Skyline query processing

Orestis Gkorgkas

Norwegian University of Science and Technology

August 12, 2015

Outline

Skyline queries

Basic algorithms

Multi-threaded algorithms

Skyline in distributed systems

Skyline on Map-Reduce

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Basic algorithms

Multi-threaded algorithms

Skyline in distributed systems

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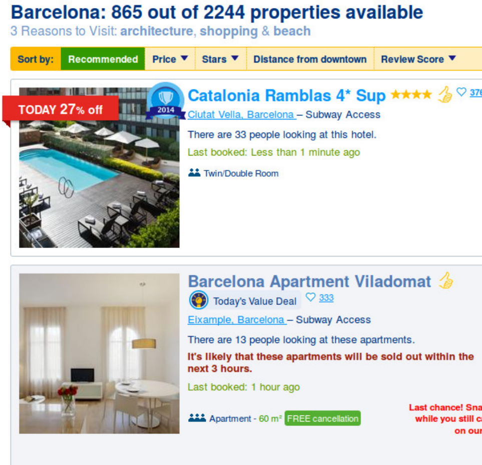
Skyline Queries

Users often have multiple search criteria

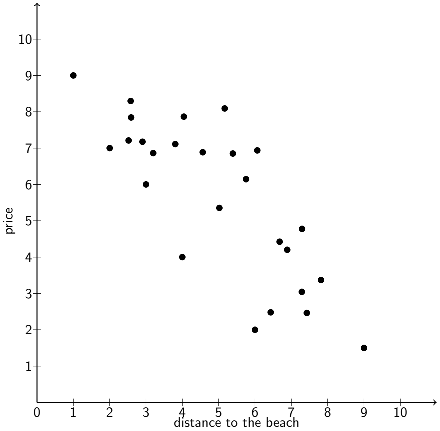
- Price
- Location
- Cleanliness
- Stars
- Overall quality



Skyline Queries

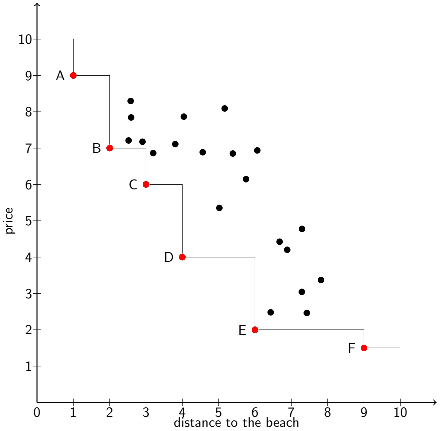
- Items are usually ranked according to a single feature
- Users get overwhelmed by the number of all possible options
  - It becomes difficult to find the item that suits their needs
- **Usually there is no single best item**
- **But there are many options that are definitely worse than others**
- How can we keep only the good options?
  - Skyline queries

Skyline



- If a point **p** is no worse at all dimensions than a point **q** and at least better in one, then **p dominates q**
- The skyline consists of all points that are not dominated by any other point

Skyline



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Why skyline queries are important?

- Data exploration
  - They provide an overview of the available data
  - They include good options for any use preference
- Multi-criteria decision analysis
  - Especially useful when client's processing resources are limited
- Route planning
  - Evaluation of multiple traveling costs

Skyline queries variations

- Constraint skyline queries
  - Constrains are imposed to the range of some of the dimensions
  - e.g. Skyline for the hotels are that are not further than 500m from beach
- Skylines over a subset of dimensions
- Dynamic skylines
  - Each dimension corresponds to a function
  - e.g. Restaurants that are the closest to my current position their closing time is as later as possible from current time
- Skylines over joins
- Skyband queries
- ...

Skyline queries over different settings

- Centralized processing
  - Single-thread algorithms
    - Index-free
    - Index-based
  - Multi-threaded algorithms
  - Skylines on GPU
- Distributed processing
  - Peer-to-peer systems
  - Skyline on Map-Reduce

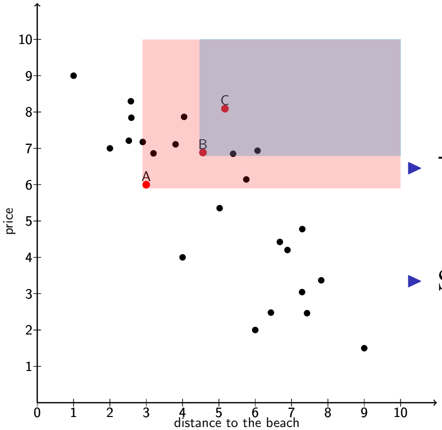
A naive algorithm

- Pairwise comparison of all points
- Can be implemented as a nested SQL query
- High complexity ($O(n^2)$)

```
SELECT * FROM HOTELS outer
WHERE outer NOT EXISTS (
SELECT * FROM HOTELS inner
inner.distance <=outer.distance AND
inner.price <= outer.price AND
(inner.distance <outer.distance OR
inner.price < outer.price
));
```

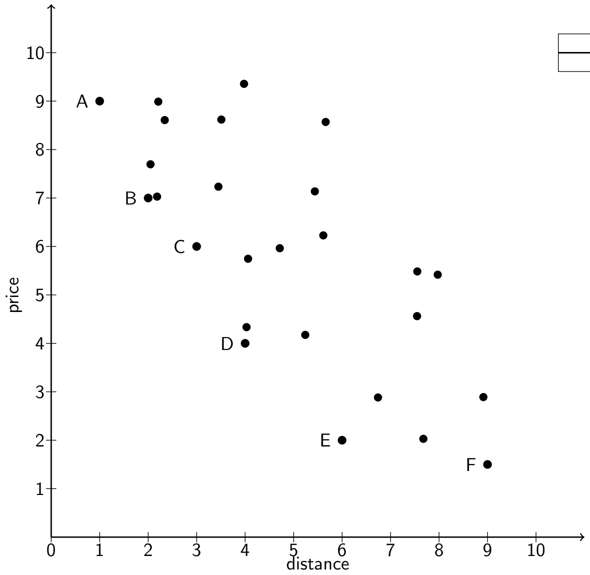
Outline

Properties of skylines



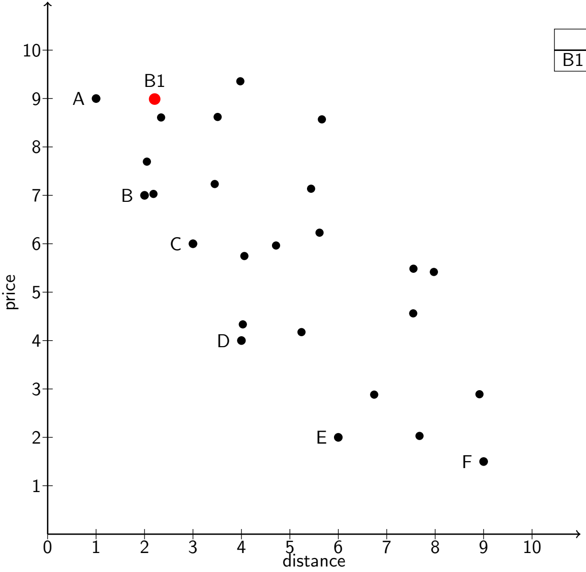
- Transitivity
  - If A **dominates** B and B **dominates** C $\Rightarrow$ A **dominates** C
- $\mathrm{Sk}(A_1 \bigcup A_2) = \mathrm{Sk}(\mathrm{Sk}(A_1) \bigcup \mathrm{Sk}(A_2))$

Block Nested Loops



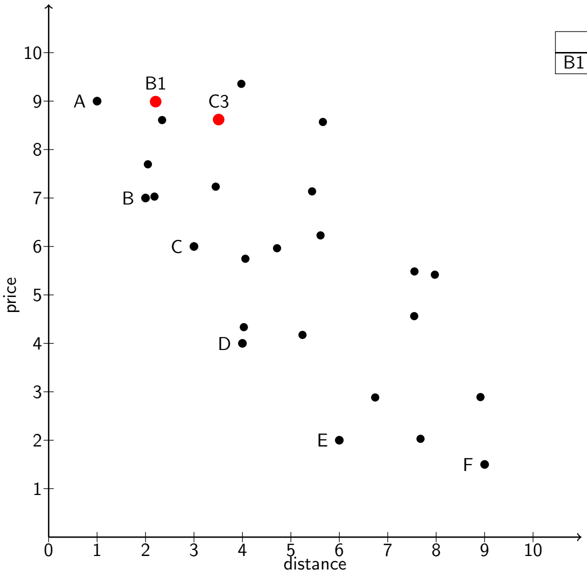
Window		

Block Nested Loops



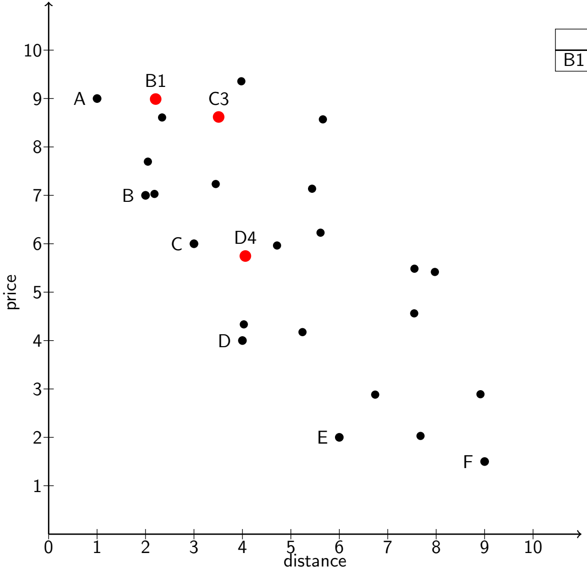
Window		
B1		

Block Nested Loops



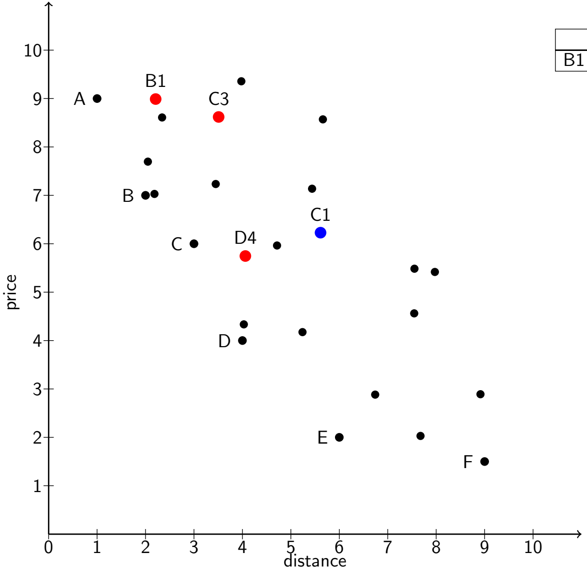
Window		
B1	C3	

Block Nested Loops



Window		
B1	C3	D4

Block Nested Loops



Window		
B1	C3	D4

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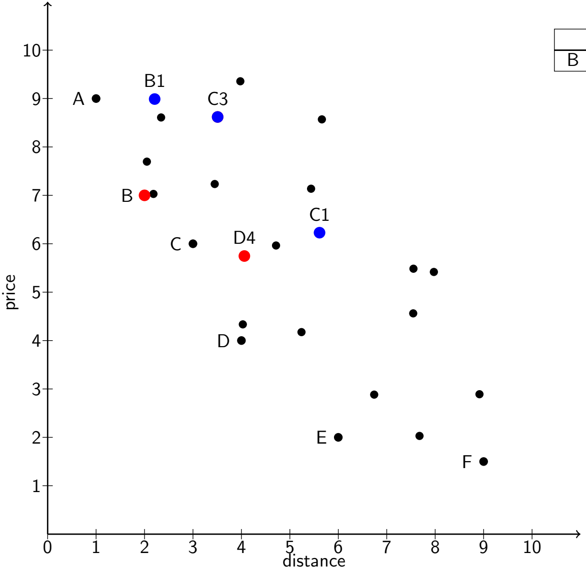
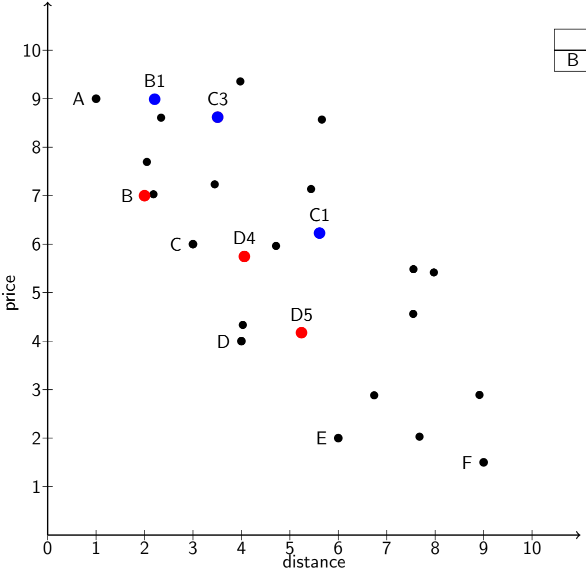


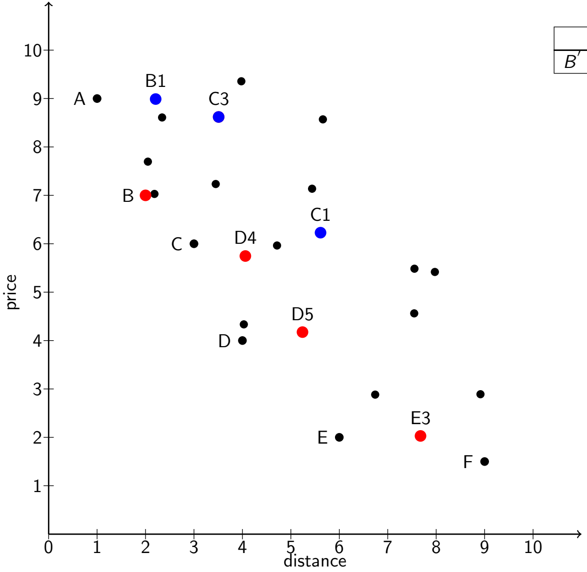
Window		
B		D4

Block Nested Loops



Window		
B	D5	D4

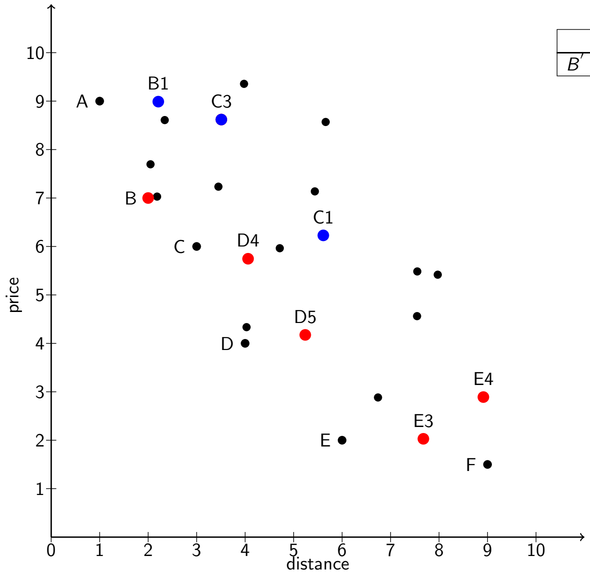
Block Nested Loops



Window		
B'	$D5'$	$D4'$

Temp. file
E3

Block Nested Loops



Window		
B'	$D5'$	$D4'$

Temp. file
E3
E4

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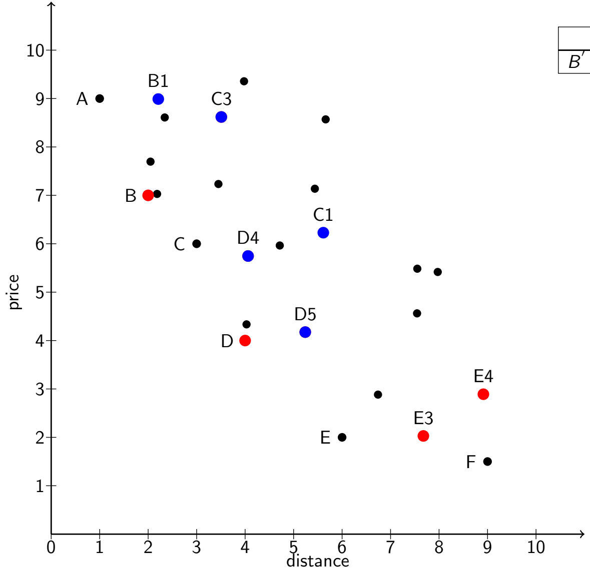
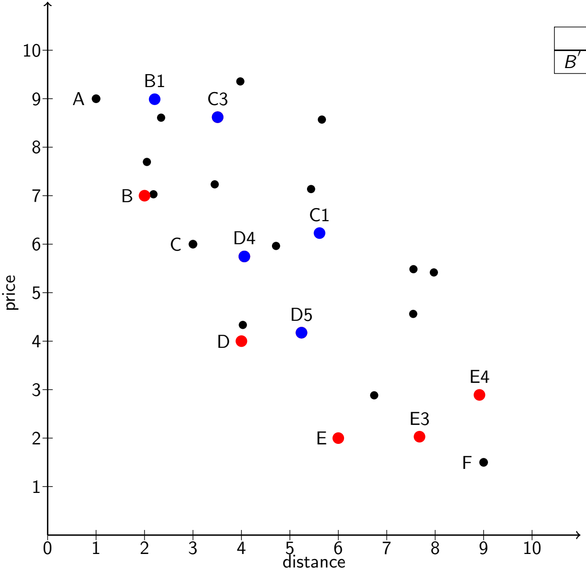


Window		
B'	D	

Temp. file
E3
E4

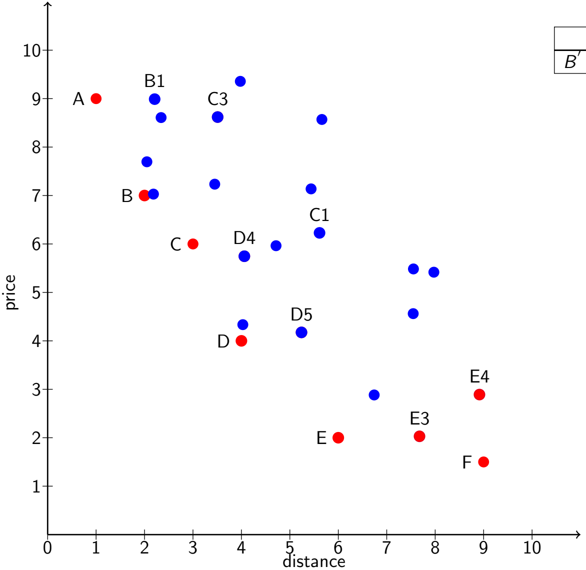
Block Nested Loops



Window		
B'	D	E

Temp. file
E3
E4

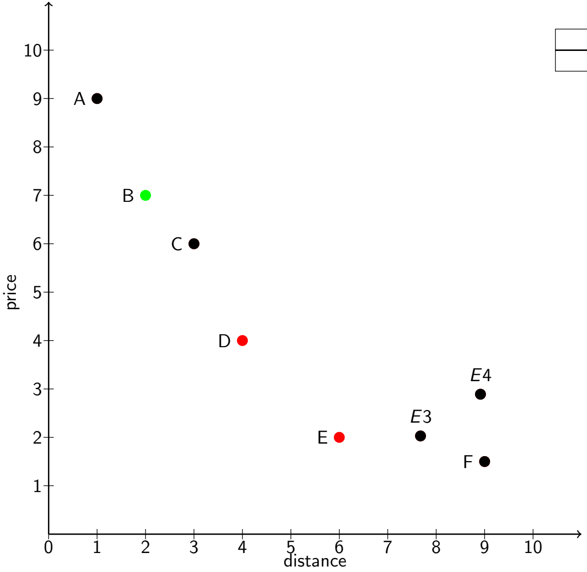
Block Nested Loops



Window		
B'	D	E

Temp. file
E3
E4
A
C
F

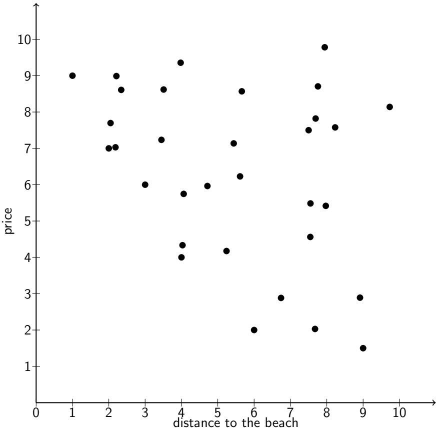
Block Nested Loops



Window		
	D	*E*

Temp. file
E3
E4
A
C
F

How can we improve the performance?



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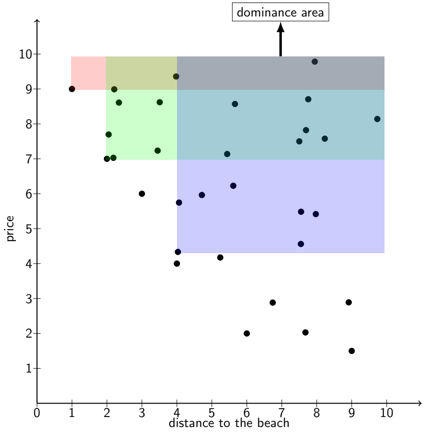
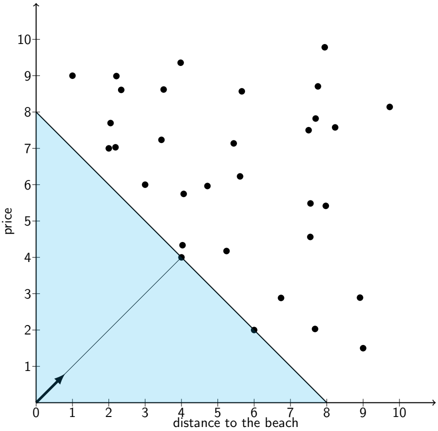


- Select points with **large dominance area**
  - Put “killer” points first in the BNL window

How can we improve the performance?



- Select points with **large dominance area**
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- Perform a sorted access based on a **scoring function**
  - Skyline points always appear before the points they dominate for any monotonic function
  - We do not need to process all objects

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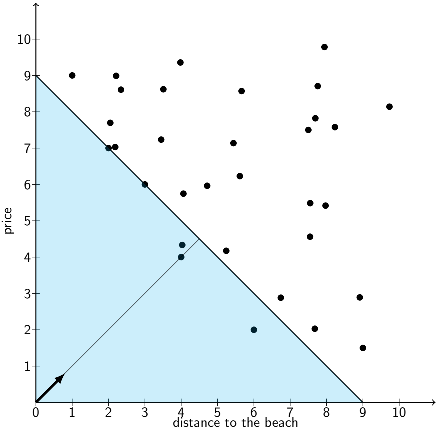

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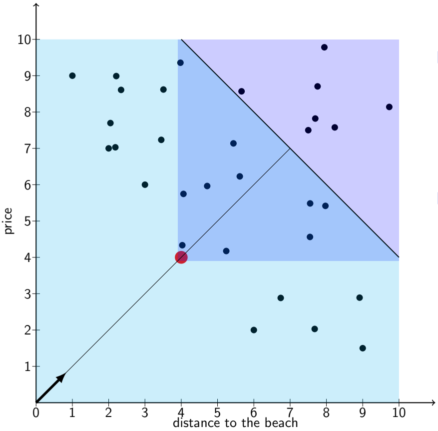

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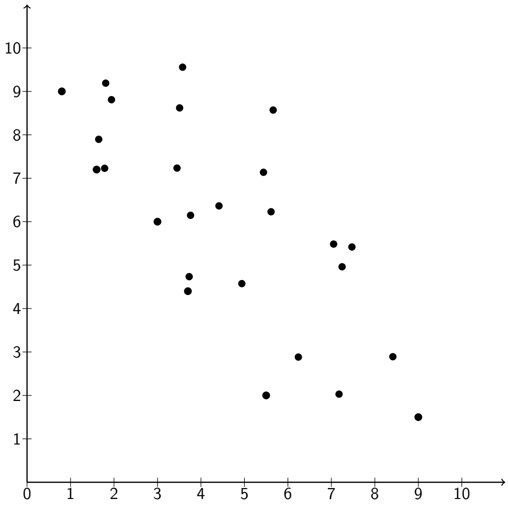
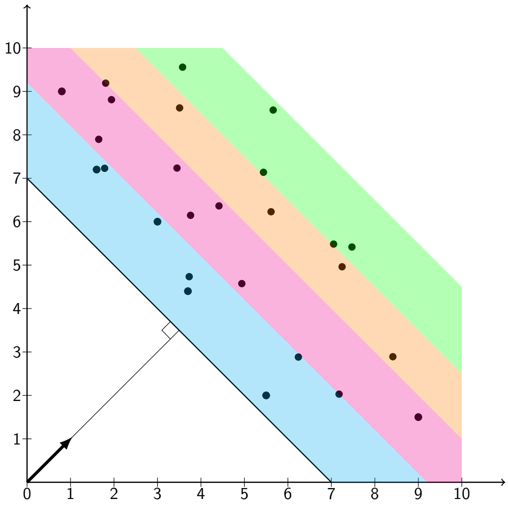
Outline

Multi-threaded processing



Multi-threaded processing



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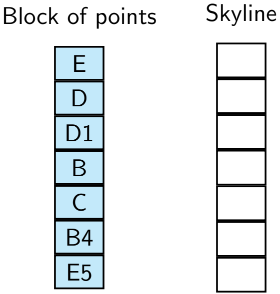


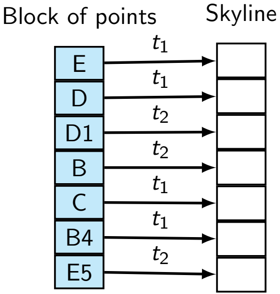
Step 1: Each point is compared independently against the skyline

- If dominated by the skyline it is marked for removal

Step 2: Each surviving point is compared against the points with better score

- Some unnecessary comparisons can be made

Multi-threaded processing



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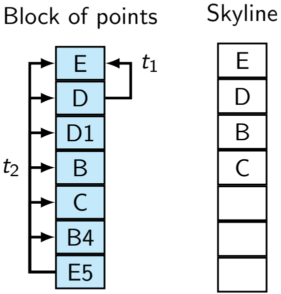

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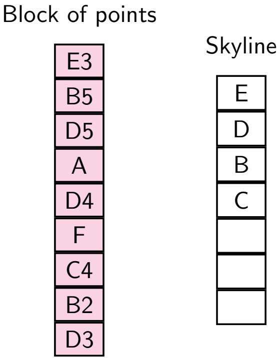

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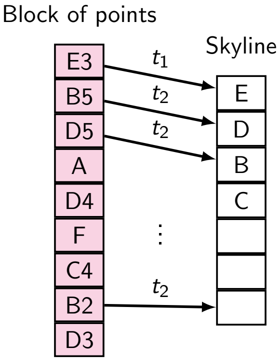

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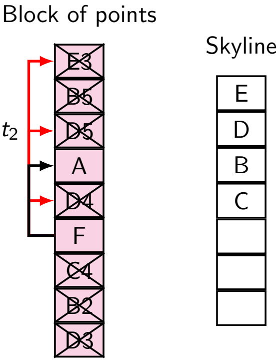

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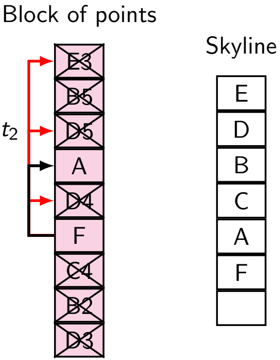

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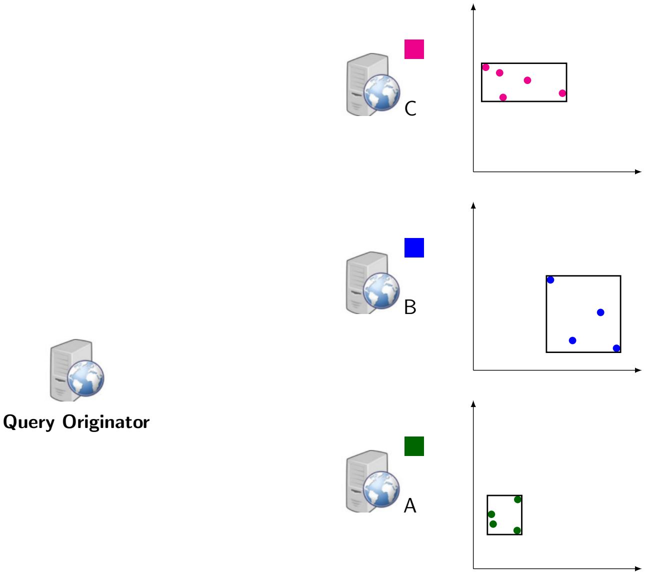
Outline

Properties of a good distributed algorithm

- Low latency - Short response time
- Parallelism
- Minimize network traffic
  - Avoid accessing unnecessary nodes
  - Minimize the transfered data
- Minimize local processing time

Distributed skyline queries



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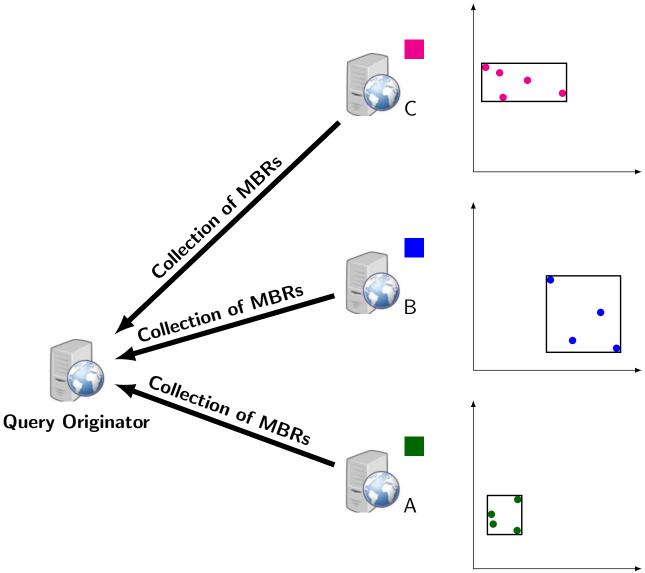

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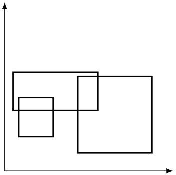
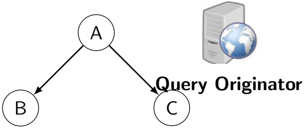
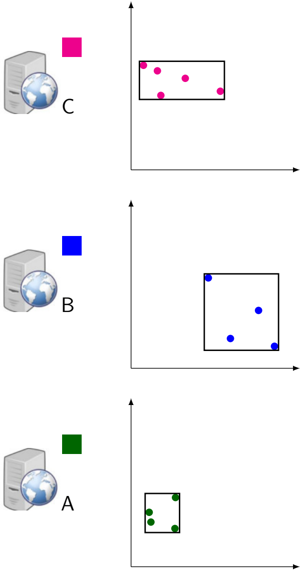


Server makes an execution plan





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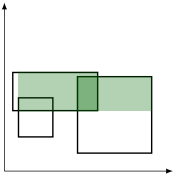

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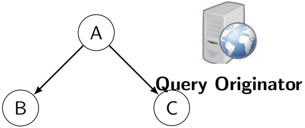

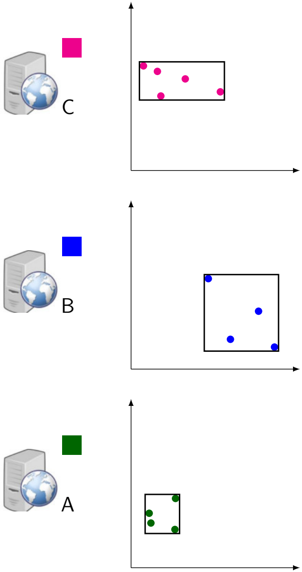

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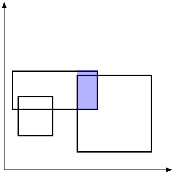

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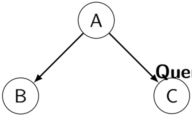
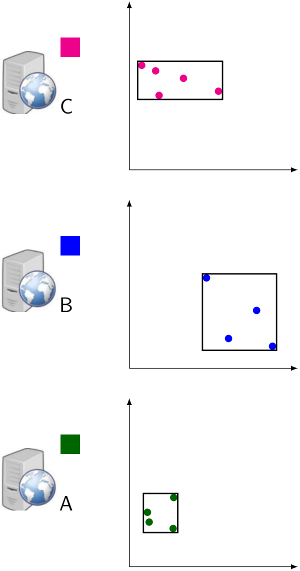


Query Originator



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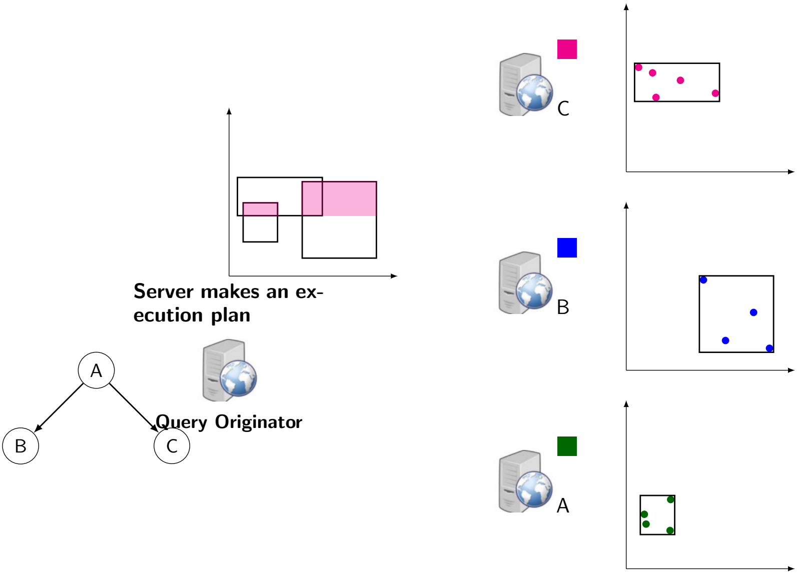

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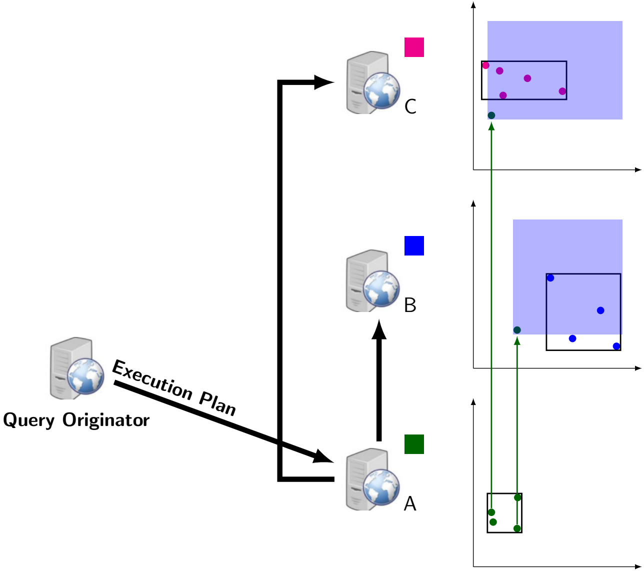

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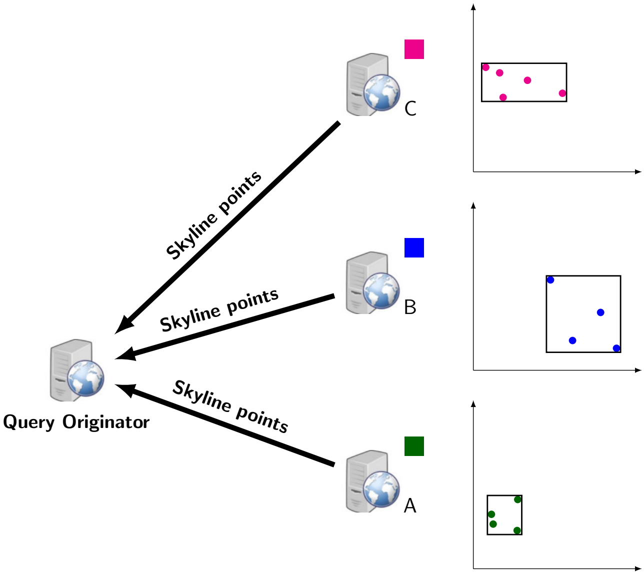
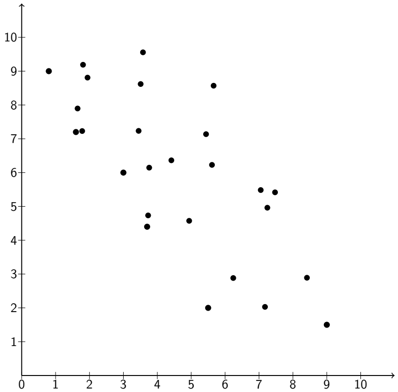


Outline

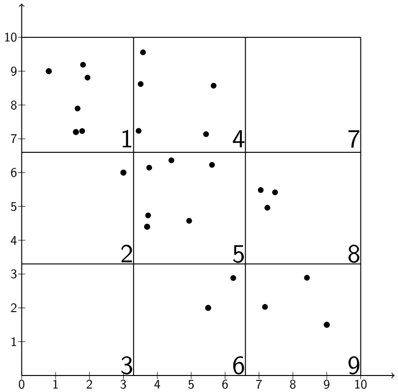
Skyline on Map-Reduce

- Every job is split into a Map and a Reduce phase
  - Map(k_1, v_1)$\rightarrow$ list(k_2, v_2)
  - Reduce($k_2, list(v_2)$) $\rightarrow$ List(v_3)
- The mappers do not communicate with each other

Skyline on Map-Reduce



Skyline on Map-Reduce



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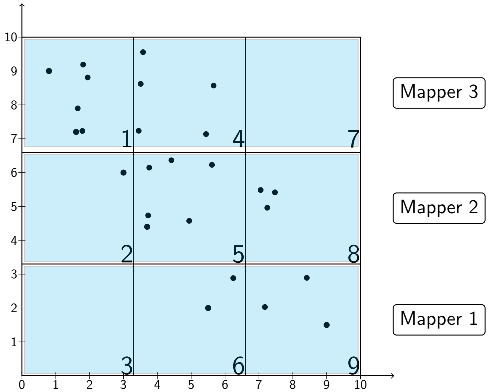

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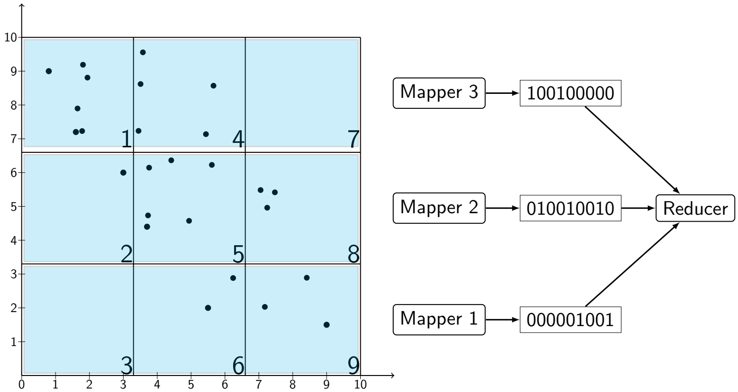

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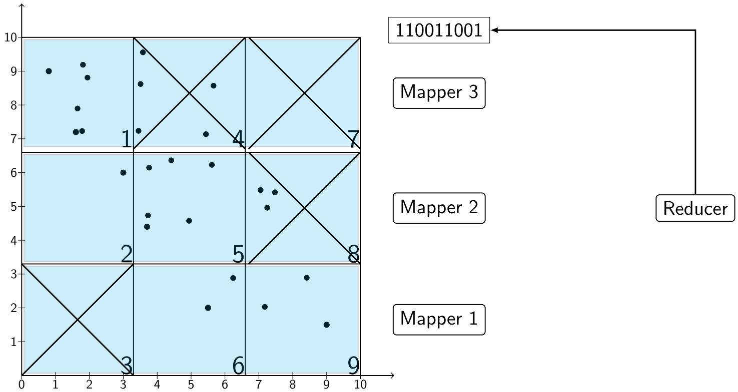

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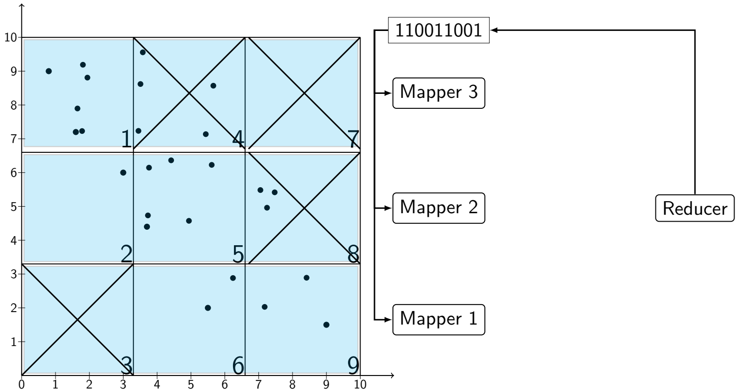

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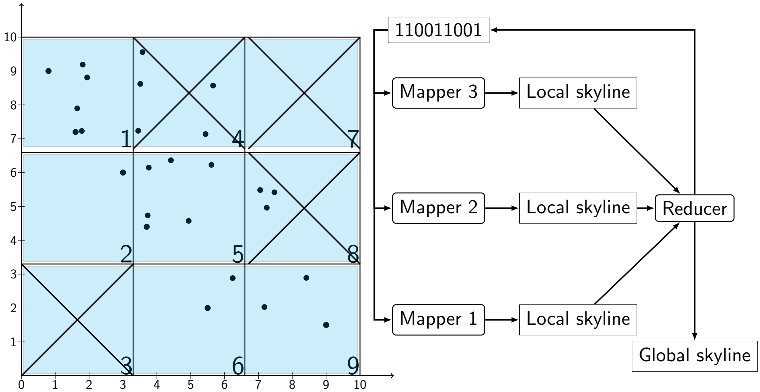

Conclusion

- Skyline queries return not dominated points
- Efficiency can be improved in many ways
  - Presorting and filtering
  - Indexes
    - Indexes cannot always be used
    - e.g. Data streams and custom user queries
  - Parallelization
    - Multi-threading
    - Distributed systems
- There are many aspects we did not cover

Thank you

Thank you for your attention!

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