A Forward Scan based Plane Sweep Algorithm for Parallel Interval Joins

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[2] University of Ioannina, Greece

Interval Joins

employee	start	end
John	1994	2006
Mary	1992	2002

employee	start	end
Jane	1990	1993
Bob	1995	1996
Hugo	1997	2003
Helen	2005	2007
Tom	2006	2008

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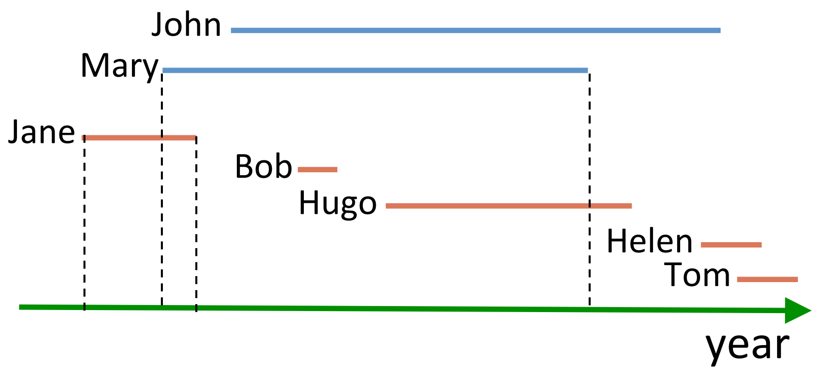

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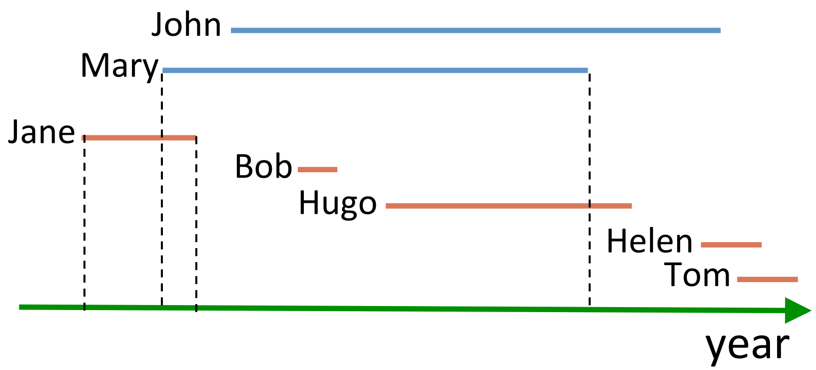

Find all pair of employees whose period of work on D1 and D2 intersect

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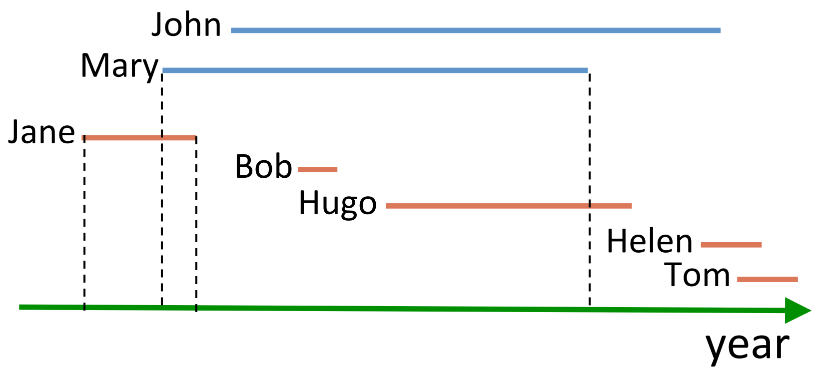

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- Applications
  - Temporal databases
  - Multidimensional data management
  - Uncertain data management

Our focus

- Efficient evaluation of interval joins
  - Single-threaded processing
    - Simple plane sweep based method
    - Competitive to state-of-the-art
  - Parallel processing
    - Partitioning-based join
    - Share nothing

SINGLE-THREADED PROCESSING

Related work

Nested loops &
Sort-merge join

[Segev and Gunadhi, VLDB'89]
[Gunadhi and Segev, ICDE'91]

Index-based

[Zhang et al., ICDE'02]
[Enderle et al., SIGMOD'04]

Partitioning-
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[Soo et al., ICDE'94]
[Dignös et al., SIGMOD'14]
[Cafagna and Böhlen, VLDBJ'17]

Plane-sweep
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[Brinkhoff al., SIGMOD'93]
[Arge et al., VLDB'98]
[Piatov et al., ICDE'16]

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Plane-sweep based

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[Piatov et al., ICDE'16]

Plane sweep methods

- Endpoint-Based Join (EBI/LEBI)

[Piatov et al., ICDE'16]

  - Sweep line stops both on *start* and *end*
  - Backwards scan, Gapless hash map buffers open intervals

Pros

✓ No domain-point comparisons
✓ Tailored to modern hardware
✓ Main memory cache-aware
✓ Fast

Cons

✗ Special structure needed

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- Forward Scan based (FS)

[Brinkhoff et al., SIGMOD'93]

  - Sweep lines stops only on *start*

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✓ Simple
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✗ $|R| + |S| + |R \bowtie S|$ comparisons in total

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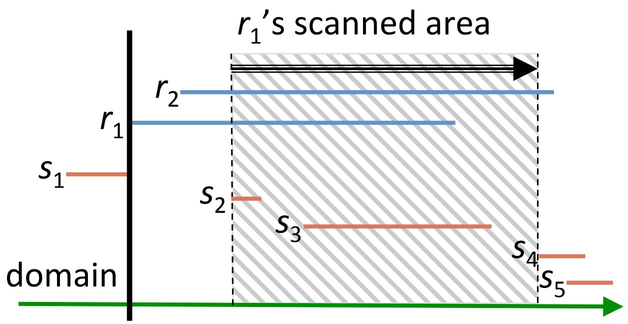
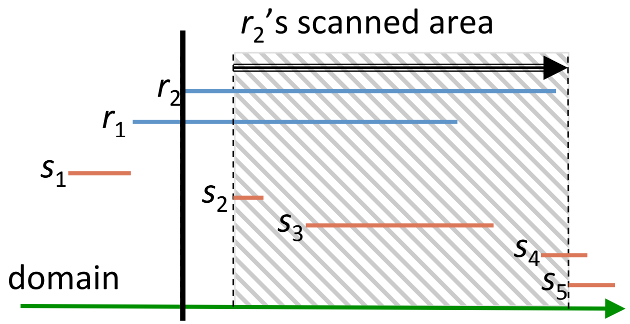
Optimizing FS

FS





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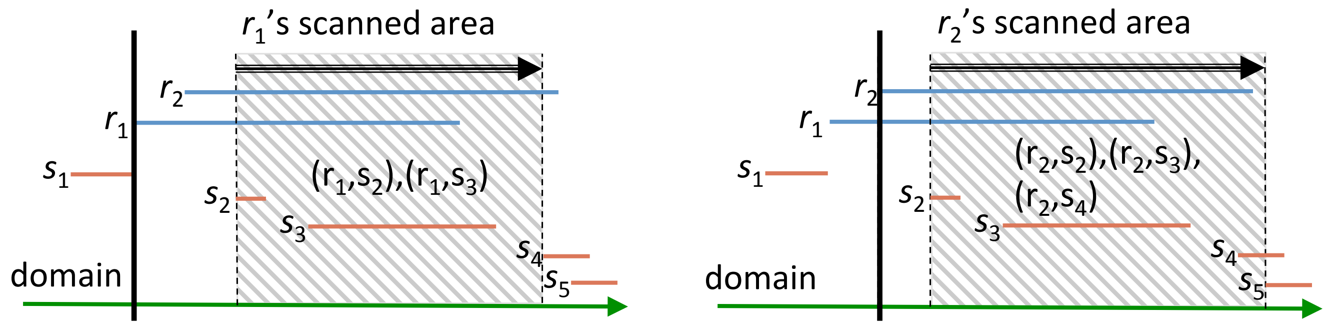

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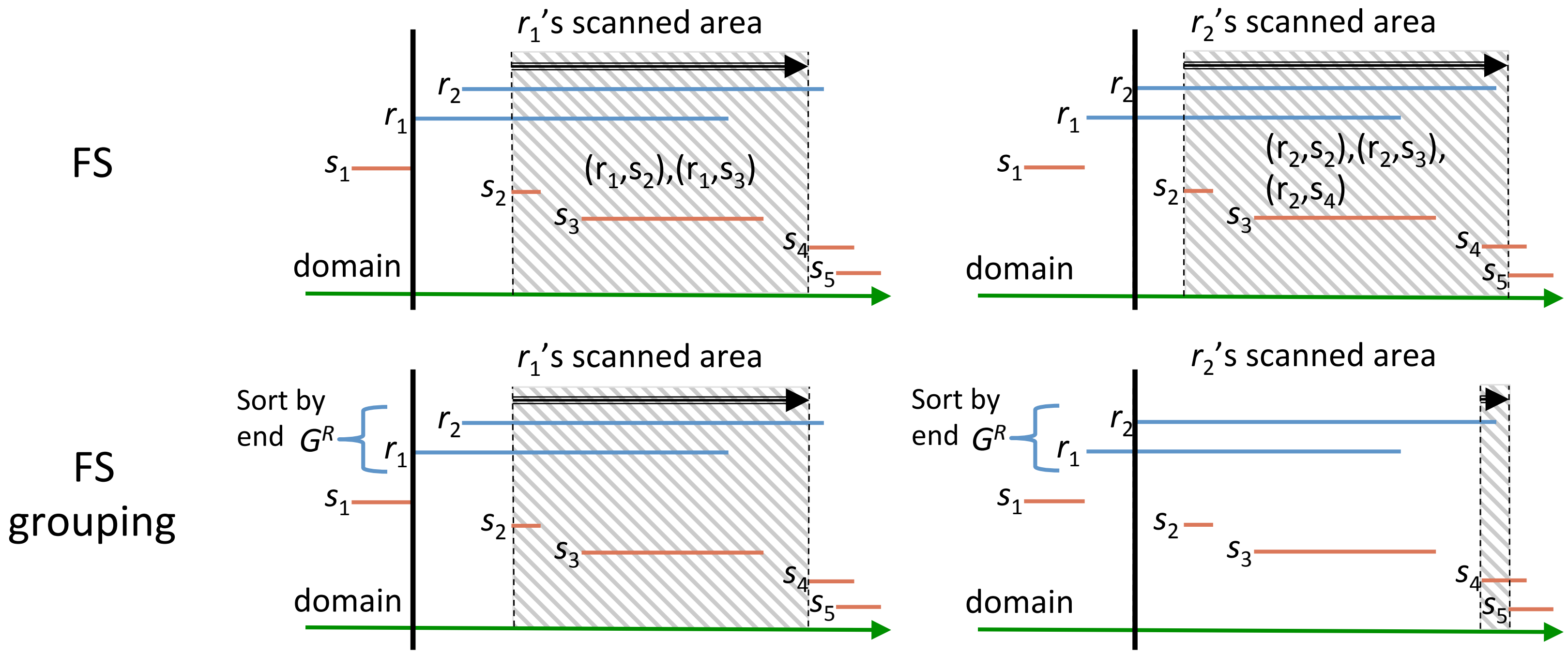

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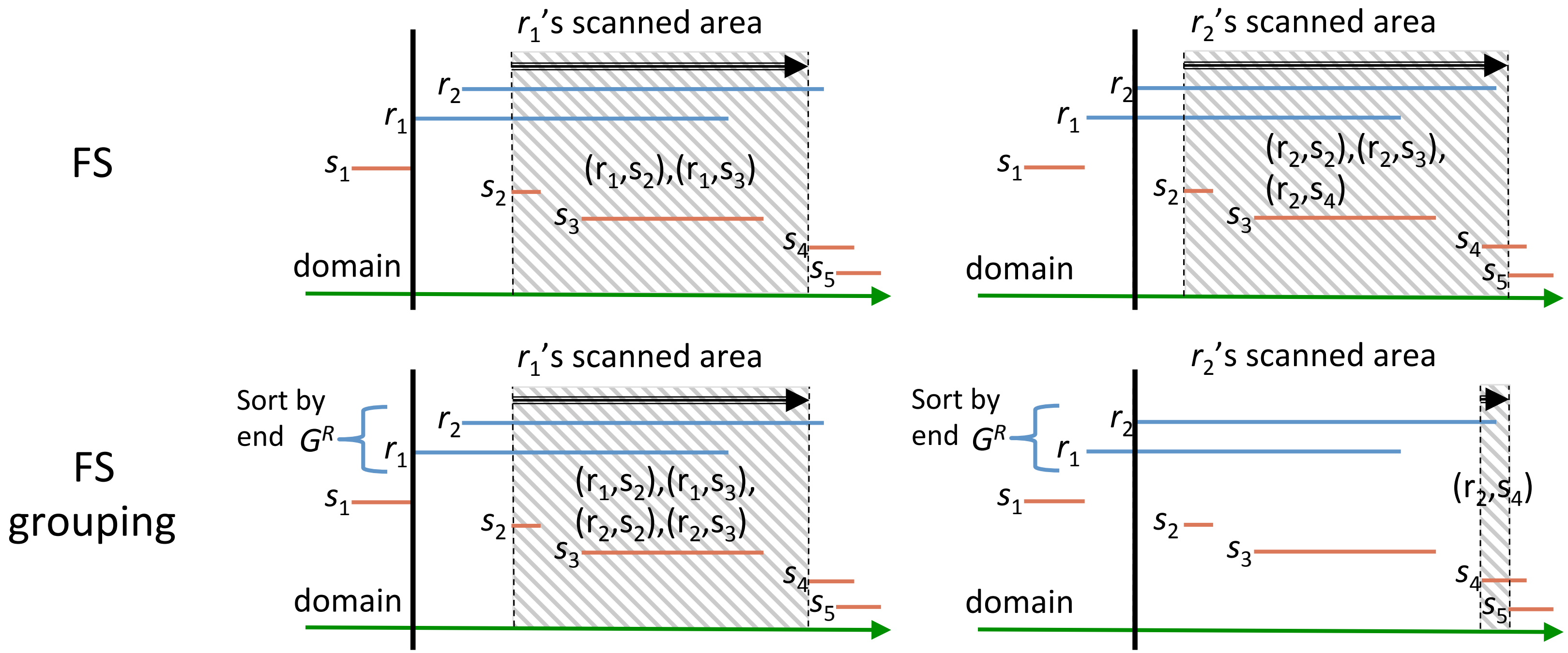

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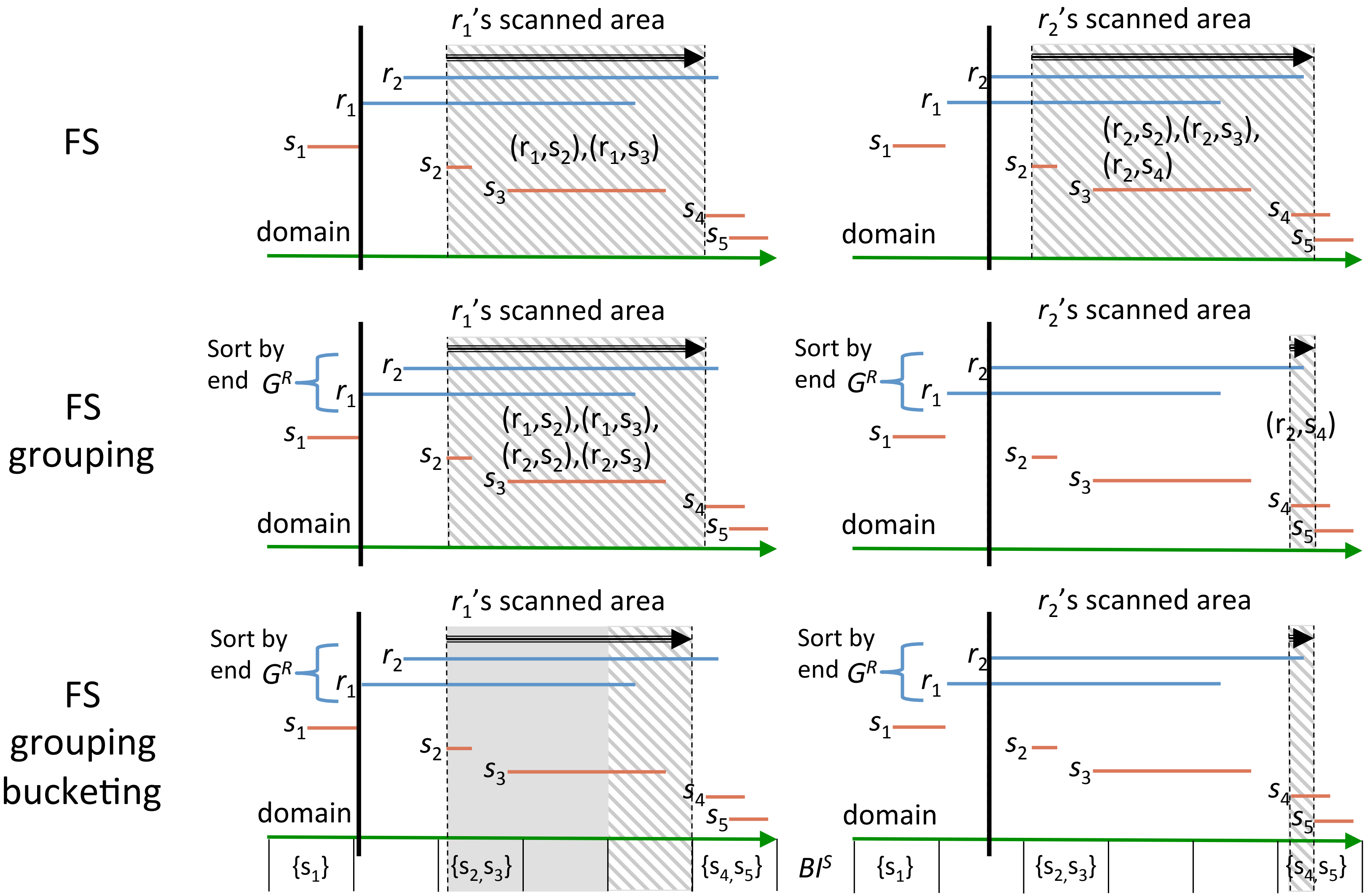

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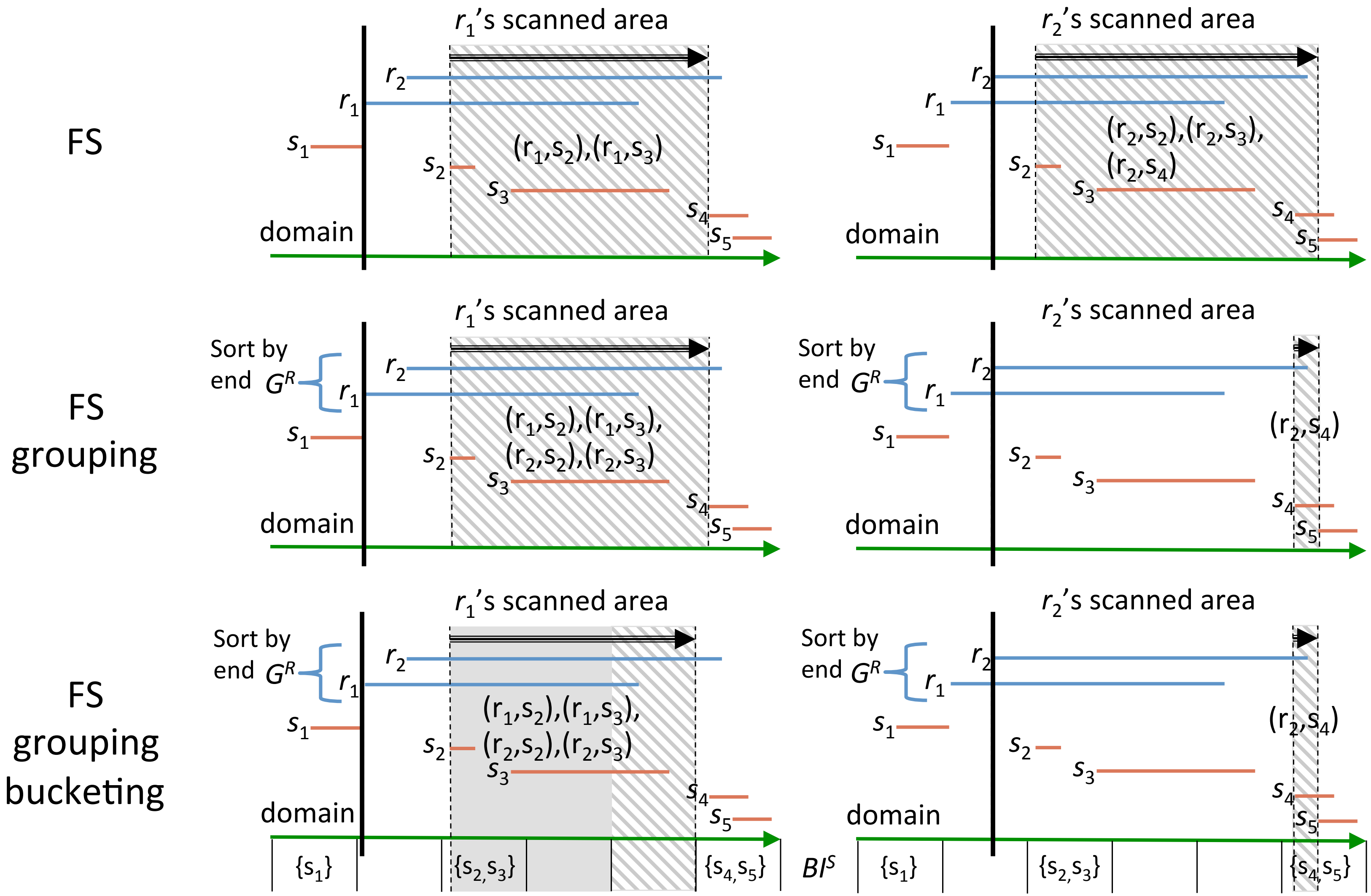
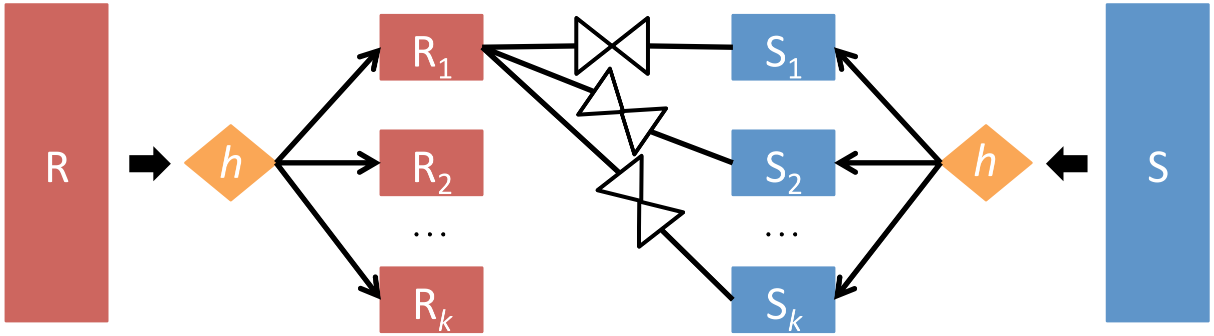


PARALLEL PROCESSING

Hash-based partitioning

[Piatov et al., ICDE’16]



- Idea
  - Randomly split each input into *k* partitions using hash function *h*
  - Evaluate k^2 independent partition joins

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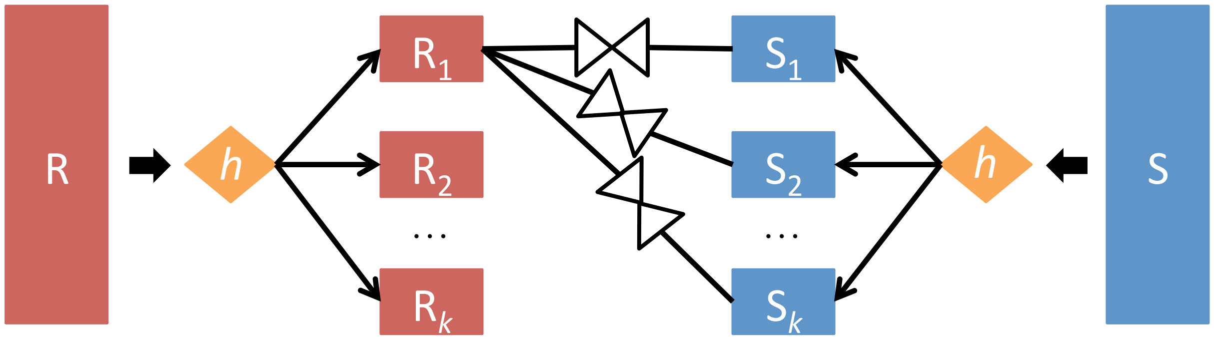

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✓ Load balancing

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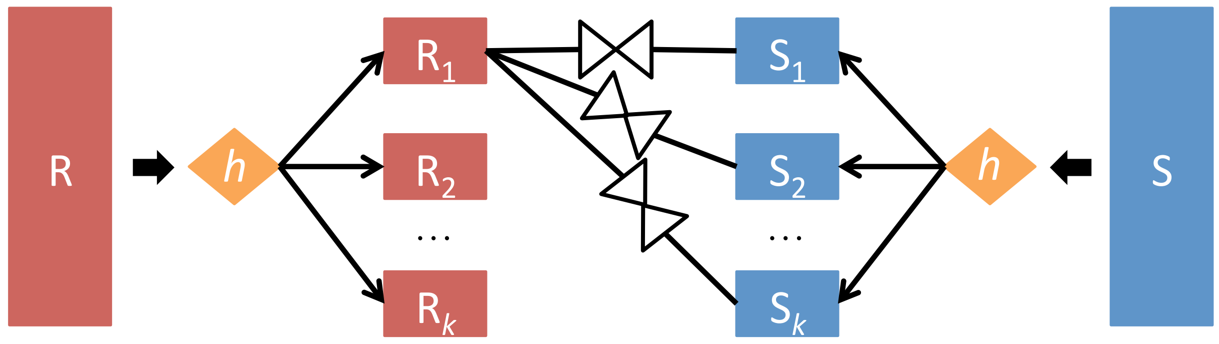

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✓ Simple

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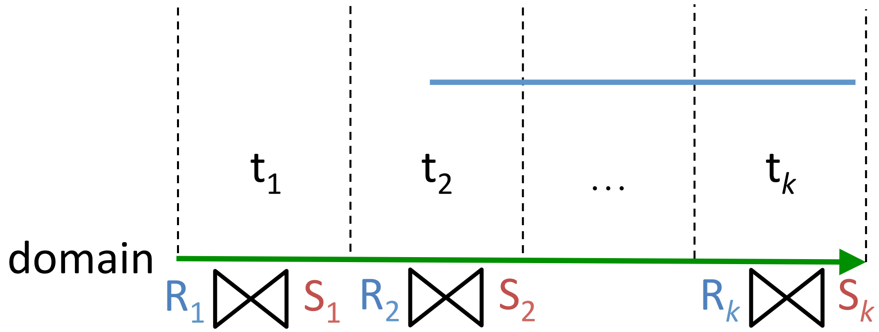
Cons

✗ Domain-point comparisons rise
  - $2 \cdot k \cdot (|R|+|S|)$ for EBI/LEBI, $k \cdot (|R|+|S|)$ for FS

✗ Degree of parallelism
  - n CPU cores → $k = \sqrt{n}$ partitions

Domain-based partitioning



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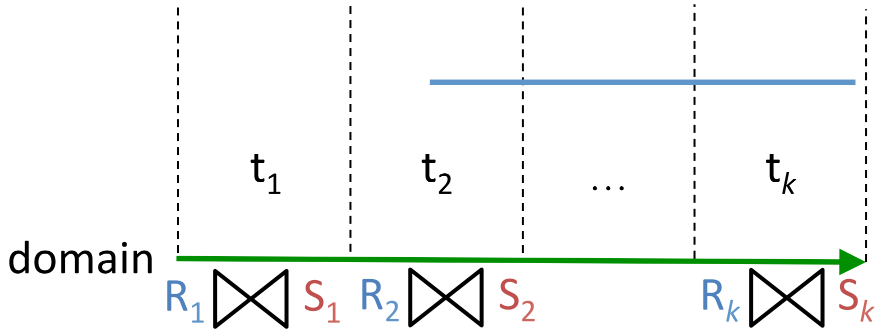

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✓ Automatic duplicate elimination

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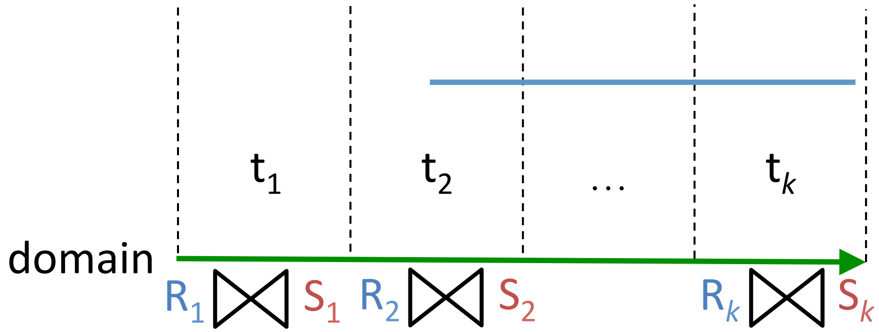

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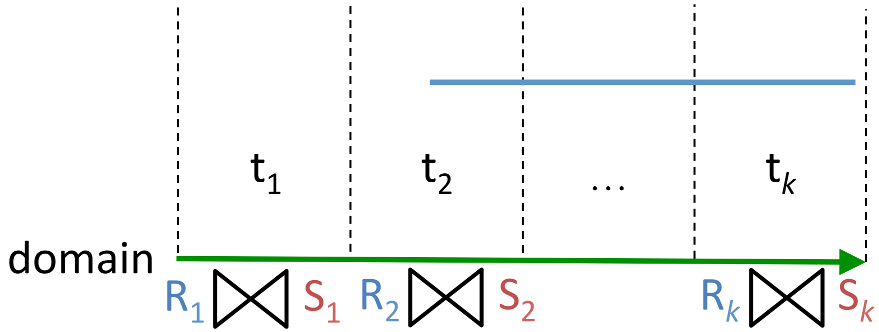

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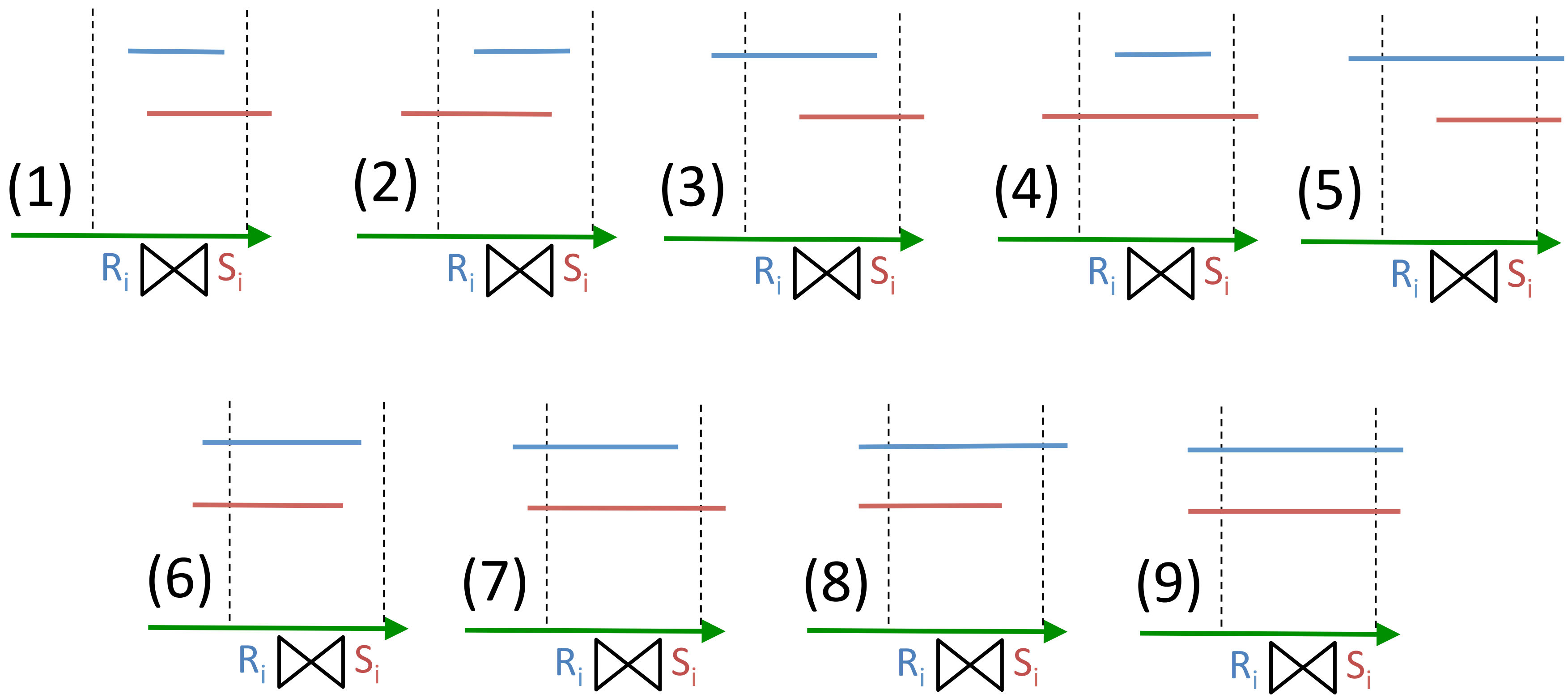
Mini-joins break down

- 3 types of intervals → 9 types of mini-tasks



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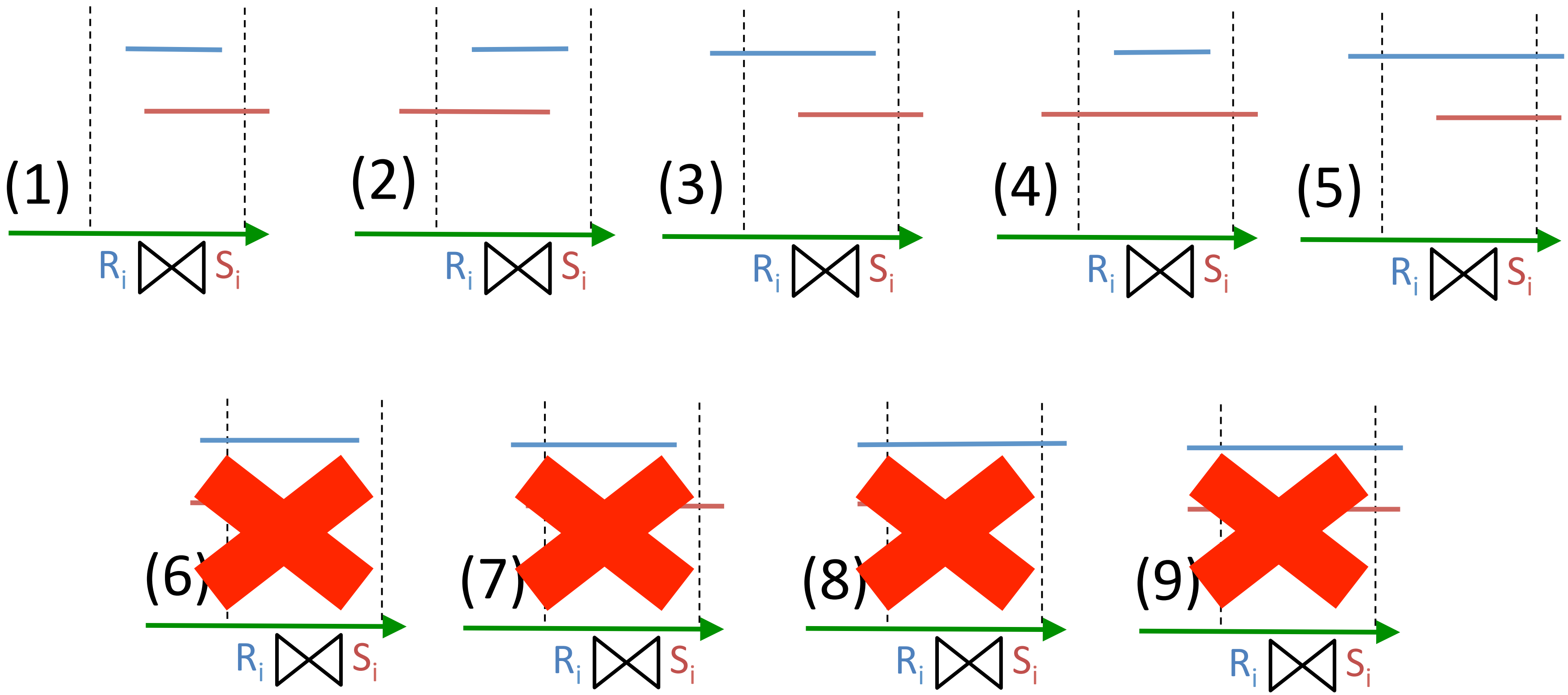

Duplicate results elimination

Mini-joins break down

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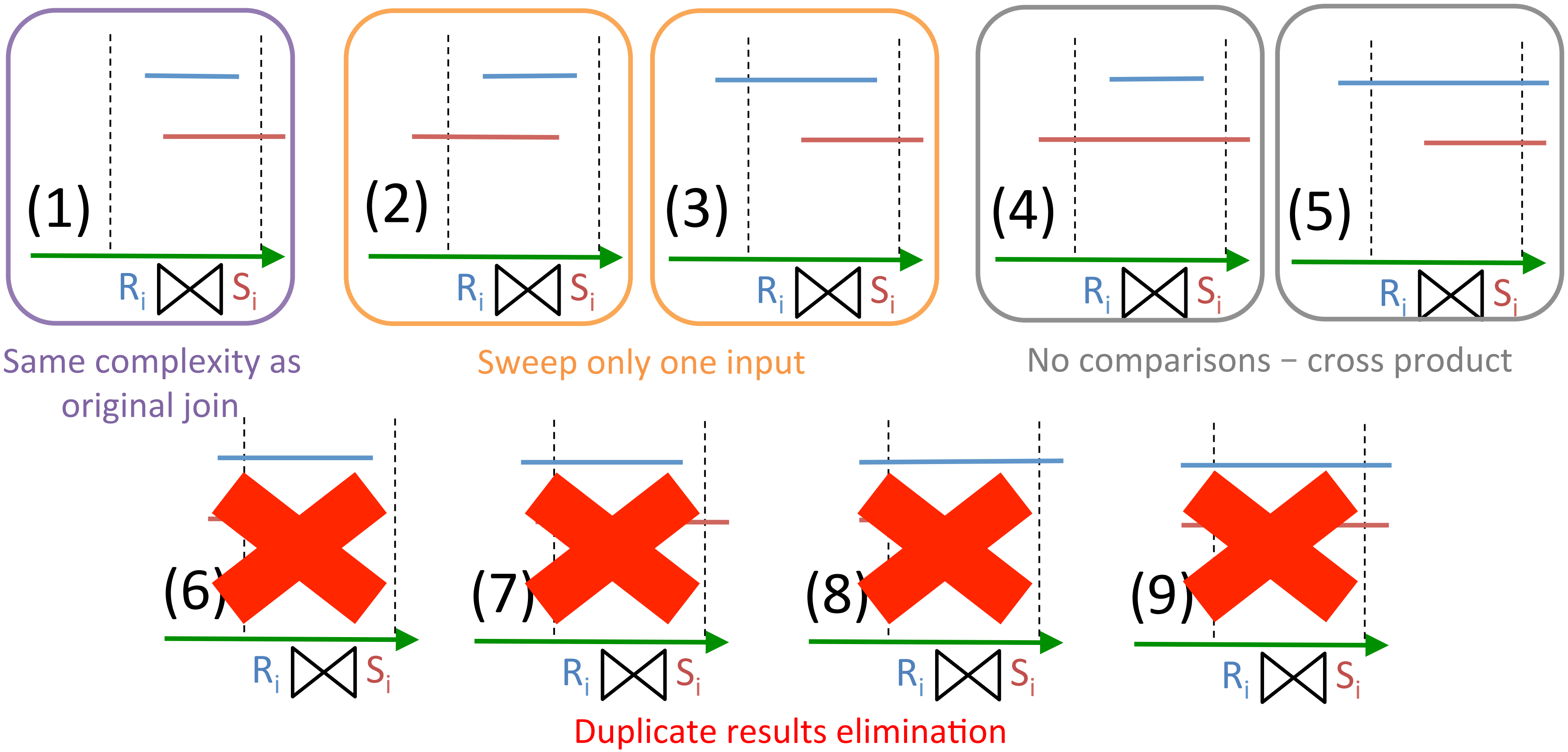

Greedy scheduling

- Idea
  - Distribute $1 + 5 \cdot (k\text{-}1)$ mini-joins to different cores
  - Evenly distribute load → minimize max load
  - NP-hard problem
    - Greedy approximation algorithm

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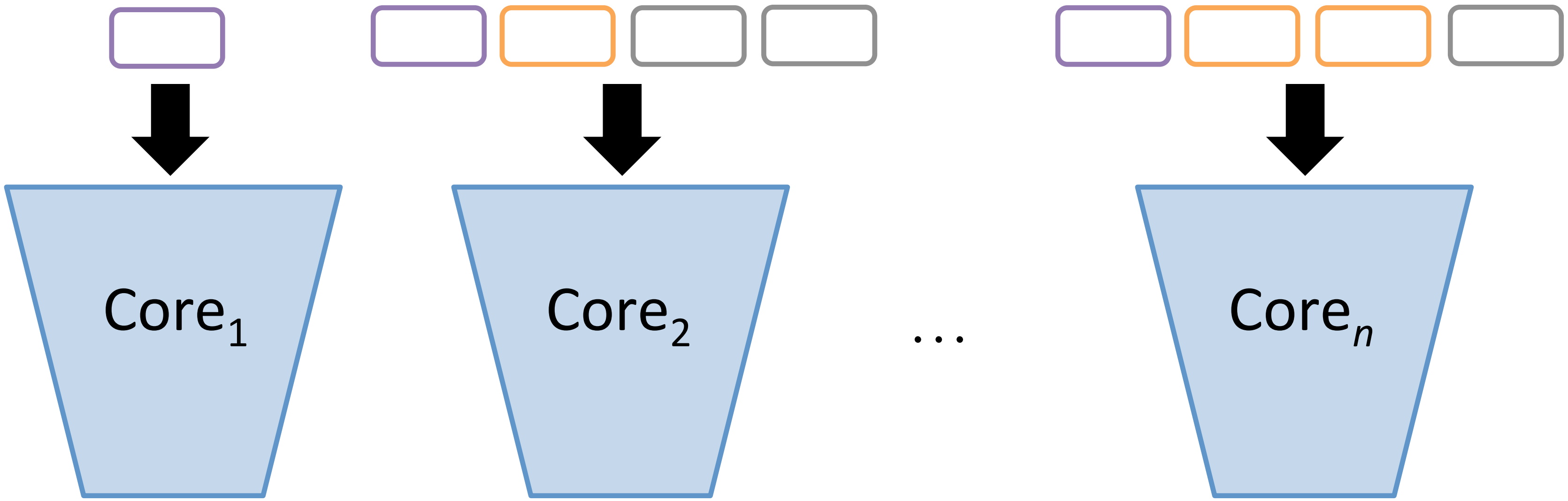

Adaptive partitioning

- Idea
  - Create an initial uniform partitioning
  - Employ a very fine tiling – granules
  - Move load between neighboring tiles
    - Move granules between neighboring tiles
    - Reposition borders of tiles

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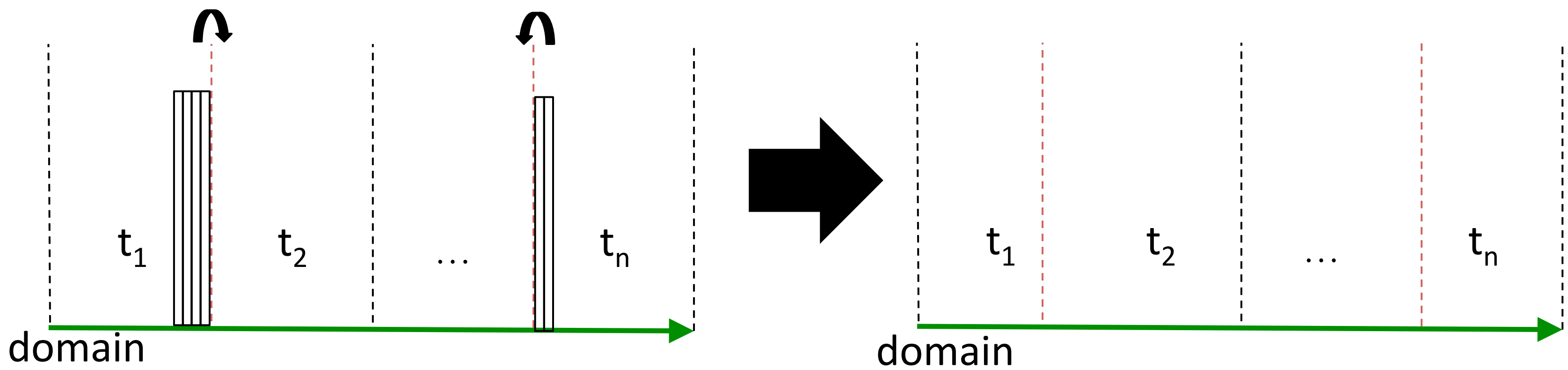
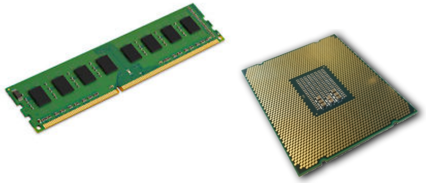
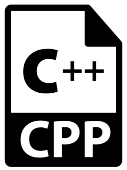


EXPERIMENTAL ANALYSIS

Setup

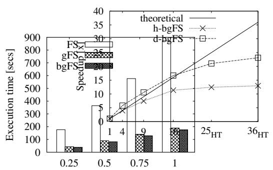


- Hardware
  - dual 10-core Intel(R) Xeon(R) CPU E5-2687W v3 @ 3.10 GHz with 128 GBs of RAM
  - Hyper-threading enabled, up to 40 threads



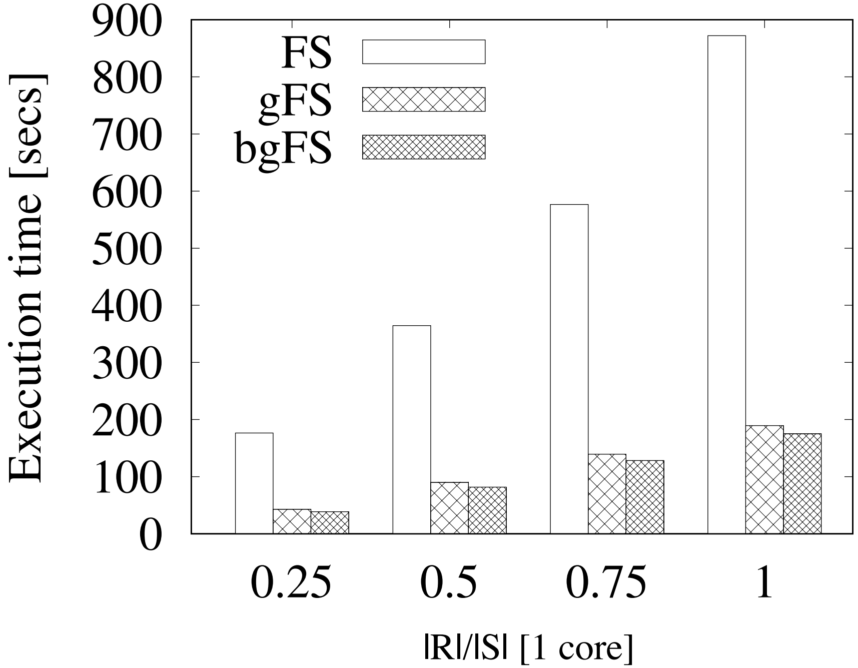
- Software
  - Workload [ICDE'16] → XOR of *start*
  - Loop unrolling forced, OpenMP for multi-threading

- Datasets
  - WEBKIT git repo, interval = period of time file unchanged
  - BOOKS Aarhus libraries, interval = period of time book lent
  - Synthetic
    - Interval duration follows exponential distribution, uniformly distributed *start* plus peaks

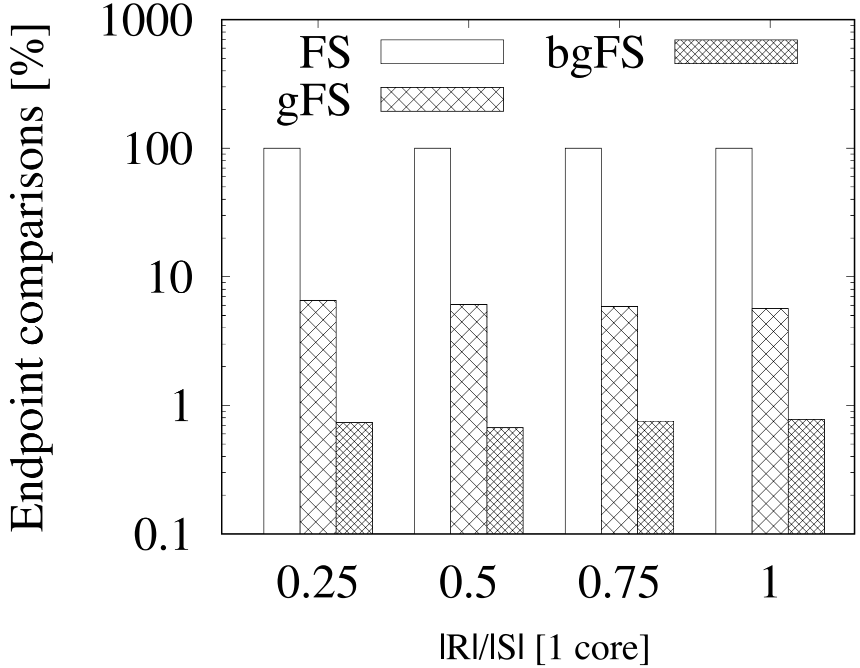


- Experiments
  - Execution time, # comparisons, memory footprint
  - Both self joins and non-self joins
  - Vary |R|/|S|, # cores (threads)

Optimizing FS

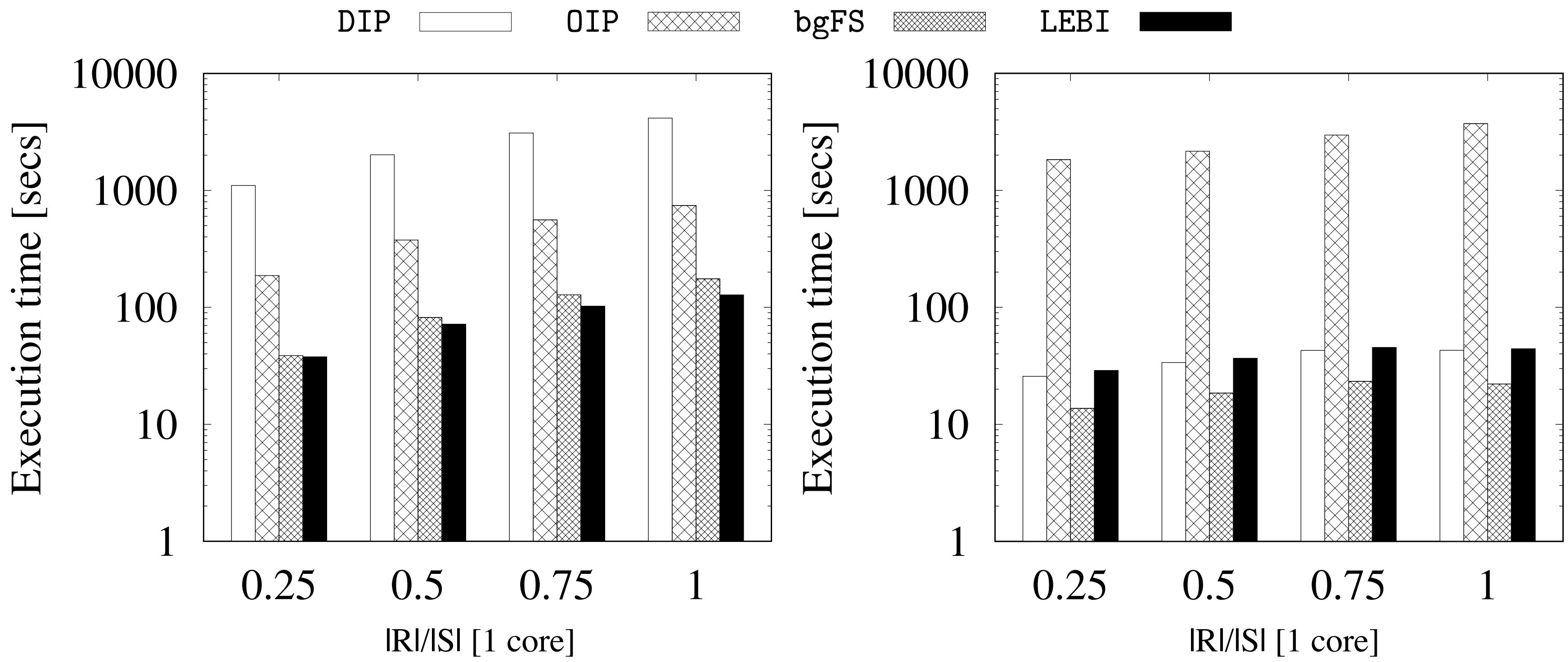


WEBKIT



WEBKIT

Single-threaded processing



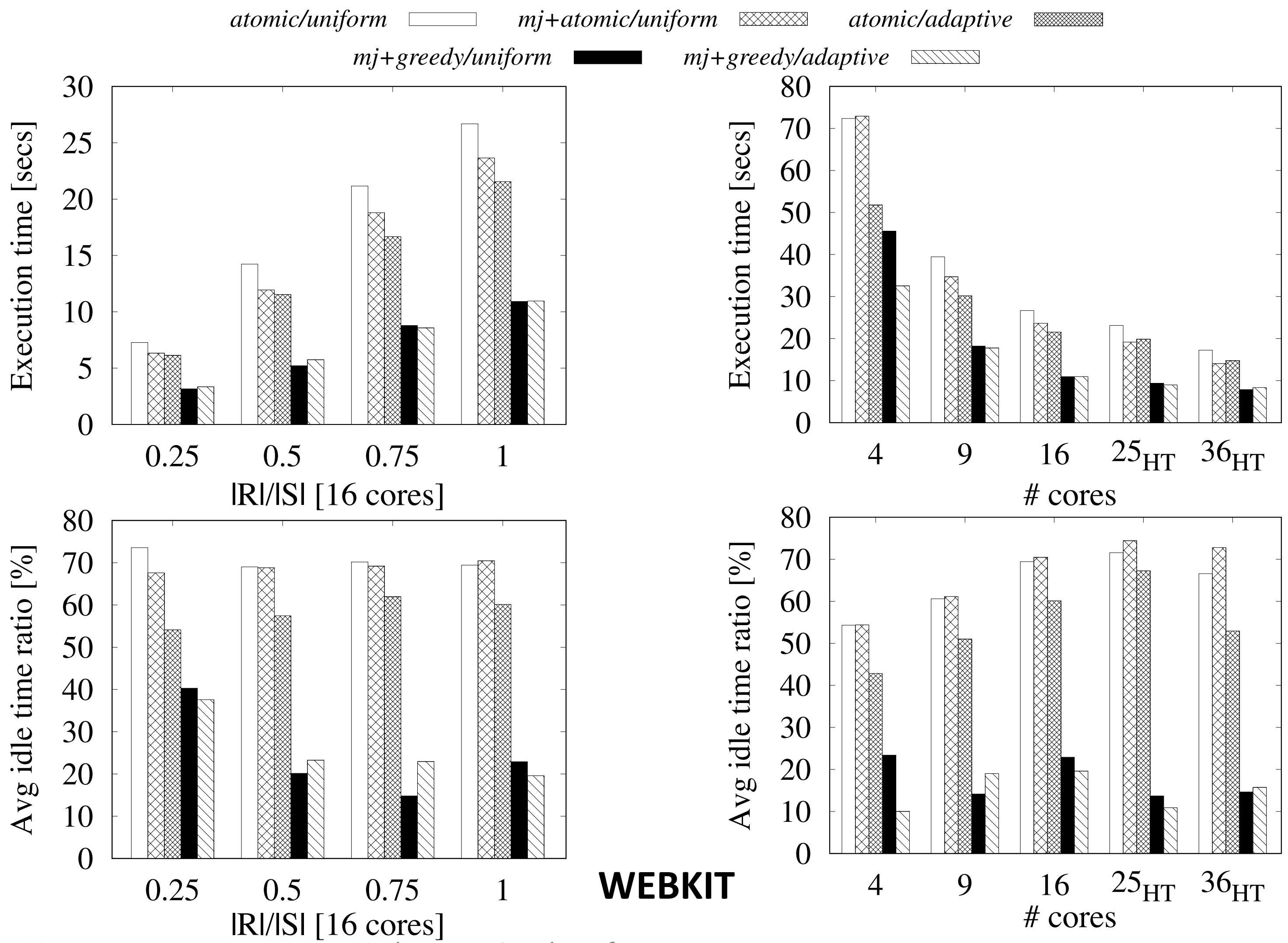
WEBKIT

GREEND

[Cafagna and Bölhen, VLDBJ’17]

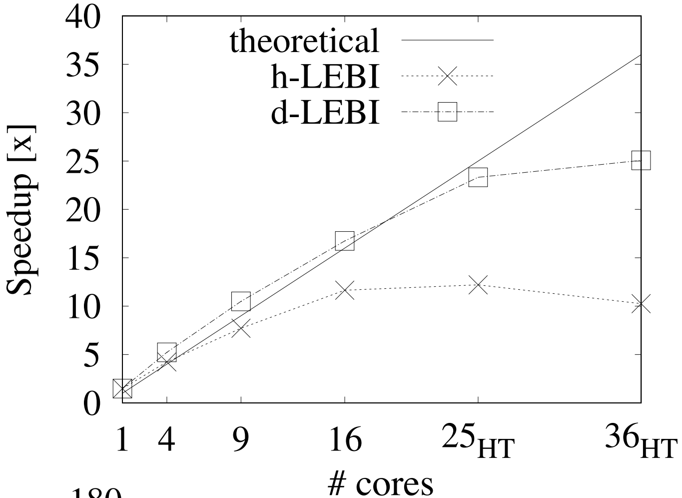
DIP: [Cafagna and Bölhen, VLDBJ’17]
OIP: [Dignös et al., SIGMOD’14]

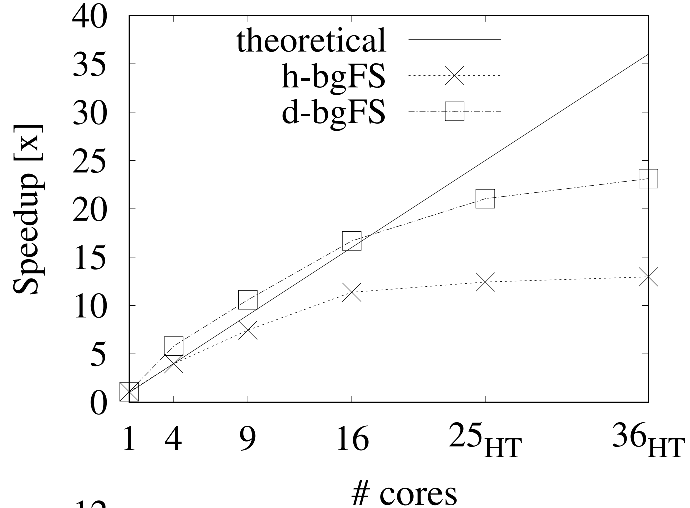
Optimizing Domain-based Paradigm

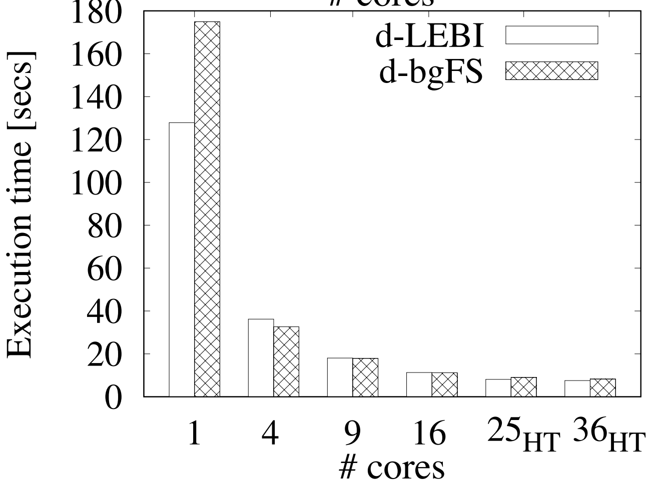


WEBKIT

Parallel processing







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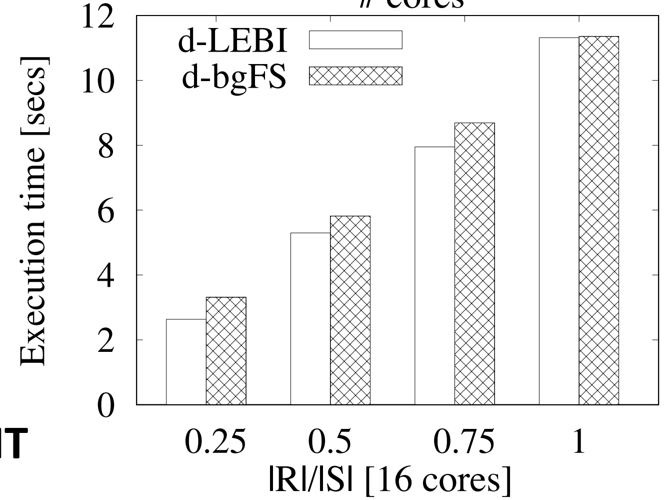


To sum up

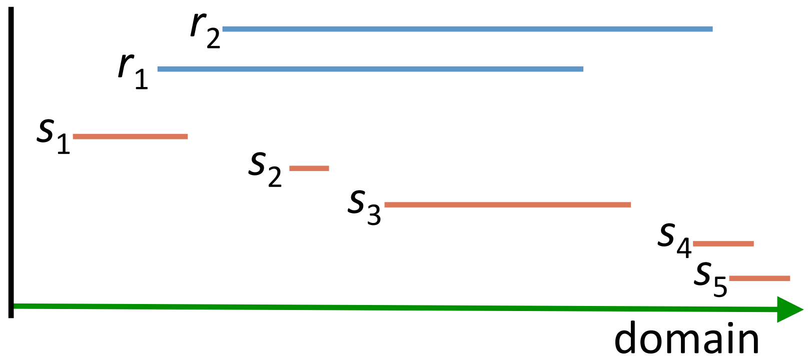
- Contributions
  - Efficient evaluation of interval joins
  - Single-threaded processing
    - Optimized bgFS, competitive to state-of-the-art EBI/LEBI
    - Lower memory footprint
  - Parallel processing
    - Novel domain-based partitioning paradigm
    - Higher speedup
- Future work
  - Other types of temporal joins
  - Other types of temporal operators
  - Parallel processing
    - Data-level parallelism, share data between threads

Questions ?

EXTRAS

Endpoint-Based Join (EBI/LEBI)

[Piatov et al., ICDE'16]



Endpoint indices

$EI^R = \{r_1.\mathit{start}, r_2.\mathit{start}, r_1.\mathit{end}, r_2.\mathit{end}\}$

$EI^S = \{s_1.\mathit{start}, s_1.\mathit{end}, s_2.\mathit{start}, s_2.\mathit{end}, s_3.\mathit{start}, s_3.\mathit{end}, s_4.\mathit{start}, s_5.\mathit{start}, s_4.\mathit{end}, s_5.\mathit{end}\}$

Active sets

$A^R = \{\}$

$A^S = \{\}$

Result

$\{\}$

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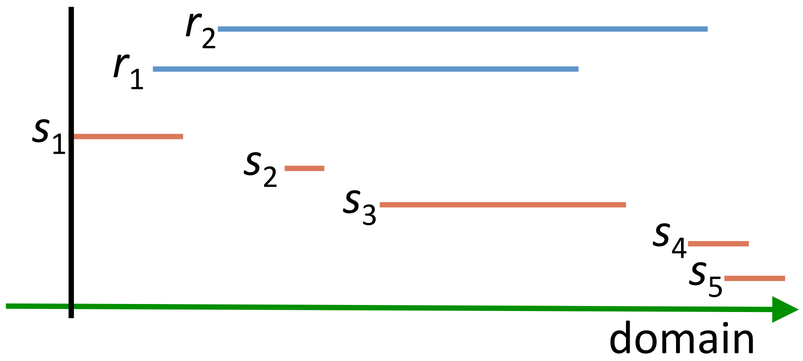

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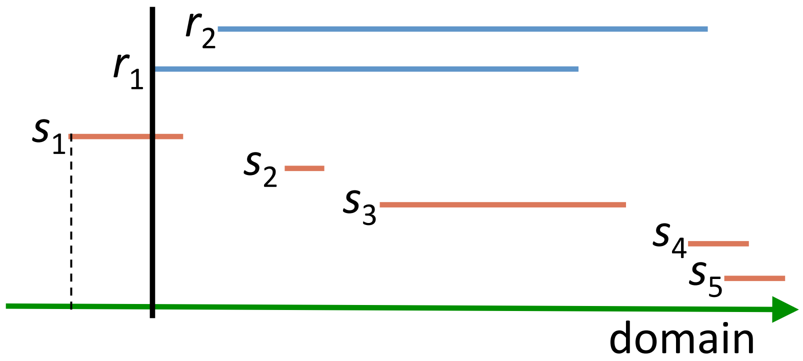

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$EI^R = \{r_1.start, r_2.start, r_1.end, r_2.end\}$

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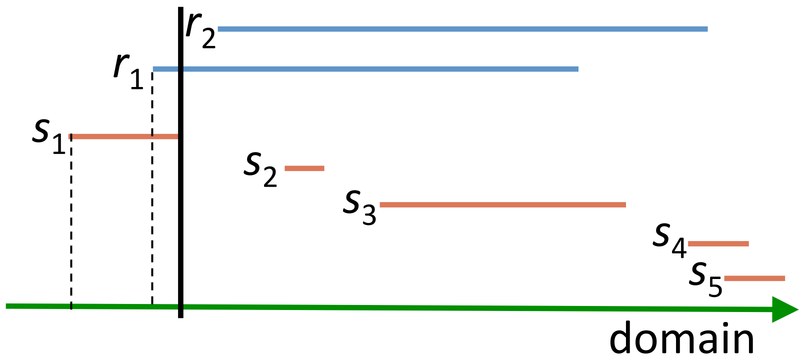

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Active sets

$A^R = \{\}$

$A^S = \{\cancel{s_1}\}$

Result

$\{(r_1,s_1)\}$

Endpoint-Based Join (EBI/LEBI)

[Piatov et al., ICDE'16]

Pros

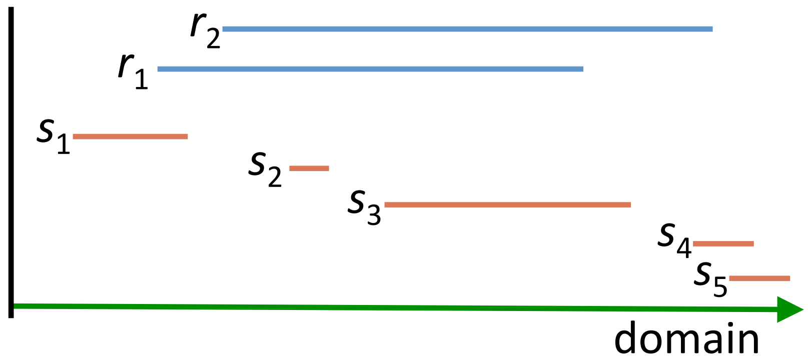
- ✓ No domain-point comparisons when producing results
- ✓ Tailored to modern hardware
- ✓ Main memory cache-aware
- ✓ Fast

Cons

- ✗ Special data structure needed for active sets, support for efficient updates and scans

Forward Scan based (FS)

[Brinkhoff et al., SIGMOD'93]



Sorted inputs

R = {r_1, r_2}

S = {s_1, s_2, s_3, s_4, s_5}

Result

{}

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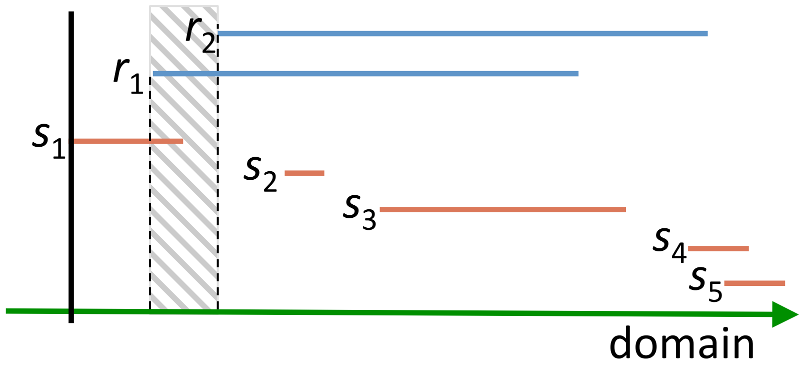

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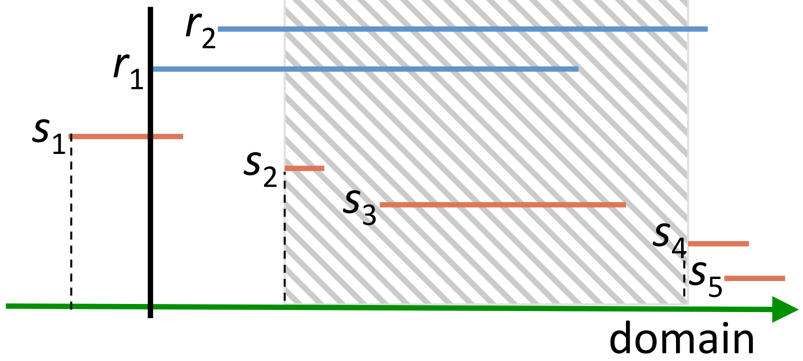

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Result

{(r_1,s_1), (r_1,s_2), (r_1,s_3)}

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[Brinkhoff et al., SIGMOD'93]

Pros

✓ Simple

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Cons

✗ Each join result requires a domain-point comparison, $|R| + |S| + |R \bowtie S|$ comparisons in total

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