Dynamic Task Graph Adaptation with Recursive Tasks

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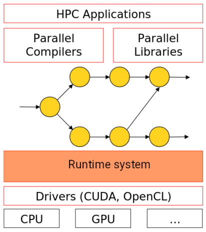
February 2024

Task-based Programming

- Motivations:
  - > Portable frameworks.
  - > Exploit complex architectures.
- Applications: Directed Acyclic Graph (DAG).
- Runtime systems: scheduling, data management, communications, . . .



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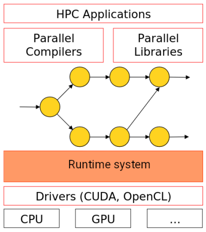
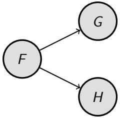


STF: Sequential Task Flow

- Dependencies:
  - Automatically inferred.
  - Order of submission.

```
F(a)
G(a, b)
H(a, c)
```

```
submit(F, a:RW)
submit(G, a:R, b:RW)
submit(H, a:R, c:RW)
wait_tasks_completion()
```



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- Overhead: large number of non-ready tasks.
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- GPUs versus CPUs.
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- Adapt task implementation *at runtime*.
- No spurious synchronization.

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2. Fine-grained dependencies.
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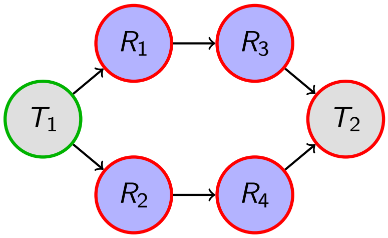

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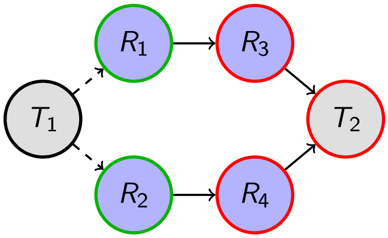

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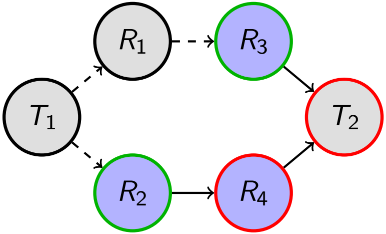

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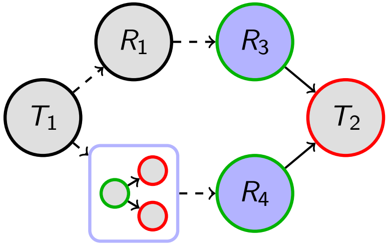

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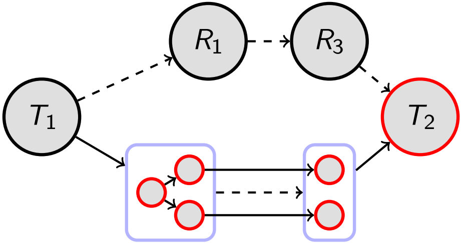

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   > Automatic data partition.

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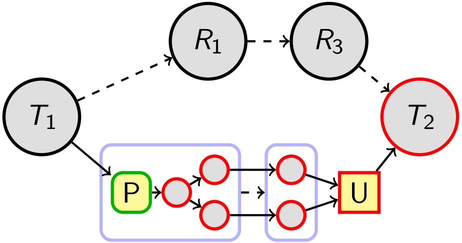

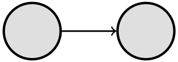

Runtime	Fine-grain Dependencies	Automatic data Partition	Heterogeneity
TaskFlow			
PaRSEC			
IRIS			
OmpSs			
StarPU			

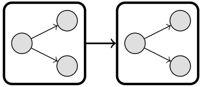

Figure: Barrier between parent tasks

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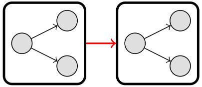

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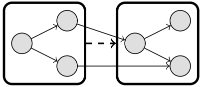

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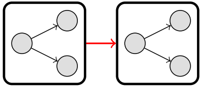

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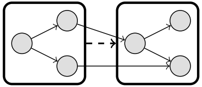

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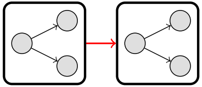

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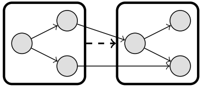

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Which task should we split?

When do we choose to split task?

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Efficiency VS Completion Time

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When do we choose to split task?

Submission, execution, ...

Exploit informations

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1. Split efficiency.

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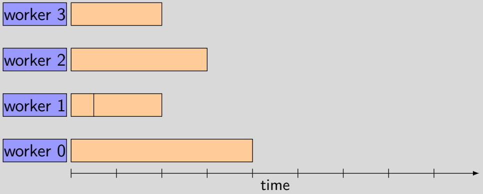
Split the task - Gantt chart



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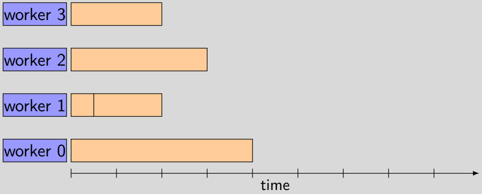

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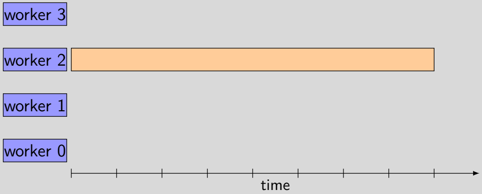

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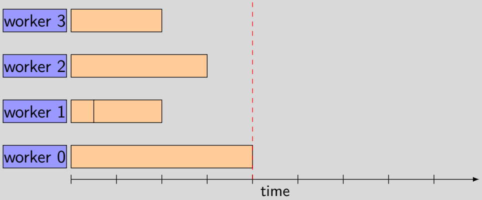

Completion time: 4 units.

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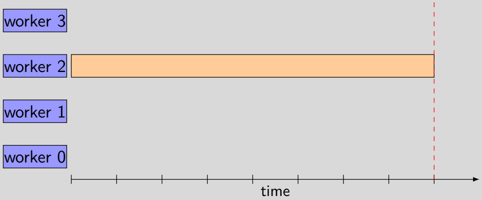

Completion time: 8 units.

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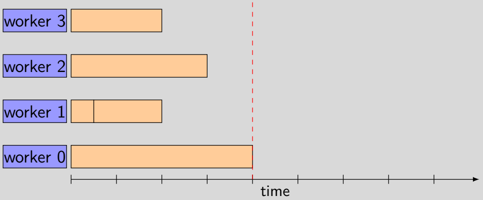
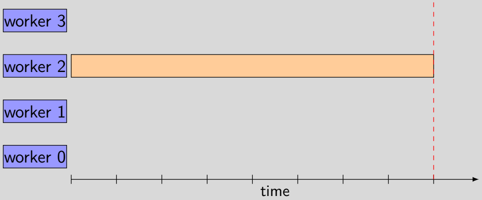


Completion time: 4 units.
Cumulated time: 11 units.

Not split the task - Gantt chart



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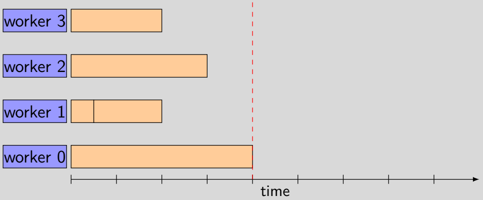

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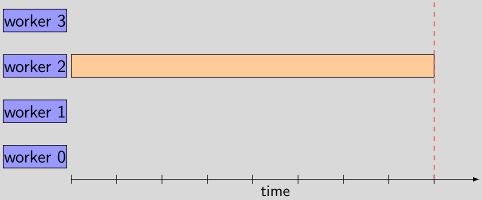

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Completion Time versus Efficiency

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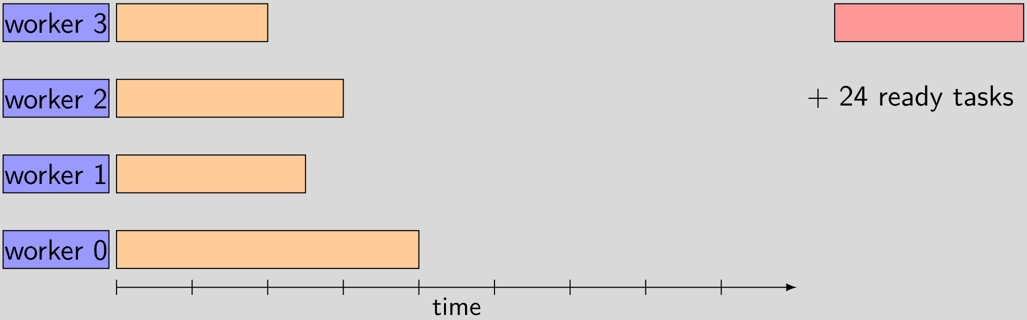

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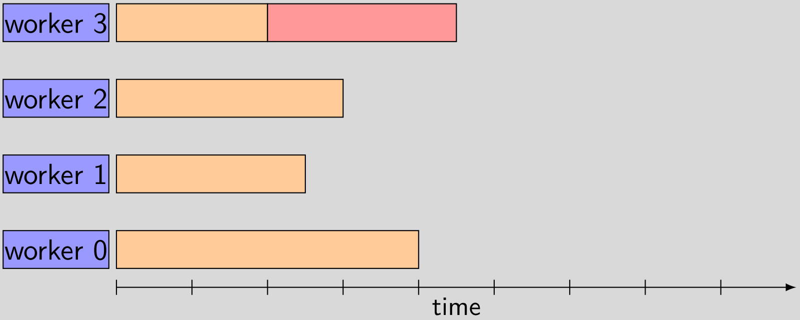

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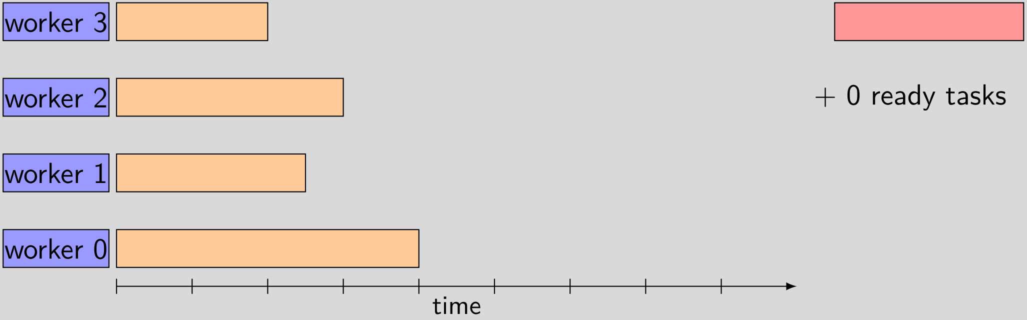
Situation 2



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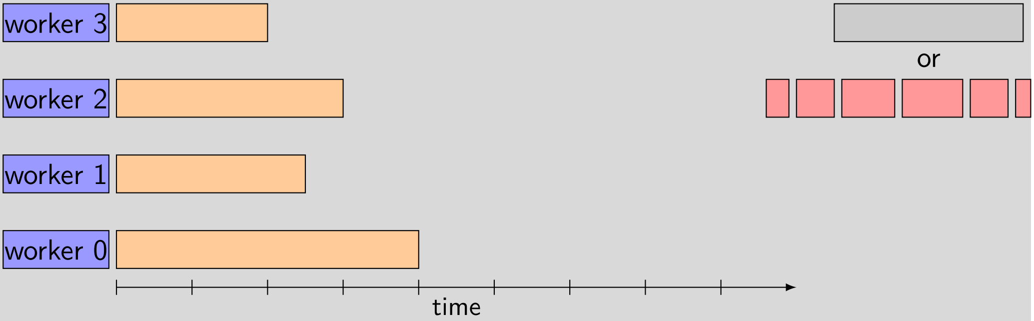
Situation 2 : Starvation



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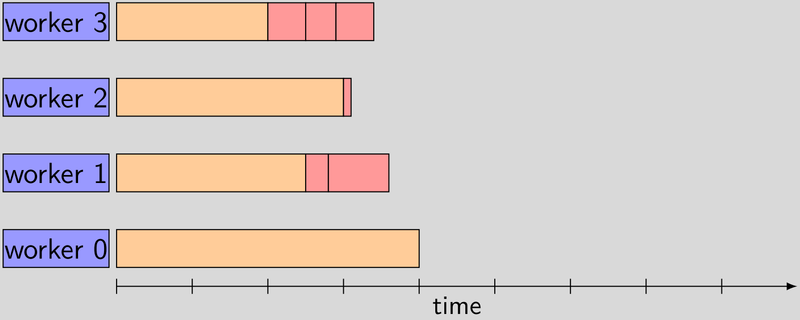

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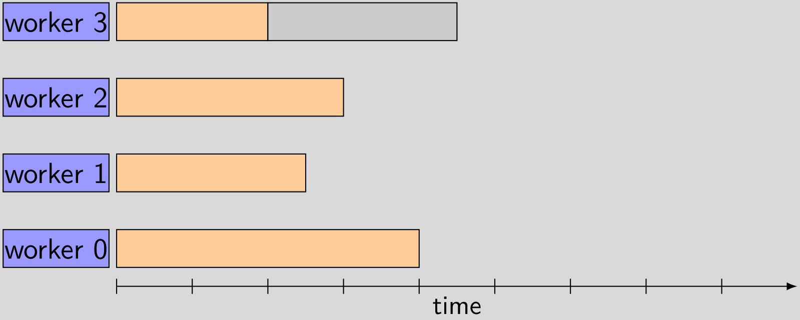
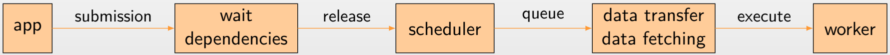
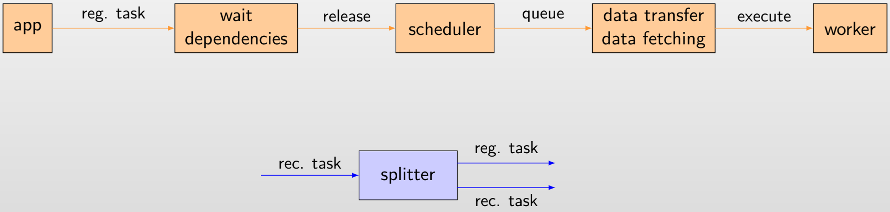


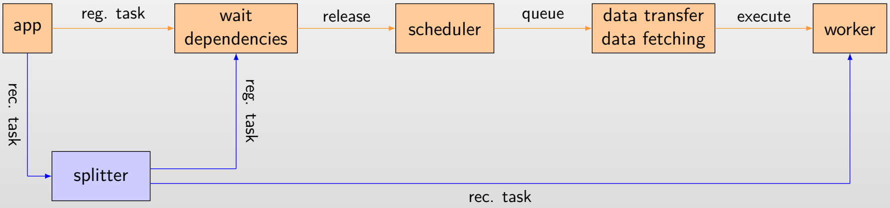
Task life path



Adding the splitter



Position of the splitter - at submission



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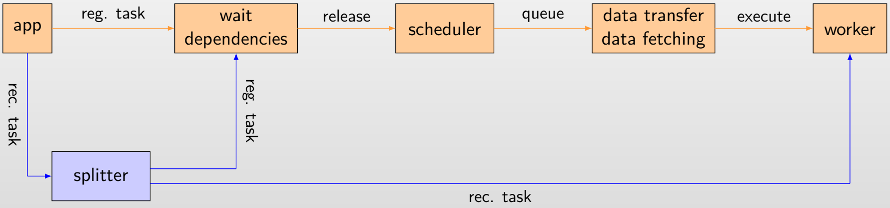

- Easy.

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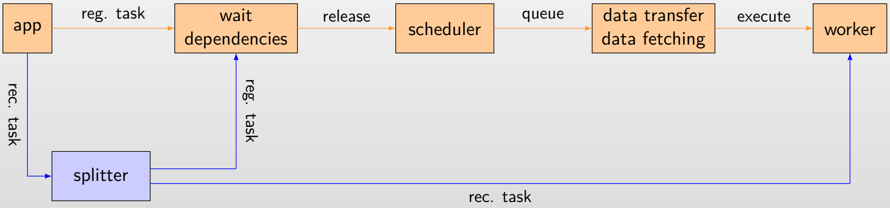
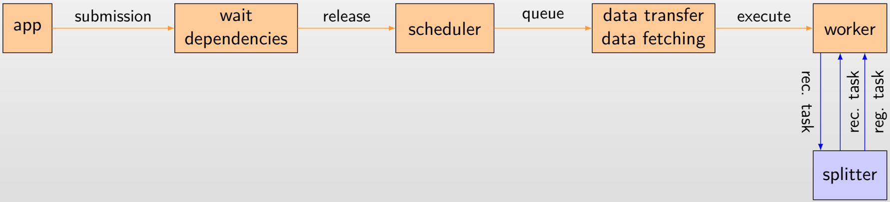


- Easy.
- Lack of information.

Position of the splitter - Execution



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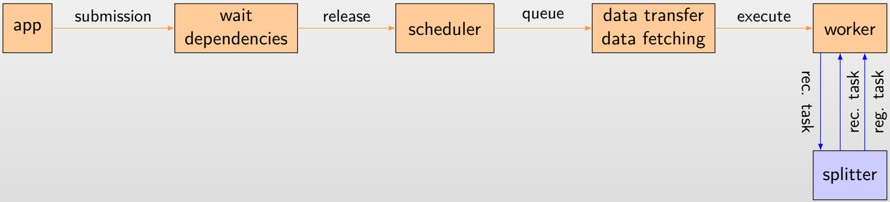

- Runtime information.

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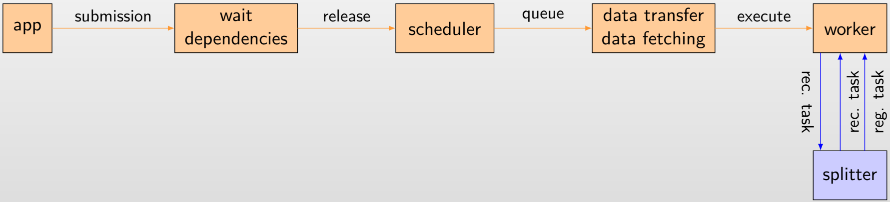
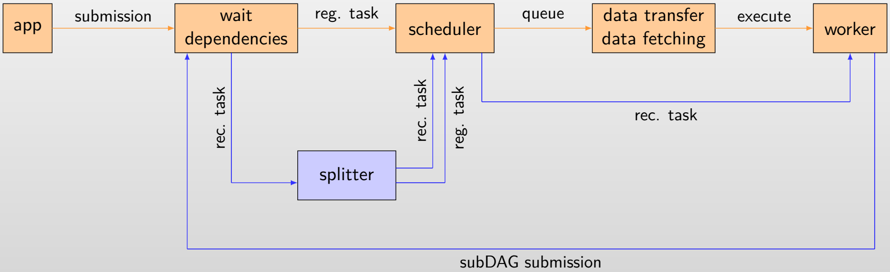


- Runtime information.
- Useless data transfer: cancel decision.

Position of the splitter - trade-off



Recursive Task Path - Release dependency

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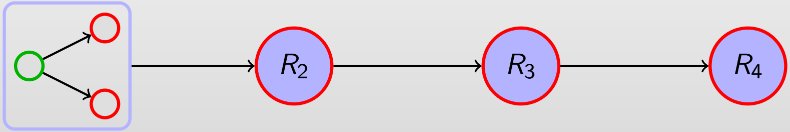

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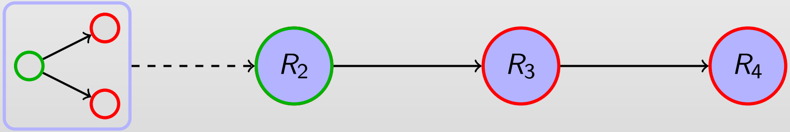

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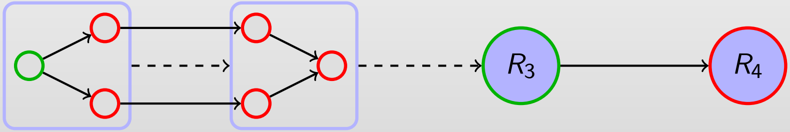

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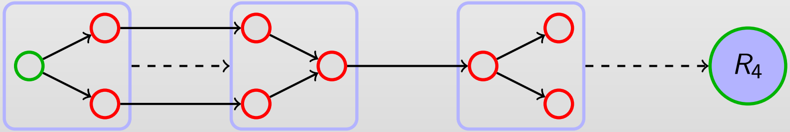

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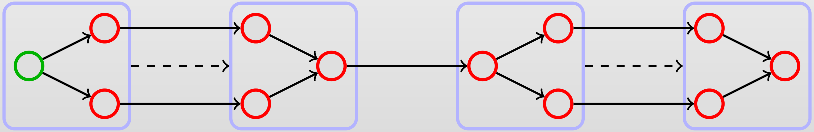

Over-synchronization solution

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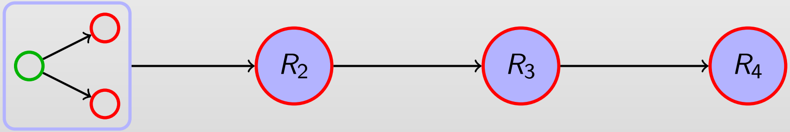

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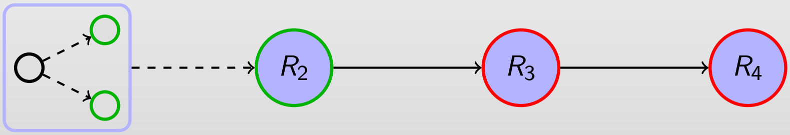

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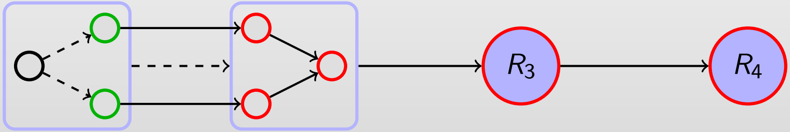

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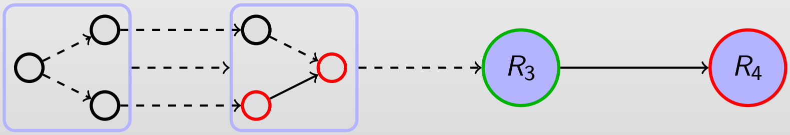

The tests were run on PlaFRIM's `bora` nodes:

- 2x 18-core Cascade Lake Intel Xeon Skylake Gold 6240 @ 2.6 GHz
- 192 GB (5.3 GB/core) (@2933 MHz)
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Tile sizes choosen :

- 1120 : "big" : the most efficient.
- 280 : "small": no lack of parallelism.
- 560 : "mid": trade-off.

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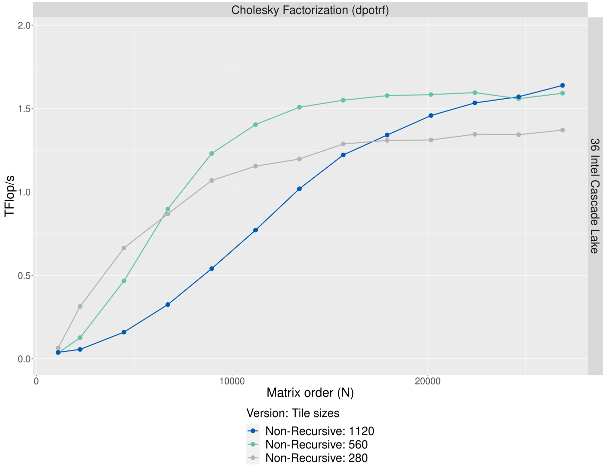
We split a task if:

- $N_{ready} \leq 4N_{cores}$
- Split efficiency $\geq 50\%$.

Benchmarks - Cholesky Factorization



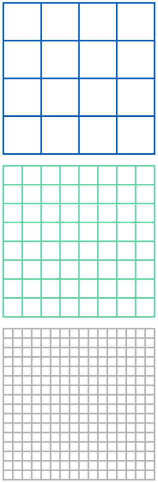
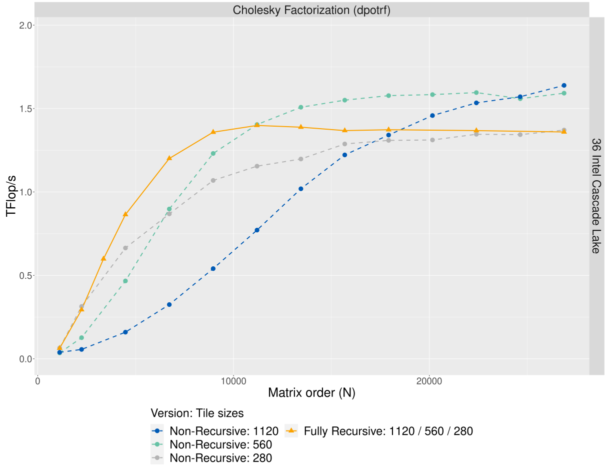
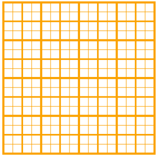


Figure: Performance comparison between different Cholesky Factorization versions.





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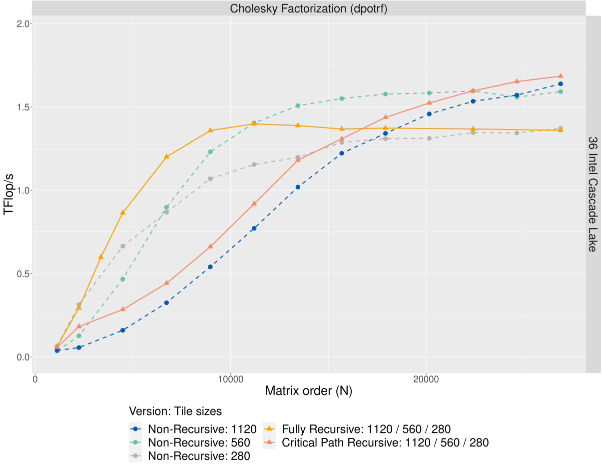

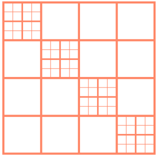

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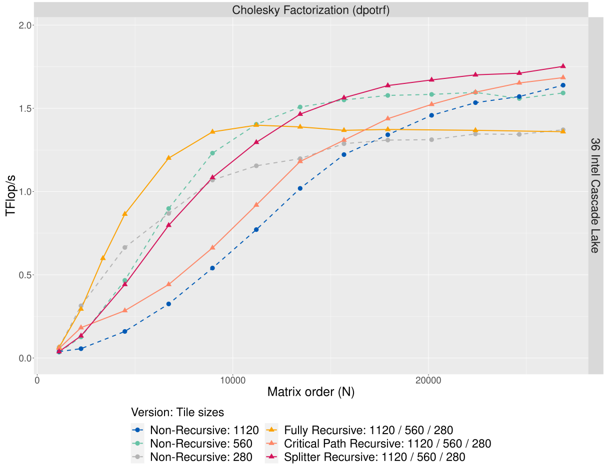

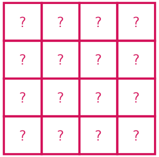

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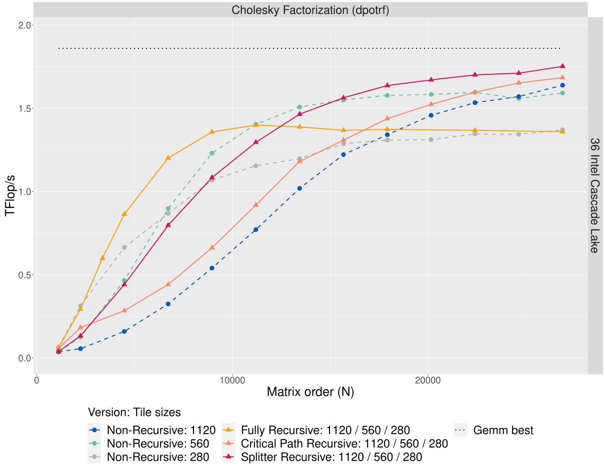

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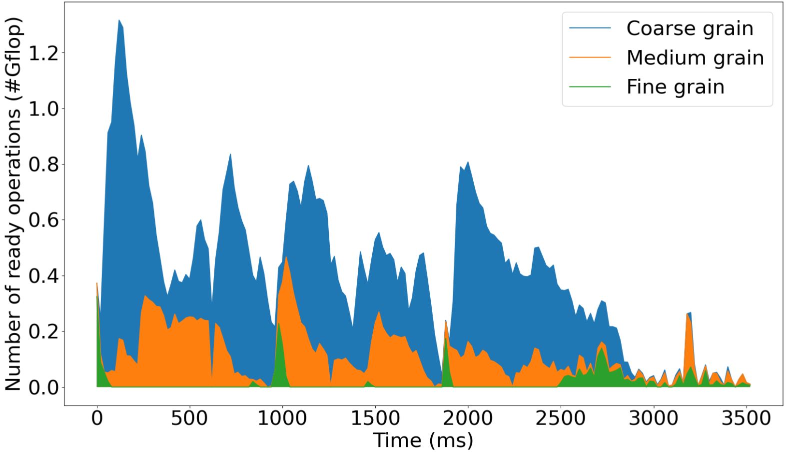
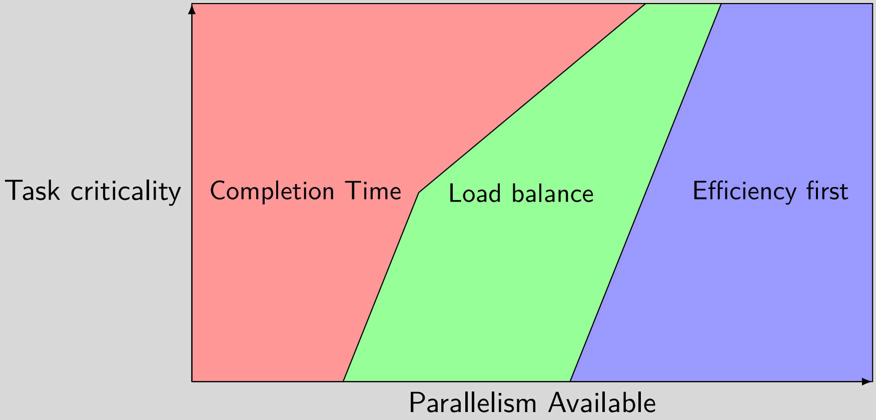


Figure: Flops evolution according to execution time during recursive-splitter Cholesky Factorization execution, with matrix of size 26880.

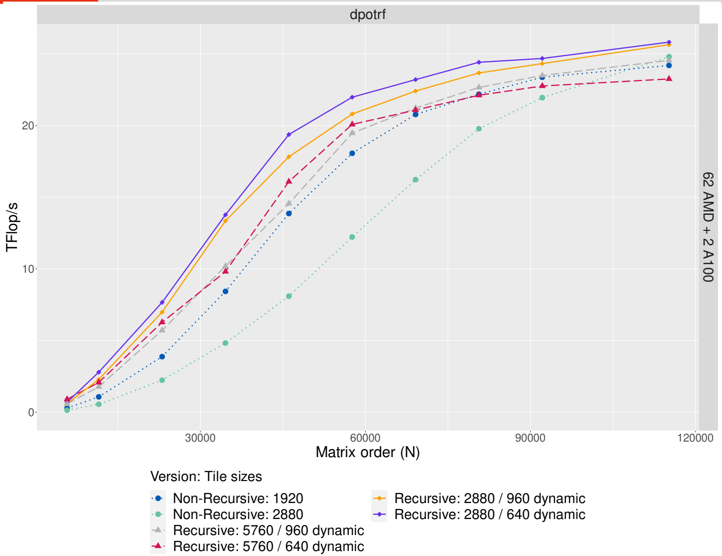
- Recursive tasks:
  - Insert subgraph at runtime.
  - More dynamic DAG.
- Splitting task dynamically brings different questions:
  - Which task sould we split.
  - When do we choose to split.

Future Work

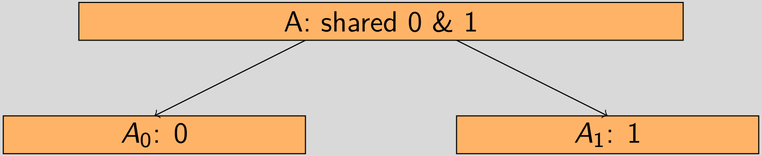
- Scheduling questions:
  - How should we split tasks ?
- Extend current work:
  - Heterogeneous platforms.
  - Distributed recursive tasks.


Task criticality
Completion Time
Load balance
Efficiency first
Parallelism Available

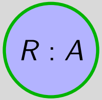
Heterogeneous



Shared data



Auto-pruning



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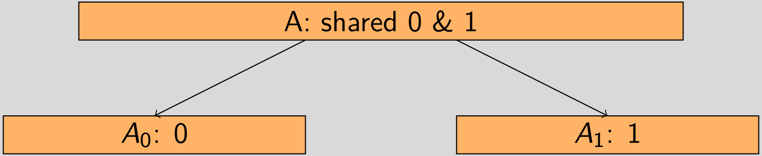

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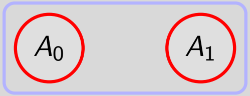

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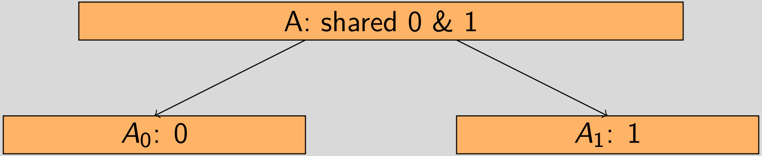
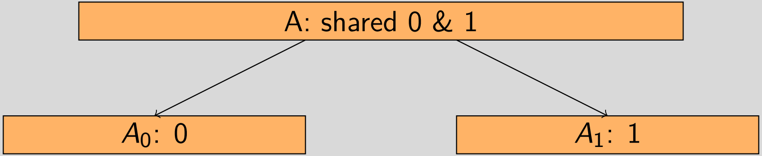


Auto-pruning

Node 0 :

Shared data



Auto-pruning

Node 1 :