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Neighbour-finding with trees

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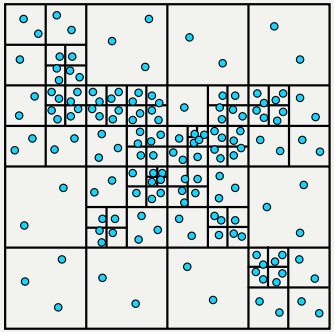

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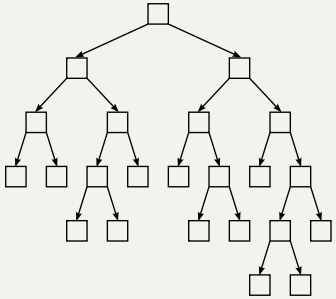

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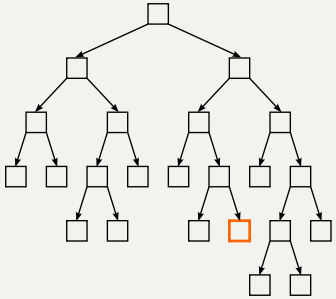

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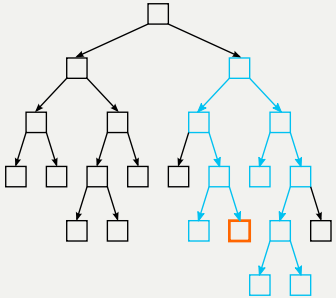

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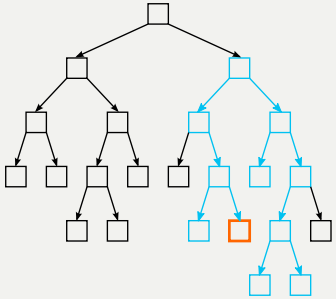

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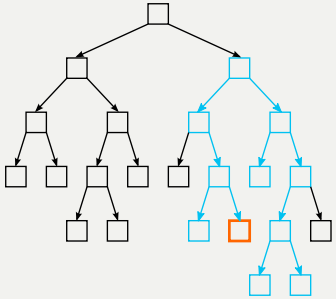

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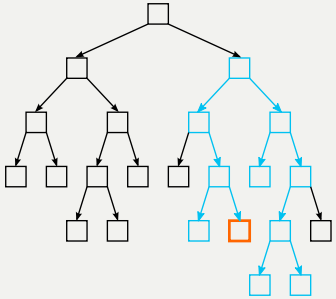

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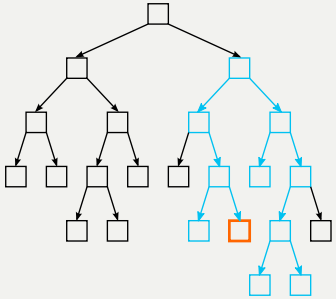
- Parallelization is trivial, but only because symmetries are not exploited.



Task-based algorithms for SPH

Hierarchical cell pairs

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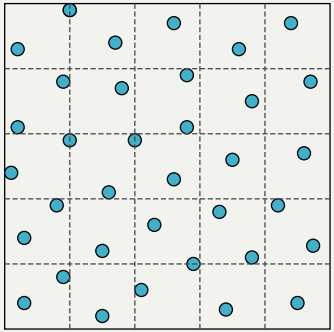

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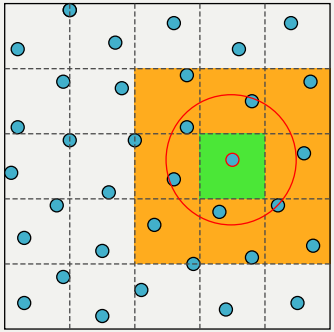

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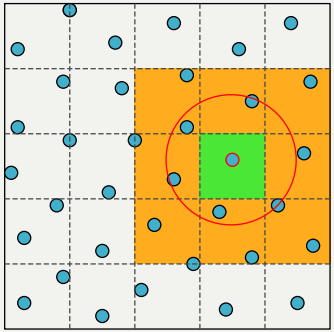

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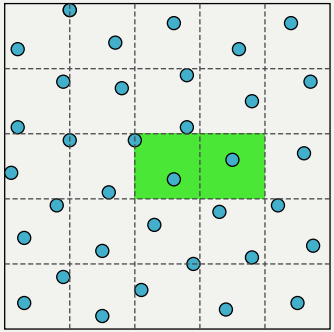

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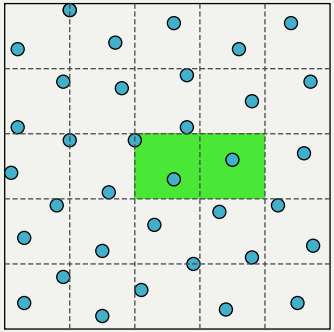

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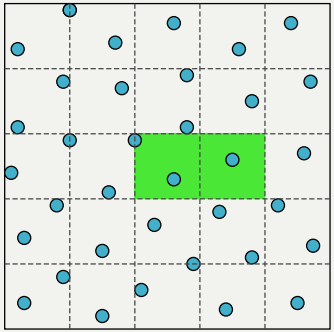
  $\longrightarrow$ Instead of traversing the tree for each particle, we traverse a list of cells and cell pairs and compute all interactions.



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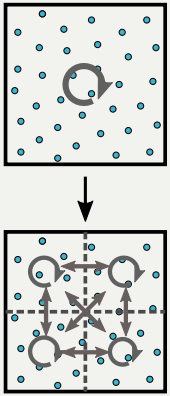
- If the particles in a cell are sufficiently small, the self-interaction task can be split.



Task-based algorithms for SPH

Hierarchical cell pairs

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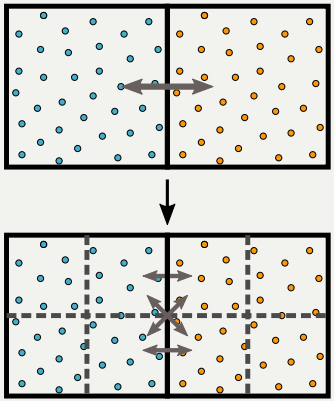

Task-based algorithms for SPH

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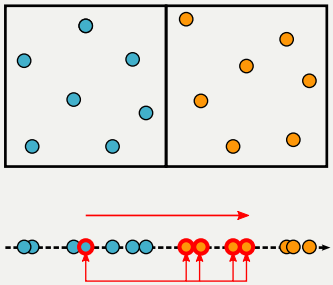
- If the particles in a cell are sufficiently small, the self-interaction task can be split.
- Likewise, if the particles in a cell-pair are sufficiently small, the task can be split as well.
- Finally, the particles in each cell pair are first sorted along the cell pair axis to speed-up neighbour-finding.



Task-based algorithms for SPH

Task hierarchy

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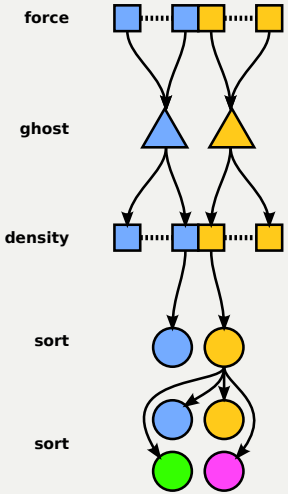
- Three main task types: Sorting, self-interactions, and pair-interactions.



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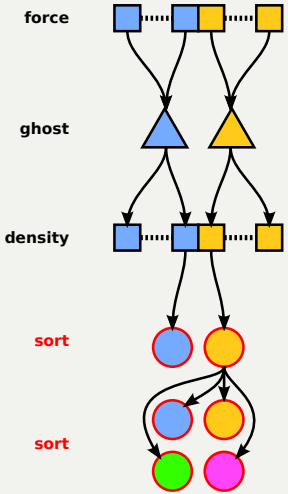

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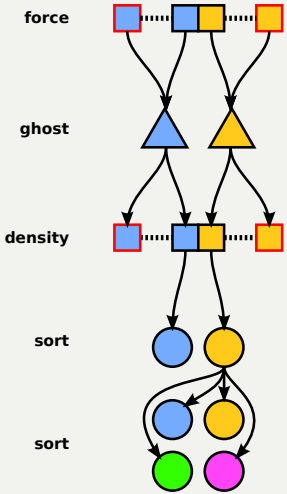

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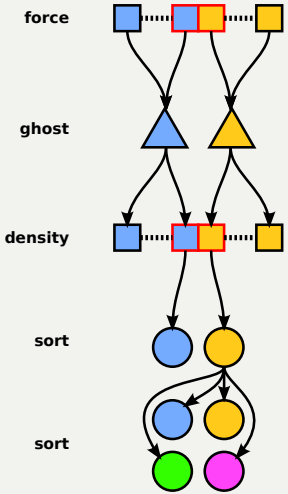

Task-based algorithms for SPH

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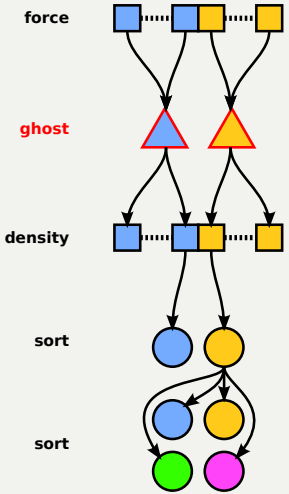

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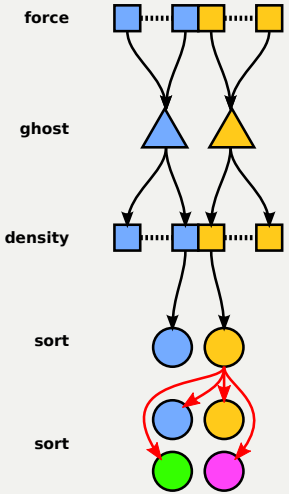

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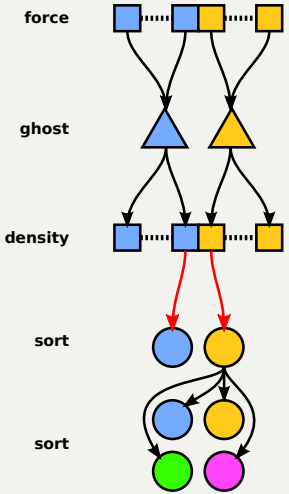

Task-based algorithms for SPH

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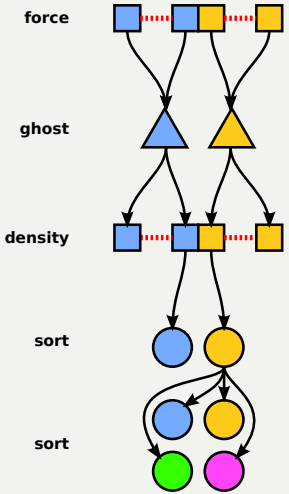
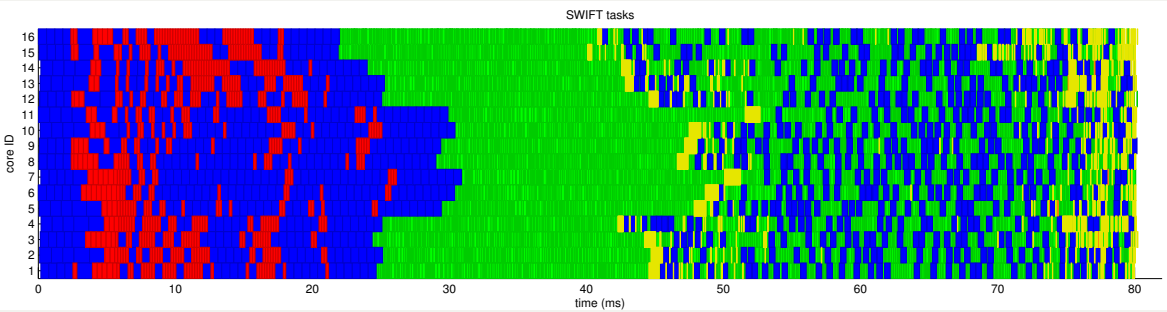
- Each sorting task depends on the sorting tasks of its sub-cells (merge-sort).
- Each pair-interaction task depends on the sort tasks of the cells involved.
- Tasks on overlapping cells conflict, i.e. they can not execute concurrently.



Task-based algorithms for SPH

Dynamic task allocation



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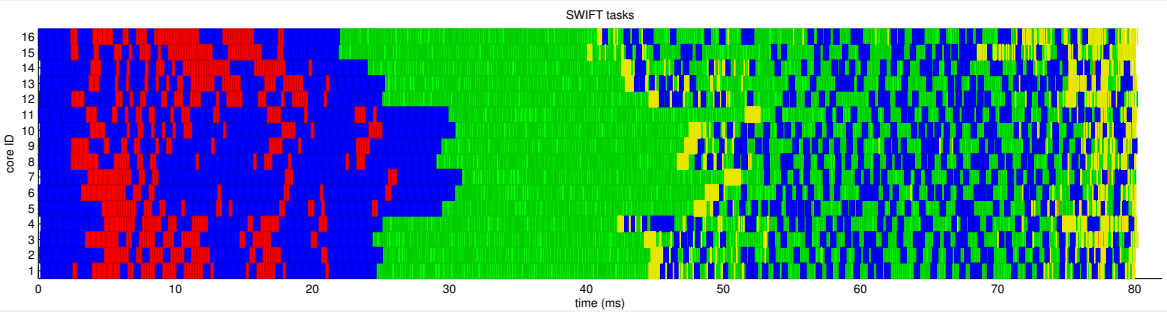

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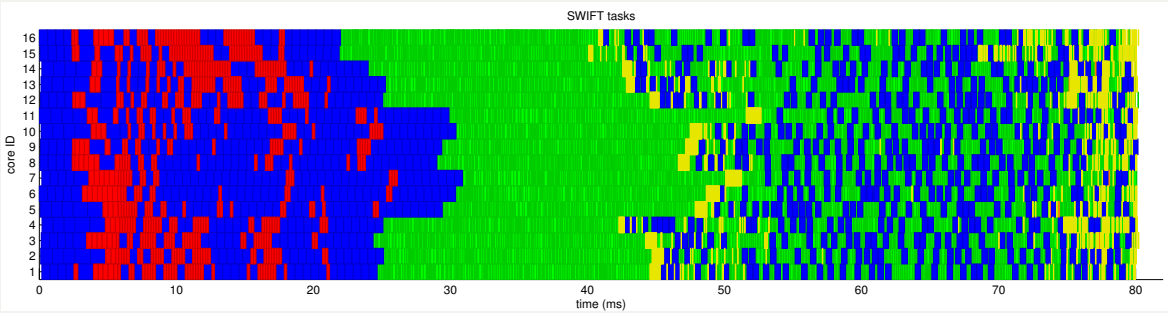

- Each core has it's own task queue and uses work-stealing when empty.
- Each core has a preference for tasks involving cells which were used previously to improve cache re-use.

Task-based algorithms for SPH

Parallel efficiency and scaling

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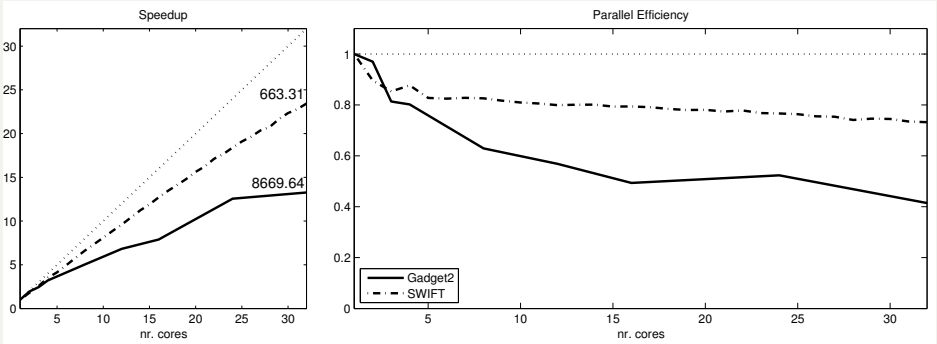

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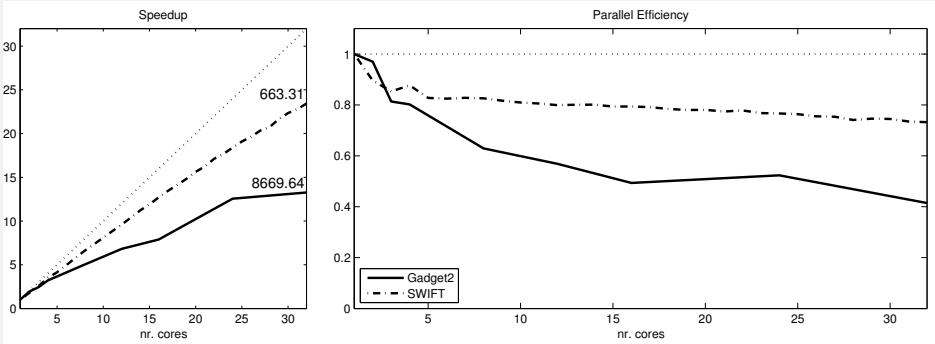

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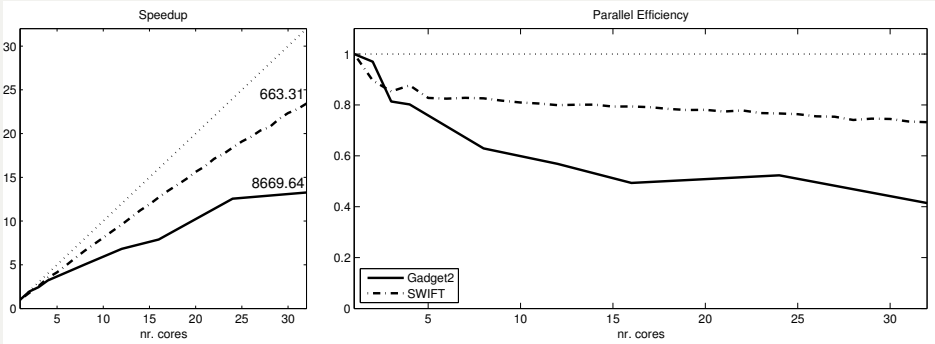

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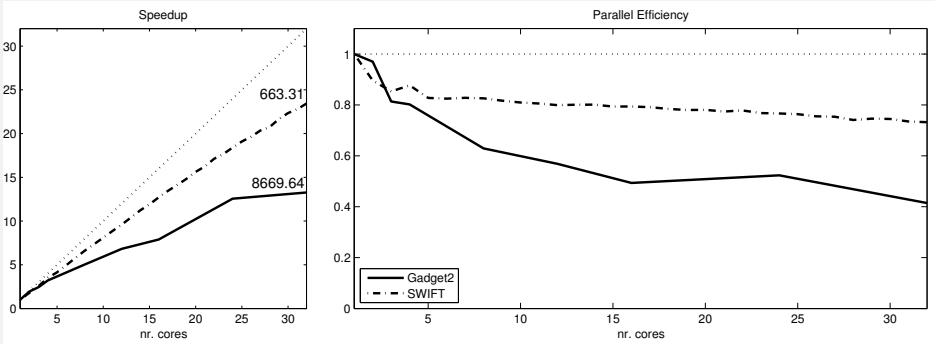

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- Tasks can also be shared between the CPU and a GPU.

Conclusions
Take-home messages

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- In order to continue getting *faster*, programs need to become *more parallel*.
  $\longrightarrow$ If a program has reached its maximum degree of parallelism, it won't get any faster. Ever.
- On shared-memory systems, asynchronous task-based parallelism solves most problems with concurrency and scaling.
  $\longrightarrow$ But we still need to develop task-based algorithms for specific problems, e.g. SPH simulations.
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Thank you for your attention!