DeepLearning.AI

Data Storage and Queries

Queries

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Queries

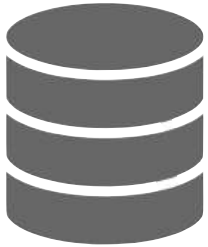
Week 3 Overview

What is a Query?

Query

A statement that you write in a specific query language to retrieve or act on data.

Course 2 Lab



SQL queries

Relational Database Management System

```
%%sql
UPDATE category_copy
SET last_update = '2020-09-12 08:00:00.000';

UPDATE category_copy
SET category_id = '2'
WHERE name = 'Animation';
```

```
%%sql
SELECT *
FROM category_copy;
```

```
%%sql
INSERT INTO category_copy
VALUES
('1', 'Horror', '2006-02-15 09:46:27.000'),
('10', 'Animation', '2006-02-15 09:46:27.000'),
('20', 'Pop', '2006-02-15 09:46:27.000');
```

What is a Query?

Query

A statement that you write in a specific query language to retrieve or act on data.

Course 2 Lab

Amazon Object Storage

SQL-Like queries

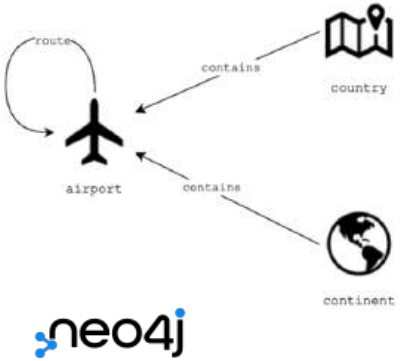
```
file_s3_key = 'csv/ratings_ml_training_dataset.csv'
kwargs = {'ExpressionType': 'SQL',
          'Expression': """SELECT * FROM s3object s WHERE s.\"productline\" = 'Trains' LIMIT 20""",
          'InputSerialization': {'CSV': {"FileHeaderInfo": "Use"}, 'CompressionType': 'NONE'},
          'OutputSerialization': {'CSV': {}},
}

response = s3_select_object_content(bucket_name=BUCKET_NAME, object_key=file_s3_key, **kwargs)
```

What is a Query?

Query

A statement that you write in a specific query language to retrieve or act on data.

Course 3 Week 1 Lab



Cypher queries

```
query = """
        MATCH (a:Airport)-[:Route]-(b:Airport)
        RETURN a,b
        LIMIT 10
        """
records = execute_query(query)
print(records)
```

```
query = "MATCH ()-[r:Route]->() RETURN avg(r.dist)"
records = execute_query(query)
print(records)
```

What is a Query?

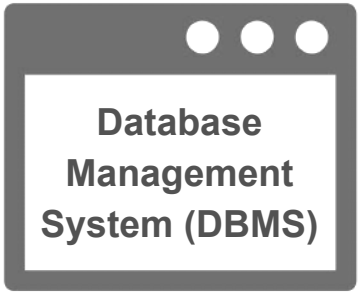
Query

A statement that you write in a specific query language to retrieve or act on data.

Query Languages

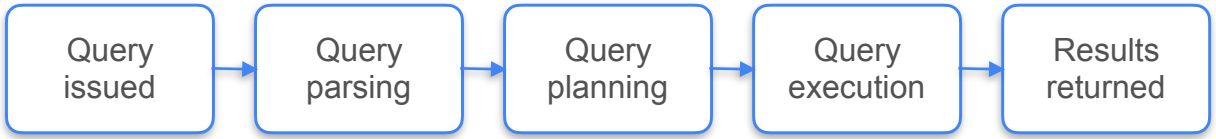
Declarative language

- Your queries describe what data you want to retrieve
- Execution steps are abstracted from you and handled by the DBMS



Week 3 Plan

- The journey of a query



- Techniques to improve SQL query performance (eg. database index)
- Many SQL query techniques are applicable to other query languages
- Aggregating queries: columnar versus row storage
- Queries on streaming data

Labs

- Advanced SQL statements
- Execution time of an analytical query on row versus columnar storage
- Time-based windowed query on streaming data

Amazon Managed Service for Apache Flink

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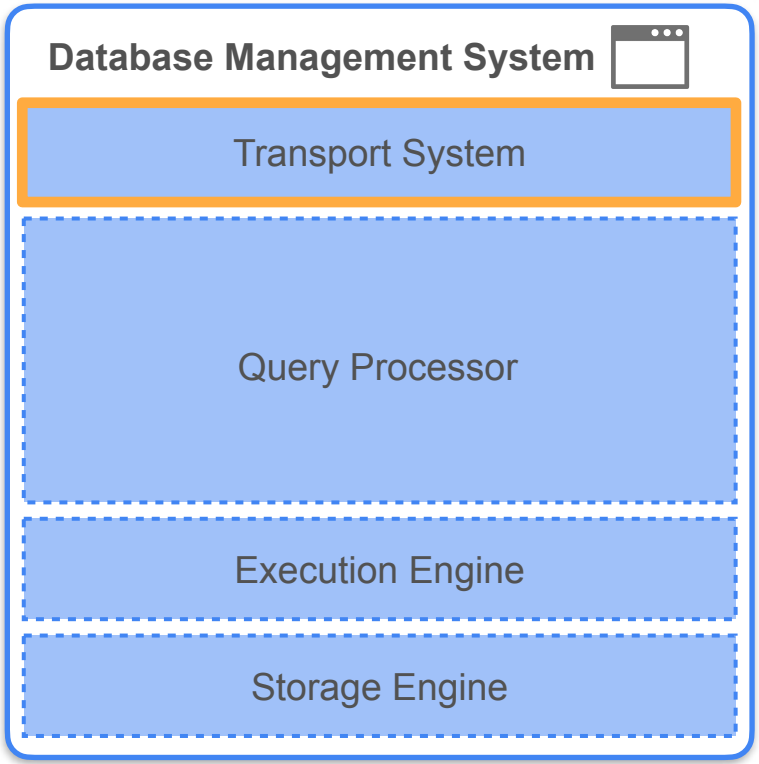
Queries

The Life of a Query

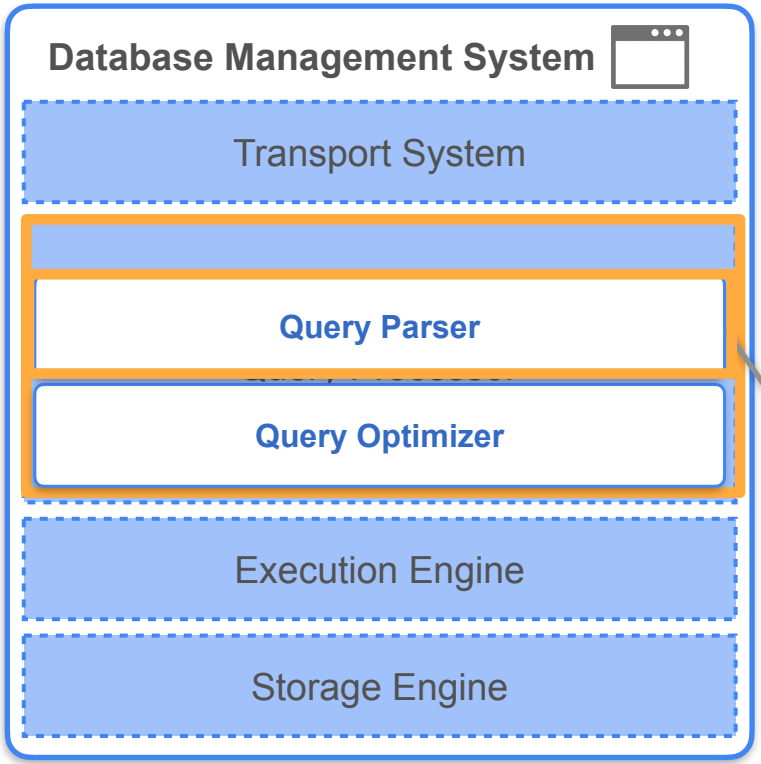
Life of a Query

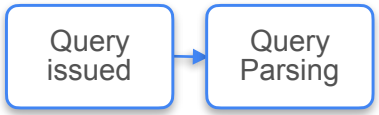


Query issued

```
SELECT  *  FROM  customer;
```

Life of a Query





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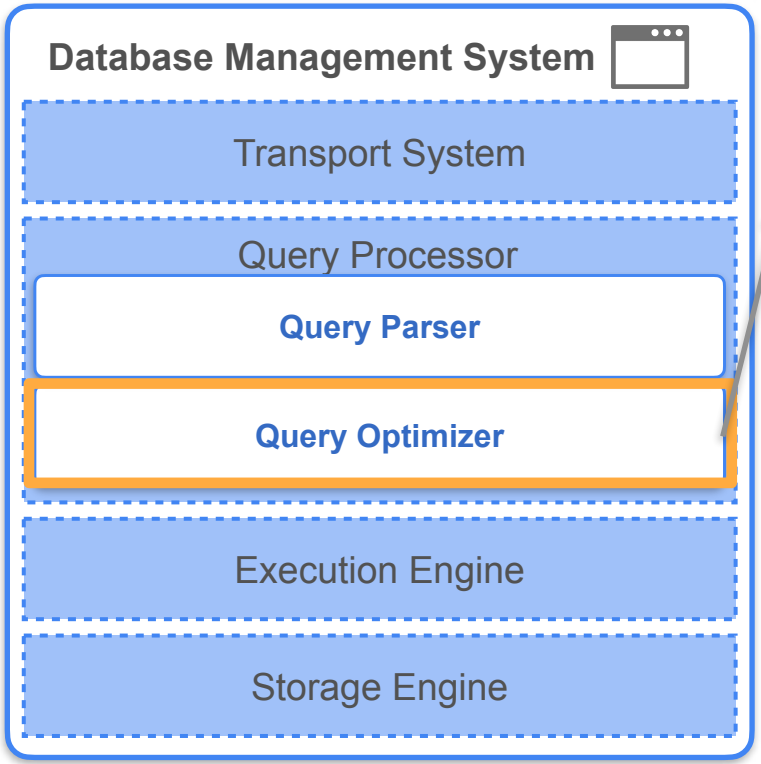
- Breaks down the query into query tokens
- Checks proper syntax and validates the query
- Performs control checks
- 0101 Converts into bytecode

Life of a Query



Query issued → Query parsing → Query planning

Devises an execution plan:

Finds a strategy that uses available resources most efficiently

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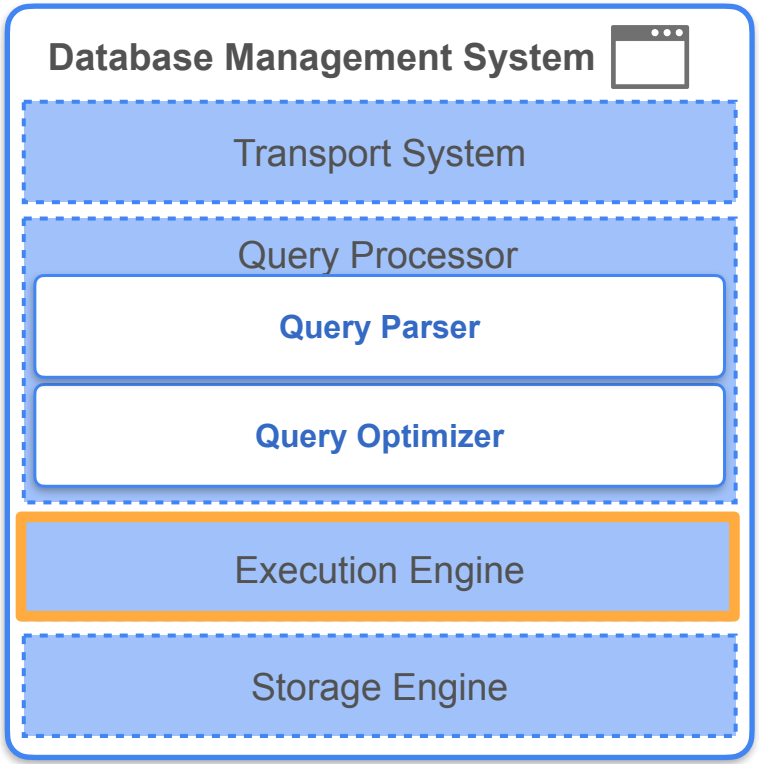
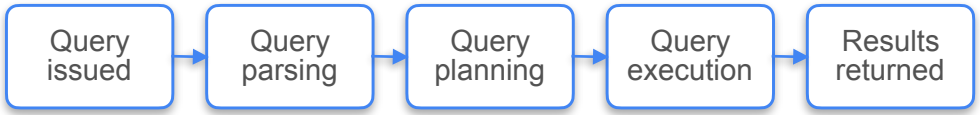
Generates various plans

- Considerations:
  - types of operations
  - presence of indexes
  - data scan size
- Calculates cost:
  - data transfer I/O cost
  - computation and memory usage cost
- Picks the least expensive execution plan

Life of a Query





Execution plan → Query results

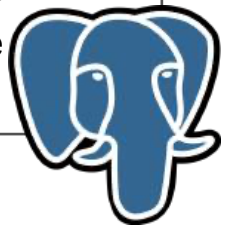
Understanding Query Performance

`EXPLAIN`

- Sequence of steps to execute the query
- Resource consumption
- Performance statistics in each query stage

Understanding Query Performance

customer
customer_id
store_id
first_name
last_name
email
address_id
activebool
create_date
last_update
active



PostgreSQL

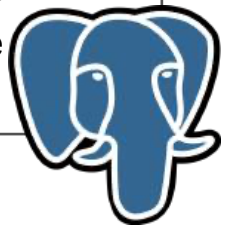
```
EXPLAIN SELECT * FROM customer;

QUERY PLAN
_____________________________________

Seq Scan on customer (cost=0.00..14.99 rows=599 width=70)
```

Understanding Query Performance

customer
customer_id
store_id
first_name
last_name
email
address_id
activebool
create_date
last_update
active



PostgreSQL

```
EXPLAIN SELECT * FROM customer;

QUERY PLAN
------------------------------------------------
Seq Scan on customer (cost=0.00..14.99 rows=599 width=70)
```

startup cost for query processing

total cost for execution

Understanding Query Performance

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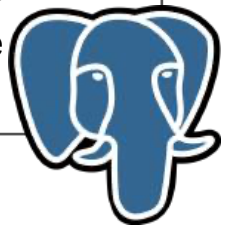
customer_id
store_id
first_name
last_name
email
address_id
activebool
create_date
last_update
active



PostgreSQL

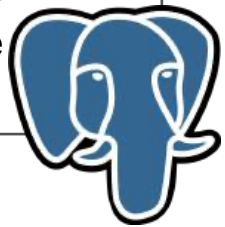
```
EXPLAIN SELECT * FROM customer;

QUERY PLAN
------------------------------------------
Seq Scan on customer (cost=0.00..14.99 rows=599 width=70)
```

estimated number of returned rows

expected row width

Understanding Query Performance

customer
customer_id
store_id
first_name
last_name
email
address_id
activebool
create_date
last_update
active



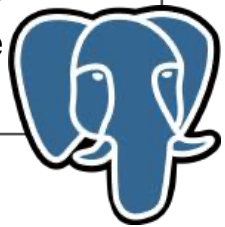
PostgreSQL

```
EXPLAIN SELECT * FROM customer;

QUERY PLAN
------------------------------------------
Seq Scan on customer (cost=0.00..14.99 rows=599 width=70)
```

Startup cost: 0 cost units
Total cost: 14.99 cost units
Return 599 rows

Understanding Query Performance

customer
customer_id
store_id
first_name
last_name
email
address_id
activebool
create_date
last_update
active



PostgreSQL

```
EXPLAIN SELECT * FROM customer;

QUERY PLAN
_____________________________________

Seq Scan on customer (cost=0.00..14.99 rows=599 width=70)
```

Startup cost: 0 cost units
Total cost: 14.99 cost units
Return 599 rows

Index A data structure that helps you efficiently locate data

```
EXPLAIN SELECT * FROM customer WHERE customer_id = 3;

QUERY PLAN
_____________________________________

Index Scan using customer_pkey on customer
(cost=0.28. 8.29 rows=1 width=70)
```

total cost

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Queries

Advanced SQL Queries (Part 1)

Data Manipulation Operations

- CREATE
- INSERT INTO
- UPDATE
- DELETE

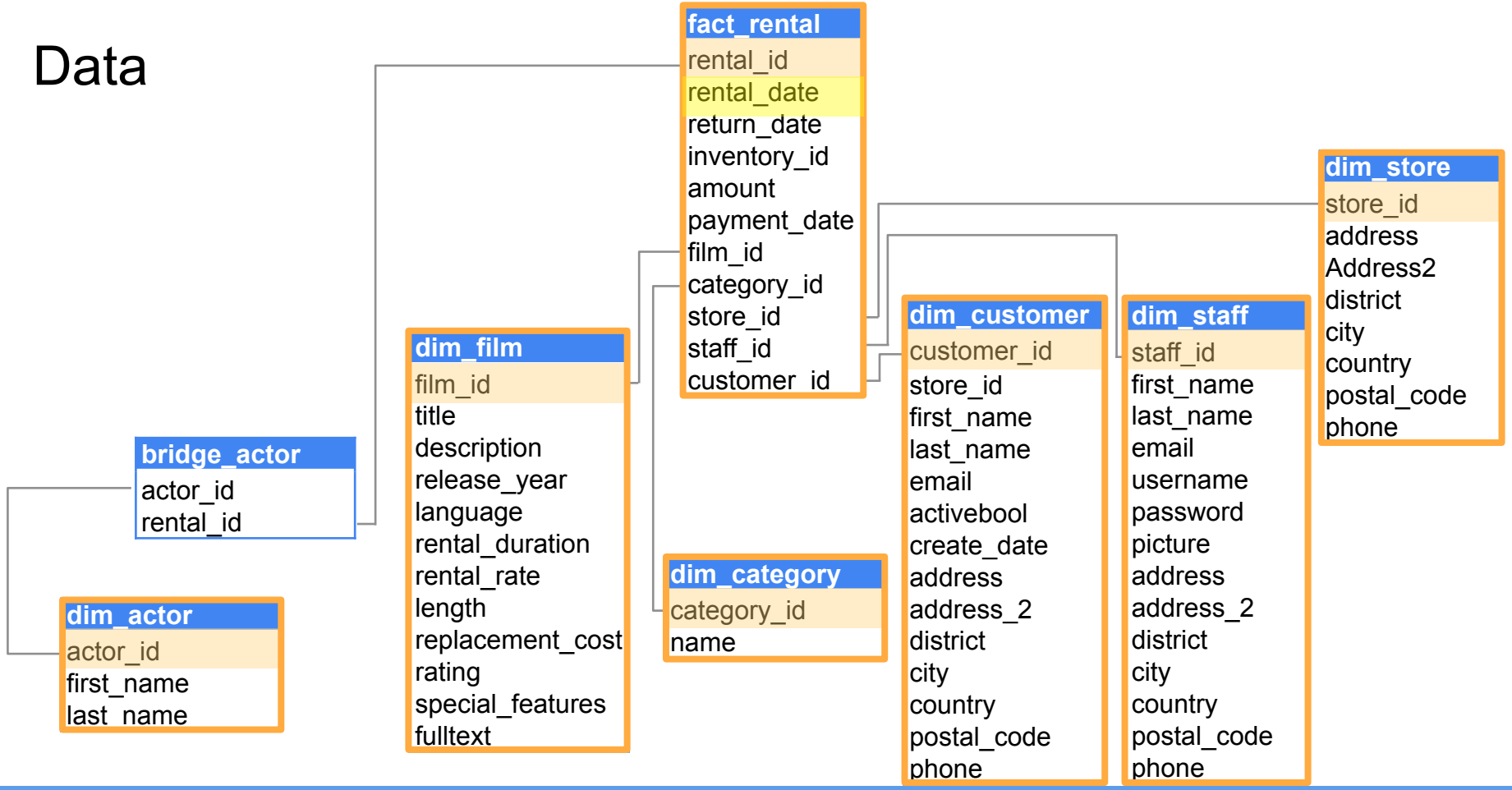
Common SQL Commands

- SELECT
- COUNT, SUM, AVG, MIN and MAX
- FROM
- JOIN
- WHERE
- GROUP BY
- ORDER BY
- LIMIT

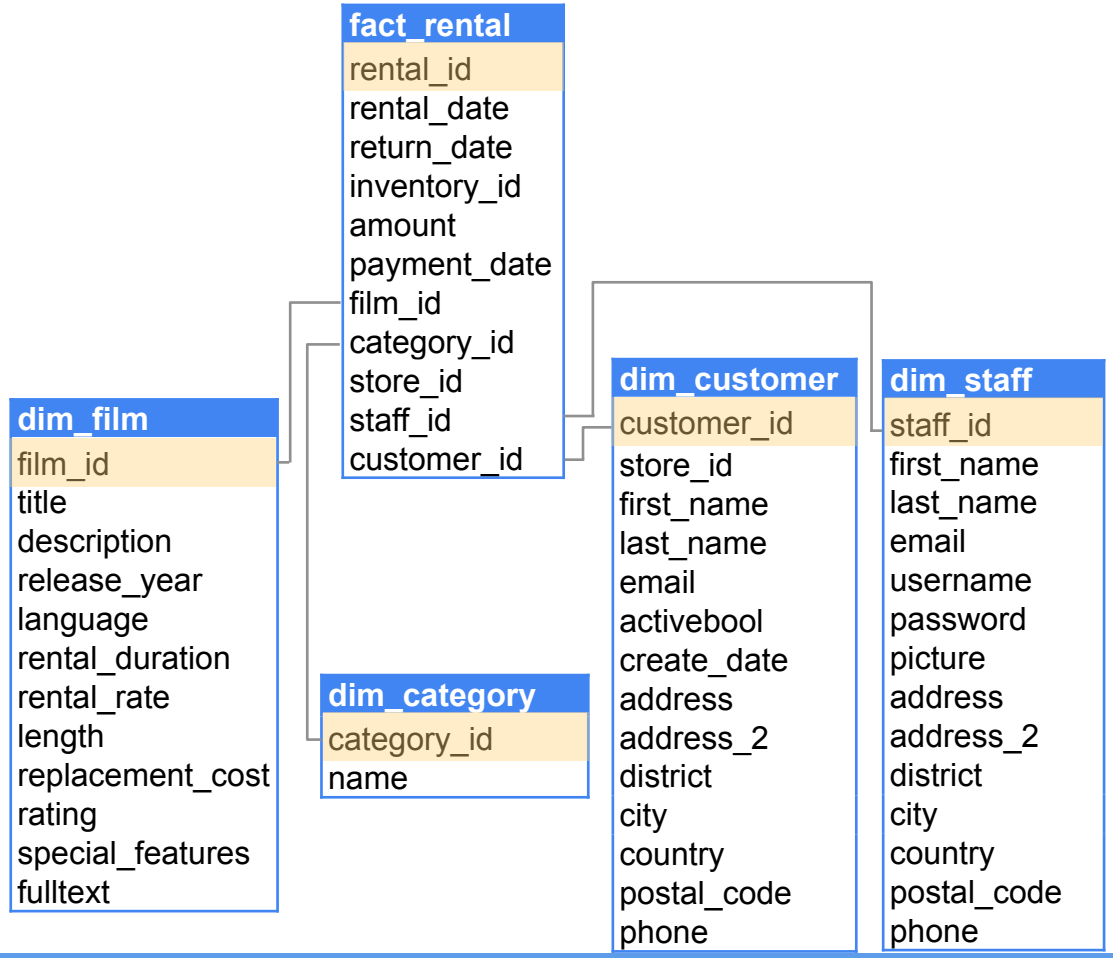
Advanced SQL Statements

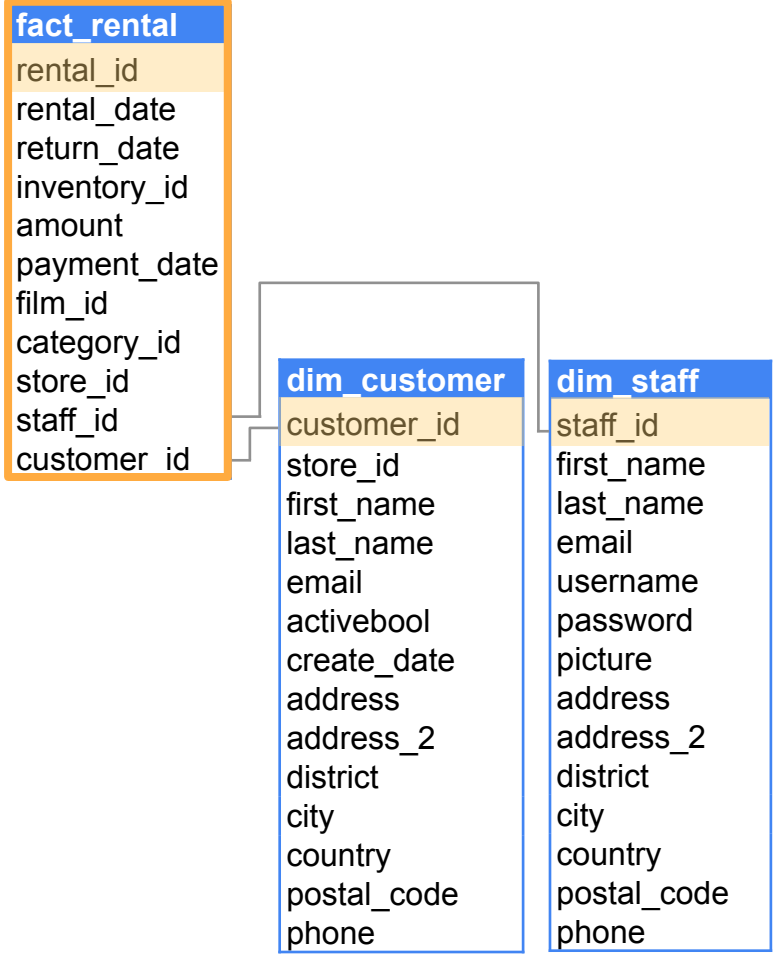
- SELECT DISTINCT
- SQL Functions
- CASE
- SQL Boolean Expressions
- Common Table Expressions (CTE)
- Subqueries
- SQL Window Functions

Data


fact_rental
rental_id
rental_date
return_date
inventory_id
amount
payment_date
film_id
category_id
store_id
staff_id
customer_id
dim_store
store_id
address
Address2
district
city
country
postal_code
phone
dim_film
film_id
title
description
release_year
language
rental_duration
rental_rate
length
replacement_cost
rating
special_features
fulltext
dim_customer
customer_id
store_id
first_name
last_name
email
activebool
create_date
address
address_2
district
city
country
postal_code
phone
dim_staff
staff_id
first_name
last_name
email
username
password
picture
address
address_2
district
city
country
postal_code
phone
bridge_actor
actor_id
rental_id
dim_category
category_id
name
dim_actor
actor_id
first_name
last_name

Data

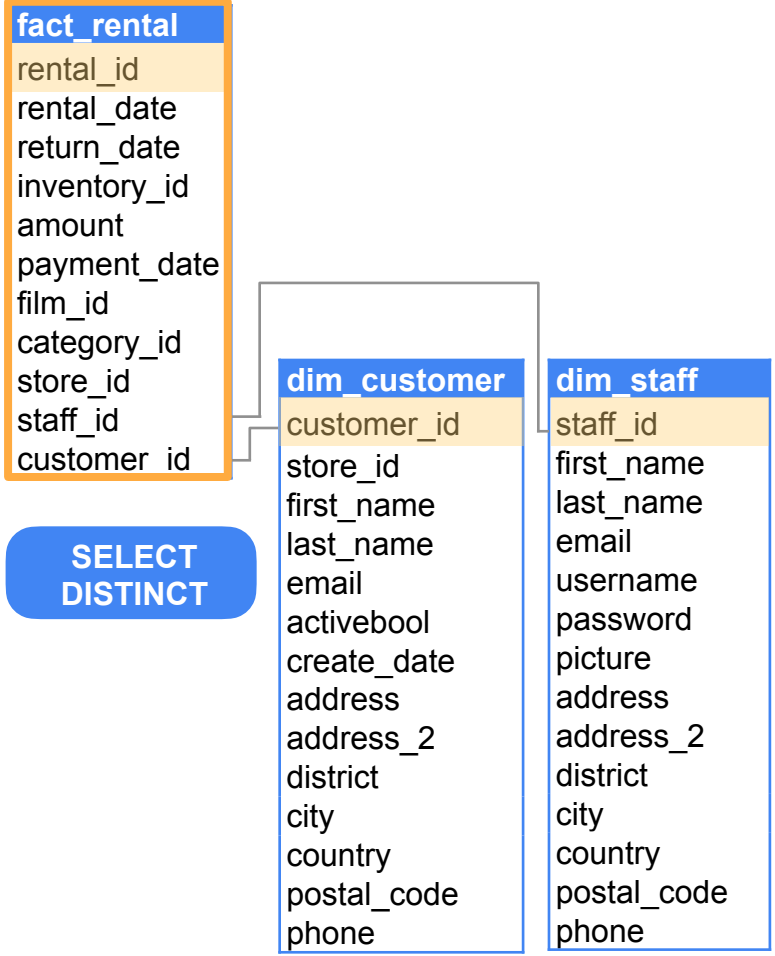

fact_rental
rental_id
rental_date
return_date
inventory_id
amount
payment_date
film_id
category_id
store_id
staff_id
customer_id
dim_film
film_id
title
description
release_year
language
rental_duration
rental_rate
length
replacement_cost
rating
special_features
fulltext
dim_category
category_id
name
dim_customer
customer_id
store_id
first_name
last_name
email
activebool
create_date
address
address_2
district
city
country
postal_code
phone
dim_staff
staff_id
first_name
last_name
email
username
password
picture
address
address_2
district
city
country
postal_code
phone



Get which staff member served which customer.

```
In [ ]:  %%sql
         SELECT
         FROM fact_rental
```

```
In [ ]:
```



SELECT DISTINCT

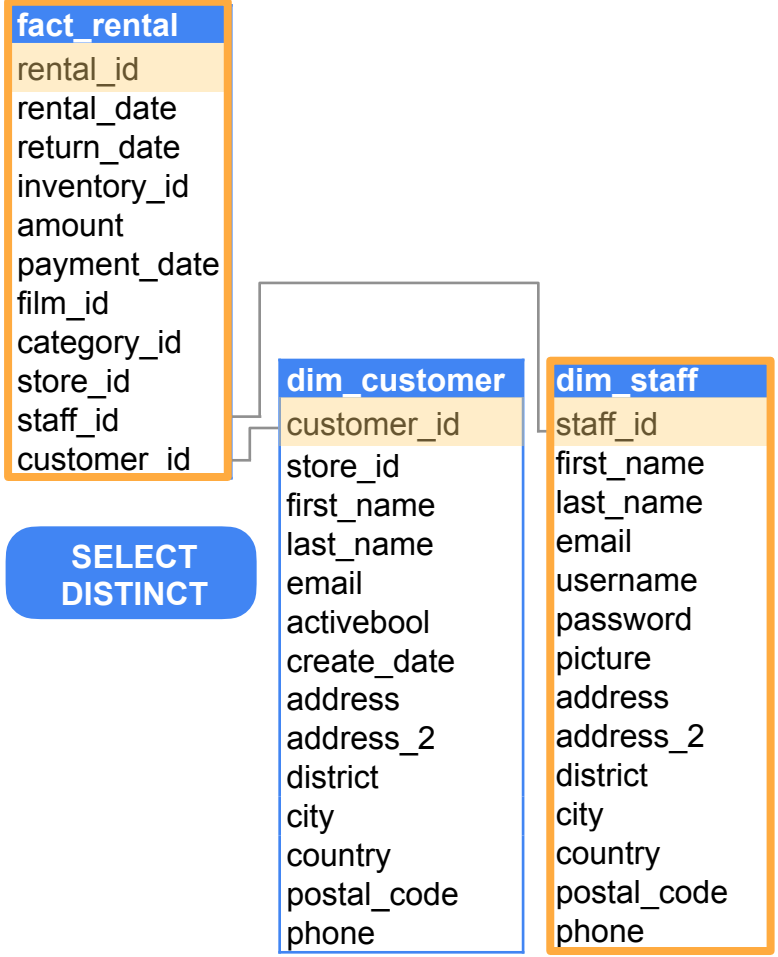
Get which staff member served which customer.

```
In [2]:
%%sql
SELECT
fact_rental.staff_id,
fact_rental.customer_id
FROM fact_rental
```

```
 * mysql+pymysql://root:***@localhost:3306/sakila_star
16044 rows affected.
```

Out[2]:

staff_id	customer_id
1	130
1	459
1	408
2	333
1	222
1	549



SELECT DISTINCT

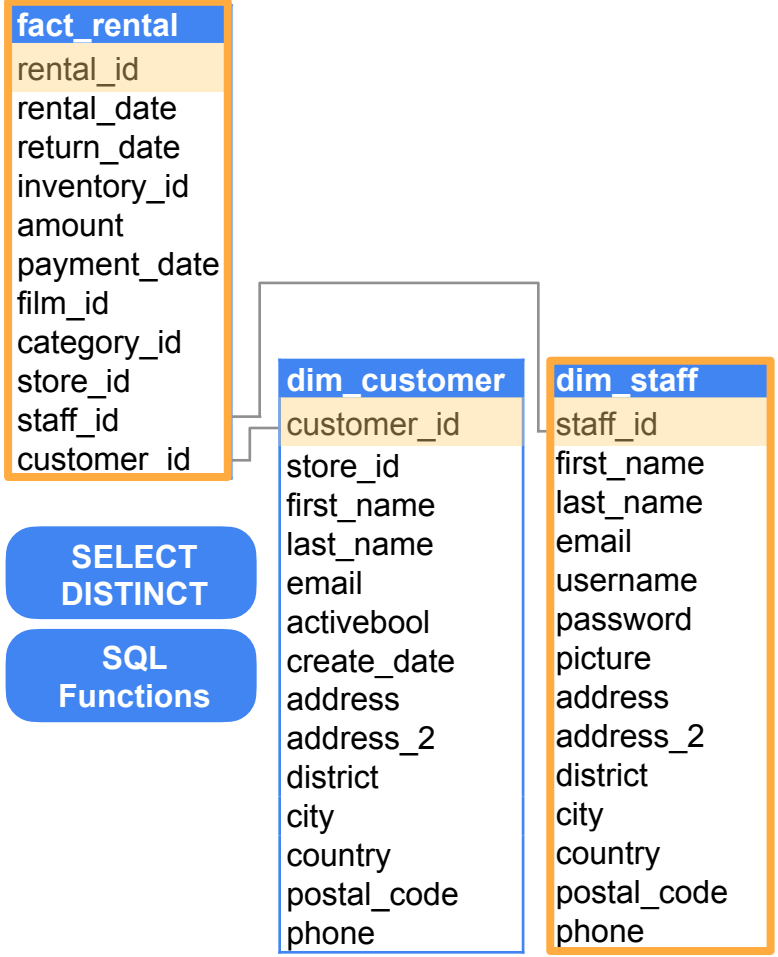
Get which staff member served which customer.

```
In [3]:  %%sql
         SELECT DISTINCT
         fact_rental.staff_id,
         fact_rental.customer_id
         FROM fact_rental
```

```
 * mysql+pymysql://root:***@localhost:3306/sakila_star
1198 rows affected.
```

Out[3]:

staff_id	customer_id
1	130
1	459
1	408
2	333
1	222
1	549



SELECT DISTINCT

SQL Functions

Get which staff member served which customer.

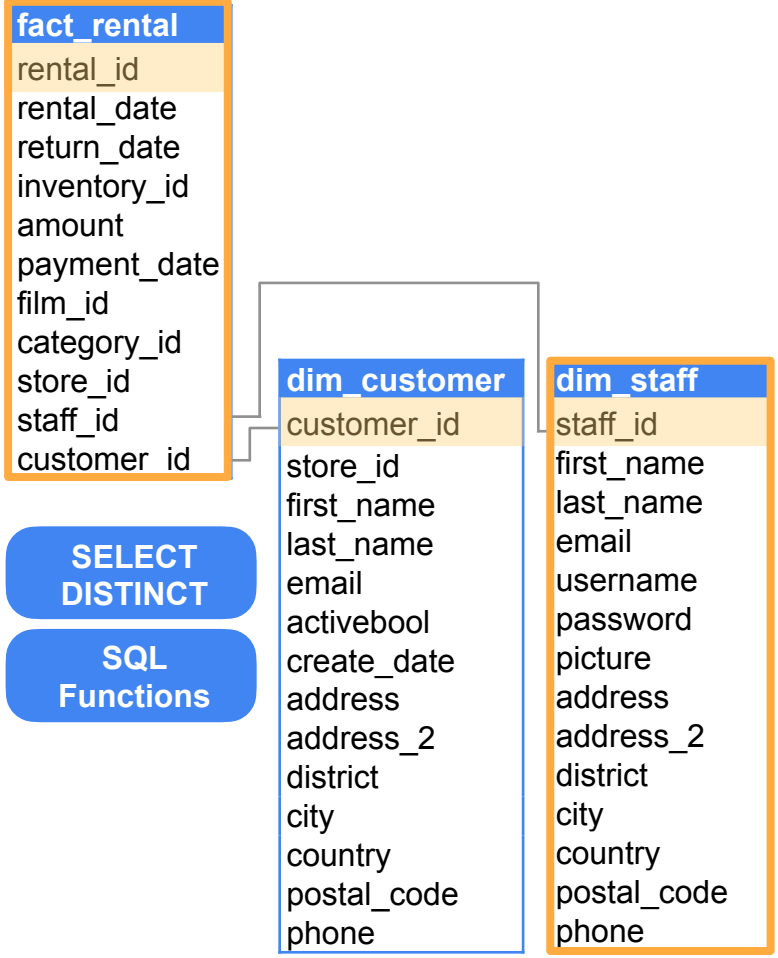
```
In [2]: %%sql
SELECT DISTINCT
fact_rental.staff_id,
dim_staff.first_name, dim_staff.last_name,
fact_rental.customer_id
FROM fact_rental
JOIN dim_staff ON fact_rental.staff_id = dim_staff.staff_id

 * mysql+pymysql://root:***@localhost:3306/sakila_star
1198 rows affected.
```

Out[2]:

staff_id	first_name	last_name	customer_id
1	Mike	Hillyer	130
1	Mike	Hillyer	459
1	Mike	Hillyer	408
2	Jon	Stephens	333
1	Mike	Hillyer	222

CONCAT() LOWER() UPPER()



SELECT DISTINCT

SQL Functions

Get which staff member served which customer.

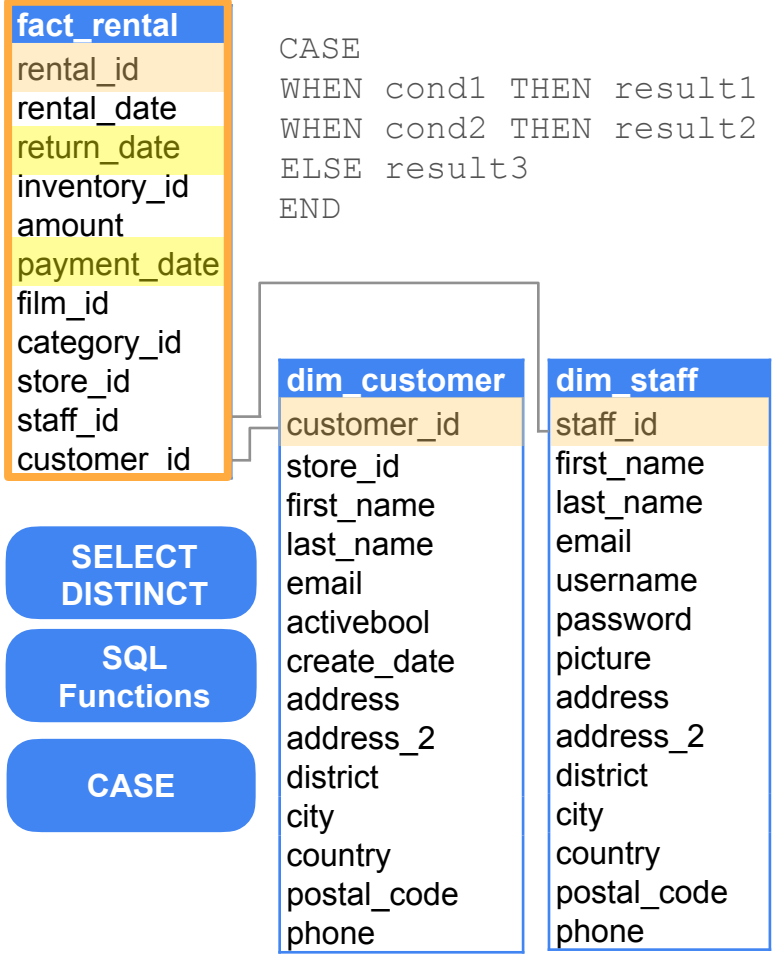
```
In [3]: %%sql
SELECT DISTINCT
fact_rental.staff_id,
CONCAT(dim_staff.first_name, ' ', dim_staff.last_name) AS staff_name,
fact_rental.customer_id
FROM fact_rental
JOIN dim_staff ON fact_rental.staff_id = dim_staff.staff_id

 * mysql+pymysql://root:***@localhost:3306/sakila_star
1198 rows affected.
```

Out[3]:

staff_id	staff_name	customer_id
1	Mike Hillyer	130
1	Mike Hillyer	459
1	Mike Hillyer	408
1	Mike Hillyer	222
1	Mike Hillyer	549

CONCAT() LOWER() UPPER() SUBSTR()




```
CASE
WHEN cond1 THEN result1
WHEN cond2 THEN result2
ELSE result3
END
```

SELECT DISTINCT

SQL Functions

CASE

Check whether a customer made an on-time payment.

fact_rental
rental_id
rental_date
return_date
inventory_id
amount
payment_date
film_id
category_id
store_id
staff_id
customer_id

dim_customer
customer_id
store_id
first_name
last_name
email
activebool
create_date
address
address_2
district
city
country
postal_code
phone

dim_staff
staff_id
first_name
last_name
email
username
password
picture
address
address_2
district
city
country
postal_code
phone

SELECT DISTINCT

SQL Functions

CASE

```
CASE
WHEN cond1 THEN result1
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ELSE result3
END
```
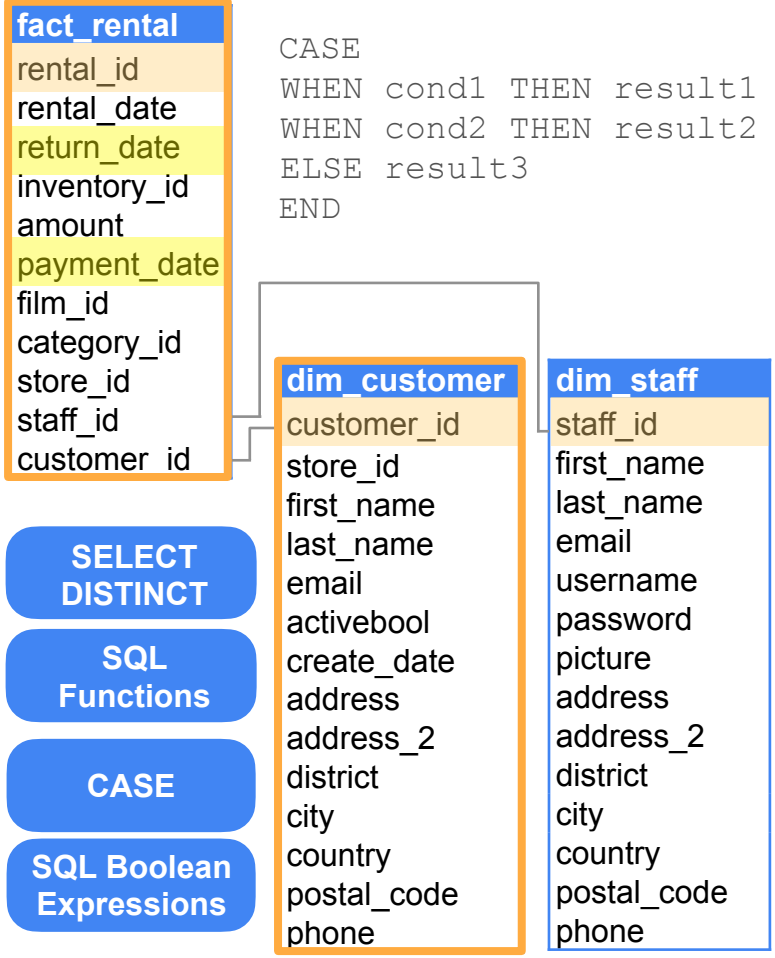

Check whether a customer made an on-time payment.

1	Mike H	446
1	Mike H	319
1	Mike H	575

In [ ]:
```
%%sql
SELECT
FROM fact_rental
```

In [ ]:




```
CASE
WHEN cond1 THEN result1
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ELSE result3
END
```

- SELECT DISTINCT
- SQL Functions
- CASE
- SQL Boolean Expressions

Check whether a customer made an on-time payment.

- Customers located in the United States and Canada
- Rentals occurred between Mayo 24, 2005 and July 26, 2005

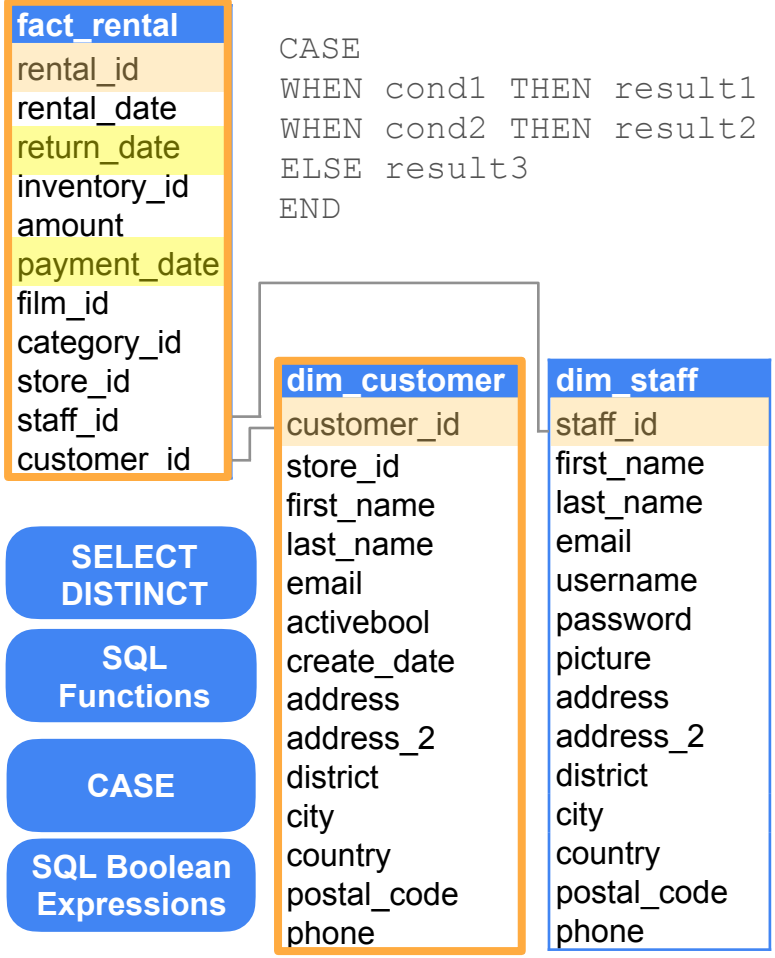
In [5]:

```
%%sql
SELECT
fact_rental.customer_id,
fact_rental.rental_id,
(CASE
WHEN payment_date<return_date THEN 1
ELSE 0
END) AS on_time_payment
FROM fact_rental
LIMIT 5
```

```
 * mysql+pymysql://root:***@localhost:3306/sakila_star
5 rows affected.
```

Out[5]:

customer_id	rental_id	on_time_payment
130	1	0
459	2	0
408	3	0
333	4	0

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```

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WHEN payment_date<return_date THEN 1
ELSE 0
END) AS on_time_payment
FROM fact_rental
JOIN dim_customer ON dim_customer.customer_id=fact_rental.customer_id
LIMIT 5
```
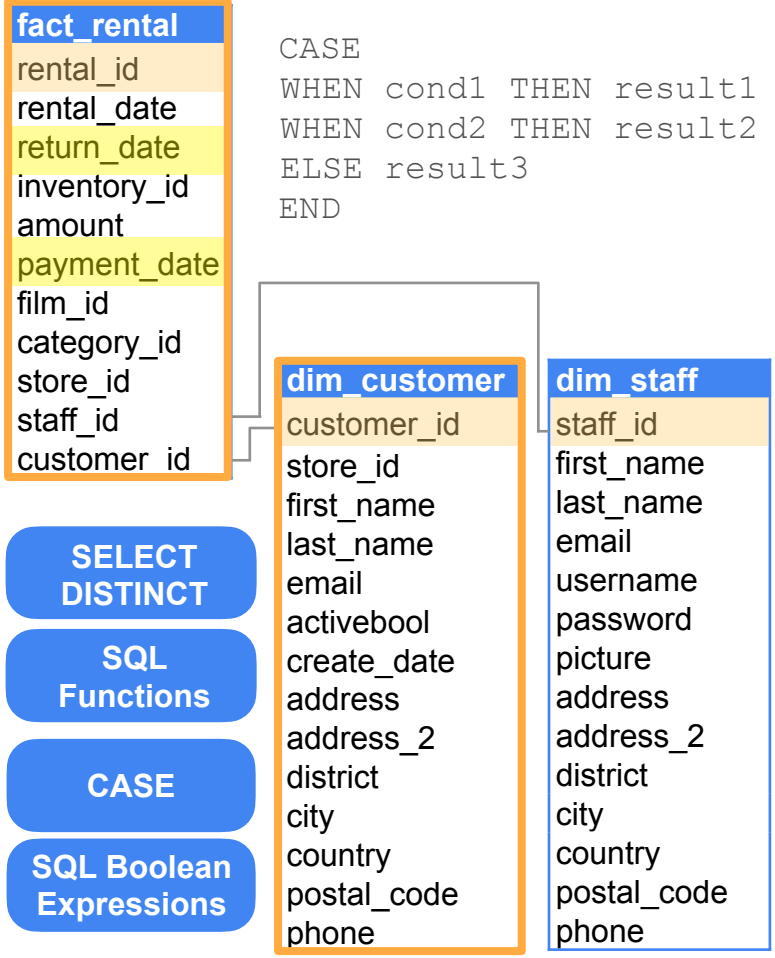

```
 * mysql+pymysql://root:***@localhost:3306/sakila_star
5 rows affected.
```

Out[5]:

customer_id	rental_id	on_time_payment
130	1	0
459	2	0
408	3	0

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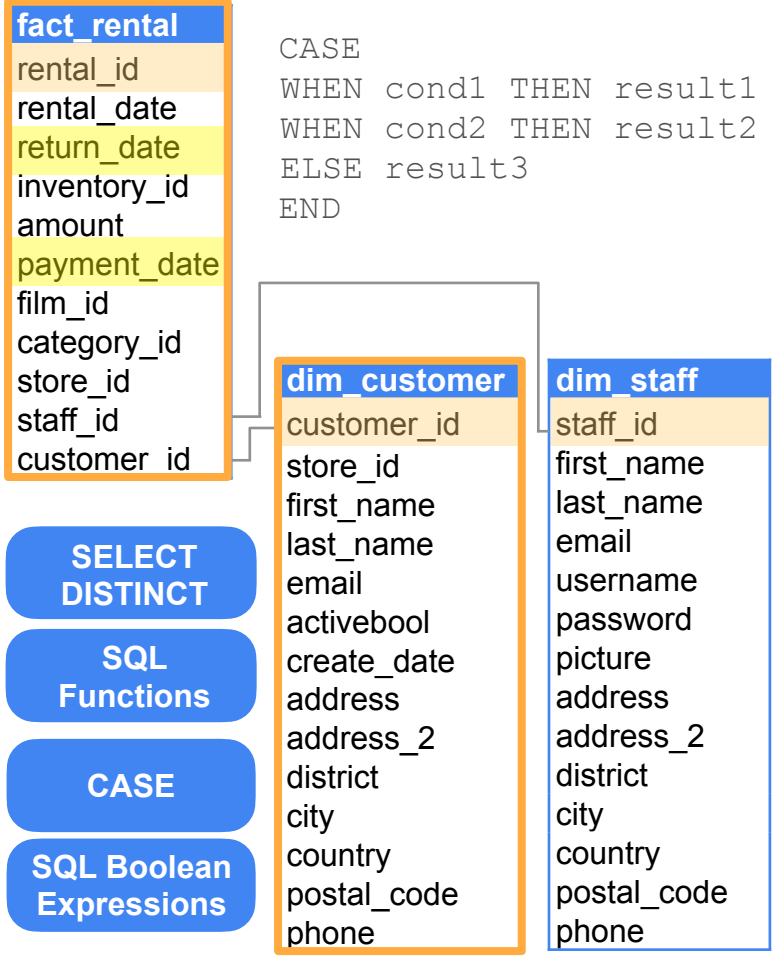
%%sql
SELECT
fact_rental.customer_id,
fact_rental.rental_id,
(CASE
WHEN payment_date<return_date THEN 1
ELSE 0
END) AS on_time_payment
FROM fact_rental
JOIN dim_customer ON dim_customer.customer_id=fact_rental.customer_id
WHERE dim_customer.country="United States"
OR dim_customer.country= "Canada"
LIMIT 5
```

```
 * mysql+pymysql://root:***@localhost:3306/sakila_star
5 rows affected.
```

Out[5]:

customer_id	rental_id	on_time_payment
130	1	0
459	2	0

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fact_rental.rental_id,
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END) AS on_time_payment
FROM fact_rental
JOIN dim_customer ON dim_customer.customer_id=fact_rental.customer_id
WHERE dim_customer.country IN ("United States", "Canada")
LIMIT 5
```
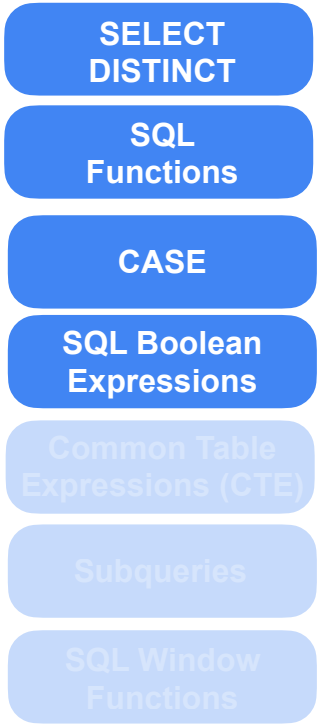

```
 * mysql+pymysql://root:***@localhost:3306/sakila_star
5 rows affected.
```

Out[5]:

customer_id	rental_id	on_time_payment
130	1	0
459	2	0

Advanced SQL Statements



DeepLearning.AI

Queries

Advanced SQL Queries (Part 2)

Advanced SQL Statements

- SELECT DISTINCT
- SQL Functions
- CASE
- SQL Boolean Expressions
- Common Table Expressions (CTE)
- Subqueries
- SQL Window Functions

```
SELECT DISTINCT
fact_rental.staff_id,
CONCAT (dim_staff.first_name,' ',
        dim_staff.last_name) AS staff_name,
fact_rental.customer_id
FROM fact_rental
JOIN dims_staff
ON fact_rental.staff_id = dim_Staff.staff_id
```

```
SELECT fact_rental.customer_id, fact_rental.rental_id,
(CASE WHEN payment_date<return_date THEN 1
      ELSE 0
 END) AS on_time_payment
FROM fact_rental
JOIN dim_customer
ON dim_customer.customer_id = fact_rental.customer_id
WHERE dim_customer.country IN ("United States", "Canada")
AND
(fact_rental.rental_date between "2005-05-24" and "2005-07-26")
```

```
SELECT DISTINCT
fact_rental.staff_id,
CONCAT (dim_staff.first_name,' ',
        dim_staff.last_name) AS staff_name,
fact_rental.customer_id
FROM fact_rental
JOIN dims_staff
ON fact_rental.staff_id = dim_Staff.staff_id
```

Find the total number of customers served by each staff member

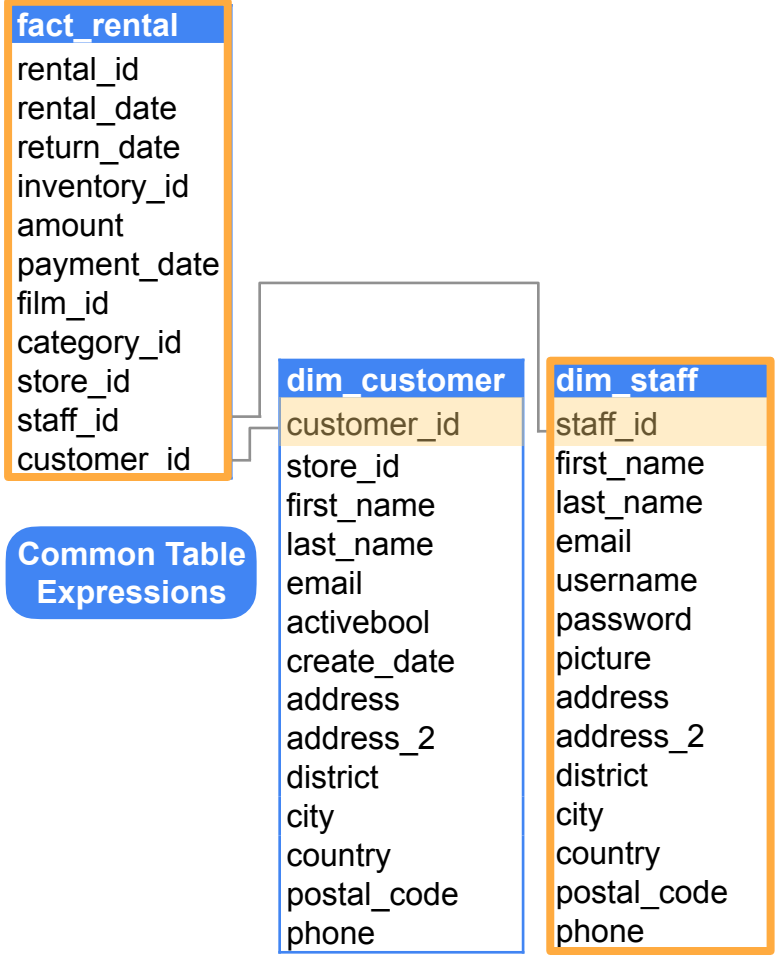
staff_id	staff_name	customer_id
1	Mike Hillyer	130
1	Mike Hillyer	459
1	Mike Hillyer	408
1	Mike Hillyer	222
1	Mike Hillyer	549

Use Common Table Expressions (CTE) to define these temporary results

```
SELECT fact_rental.customer_id, fact_rental.rental_id,
(CASE WHEN payment_date<return_date THEN 1
      ELSE 0
 END) AS on_time_payment
FROM fact_rental
JOIN dim_customer
ON dim_customer.customer_id = fact_rental.customer_id
WHERE dim_customer.country IN ("United States", "Canada")
AND
(fact_rental.rental_date between "2005-05-24" and "2005-07-26")
```

customer_id	rental_id	on_time_payment
2	320	0
2	2128	0
2	5636	0
2	5755	0
6	57	0

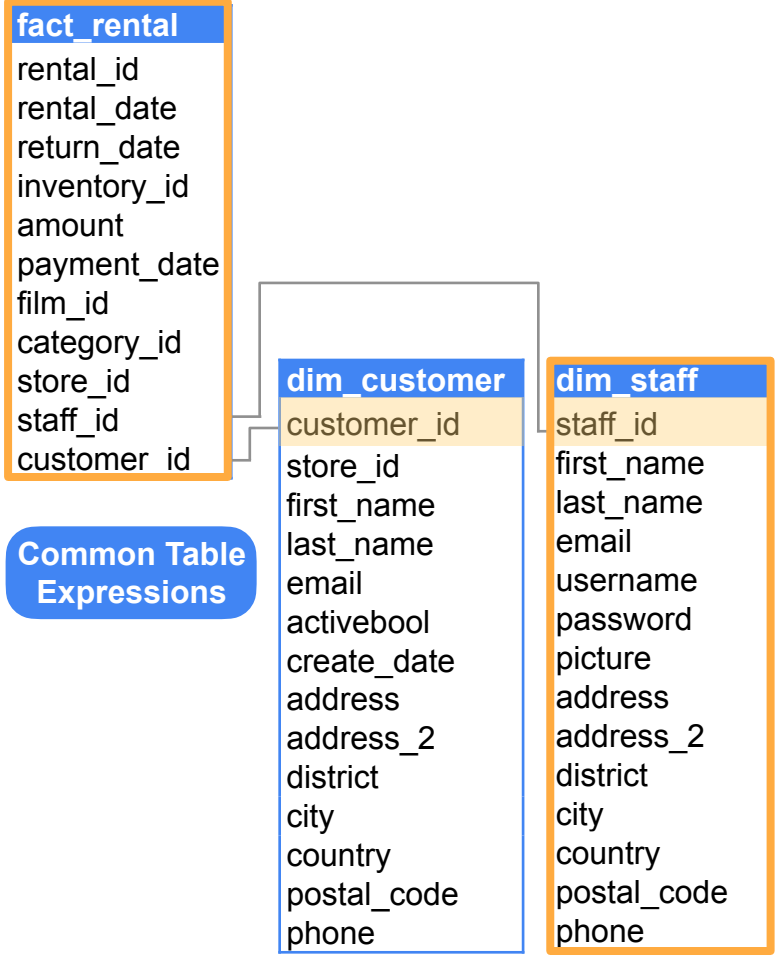
Compute for each customer the average of on_time_payment



Common Table Expressions

Find the total number of customers served by each staff member

```
In [ ]:  %%sql
```

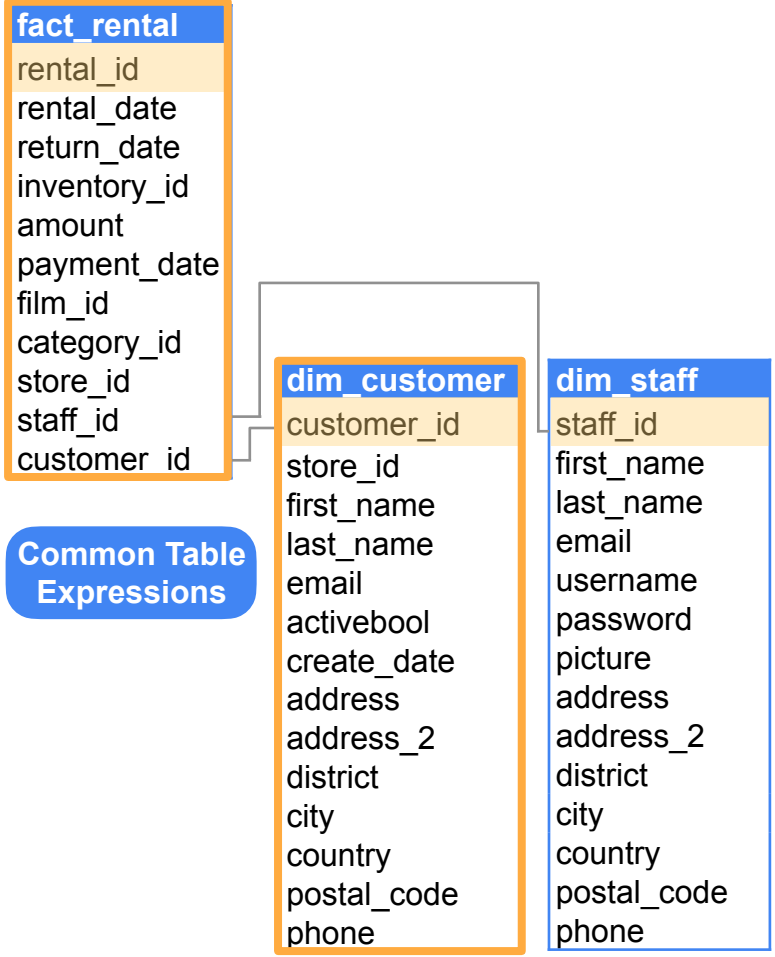


Common Table Expressions

Find the total number of customers served by each staff member

In [ ]:

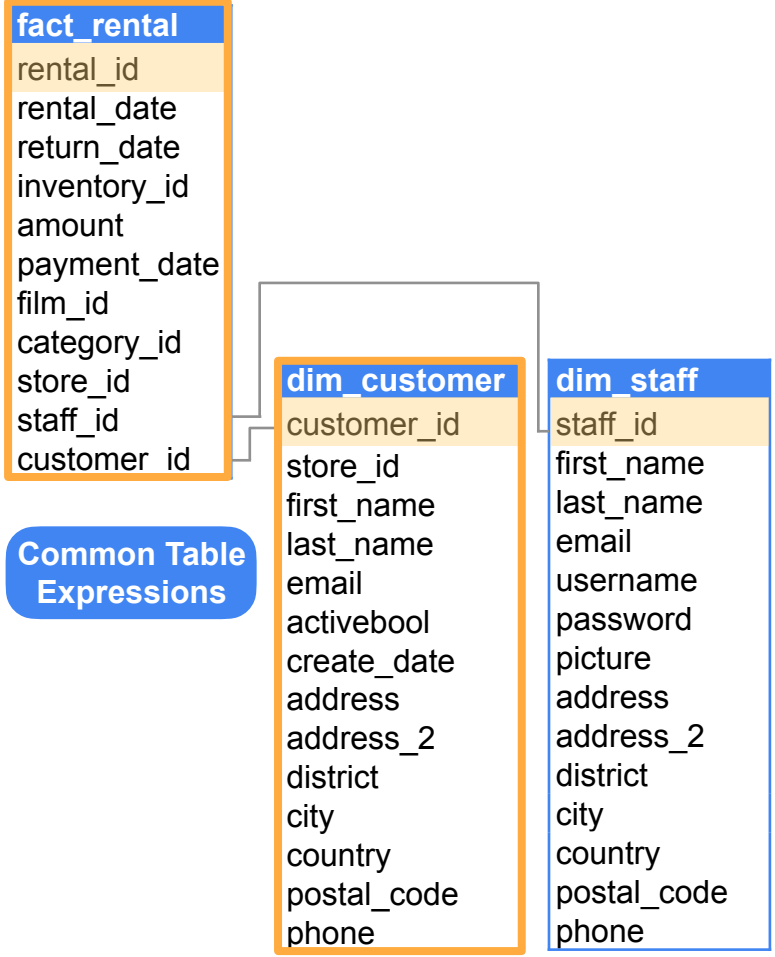
```
%%sql
WITH staff_customer_pairs AS (
SELECT DISTINCT fact_rental.staff_id,
CONCAT(dim_staff.first_name,' ',dim_staff.last_name) AS staff_name,
fact_rental.customer_id
FROM fact_rental
JOIN dim_staff ON fact_rental.staff_id = dim_staff.staff_id
)
```



Common Table Expressions

Compute the percentage of on-time payments for each customer.

```
In [ ]:  %%sql
```

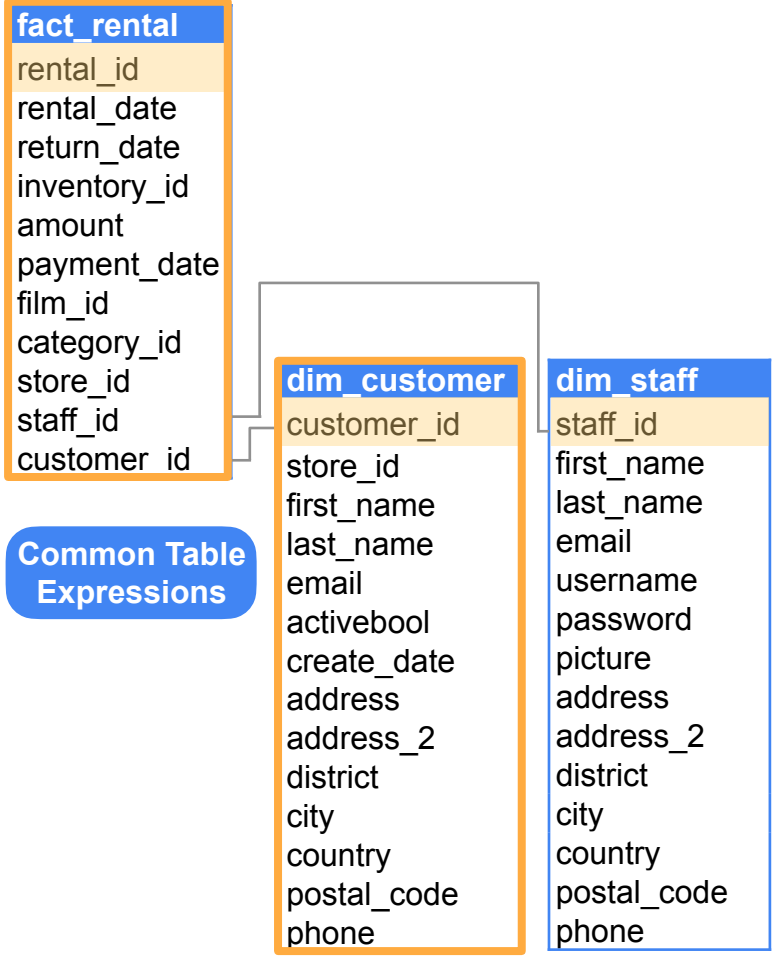


Common Table Expressions

Compute the percentage of on-time payments for each customer.

In [ ]:

```
%%sql
WITH customer_payment_info AS (
SELECT fact_rental.customer_id, fact_rental.rental_id,
(CASE
WHEN payment_date<return_date THEN 1
ELSE 0
END) AS on_time_payment
FROM fact_rental
JOIN dim_customer ON dim_customer.customer_id=fact_rental.customer_id
WHERE dim_customer.country IN ("United States", "Canada")
AND (fact_rental.rental_date between "2005-05-24" and  "2005-07-26")
)
```

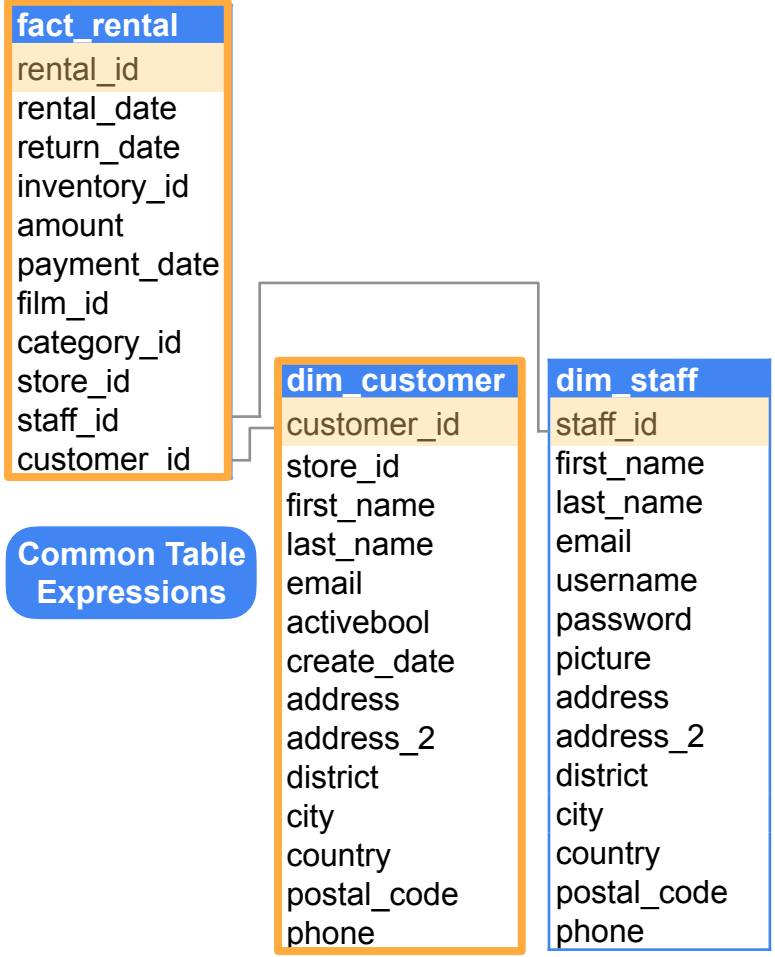


Common Table Expressions

Compute the percentage of on-time payments for each customer.

In [ ]:

```
%%sql
WITH customer_payment_info AS (
SELECT fact_rental.customer_id, fact_rental.rental_id,
(CASE
WHEN payment_date<return_date THEN 1
ELSE 0
END) AS on_time_payment
FROM fact_rental
JOIN dim_customer ON dim_customer.customer_id=fact_rental.customer_id
WHERE dim_customer.country IN ("United States", "Canada")
AND (fact_rental.rental_date between "2005-05-24" and  "2005-07-26")
)
SELECT customer_id, AVG(on_time_payment) AS percent_on_time_payment
FROM customer_payment_info
```



Common Table Expressions

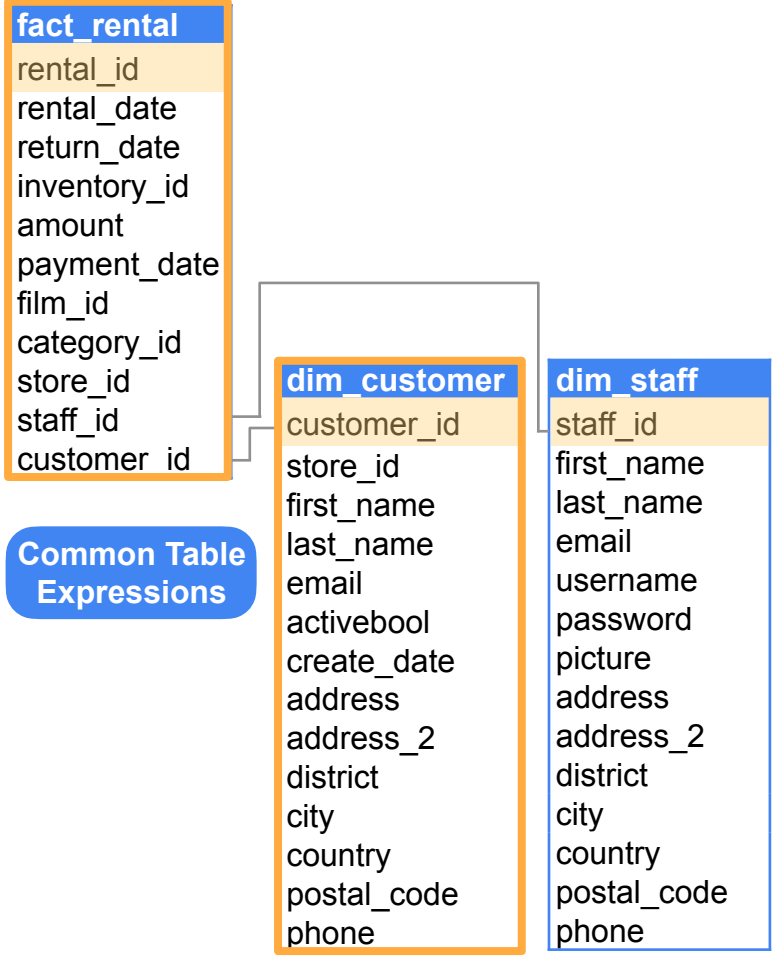
Find the maximum of the “percent on time payment” column.

```
WITH customer_payment_info AS (
SELECT fact_rental.customer_id, fact_rental.rental_id,
(CASE
WHEN payment_date<return_date THEN 1
ELSE 0
END) AS on_time_payment
FROM fact_rental
JOIN dim_customer ON dim_customer.customer_id=fact_rental.customer_id
WHERE dim_customer.country IN ("United States", "Canada")
AND (fact_rental.rental_date between "2005-05-24" and  "2005-07-26")
)
SELECT customer_id, AVG(on_time_payment) AS percent_on_time_payment
FROM customer_payment_info
GROUP BY customer_id
```

```
 * mysql+pymysql://root:***@localhost:3306/sakila_star
41 rows affected.
```

Out[3]:

customer_id	percent_on_time_payment
2	0.0000



Common Table Expressions

Find the maximum of the “percent on time payment” column.

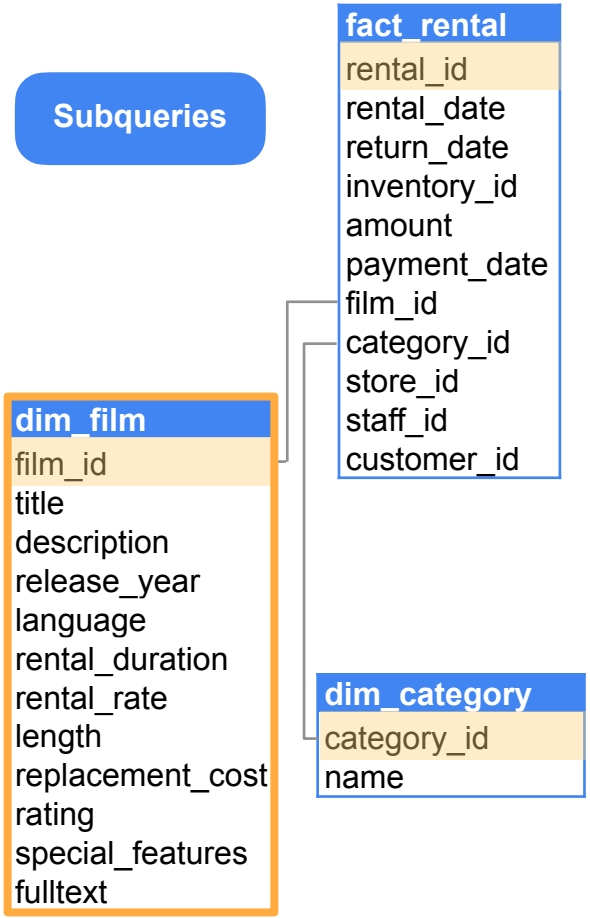
```
WITH customer_payment_info AS (
SELECT fact_rental.customer_id, fact_rental.rental_id,
(CASE
WHEN payment_date<return_date THEN 1
ELSE 0
END) AS on_time_payment
FROM fact_rental
JOIN dim_customer ON dim_customer.customer_id=fact_rental.customer_id
WHERE dim_customer.country IN ("United States", "Canada")
AND (fact_rental.rental_date between "2005-05-24" and  "2005-07-26")
), customer_percent_on_time_payment AS (
SELECT customer_id, AVG(on_time_payment) AS percent_on_time_payment
FROM customer_payment_info
GROUP BY customer_id
)
```

```
mysql+pymysql://root:***@localhost:3306/sakila_star
41 rows affected.
```

Out[5]:

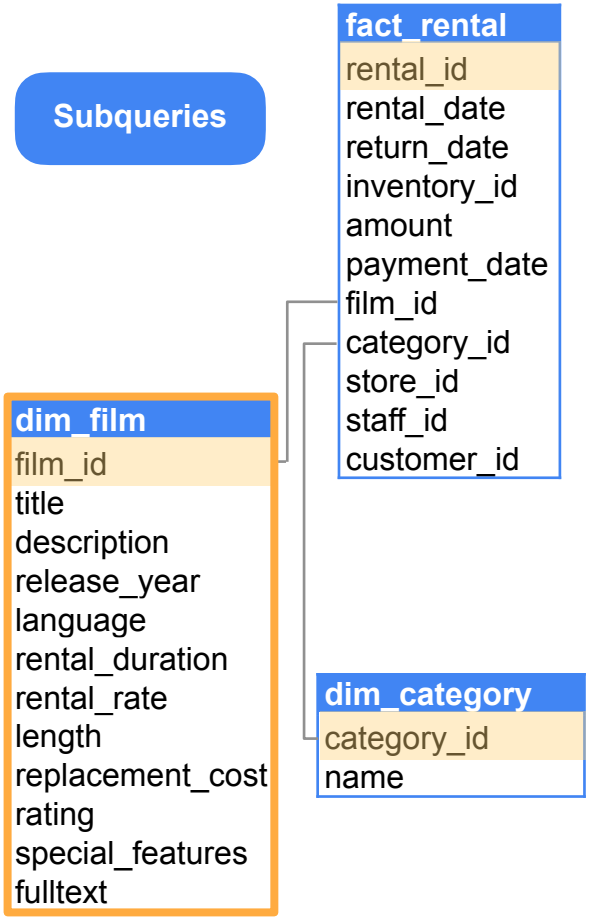
customer_id	percent_on_time_payment

Subqueries



Get the ids of the films that have length greater than the average length.

Subqueries



Get the ids of the films that have length greater than the average length.

```
In [8]: %%sql
        SELECT AVG(length) from dim_film

         * mysql+pymysql://root:***@localhost:3306/sakila_star
        1 rows affected.

Out[8]: AVG(length)
        115.2720

In [ ]: %%sql
```

SQL Window Functions

- Allows you to apply an aggregate or ranking function over a particular window or a set of rows.
- Does not group rows into a single output row: each row remains separate

```
    rank()
row_number()
```

```
SELECT column_name1,
ranking_function() OVER (
                PARTITION BY column_name1
                ORDER BY column_name3)
AS new_column
FROM table_name;
```

fact_rental

- rental_id
- rental_date
- return_date
- inventory_id
- amount
- payment_date
- film_id
- category_id
- store_id
- staff_id
- customer_id

dim_customer

- customer_id
- store_id
- first_name
- last_name
- email
- activebool
- create_date
- address
- address_2
- district
- city
- country
- postal_code
- phone

dim_category

- category_id
- name

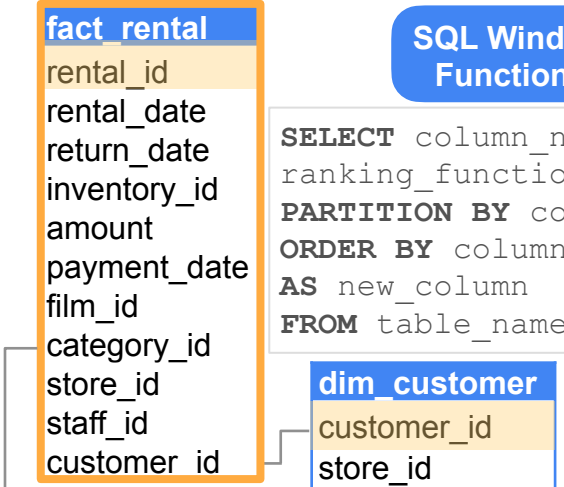
SQL Window Functions

```
SELECT column_name1,
ranking_function() OVER (
PARTITION BY column_name
ORDER BY column_name3)
AS new_column
FROM table_name
```

Compute the average duration in days that a customer spent on a film category.

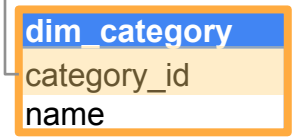
In [ ]:

```
%%sql
SELECT

FROM fact_rental
JOIN dim_category
ON fact_rental.category_id = dim_category.category_id
```



SQL Window Functions

```
SELECT column_name1,
ranking_function() OVER (
PARTITION BY column_name
ORDER BY column_name3)
AS new_column
FROM table_name
```



Compute the average duration in days that a customer spent on a film category.

```
In [ ]:
%%sql
SELECT
fact_rental.customer_id,
dim_category.name,
avg(datediff(return_date, rental_date)) AS average_rental_days
FROM fact_rental
JOIN dim_category
ON fact_rental.category_id = dim_category.category_id
```

fact_rental
- rental_id
- rental_date
- return_date
- inventory_id
- amount
- payment_date
- film_id
- category_id
- store_id
- staff_id
- customer_id

dim_customer
- customer_id
- store_id
- first_name
- last_name
- email
- activebool
- create_date
- address
- address_2
- district
- city
- country
- postal_code
- phone

dim_category
- category_id
- name

SQL Window Functions

```
SELECT column_name1,
ranking_function() OVER (
PARTITION BY column_name
ORDER BY column_name3)
AS new_column
FROM table_name
```

Add a column that shows for each customer the rank of each category based on the rental days.

```
In [10]: %%sql
SELECT
fact_rental.customer_id,
dim_category.name,
avg(datediff(return_date, rental_date)) AS average_rental_days
FROM fact_rental
JOIN dim_category
ON fact_rental.category_id = dim_category.category_id
GROUP BY fact_rental.customer_id, dim_category.name
ORDER BY fact_rental.customer_id, average_Rental_days DESC
```

Out[10]:

customer_id	name	average_rental_days
1	Documentary	9.0000
1	Travel	8.0000
1	Games	6.0000
1	Music	5.5000
1	Comedy	5.4000

fact_rental
- rental_id
- rental_date
- return_date
- inventory_id
- amount
- payment_date
- film_id
- category_id
- store_id
- staff_id
- customer_id

dim_customer
- customer_id
- store_id
- first_name
- last_name
- email
- activebool
- create_date
- address
- address_2
- district
- city
- country
- postal_code
- phone

dim_category
- category_id
- name

SQL Window Functions

```
SELECT column_name1,
ranking_function() OVER (
PARTITION BY column_name
ORDER BY column_name3)
AS new_column
FROM table_name
```

Add a column that shows for each customer the rank of each category based on the rental days.

```
n [10]: %%sql
WITH customer_info AS (
SELECT
fact_rental.customer_id,
dim_category.name,
avg(datediff(return_date, rental_date)) AS average_rental_days
FROM fact_rental
JOIN dim_category
ON fact_rental.category_id = dim_category.category_id
GROUP BY fact_rental.customer_id, dim_category.name
ORDER BY fact_rental.customer_id, average_Rental_days DESC
)
```

```
 * mysql+pymysql://root:***@localhost:3306/sakila_star
7741 rows affected.
```

Out[10]:

customer_id	name	average_rental_days
1	Documentary	9.0000
1	Travel	8.0000

fact_rental

- rental_id
- rental_date
- return_date
- inventory_id
- amount
- payment_date
- film_id
- category_id
- store_id
- staff_id
- customer_id

dim_customer

- customer_id
- store_id
- first_name
- last_name
- email
- activebool
- create_date
- address
- address_2
- district
- city
- country
- postal_code
- phone

dim_category

- category_id
- name

SQL Window Functions

```
SELECT column_name1,
ranking_function() OVER (
PARTITION BY column_name
ORDER BY column_name3)
AS new_column
FROM table_name
```

Add a column that shows for each customer the rank of each category based on the rental days.

```
In [10]: %%sql
WITH customer_info AS (
SELECT
fact_rental.customer_id,
dim_category.name,
avg(datediff(return_date, rental_date)) AS average_rental_days
FROM fact_rental
JOIN dim_category
ON fact_rental.category_id = dim_category.category_id
GROUP BY fact_rental.customer_id, dim_category.name
ORDER BY fact_rental.customer_id, average_rental_days DESC
)
SELECT customer_id, name, average_rental_days
FROM customer_info

 * mysql+pymysql://root:***@localhost:3306/sakila_star
7741 rows affected.

Out[10]: customer_id  name  average_rental_days
```

fact_rental
- rental_id
- rental_date
- return_date
- inventory_id
- amount
- payment_date
- film_id
- category_id
- store_id
- staff_id
- customer_id

dim_customer
- customer_id
- store_id
- first_name
- last_name
- email
- activebool
- create_date
- address
- address_2
- district
- city
- country
- postal_code
- phone

dim_category
- category_id
- name

SQL Window Functions

```
SELECT column_name1,
ranking_function() OVER (
PARTITION BY column_name
ORDER BY column_name3)
AS new_column
FROM table_name
```

Add a column that shows for each customer the rank of each category based on the rental days.

```
n [10]:  %%sql
WITH customer_info AS (
SELECT
fact_rental.customer_id,
dim_category.name,
avg(datediff(return_date, rental_date)) AS average_rental_days
FROM fact_rental
JOIN dim_category
ON fact_rental.category_id = dim_category.category_id
GROUP BY fact_rental.customer_id, dim_category.name
ORDER BY fact_rental.customer_id, average_rental_days DESC
)
SELECT customer_id, name, average_rental_days,
rank() OVER
(PARTITION BY customer_id ORDER BY average_rental_days DESC)
AS rank_category
FROM customer_info

 * mysql+pymysql://root:***@localhost:3306/sakila_star
7741 rows affected.
```

rank(): assigns same rank to rows there's a tie
row_number(): assigns different ranks when there's a tie

fact_rental
- rental_id
- rental_date
- return_date
- inventory_id
- amount
- payment_date
- film_id
- category_id
- store_id
- staff_id
- customer_id

dim_customer
- customer_id
- store_id
- first_name
- last_name
- email
- activebool
- create_date
- address
- address_2
- district
- city
- country
- postal_code
- phone

dim_category
- category_id
- name

SQL Window Functions

```
SELECT column_name1,
ranking_function() OVER (
PARTITION BY column_name
ORDER BY column_name3)
AS new_column
FROM table_name
```

Add a column that shows for each customer the running sum over each window.

```
n [11]:  %%sql
WITH customer_info AS (
SELECT
fact_rental.customer_id,
dim_category.name,
avg(datediff(return_date, rental_date)) AS average_rental_days
FROM fact_rental
JOIN dim_category
ON fact_rental.category_id = dim_category.category_id
GROUP BY fact_rental.customer_id, dim_category.name
ORDER BY fact_rental.customer_id, average_rental_days DESC
)
SELECT customer_id, name, average_rental_days,
rank() OVER
(PARTITION BY customer_id ORDER BY average_rental_days DESC)
AS rank_category
FROM customer_info
ORDER BY customer_id, rank_category

 * mysql+pymysql://root:***@localhost:3306/sakila_star
7741 rows affected
```

DeepLearning.AI

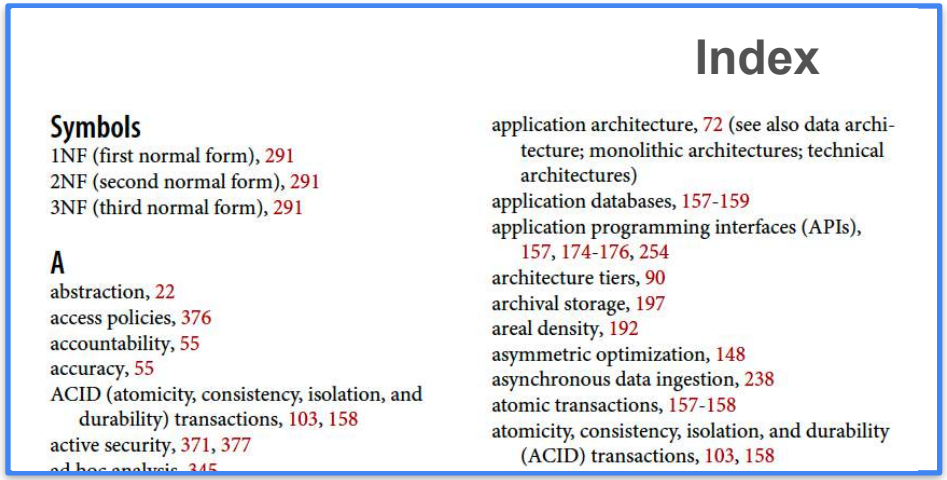
Queries

Index Deep Dive

Index

Index A separate data structure that has its own disk space and contains information that refers to the actual table

Book index: quickly find pages instead of flipping through the entire book



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Symbols

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A

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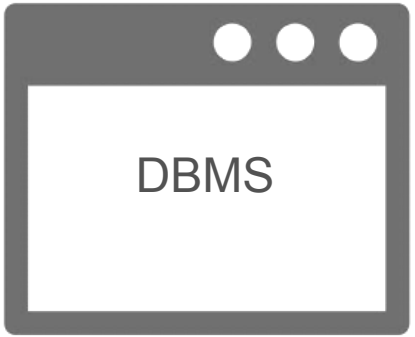
DBMS: queries data using an ordered index rather than scanning the whole table



Index

```
SELECT * FROM order  WHERE country = 'USA'
```

Order ID	Price	Product SKU	Quantity	Customer ID	Store ID	Country
2	23	902348	14	56t	3	Mexico
3	56	458645	13	69t	3	Chile
4	23	902348	14	56t	3	Canada
5	45	1255893	12	87q	4	Canada
6	50	456829	13	98q	1	USA
7	34	568298	12	98q	1	USA
8	44	563783	4	67t	1	Canada
9	22	234589	5	56u	2	Brazil
10	30	267895	12	78y	3	USA
11	60	545659	14	13t	5	Mexico
….	….	….	….	….	….	….

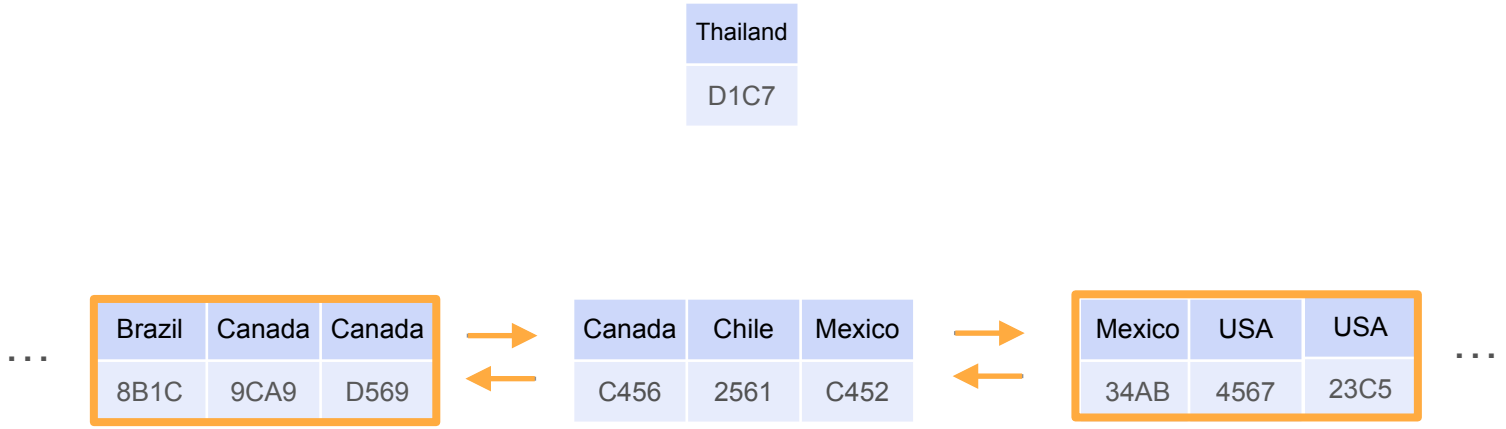
Use binary search to locate the USA rows

Index

Country	Row Address
…	…
Brazil	8B1C
Canada	9CA9
Canada	D569
Canada	C456
Chile	2561
Mexico	C452
Mexico	34AB
USA	4567
USA	23C5
USA	7C6E
….	….

Index

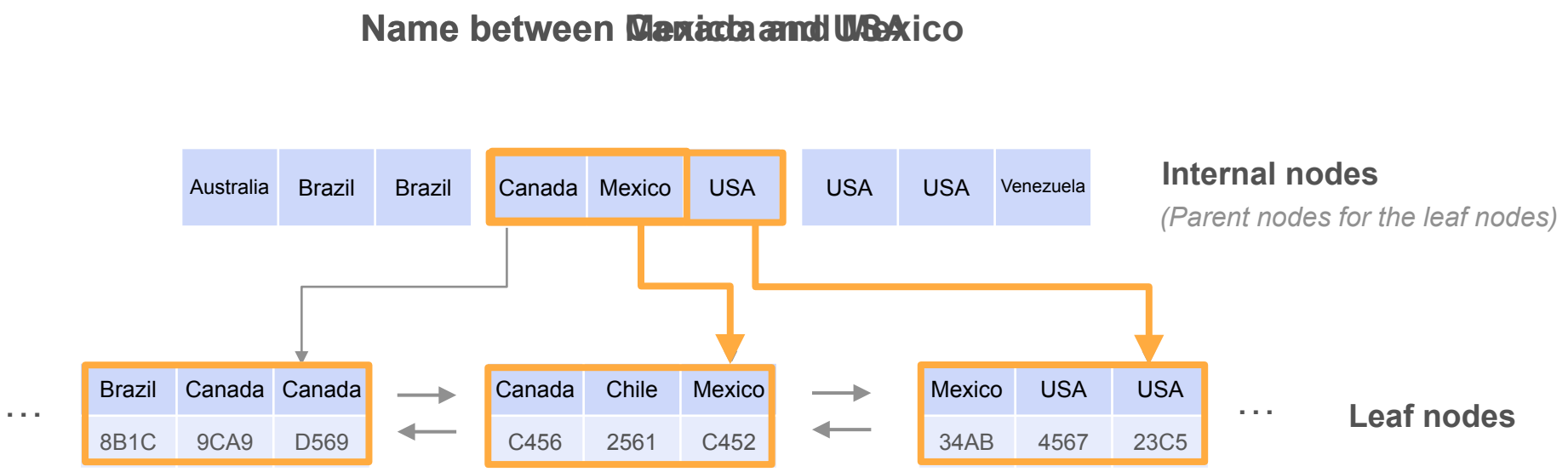
- The physical location of the blocks does not matter
- This structure facilitates the update of the index when data is inserted or deleted



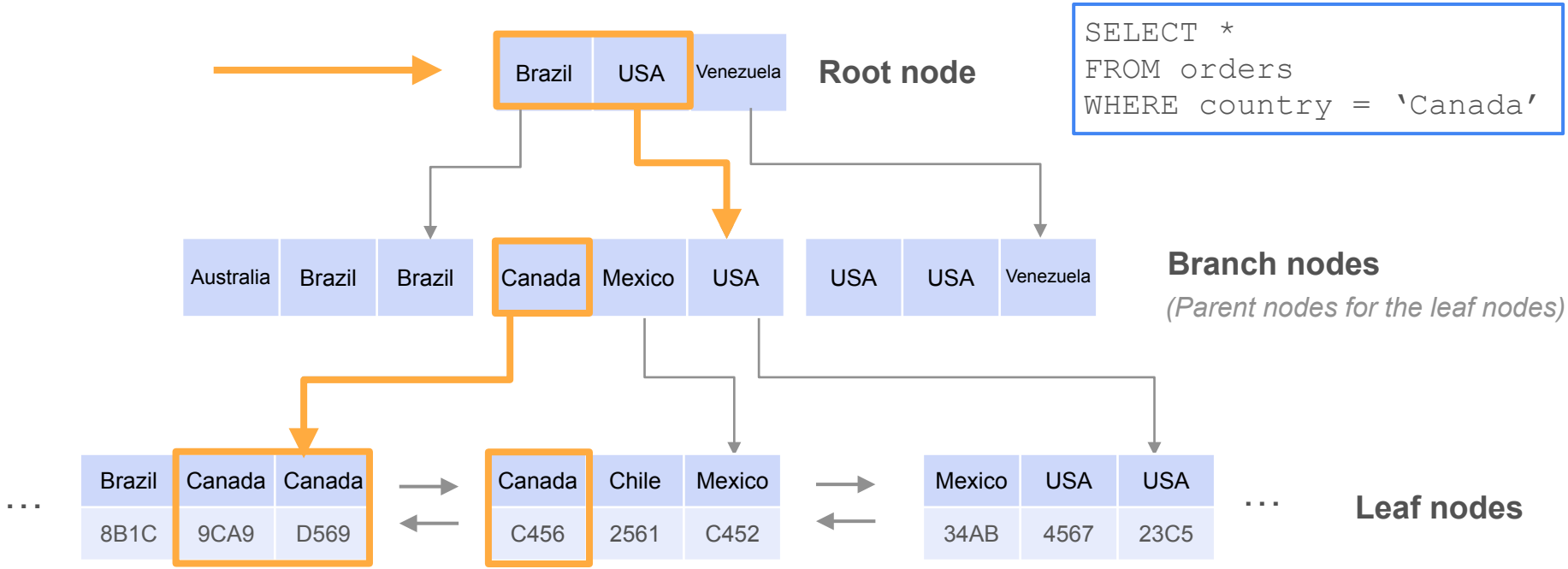
Index

Country	Row Address
…	…
Brazil	8B1C
Canada	9CA9
Canada	D569
Canada	C456
Chile	2561
Mexico	C452
Mexico	34AB
USA	4567
USA	23C5
USA	7C6E
….	….

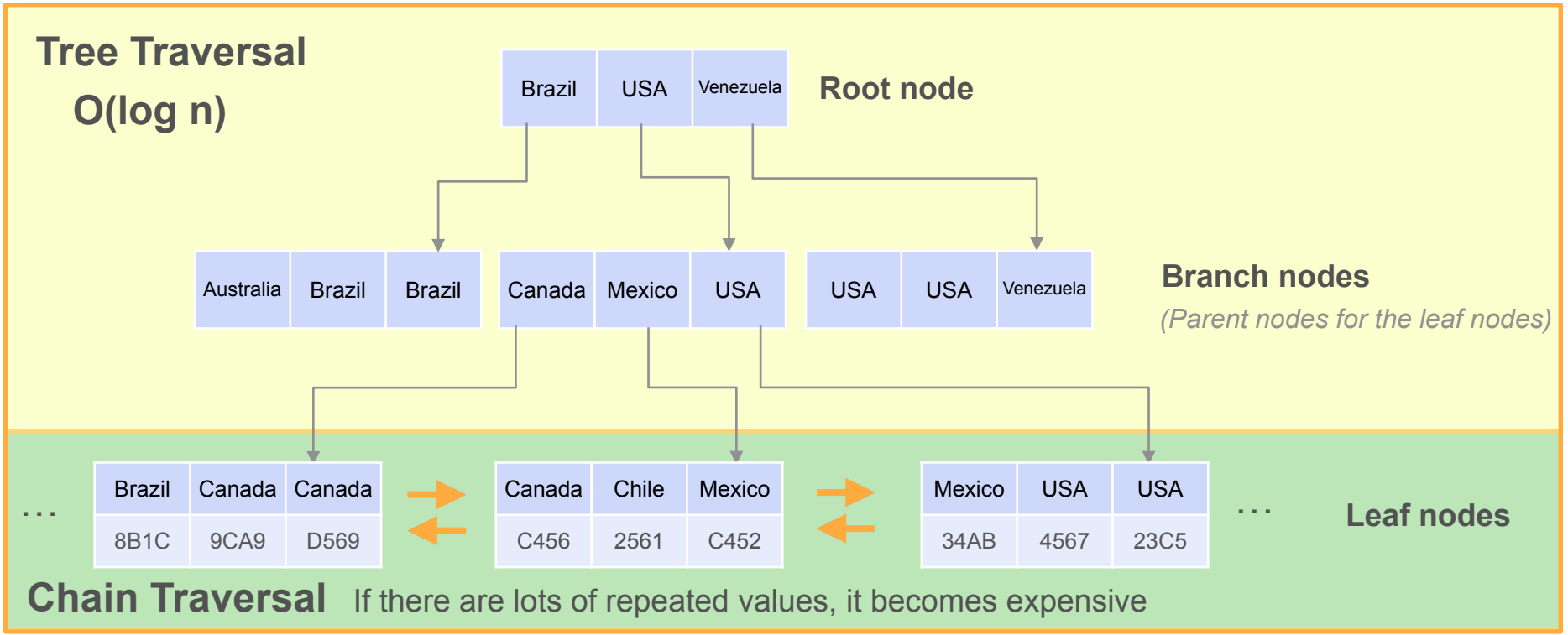
Balanced Search Tree (B-Tree)



Balanced Search Tree (B-Tree)



Balanced Search Tree (B-Tree)



Index

payment
payment_id *(primary key)*
customer_id
staff_id
rental_id
amount
payment_date

```
EXPLAIN  SELECT * FROM payment WHERE rental_id = 1;

QUERY PLAN
-------------------------------------------
Seq Scan on payment (cost=0.00. 290.45 rows=1 width=26)
```

Create an index for the rental_id column

```
CREATE INDEX rental_idx ON payment (rental_id);

EXPLAIN  SELECT * FROM payment WHERE rental_id = 1;

QUERY PLAN
-------------------------------------------
Index Scan using rental_idx on payment
(cost=0.29..8.30 rows=1 width=26)
```

Columnar Storage

Amazon Redshift

Sort Key: one or more columns

- Sorts the data according to the sort key
- Stores the sorted data on disk

Sort key

Order ID	Product SKU	Quantity	Customer ID	Country
2	902348	14	56t	Mexico
3	458645	13	69t	Chile
4	902348	14	56t	Canada
5	1255893	12	87q	Canada
6	456829	13	98q	USA
7	568298	12	98q	USA
8	563783	4	67t	USA
9	234589	5	56u	Brazil
10	267895	12	78y	Canada
11	545659	14	13t	Mexico

Columnar Storage

Amazon Redshift

Sort Key: one or more columns

- Sorts the data according to the sort key
- Stores the sorted data on disk

Also known as cluster key.

Sort key

Order ID	Product SKU	Quantity	Customer ID	Country
9	234589	5	56u	Brazil
3	458645	13	69t	Chile
10	267895	12	78y	Canada
4	902348	14	56t	Canada
5	1255893	12	87q	Canada
2	902348	14	56t	Mexico
11	545659	14	13t	Mexico
6	456829	13	98q	USA
7	568298	12	98q	USA
8	563783	4	67t	USA

Stored on disk

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Queries

Retrieving Only the Data You Need

Avoid Select *

Query: `SELECT * FROM order`

Order ID	Price	Product SKU	Quantity	Customer ID	Store ID	Country
1	40	458650	10	67t	3	Canada
2	23	902348	14	56t	3	Columbia
3	56	458645	13	69t	3	Chile
4	23	902348	14	56t	3	Canada
5	45	1255893	12	87q	4	Canada
6	50	456829	13	98q	1	USA
7	34	568298	12	98q	1	USA
8	44	563783	4	67t	1	USA
9	22	234589	5	56u	2	Brazil
10	30	267895	12	78y	3	Canada
11	60	545659	14	13t	5	Mexico

- Large amounts of data need to be transferred from disk.

Avoid Select *

Query: `SELECT * from order`

Order ID	Price	Product SKU	Quantity	Customer ID	Store ID	Country
1	40	458650	10	67t	3	Canada
2	23	902348	14	56t	3	Columbia
3	56	458645	13	69t	3	Chile
4	23	902348	14	56t	3	Canada
5	45	1255893	12	87q	4	Canada
6	50	456829	13	98q	1	USA
7	34	568298	12	98q	1	USA
8	44	563783	4	67t	1	USA
9	22	234589	5	56u	2	Brazil
10	30	267895	12	78y	3	Canada
11	60	545659	14	13t	5	Mexico

- Large amounts of data need to be transferred from disk.
- Select * on you cloud pay-as-you-go databases can be expensive.
  - Charged for reading all bytes and for utilizing compute resources.

Query Tips

Pruning Exclude irrelevant data from being scanned in your query.

Row-based pruning

- Filter out rows
- Use index or sort/cluster key

```
CREATE INDEX rental_idx
ON payment (rental_id);

SELECT * FROM payment
WHERE rental_id = 1;
```

Column-based pruning

- Specify the columns you need

```
SELECT customer_id,
       rental_id
FROM payment;
```

Partition pruning

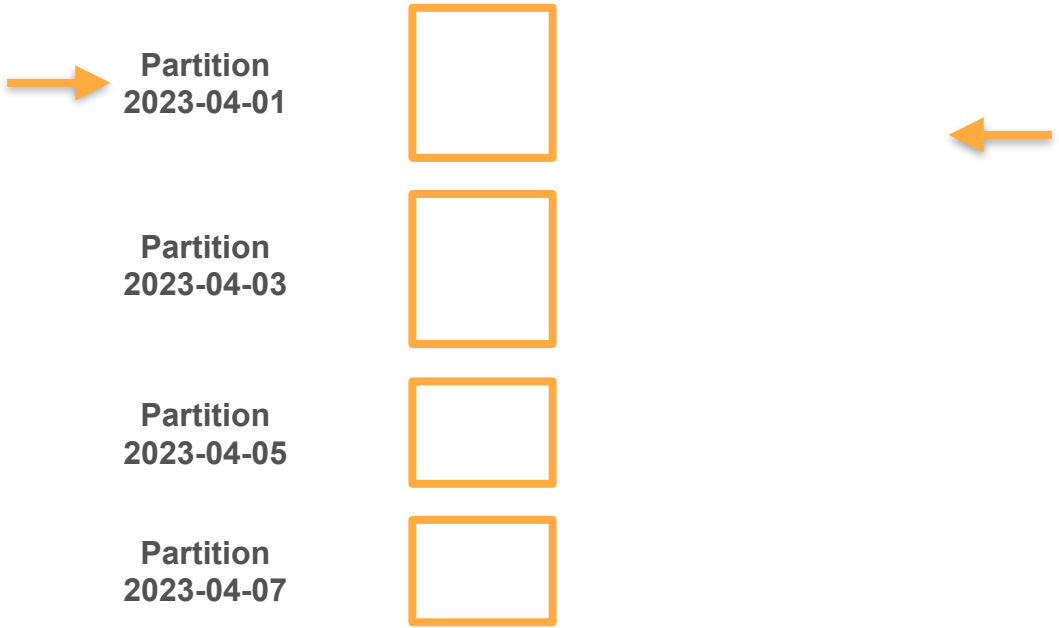
- Scan specific partitions
- Partitions are based on a partition key

Partitioning

Sorted by Country, not partitioned

Order ID	Order Date	Product SKU	Quantity	Country
9	2023-04-07	234589	5	Brazil
4	2023-04-05	902348	14	Canada
5	2023-04-07	1255893	12	Canada
10	2023-04-01	267895	12	Canada
3	2023-04-03	458645	13	Chile
2	2023-04-01	902348	14	Mexico
11	2023-04-03	545659	14	Mexico
6	2023-04-01	456829	13	USA
7	2023-04-03	568298	12	USA
8	2023-04-05	563783	4	USA

Partitioned by Date
Each partition is sorted by Country



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Queries

The Join Statement

Example on Join

```
SELECT * FROM orders
JOIN customers
ON customers.id = orders.customer_id
```

orders

order_id	customer_id	product_id	date_time	purchase_amount
1	1	1	12/08/2024	700
2	1	2	12/08/2024	99
3	1	3	12/08/2024	100
4	2	4	12/08/2024	899
5	3	4	12/08/2024	899
6	4	4	12/08/2024	899

customers

id	first_name	last_name	address
1	Jane	Doe	74th St
2	Mary	Ann	19th Ave.
3	John	Ken	2st Link
4	Ivy	Tan	67th St.

Example on Join

```
SELECT * FROM orders
JOIN customers
ON customers.id = orders.customer_id
```

orders

order_id	customer_id	product_id	date_time	purchase_amount
1	1	1	12/08/2024	700
2	1	2	12/08/2024	99
3	1	3	12/08/2024	100
4	2	4	12/08/2024	899
5	3	4	12/08/2024	899
6	4	4	12/08/2024	899

customers

id	first_name	last_name	address
1	Jane	Doe	74th St
2	Mary	Ann	19th Ave.
3	John	Ken	2st Link
4	Ivy	Tan	67th St.

Combined Table

order_id	customer_id	product_id	date_time	purchase_amount	id	first_name	last_name	address

Example on Join

```
SELECT * FROM orders
JOIN customers
ON customers.id = orders.customer_id
```

orders

order_id	customer_id	product_id	date_time	purchase_amount
1	1	1	12/08/2024	700
2	1	2	12/08/2024	99
3	1	3	12/08/2024	100
4	2	4	12/08/2024	899
5	3	4	12/08/2024	899
6	4	4	12/08/2024	899

customers

id	first_name	last_name	address
1	Jane	Doe	74th St
2	Mary	Ann	19th Ave.
3	John	Ken	2st Link
4	Ivy	Tan	67th St.

Combined Table

order_id	customer_id	product_id	date_time	purchase_amount	id	first_name	last_name	address
1	1	1	12/08/2024	700	1	Jane	Doe	74th St
2	1	2	12/08/2024	99	1	Jane	Doe	74th St
3	1	3	12/08/2024	100	1	Jane	Doe	74th St
4	2	4	12/08/2024	899	2	Mary	Ann	19th Ave.
5	3	4	12/08/2024	899	3	John	Ken	2st Link
6	4	4	12/08/2024	899	4	Ivy	Tan	67th St.

Example on Join

```
SELECT * FROM orders
JOIN customers
ON customers.id = orders.customer_id
```

Inner Join

Combines data from only the rows that share a matching customer id in both tables

Combined Table

order_id	customer_id	product_id	date_time	purchase_amount	id	first_name	last_name	address
1	1	1	12/08/2024	700	1	Jane	Doe	74th St
2	1	2	12/08/2024	99	1	Jane	Doe	74th St
3	1	3	12/08/2024	100	1	Jane	Doe	74th St
4	2	4	12/08/2024	899	2	Mary	Ann	19th Ave.
5	3	4	12/08/2024	899	3	John	Ken	2st Link
6	4	4	12/08/2024	899	4	Ivy	Tan	67th St.

Method 1 - Nested Loop Join

orders

order_id	customer_id	product_id	date_time	purchase_amount
1	1	1	12/08/2024	700
2	1	2	12/08/2024	99
3	1	3	12/08/2024	100
4	2	4	12/08/2024	899
5	3	4	12/08/2024	899
6	1	4	12/08/2024	899

customers

id	first_name	last_name	address
1	Jane	Doe	74th St
2	Mary	Ann	19th Ave.
3	John	Ken	2st Link
4	Ivy	Tan	67th St.

Combined Table

order_id	customer_id	product_id	date_time	purchase_amount	id	first_name	last_name	address
1	1	1	12/08/2024	700	1	Jane	Doe	74th St
2	1	2	12/08/2024	99	1	Jane	Doe	74th St
3	1	3	12/08/2024	100	1	Jane	Doe	74th St
4	2	4	12/08/2024	899	2	Mary	Ann	19th Ave.
5	3	4	12/08/2024	899	3	John	Ken	2st Link
6	4	4	12/08/2024	899	4	Ivy	Tan	67th St.

Method 2 - Index-Based Nested-Loop

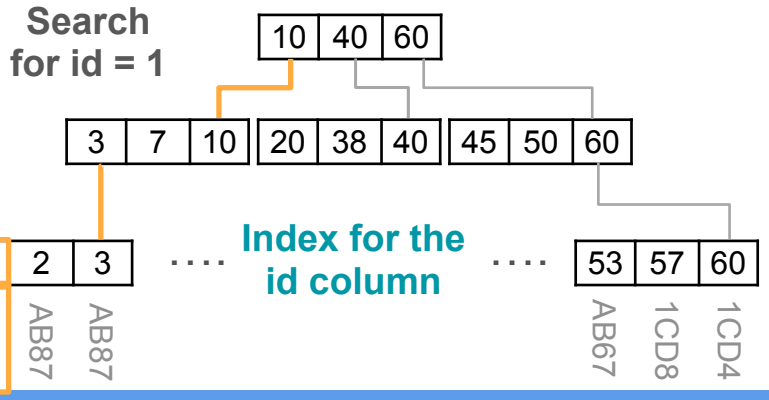
Can be used when an index exists for one of the join attributes

orders

order_id	customer_id	product_id	date_time	purchase_amount
1	1	1	12/08/2024	700
2	1	2	12/08/2024	99
3	1	3	12/08/2024	100
4	2	4	12/08/2024	899
5	3	4	12/08/2024	899
6	4	4	12/08/2024	899

customers

id	first_name	last_name	address
1	Jane	Doe	74th St
2	Mary	Ann	19th Ave.
3	John	Ken	2st Link
4	Ivy	Tan	67th St.



Method 2 - Index-Based Nested-Loop

Can be used when an index exists for one of the join attributes

orders

order_id	customer_id	product_id	date_time	purchase_amount
1	1	1	12/08/2024	700
2	1	2	12/08/2024	99
3	1	3	12/08/2024	100
4	2	4	12/08/2024	899
5	3	4	12/08/2024	899
6	4	4	12/08/2024	899

customers

id	first_name	last_name	address
1	Jane	Doe	74th St
2	Mary	Ann	19th Ave.
3	John	Ken	2st Link
4	Ivy	Tan	67th St.

Combined Table

order_id	customer_id	product_id	date_time	purchase_amount	id	first_name	last_name	address
1	1	1	12/08/2024	700	1	Jane	Doe	74th St
2	1	2	12/08/2024	99	1	Jane	Doe	74th St
3	1	3	12/08/2024	100	1	Jane	Doe	74th St
4	2	4	12/08/2024	899	2	Mary	Ann	19th Ave.
5	3	4	12/08/2024	899	3	John	Ken	2st Link
6	4	4	12/08/2024	899	4	Ivy	Tan	67th St.

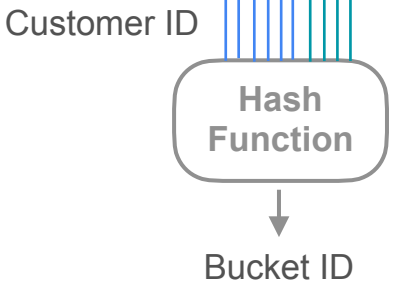
Method 3 - Hash-Join

orders

order_id	customer_id	product_id	date_time	purchase_amount
1	1	1	12/08/2024	700
2	1	2	12/08/2024	99
3	1	3	12/08/2024	100
4	2	4	12/08/2024	899
5	3	4	12/08/2024	899
6	4	4	12/08/2024	899

customers

id	first_name	last_name	address
1	Jane	Doe	74th St
2	Mary	Ann	19th Ave.
3	John	Ken	2st Link
4	Ivy	Tan	67th St.



Method 3 - Hash-Join

orders

order_id	customer_id	product_id	date_time	purchase_amount
1	1	1	12/08/2024	700
2	1	2	12/08/2024	99
3	1	3	12/08/2024	100
4	2	4	12/08/2024	899
5	3	4	12/08/2024	899
6	4	4	12/08/2024	899

customers

id	first_name	last_name	address
1	Jane	Doe	74th St
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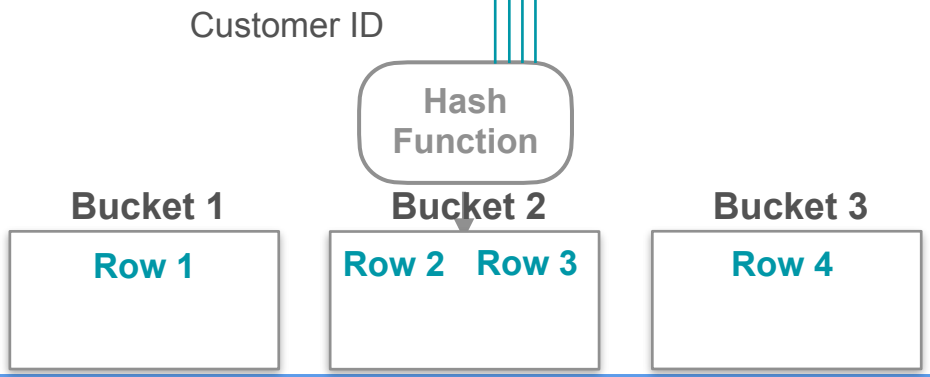

Method 3 - Hash-Join

orders

order_id	customer_id	product_id	date_time	purchase_amount
1	1	1	12/08/2024	700
2	1	2	12/08/2024	99
3	1	3	12/08/2024	100
4	2	4	12/08/2024	899
5	3	4	12/08/2024	899
6	4	4	12/08/2024	899

customers

id	first_name	last_name	address
1	Jane	Doe	74th St
2	Mary	Ann	19th Ave.
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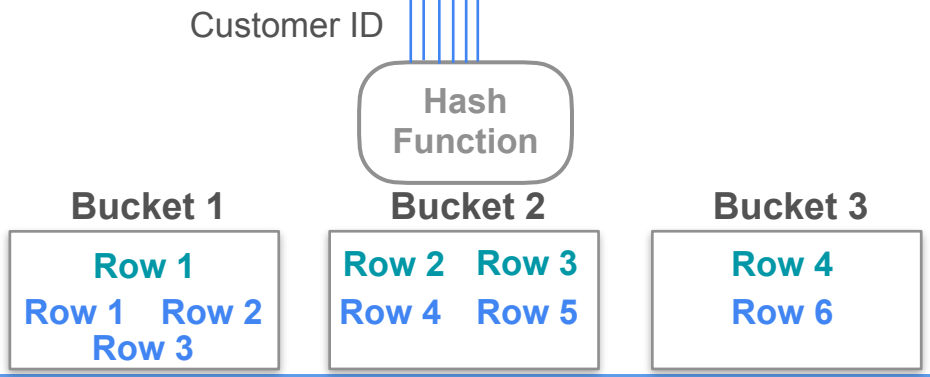


Method 3 - Hash-Join

orders

order_id	customer_id	product_id	date_time	purchase_amount
1	1	1	12/08/2024	700
2	1	2	12/08/2024	99
3	1	3	12/08/2024	100
4	2	4	12/08/2024	899
5	3	4	12/08/2024	899
6	4	4	12/08/2024	899

customers

id	first_name	last_name	address
1	Jane	Doe	74th St
2	Mary	Ann	19th Ave.
3	John	Ken	2st Link
4	Ivy	Tan	67th St.

Bucket 1

Row 1

Row 1 Row 2

Row 3

Bucket 2

Row 2 Row 3

Row 4 Row 5

Bucket 3

Row 4

Row 6

Method 3 - Hash-Join

orders

order_id	customer_id	product_id	date_time	purchase_amount
1	1	1	12/08/2024	700
2	1	2	12/08/2024	99
3	1	3	12/08/2024	100
4	2	4	12/08/2024	899
5	3	4	12/08/2024	899
6	4	4	12/08/2024	899

customers

id	first_name	last_name	address
1	Jane	Doe	74th St
2	Mary	Ann	19th Ave.
3	John	Ken	2st Link
4	Ivy	Tan	67th St.

Bucket 1

Row 1

Row 1 Row 2

Row 3

Bucket 2

Row 2 Row 3

Row 4 Row 5

Bucket 3

Row 4

Row 6

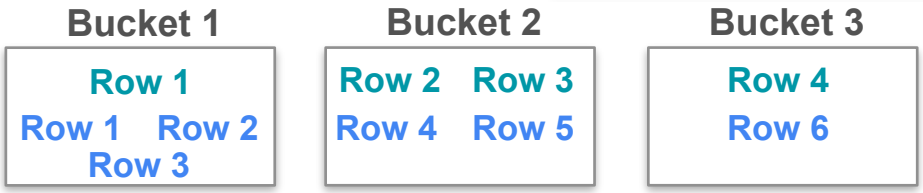
Method 3 - Hash-Join

orders

order_id	customer_id	product_id	date_time	purchase_amount
1	1	1	12/08/2024	700
2	1	2	12/08/2024	99
3	1	3	12/08/2024	100
4	2	4	12/08/2024	899
5	3	4	12/08/2024	899
6	4	4	12/08/2024	899

customers

id	first_name	last_name	address
1	Jane	Doe	74th St
2	Mary	Ann	19th Ave.
3	John	Ken	2st Link
4	Ivy	Tan	67th St.



Method 3 - Hash-Join

orders

order_id	customer_id	product_id	date_time	purchase_amount
1	1	1	12/08/2024	700
2	1	2	12/08/2024	99
3	1	3	12/08/2024	100
4	2	4	12/08/2024	899
5	3	4	12/08/2024	899
6	4	4	12/08/2024	899

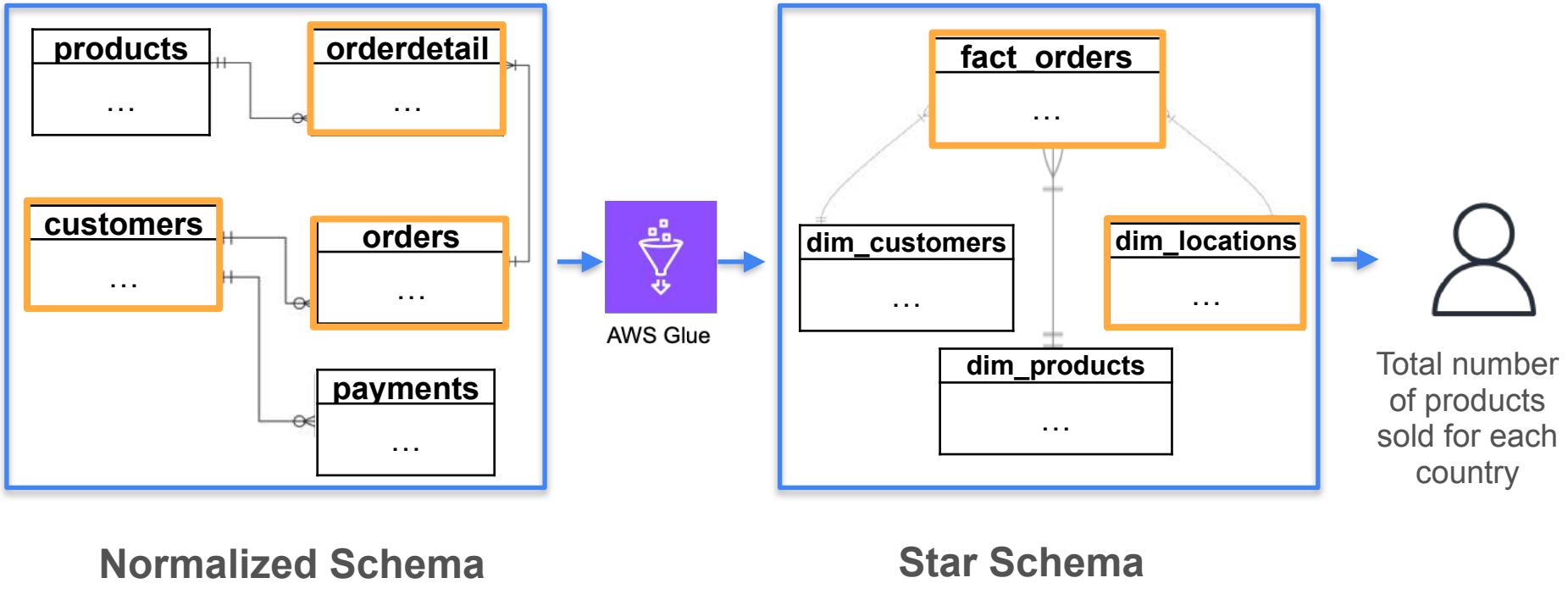
customers

id	first_name	last_name	address
1	Jane	Doe	74th St
2	Mary	Ann	19th Ave.
3	John	Ken	2st Link
4	Ivy	Tan	67th St.

Combined Table

order_id	customer_id	product_id	date_time	purchase_amount	id	first_name	last_name	address
1	1	1	12/08/2024	700	1	Jane	Doe	74th St
2	1	2	12/08/2024	99	1	Jane	Doe	74th St
3	1	3	12/08/2024	100	1	Jane	Doe	74th St
4	2	4	12/08/2024	899	2	Mary	Ann	19th Ave.
5	3	4	12/08/2024	899	3	John	Ken	2st Link
6	4	4	12/08/2024	899	4	Ivy	Tan	67th St.

Schemas and Joins



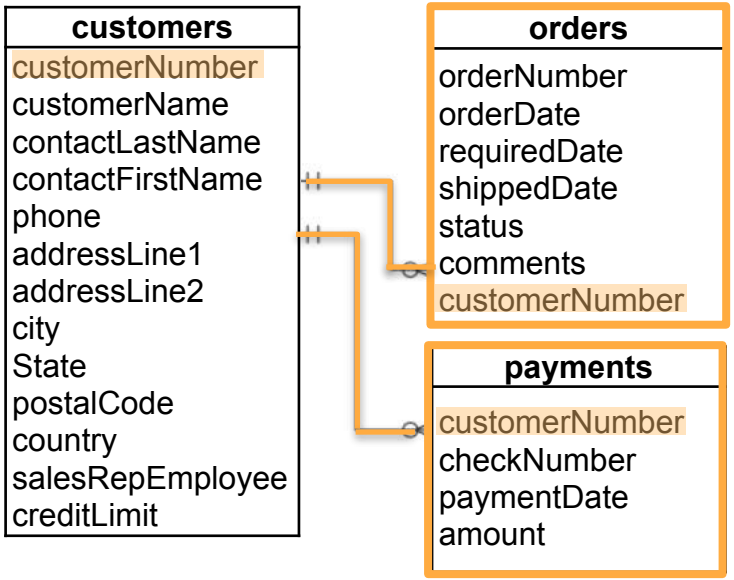
Schemas and Joins

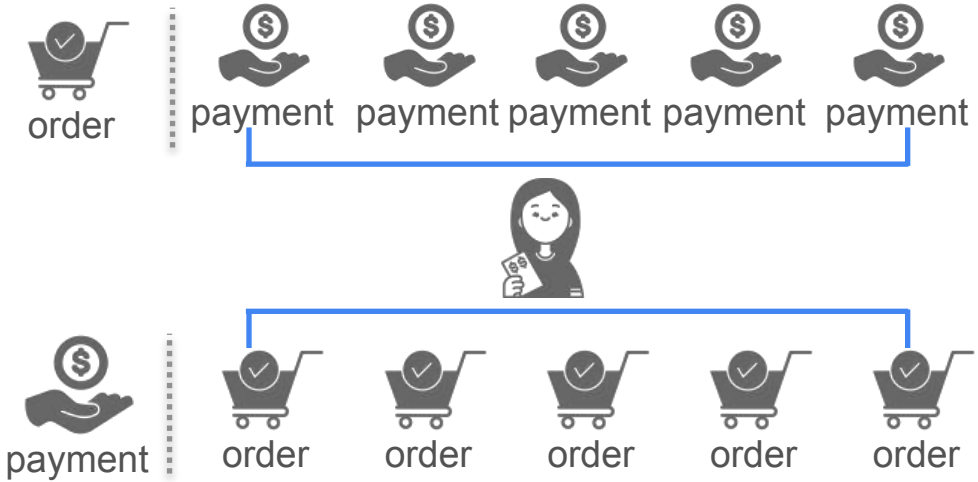
Customers info	….	Orders info	….	Payments info	….	Products info	….

No joins to perform

One Big Table (OBT)

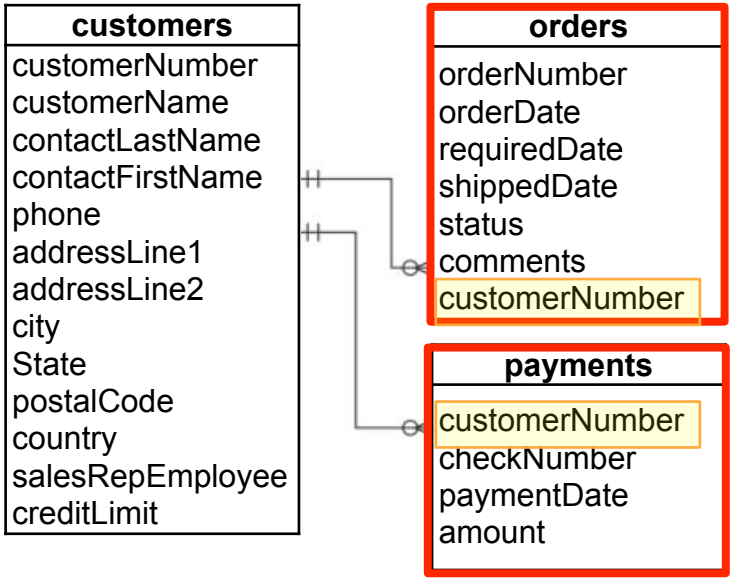
Many-to-Many Relationships





Normalized Schema

Many-to-Many Relationships



Normalized Schema

Payments

payment_date	customer Number	amount
12/1/2024	1	100
12/2/2024	1	23
1/1/2025	1	597
2/1/2025	1	89
3/1/2025	1	44

Orders

order_date	customer Number	order_number
12/1/2024	1	789VT
12/2/2024	1	786UI
3/1/2025	1	597AB
4/1/2025	1	898VB
5/1/2025	1	131MM

25 row outputs

payment_date	customer Number	amount	order_date	customer Number	order_number
12/1/2024	1	100	12/1/2024	1	789VT
12/1/2024	1	100	12/2/2024	1	786UI
12/1/2024	1	100	3/1/2025	1	597AB
12/1/2024	1	100	4/1/2025	1	898VB
12/2/2024	1	23	12/1/2024	1	789VT
12/2/2024	1	23	12/2/2024	1	786UI
12/2/2024	1	23	3/1/2025	1	597AB
	.....			.....	

Many-to-Many Relationships

Row Explosion

When a query returns more rows than what is anticipated

- Check your query to see if it correctly describes what you intended the join to do
- Add a table that correctly maps payment to orderNumber

Payments

payment_date	customer Number	amount
12/1/2024	1	100
12/2/2024	1	23
1/1/2025	1	597
2/1/2025	1	89
3/1/2025	1	44

Orders

order_date	customer Number	order_number
12/1/2024	1	789VT
12/2/2024	1	786UI
3/1/2025	1	597AB
4/1/2025	1	898VB
5/1/2025	1	131MM

25 row outputs

payment_date	customer Number	amount	order_date	customer Number	order_number
12/1/2024	1	100	12/1/2024	1	789VT
12/1/2024	1	100	12/2/2024	1	786UI
12/1/2024	1	100	3/1/2025	1	597AB
12/1/2024	1	100	4/1/2025	1	898VB
12/2/2024	1	23	12/1/2024	1	789VT
12/2/2024	1	23	12/2/2024	1	786UI
12/2/2024	1	23	3/1/2025	1	597AB
.....				.....	

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Queries

The Aggregate Queries

Aggregating Queries

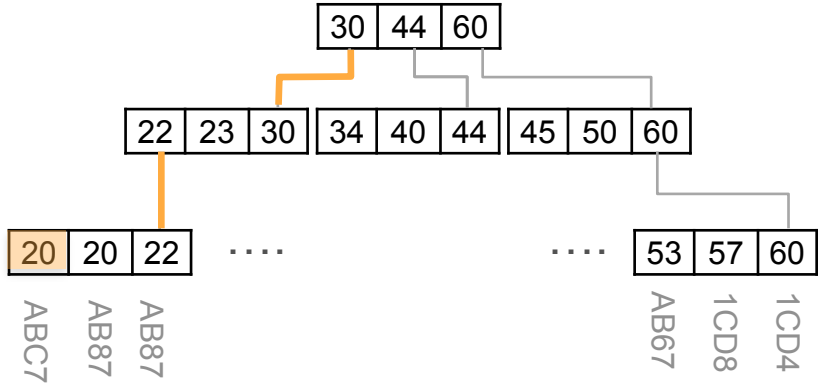
```
SELECT MIN(price)  FROM orders
```

Full Table Scan

Order ID	Price	Product SKU	Quantity	Customer ID	Store ID	Country
1	40	458650	10	67t	3	Canada
2	25	902348	14	56t	3	Canada
3	45	1255893	12	87q	4	Canada
4	50	456829	13	98q	1	USA
5	34	568298	12	98q	1	USA
6	44	563783	4	67t	1	USA
7	22	234589	5	56u	2	Brazil
8	30	267895	12	78y	3	Canada
9	60	545659	14	13t	5	Mexico

...

Use the Index *(if available)*



Aggregating Queries with GROUP BY

```
SELECT MIN(price)  FROM orders  GROUP BY country
```

Order ID	Price	Product SKU	Quantity	Customer ID	Store ID	Country
1	40	458650	10	67t	3	Canada
2	23	902348	14	56t	3	Canada
3	45	1255893	12	87q	4	Canada
4	50	456829	13	98q	1	USA
5	34	568298	12	98q	1	USA
6	44	563783	4	67t	1	USA
7	22	234589	5	56u	2	Brazil
8	30	267895	12	78y	3	Canada
9	60	545659	14	13t	5	Mexico

...

- Partitioning can be done using a sorting algorithm or hash function
- Or you can use an index to group the rows

Aggregating Queries - Row VS Columnar Storage

```
SELECT MIN(price) FROM orders
```

Order ID	Price	Product SKU	Quantity	Customer ID
1	40	458650	10	67t
2	23	902348	14	56t
3	45	125589	12	87q
4	50	456829	13	98q

Row Storage — Need to transfer all rows from disk to memory

Columnar Storage — Transfer only the relevant columns from disk to memory

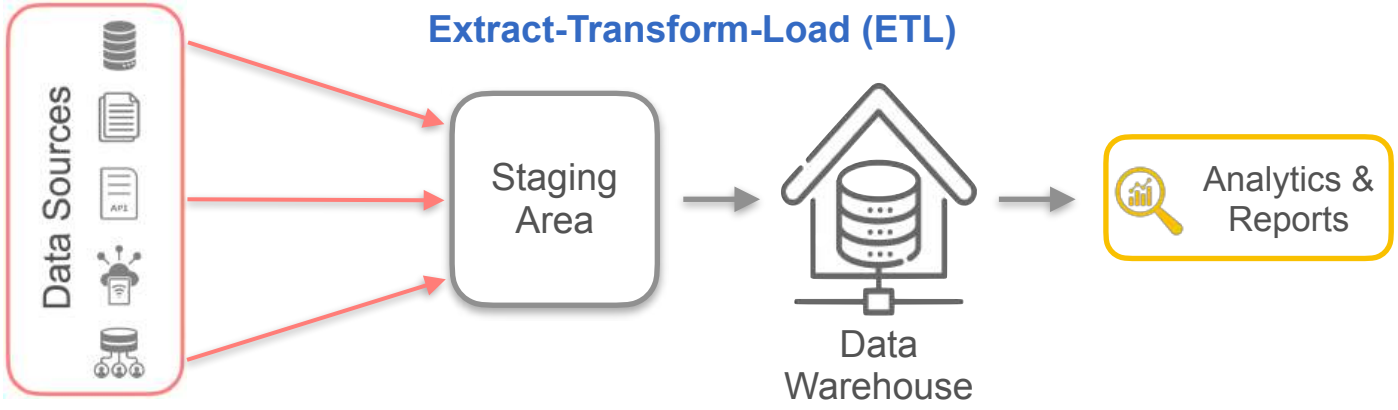
DeepLearning.AI

Queries

Amazon Redshift Cloud Data Warehouse

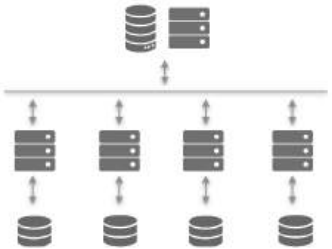
Amazon Redshift Cloud Data Warehouse

Amazon Redshift

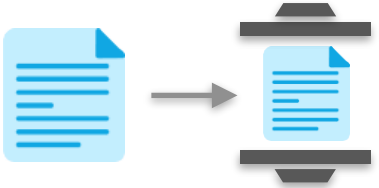


Order ID	Price	Product SKU	Quantity	Customer ID
1	40	45865	10	67t
2	23	90234	14	56t
3	45	12558	12	87q
4	50	45682	13	98q
...	...	...	...	...

Columnar Data Storage



Massively Parallel Processing (MPP)



Data Compression

Amazon Redshift - Column Storage

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
2	23	06-15-2024	14	124
3	45	07-03-2024	12	3465
4	50	08-23-2024	13	2749
…	…	…	…	…

Stores data
Column by column

Physical Storage

bytes representing 1st column	bytes representing 2nd column	bytes representing 3rd column	…

Amazon Redshift - Column Storage

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
2	23	06-15-2024	14	124
3	45	07-03-2024	12	3465
4	50	08-23-2024	13	2749
…	…	…	…	…
…	…	…	…	…
…	…	…	…	…

- Analytical Queries
- OLAP Workloads

bytes representing 1st column	bytes representing 2nd column	bytes representing 3rd column	…

Amazon Redshift - Column Storage

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
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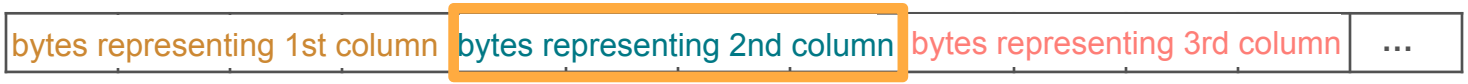
…	…	…	…	…
…	…	…	…	…
…	…	…	…	…

- Analytical Queries
- OLAP Workloads

Cost Efficiency

Speeding Up
Query Performance

Data
Warehousing



Amazon Redshift - Data Compression

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
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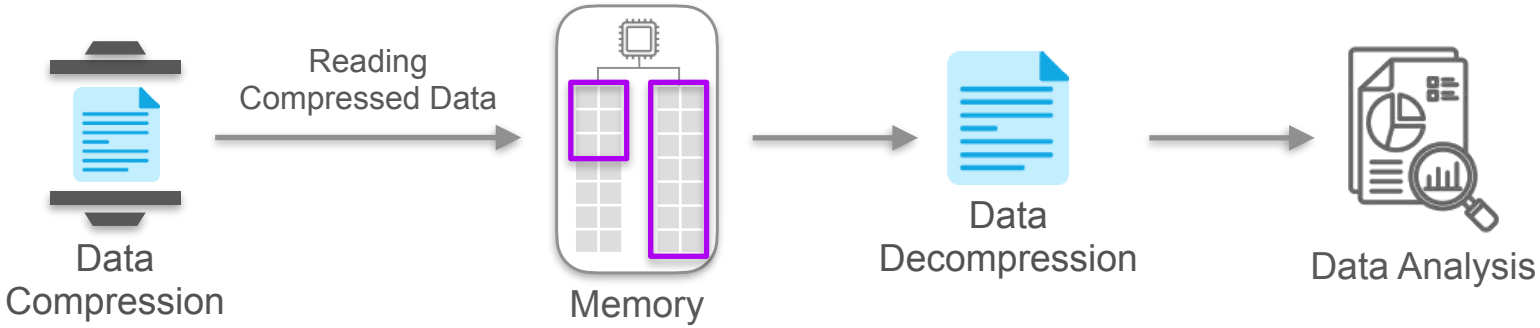
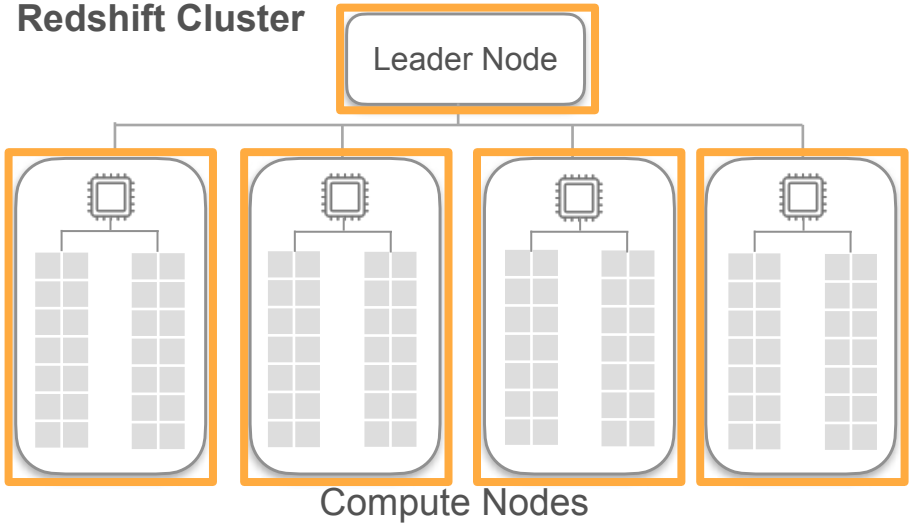
3	45	07-03-2024	12	3465
4	50	08-23-2024	13	2749
...	...	...	...	...

Columnar Storage

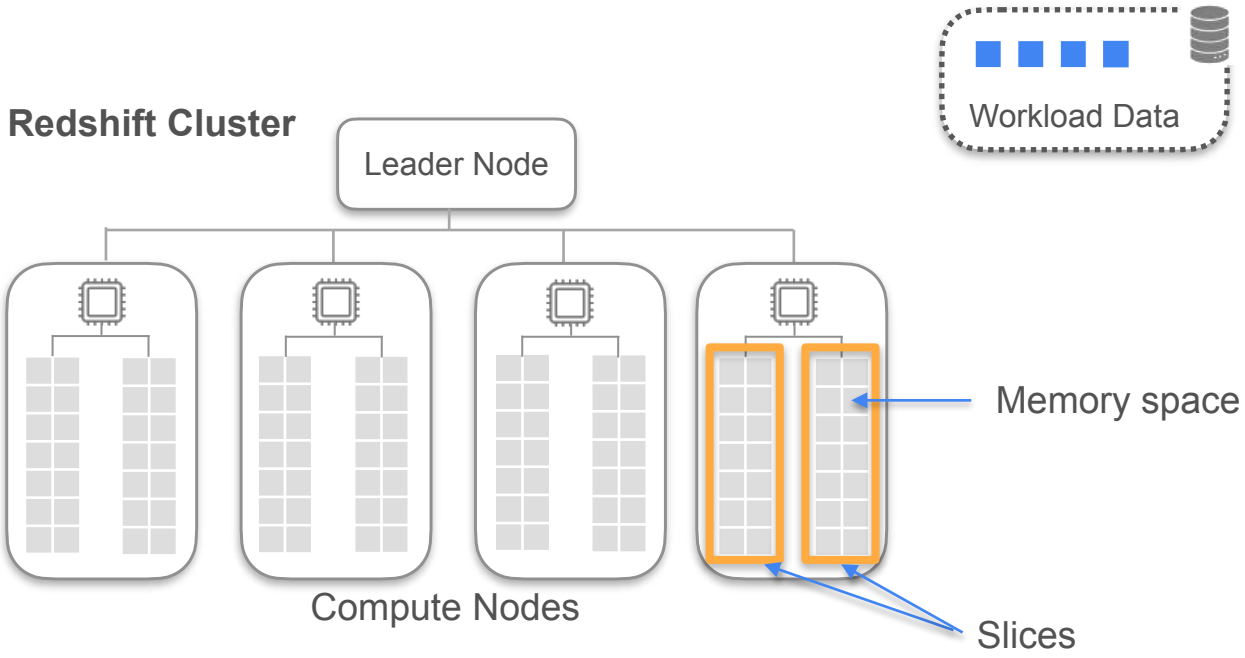
- Save storage space
- Reading less data from disk



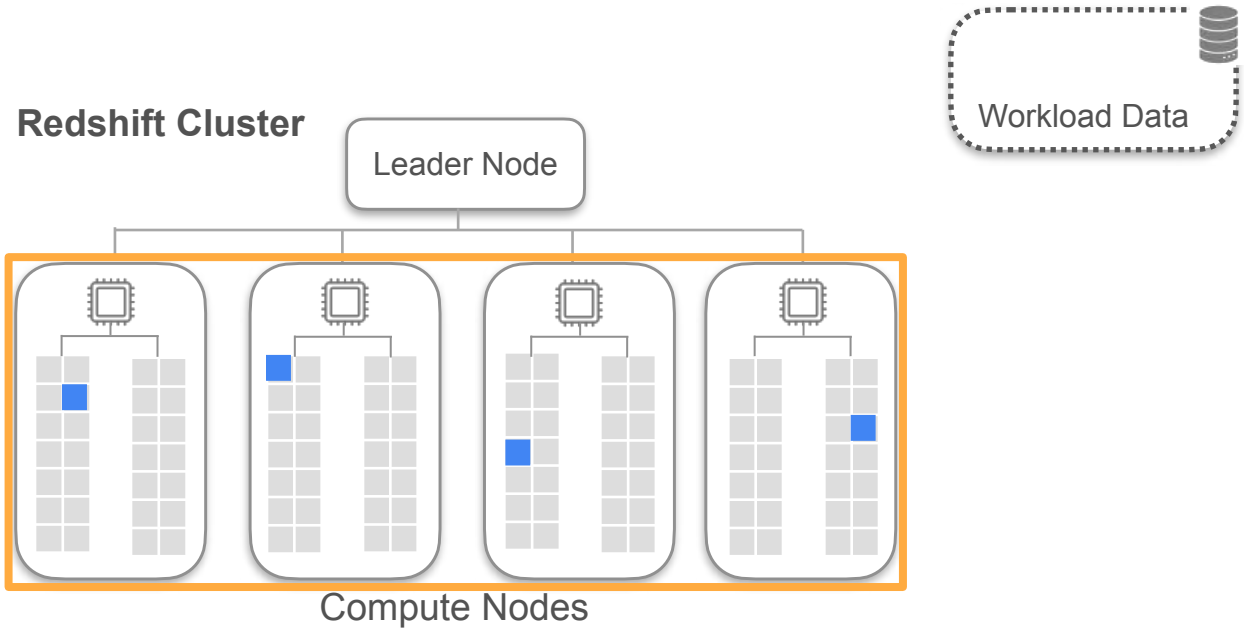
Amazon Redshift - Massive Parallel Processing



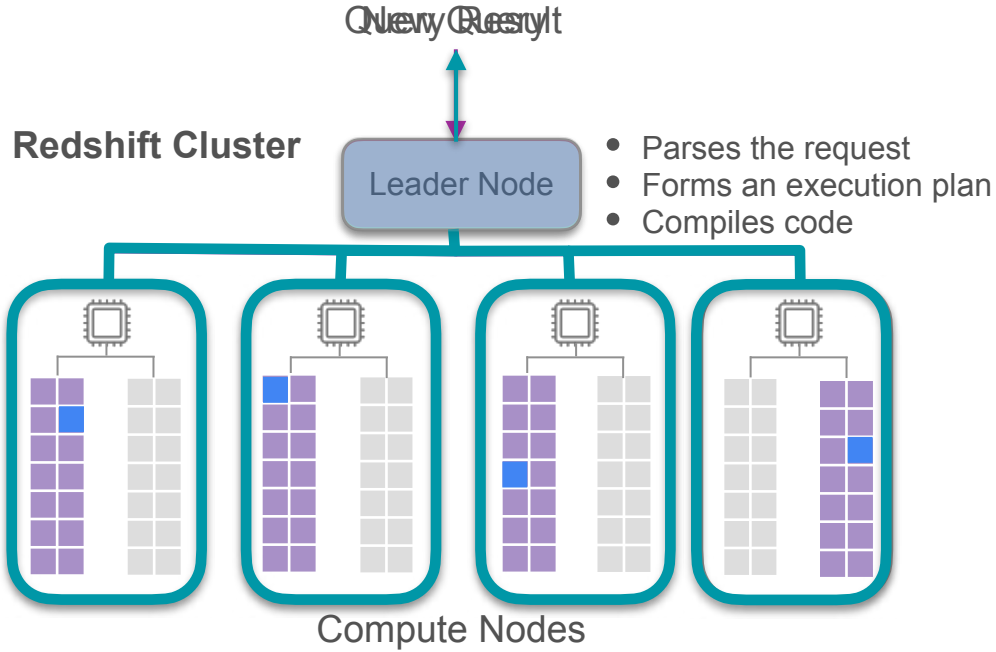
Amazon Redshift - Massive Parallel Processing



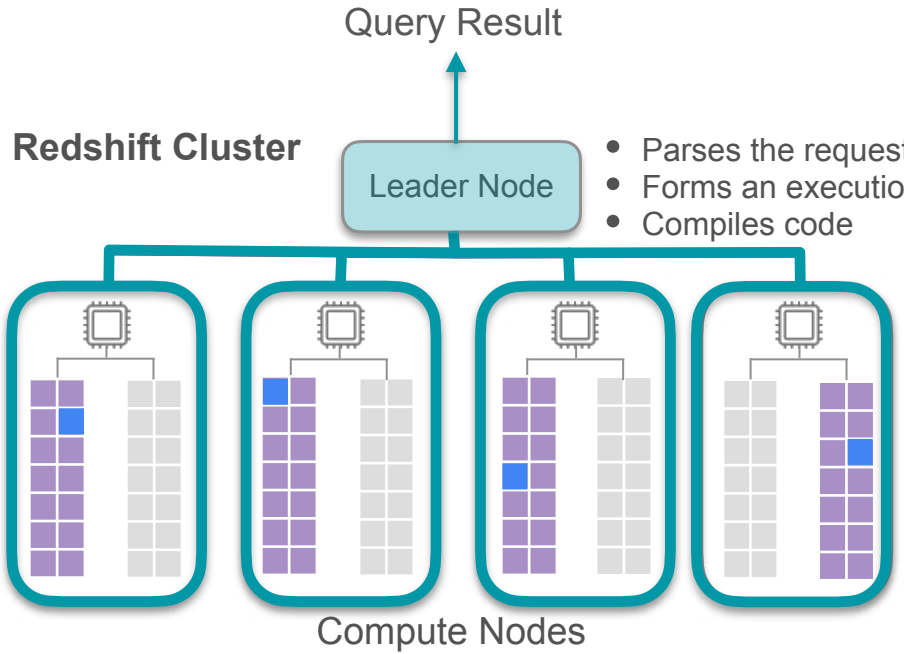
Amazon Redshift - Massive Parallel Processing



Amazon Redshift - Massive Parallel Processing



Amazon Redshift - Massive Parallel Processing



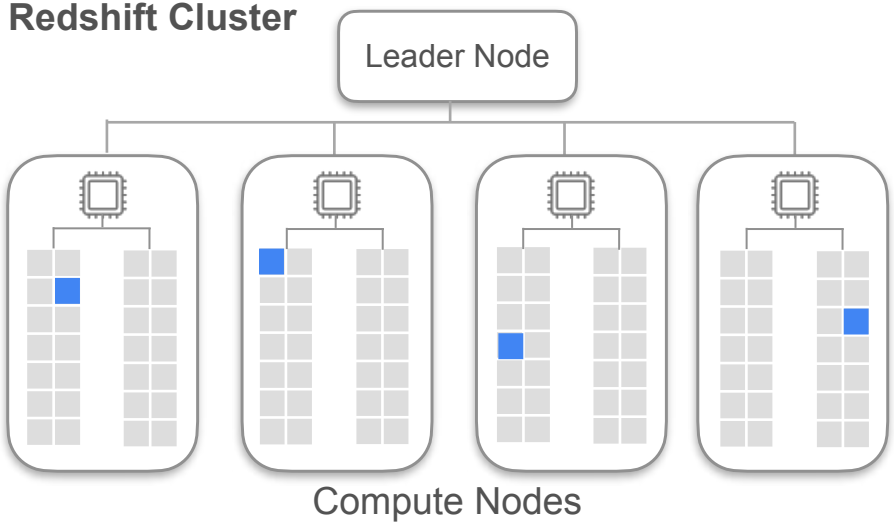
Query Performance

- Number of nodes
- Type of nodes

Table Design

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
2	23	06-15-2024	14	124
3	45	07-03-2024	12	3465
…	…	…	…	…

Redshift Cluster



Distribution Style

Sort Key

Table Design

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
2	23	06-15-2024	14	124
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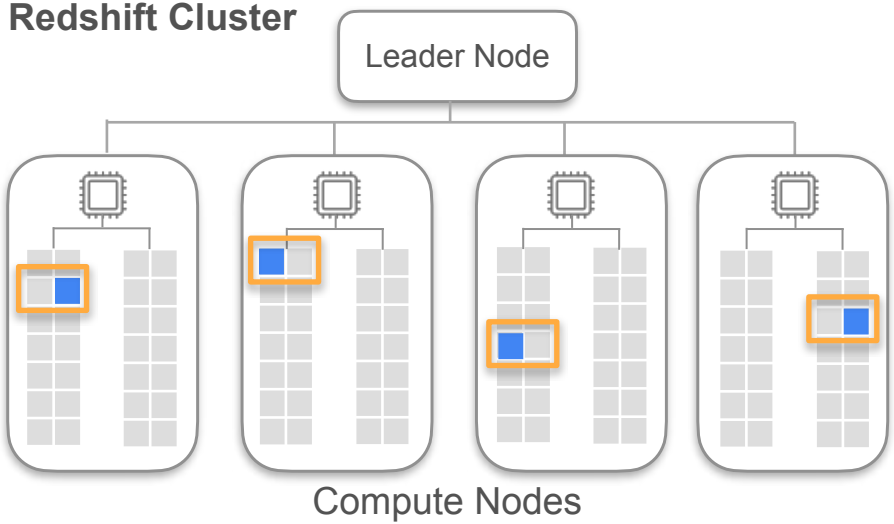
…	…	…	…	…

Redshift Cluster



Distribution Style

Sort Key

Table Design

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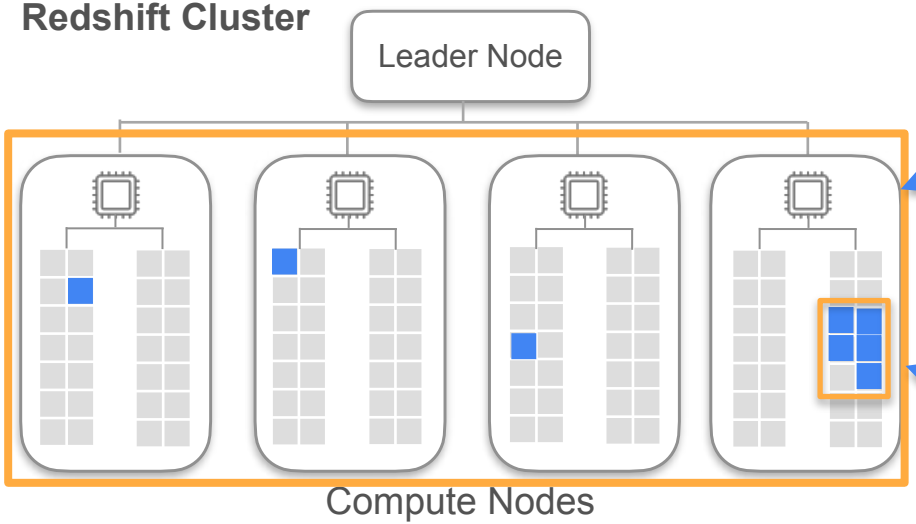
3	45	07-03-2024	12	3465
…	…	…	…	…

Distribution Style

1. Uniform Distribution across nodes

Redshift Cluster



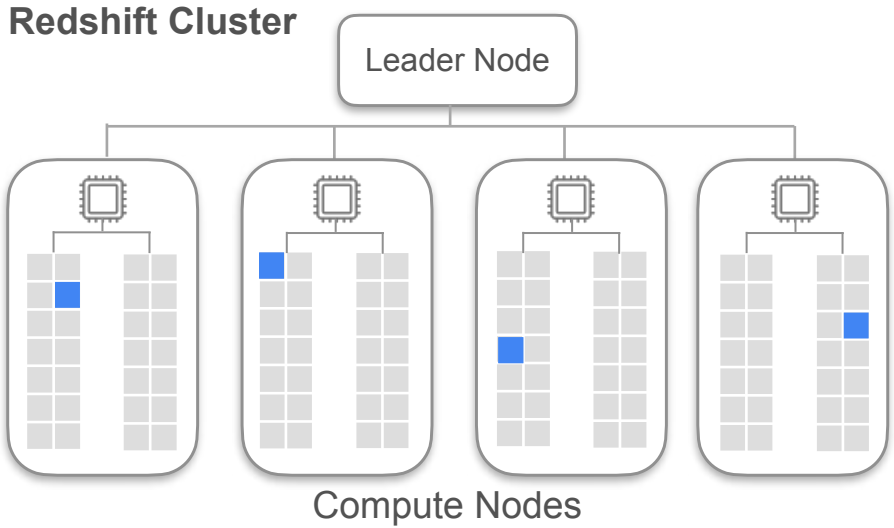
Waiting on this node

Sort Key

Uneven Distribution or Distribution Skew

Table Design

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
2	23	06-15-2024	14	124
3	45	07-03-2024	12	3465
…	…	…	…	…



Distribution Style

1. Uniform Distribution across nodes
2. Minimize data movement across nodes
   (Impact query performance and cost)

Sort Key

Table Design

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
2	23	06-15-2024	14	124
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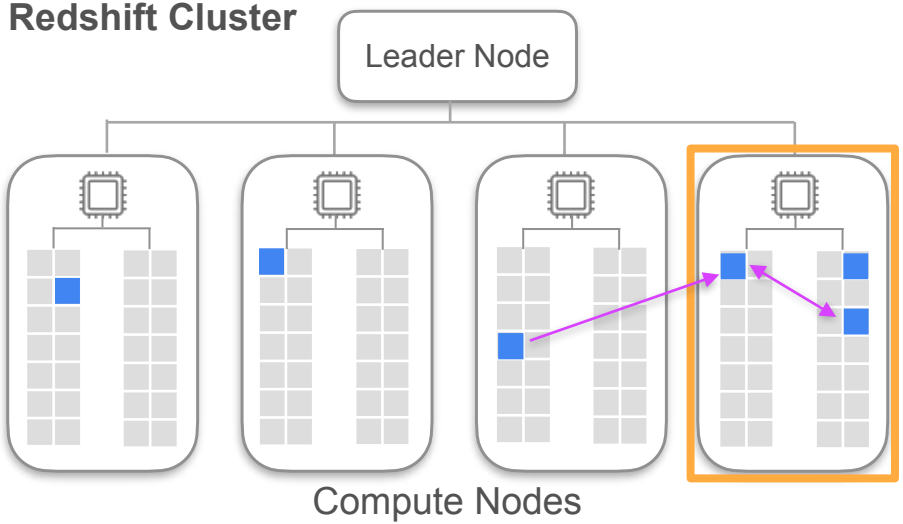
…	…	…	…	…

Redshift Cluster



Distribution Style

1. Uniform Distribution across nodes
2. Minimize data movement across nodes
   (Impact query performance and cost)

AUTO **EVEN**

KEY **ALL**

Sort Key

Table Design

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
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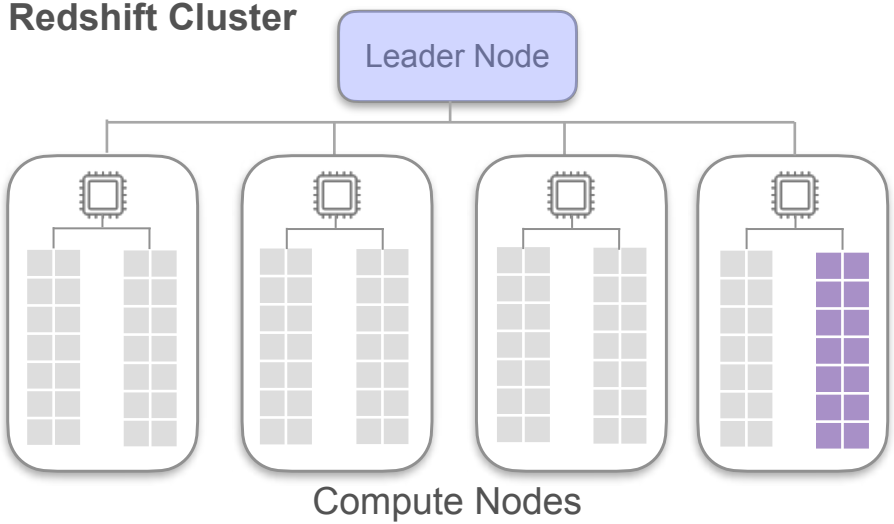
3	45	07-03-2024	12	3465
…	…	…	…	…

Redshift Cluster



Distribution Style

1. Uniform Distribution across nodes
2. Minimize data movement across nodes
   (Impact query performance and cost)

AUTO **EVEN**

KEY
- Distribute rows based on specified column

ALL

Sort Key

Table Design

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
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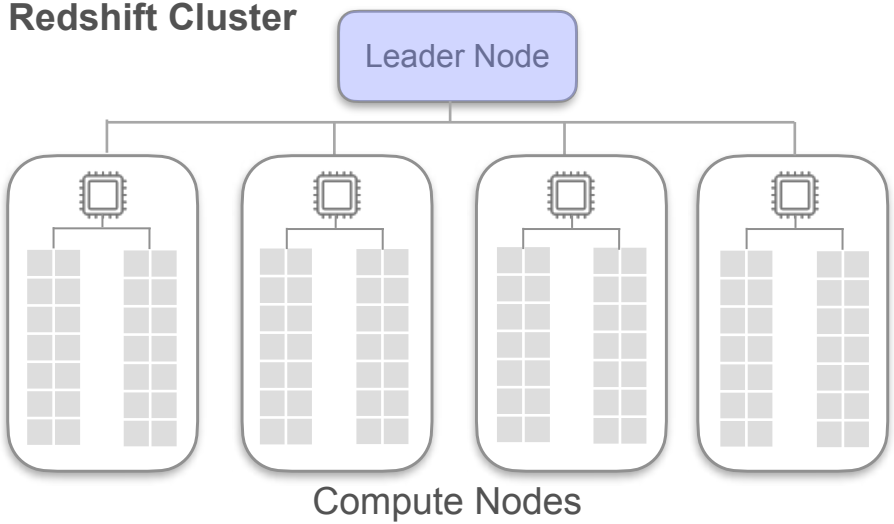
Redshift Cluster



Distribution Style

1. Uniform Distribution across nodes
2. Minimize data movement across nodes
   (Impact query performance and cost)

AUTO (ALL / EVEN / KEY)
- Default distribution style

EVEN

KEY
- Distribute rows based on specified column

ALL

Sort Key

Table Design

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
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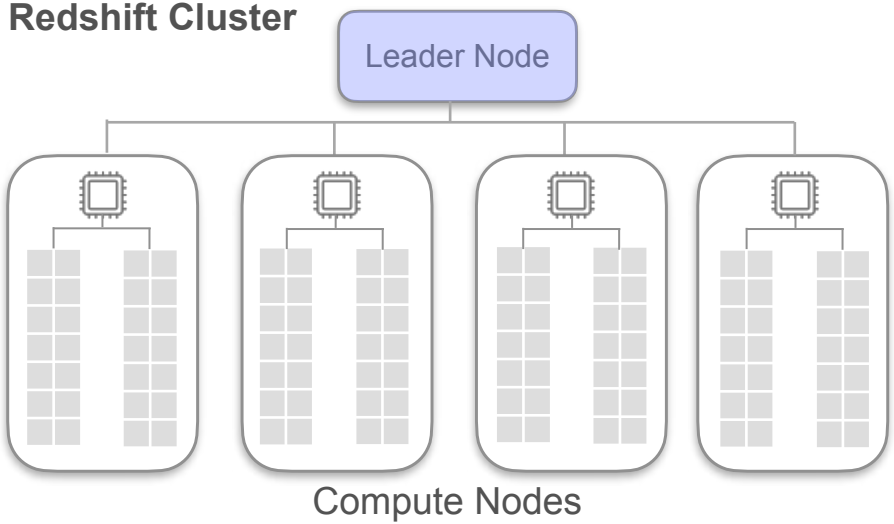
Redshift Cluster



Distribution Style

1. Uniform Distribution across nodes
2. Minimize data movement across nodes
   (Impact query performance and cost)

AUTO (ALL / EVEN / KEY)

- Default distribution style

EVEN

- Round-robin distribution
- No joins

KEY

- Distribute rows based on specified column

ALL

Sort Key

Table Design

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
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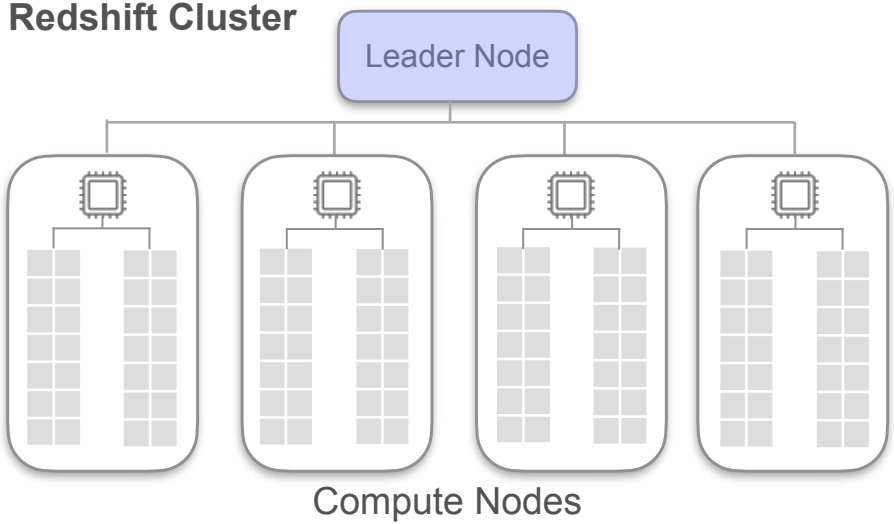
Redshift Cluster



Distribution Style

1. Uniform Distribution across nodes
2. Minimize data movement across nodes
   (Impact query performance and cost)

AUTO (ALL / EVEN / KEY)
- Default distribution style

EVEN
- Round-robin distribution
- No joins

KEY
- Distribute rows based on specified column

ALL
- Copies table to each node

Sort Key

Table Design

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
2	23	06-15-2024	14	124
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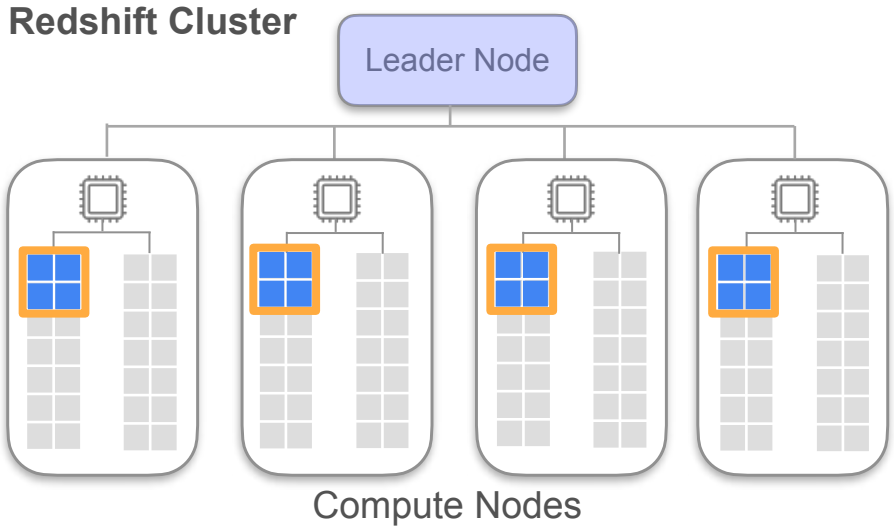


Distribution Style

1. Uniform Distribution across nodes
2. Minimize data movement across nodes
   (Impact query performance and cost)

AUTO (ALL / EVEN / KEY)
- Default distribution style

EVEN
- Round-robin distribution
- No joins

KEY
- Distribute rows based on specified column

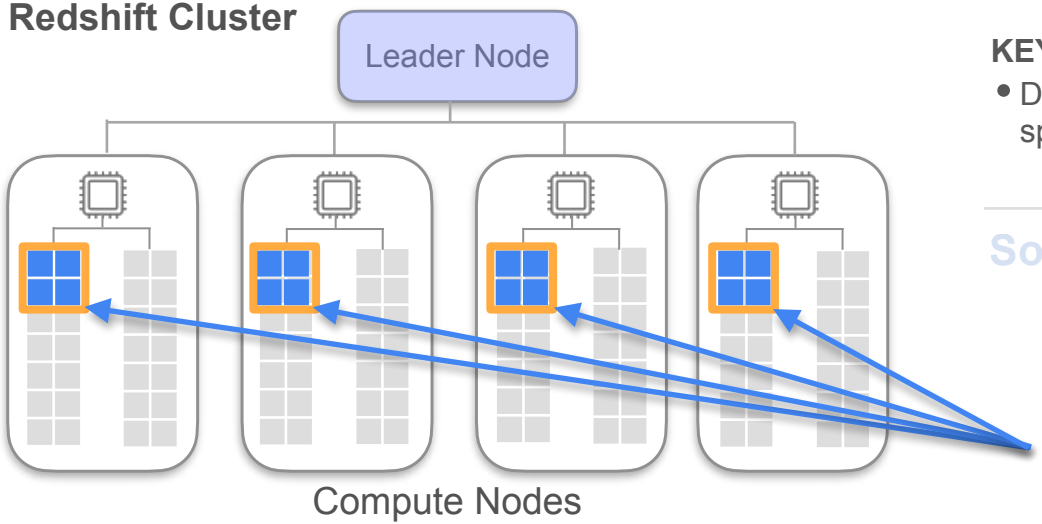
ALL
- Copies table to each node
- Eliminates data shuffling

Sort Key

Table Design

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
2	23	06-15-2024	14	124
3	45	07-03-2024	12	3465
…	…	…	…	…

Redshift Cluster



Distribution Style

1. Uniform Distribution across nodes
2. Minimize data movement across nodes
   (Impact query performance and cost)

AUTO (ALL / EVEN / KEY)
- Default distribution style

EVEN
- Round-robin distribution
- No joins

KEY
- Distribute rows based on specified column

ALL
- Copies table to each node
- Eliminates data shuffling
- Takes longer

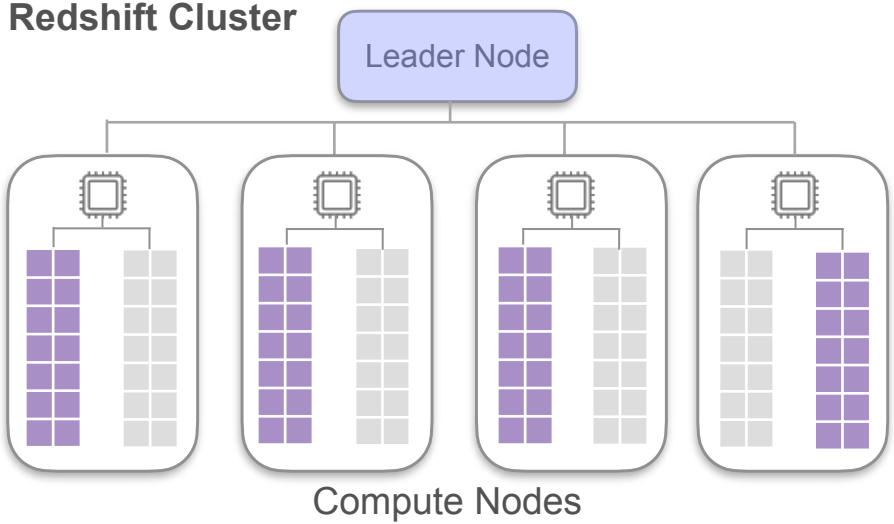
Multiples the storage required by the number of nodes

Sort Key

Table Design

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
2	23	06-15-2024	14	124
3	45	07-03-2024	12	3465
…	…	…	…	…

Redshift Cluster



Distribution Style

1. Uniform Distribution across nodes
2. Minimize data movement across nodes
   (Impact query performance and cost)

AUTO (ALL / EVEN / KEY)
- Default distribution style

EVEN
- Round-robin distribution
- No joins

KEY
- Distribute rows based on specified column

ALL
- Copies table to each node
- Eliminates data shuffling
- Takes longer

Sort Key

- Stores data on disk based on sort key
- Helps query optimizer determine optimal query plan

Table Design

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
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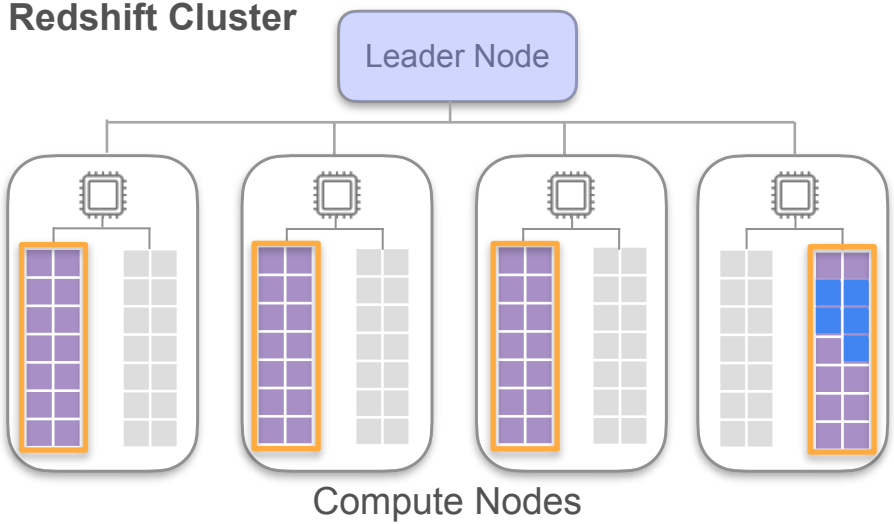
Redshift Cluster



Distribution Style

1. Uniform Distribution across nodes
2. Minimize data movement across nodes
   (Impact query performance and cost)

AUTO (ALL / EVEN / KEY)
- Default distribution style

EVEN
- Round-robin distribution
- No joins

KEY
- Distribute rows based on specified column

ALL
- Copies table to each node
- Eliminates data shuffling
- Takes longer

Sort Key

- Stores data on disk based on sort key
- Helps query optimizer determine optimal query plan
- Minimizes disk read operations
- Speed up query

Table Design

Order ID	Price	Order date	Quantity	Customer ID
1	40	05-22-2025	10	1337
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3	45	07-03-2024	12	3465
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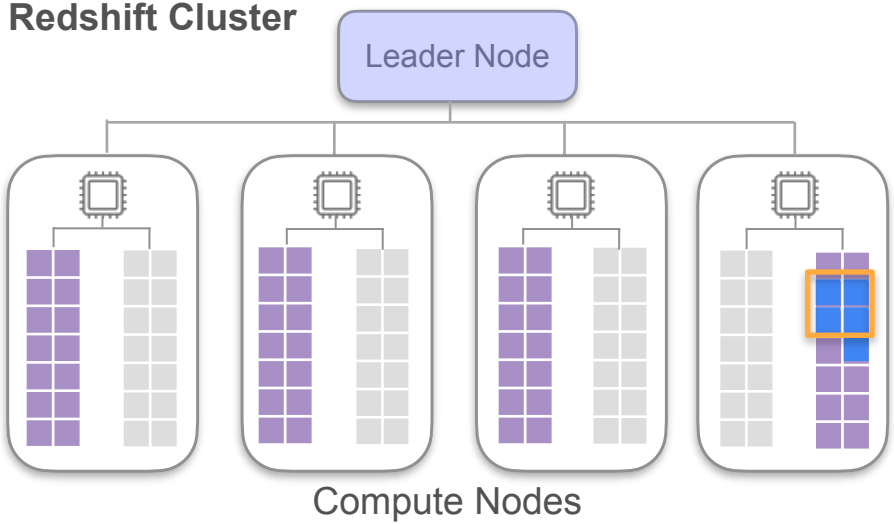
Redshift Cluster



Distribution Style

1. Uniform Distribution across nodes
2. Minimize data movement across nodes
   (Impact query performance and cost)

AUTO (ALL / EVEN / KEY)
- Default distribution style

EVEN
- Round-robin distribution
- No joins

KEY
- Distribute rows based on specified column

ALL
- Copies table to each node
- Eliminates data shuffling
- Takes longer

Sort Key (Similar to OLTP database indexes)

- Stores data on disk based on sort key
- Helps query optimizer determine optimal query plan
- Minimizes disk read operations
- Speed up query

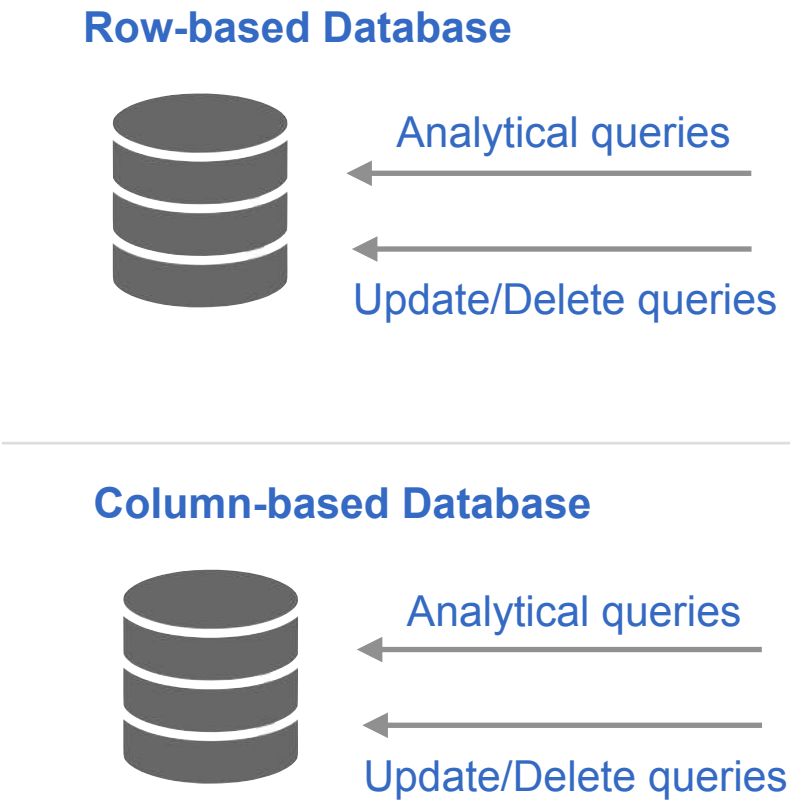
DeepLearning.AI

Lab Walkthrough

Query Comparison Between Row and Columnar Databases

Lab Overview

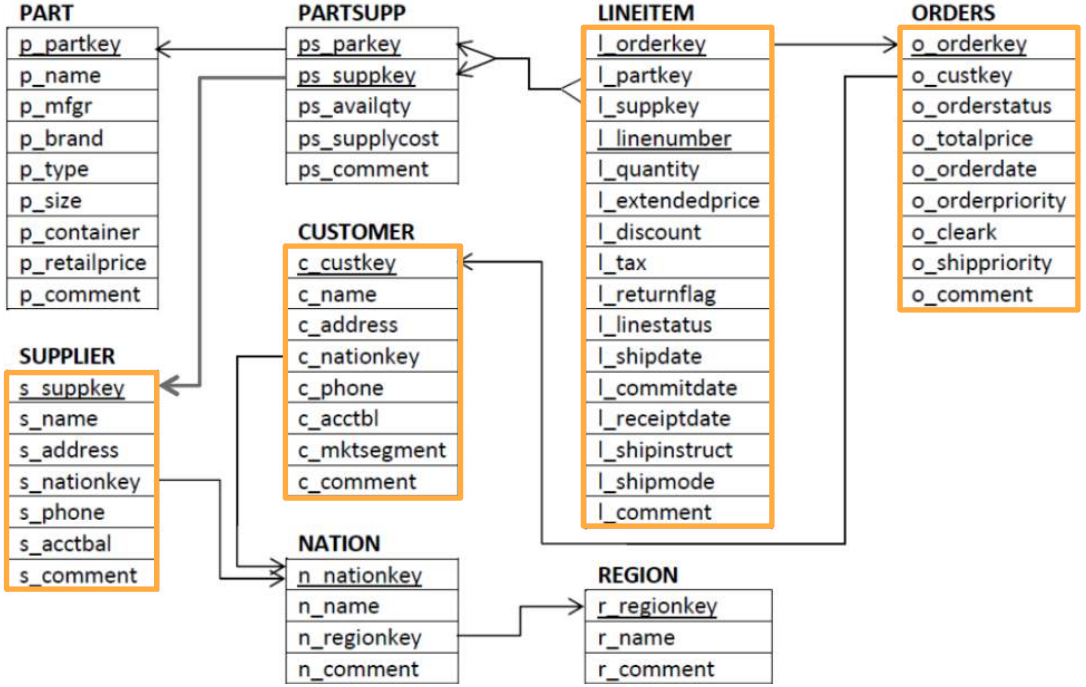
- Compare their execution times.
- In this video: overview of the dataset and the results of the experiments.



Benchmarking Dataset

TPC-H Benchmark:

Evaluate the performance of various database systems



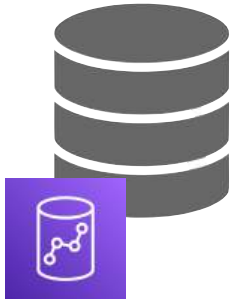
Row-based Database

PostgreSQL

5 Analytical queries

Update/Delete queries

Column-based Database



Amazon Redshift

5 Analytical queries

Update/Delete queries

Benchmarking Dataset

Generate 50 rows containing random entries:

- Write the rows and compare the execution time
- Delete the rows and compare the execution time

LINEITEM
l_orderkey
l_partkey
l_suppkey
l_linenumber
l_quantity
l_extendedprice
l_discount
l_tax
l_returnflag
l_linestatus
l_shipdate
l_commitdate
l_receiptdate
l_shipinstruct
l_shipmode
l_comment

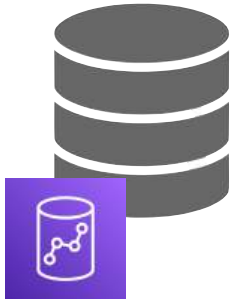
Row-based Database

Analytical queries

Update/Delete queries

PostgreSQL

Column-based Database



Analytical queries

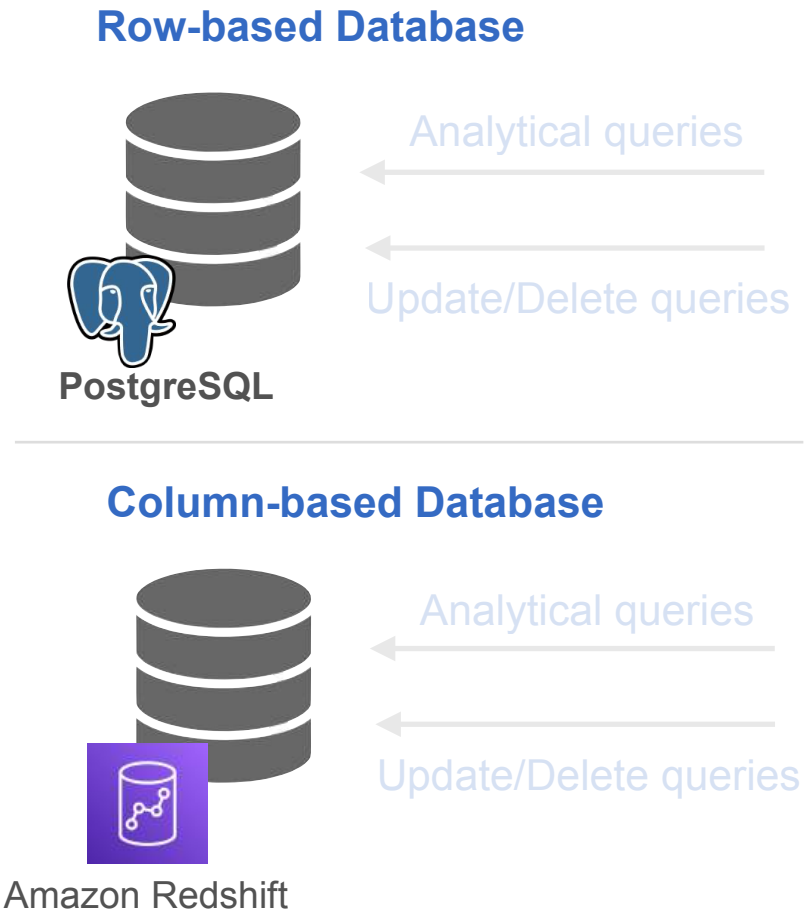
Update/Delete queries

Amazon Redshift

Lab Overview

You will first:

- Establish a connection to the redshift database
- Issue some queries

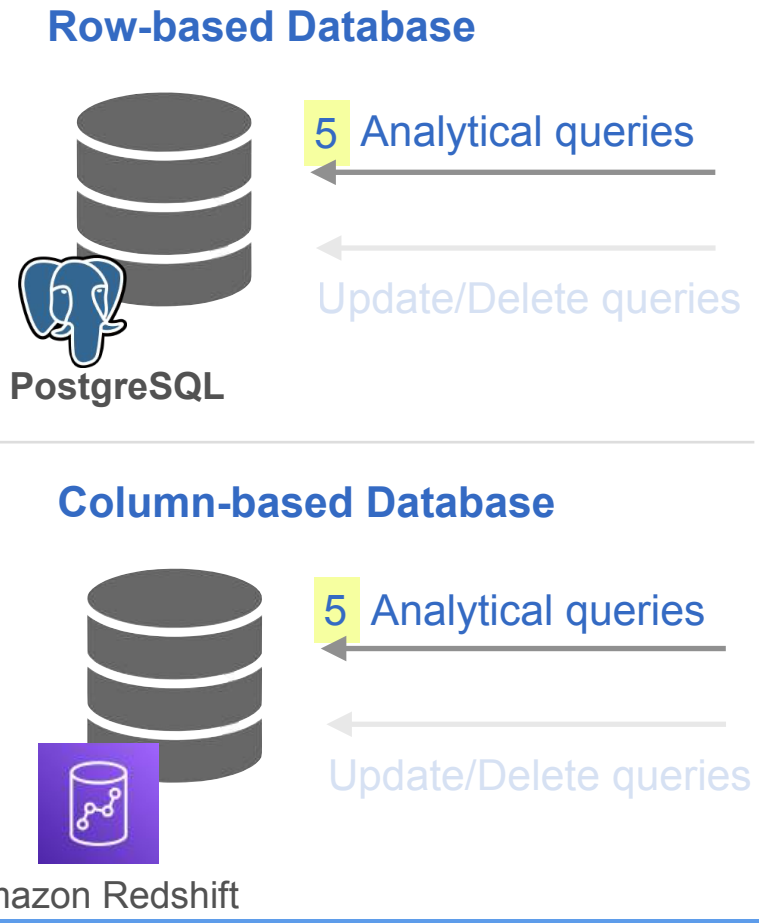


Experiments

TPC-H Benchmark

Execution times for the **analytical queries** run once

	Column-Based Database	Row-Based Database
First TPC-H query	291 ms	2 min 41 s
Second TPC-H query	87 ms	1 min 10 s
Third TPC-H query	4.33 s	5 min 35 s
Fourth TPC-H query	233 ms	1 min 16 s
Fifth TPC-H query	3.1 s	1 min 36 s



Experiments

Execution times for the **write/delete queries** run once

	Column-Based Database	Row-Based Database
Write 50 rows	7.4 s	456 ms
Delete 50 rows	16.4 s	176 ms

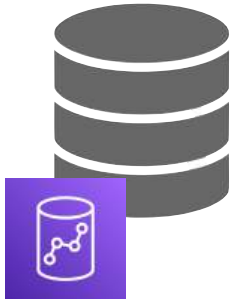
Row-based Database

PostgreSQL

Analytical queries

Update/Delete queries

Column-based Database



Amazon Redshift

Analytical queries

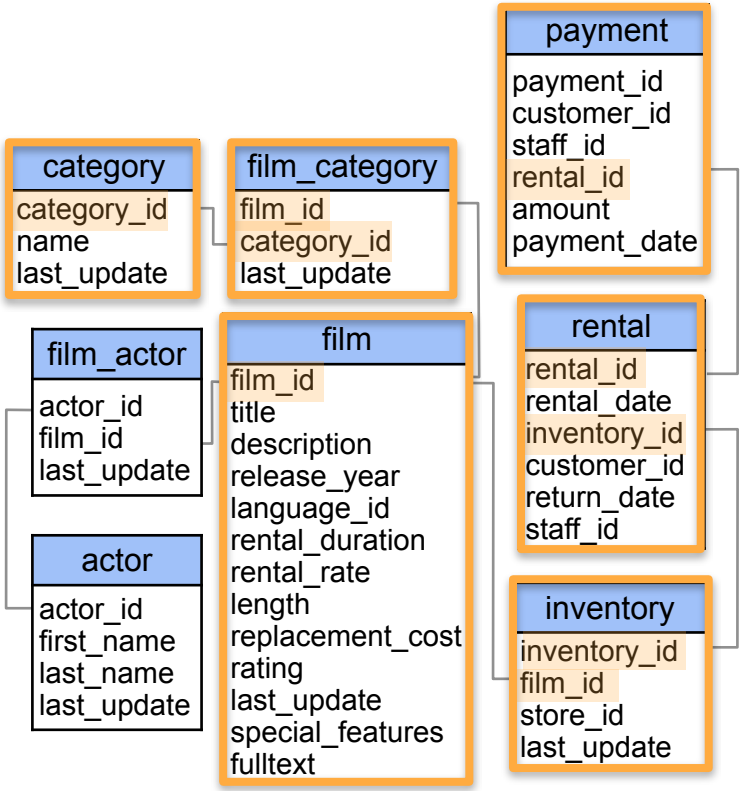
Update/Delete queries

DeepLearning.AI

Queries

Additional Query Strategies

Leverage Query Caching

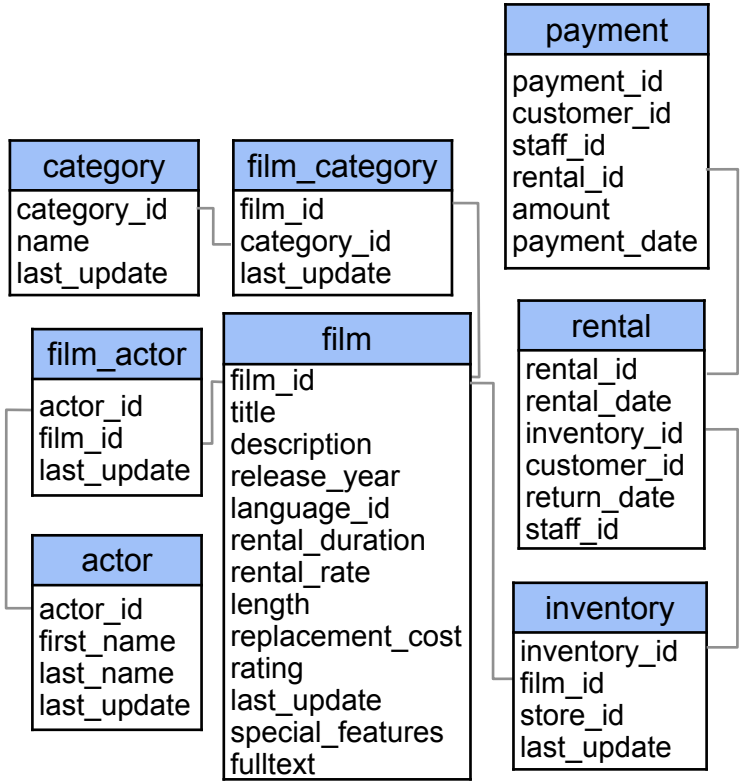


Total amount spent: family, drama, and comedy categories

```
SELECT SUM(payment.amount) AS amount
FROM payment
JOIN rental ON rental.rental_id = payment.rental_id
JOIN inventory ON inventory.inventory_id = rental.inventory_id
JOIN film ON film.film_id = inventory.film_id
JOIN film_category ON film_category.film_id = film.film_id
JOIN category ON category.category_id = film_category.category_id
WHERE category.name IN ('Family', 'Drama', 'Comedy')
GROUP BY category.name
ORDER BY amount
```

- Running a complex query frequently can be costly
- Many databases allow you to cache query results
- **Query caching** can reduce the load on your database and enhance the user experience

Prioritize Readability



Readable queries:

- Less likely to contain errors
- Simpler to debug
- Easier to collaborate on

CTE
(Common Table Expressions)

Creates a temporary result set that you can reference in your query

```
WITH selected_film AS (
      SELECT film_id
      FROM film
      WHERE title = "Rocky War"
),
film_actors_id AS (
      SELECT actor_id
      FROM film_actor
      WHERE film_id IN selected_film
)
SELECT actor.first_name, actor.last_name
FROM actor
WHERE actor_id IN film_actors_id
```

Prioritize Readability

Readable queries:

- Less likely to contain errors
- Simpler to debug
- Easier to collaborate on

CTE
(Common Table Expressions)

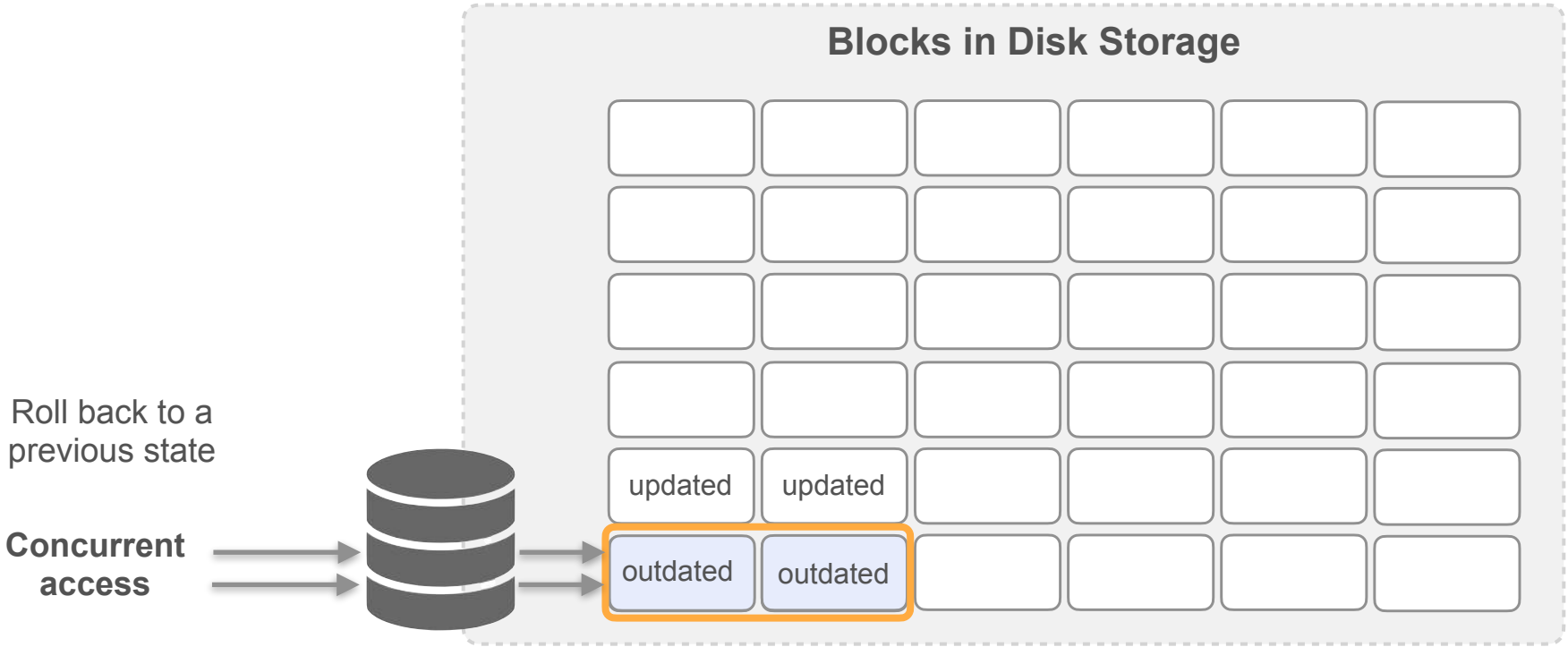
Creates a temporary result set that you can reference in your query

Nested Subqueries

```
SELECT actor.first_name, actor.last_name
FROM actor
WHERE actor.actor_id IN (
      SELECT actor_id
      FROM film_actor
      WHERE film_id = (
            SELECT film_id
            FROM film
            WHERE title = 'Rocky War'
      )
)
```

```
WITH selected_film AS (
      SELECT film_id
      FROM film
      WHERE title = "Rocky War"
),
film_actors_id AS (
      SELECT actor_id
      FROM film_actor
      WHERE film_id IN selected_film
)
SELECT actor.first_name, actor.last_name
FROM actor
WHERE actor_id IN film_actors_id
```

Database Resources

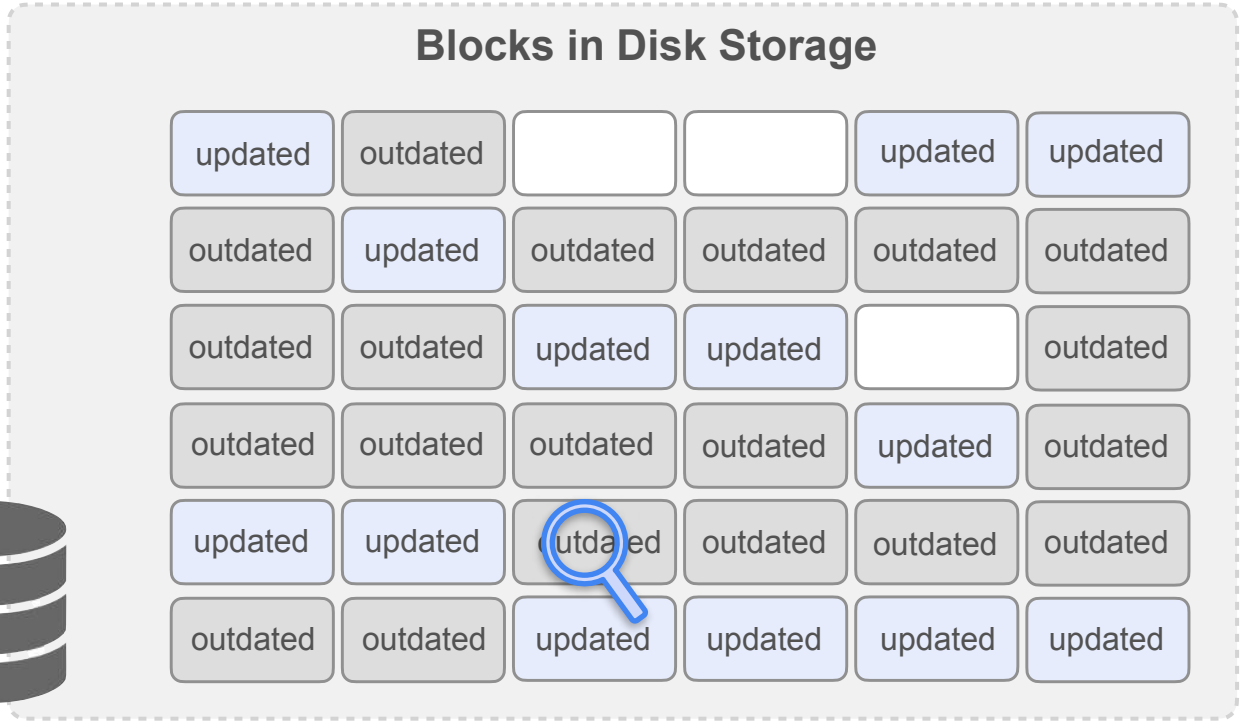


Database Resources

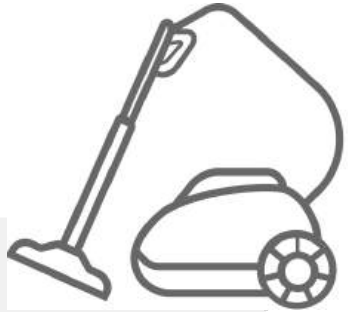
Table Bloat

The data size on the disk exceeds the actual data size

- Wasted disk space
- Slow queries
- Suboptimal and inaccurate execution plans
- Inefficient indexes



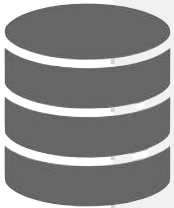
Database Resources



Vacuuming

Removing the dead records

- Critical for relational databases (PostgreSQL, MySQL)
- Familiarize yourself with the details of vacuuming



Blocks in Disk Storage

updated	outdated			updated	updated
outdated	updated	outdated	outdated	outdated	outdated
outdated	outdated	updated	updated		outdated
outdated	outdated	outdated	outdated	updated	outdated
updated	updated	outdated	outdated	outdated	outdated
outdated	outdated	updated	updated	updated	updated

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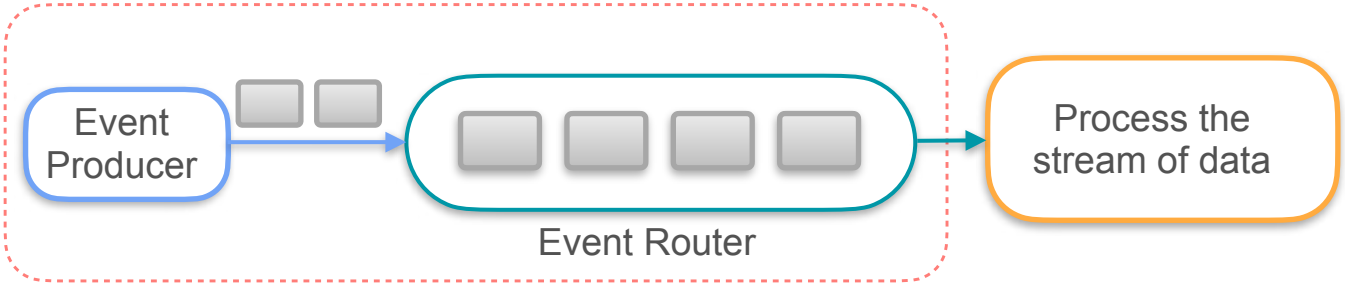
Queries

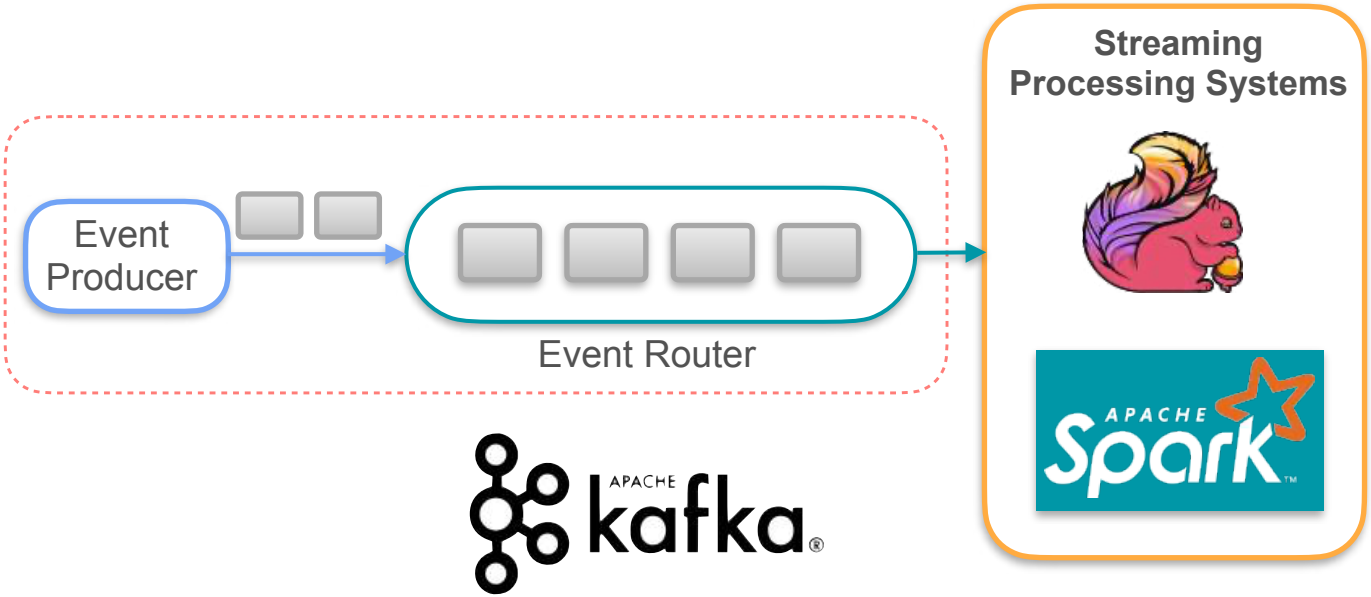
Queries on Streaming Data

Streaming System



Streaming Processing System

Apply SQL queries continuously on streaming data



Queries on Streaming Data

Windowed Query

Bound your queries using a window & apply operations over that window.
(e.g. *aggregating, adding, removing* data)

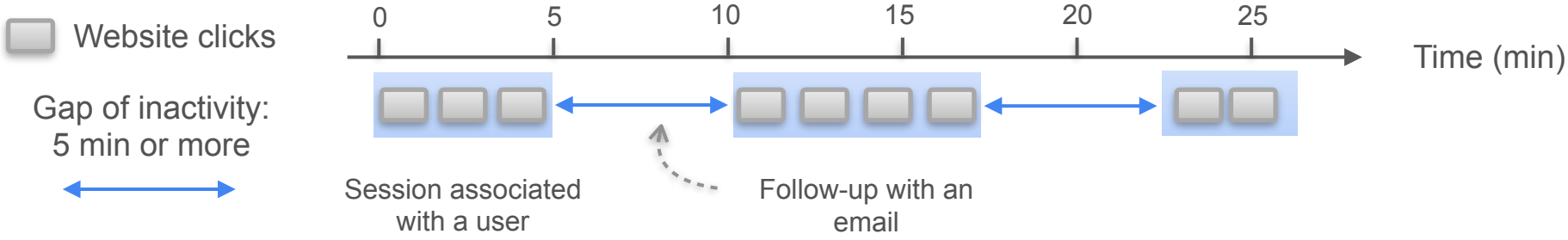
Session Window	Fixed-time Window	Sliding Window

Queries on Streaming Data

Windowed Query

Bound your queries using a window & apply operations over that window.
(e.g. *aggregating, adding, removing* data)

Session Window | Fixed-time Window | Sliding Window



Queries on Streaming Data

Windowed Query

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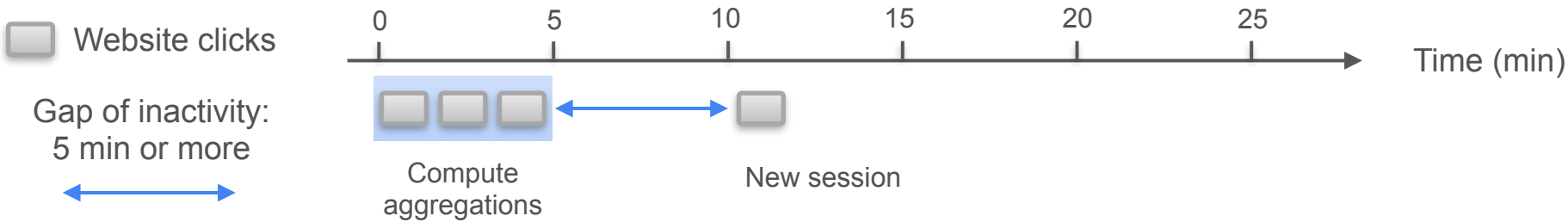
Session Window | Fixed-time Window | Sliding Window

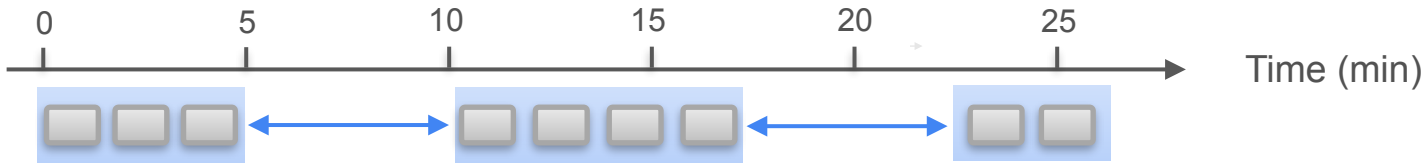


Queries on Streaming Data

Windowed Query

Bound your queries using a window & apply operations over that window.
(e.g. *aggregating, adding, removing* data)

Session Window | Fixed-time Window | Sliding Window



Queries on Streaming Data

Windowed Query

Bound your queries using a window & apply operations over that window.
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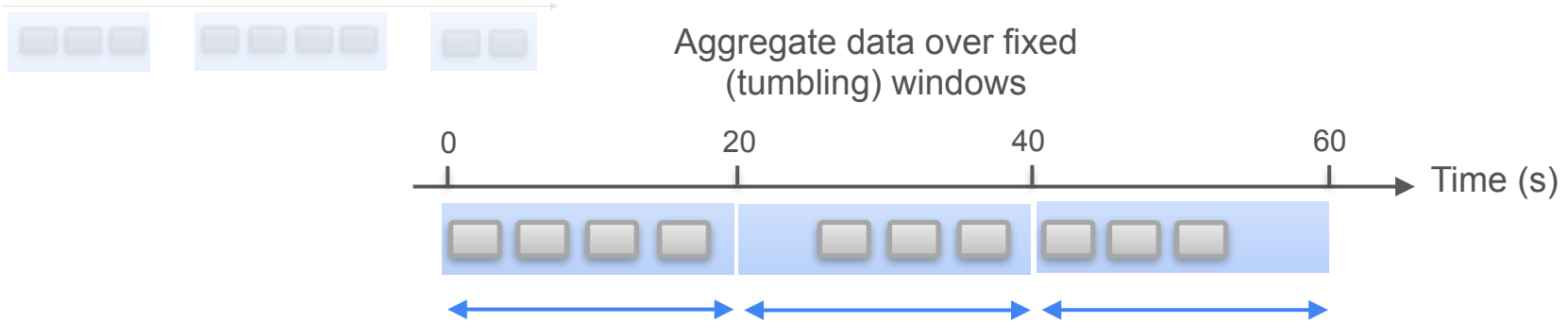
Session Window | **Fixed-time Window** | Sliding Window



Example: total number of clicks that happen every 20 seconds

Queries on Streaming Data

Windowed Query

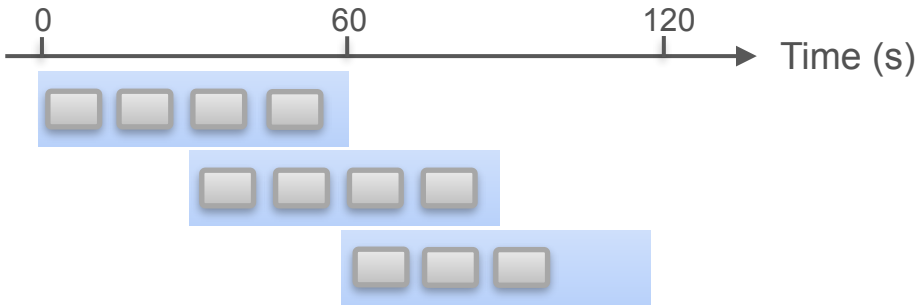
Bound your queries using a window & apply operations over that window.
(e.g. *aggregating, adding, removing* data)

Session Window

Fixed-time Window

Sliding Window

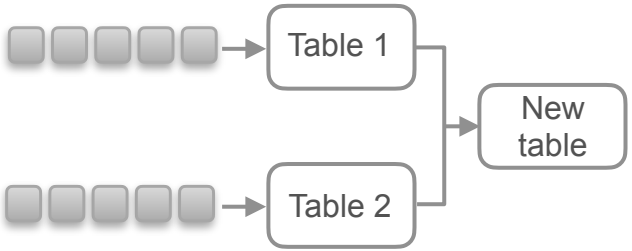
Group events into fixed time overlapping windows



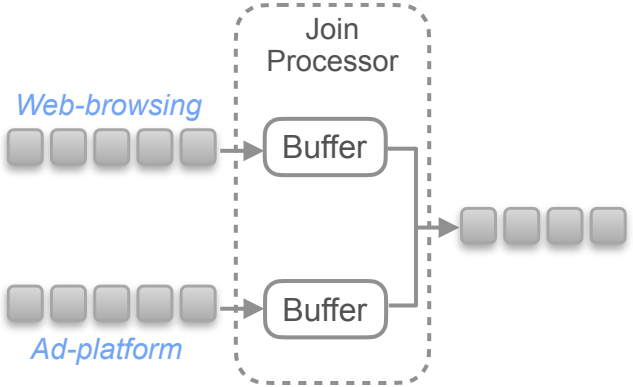
Example: calculate moving average within a time interval

Joining Data Streams

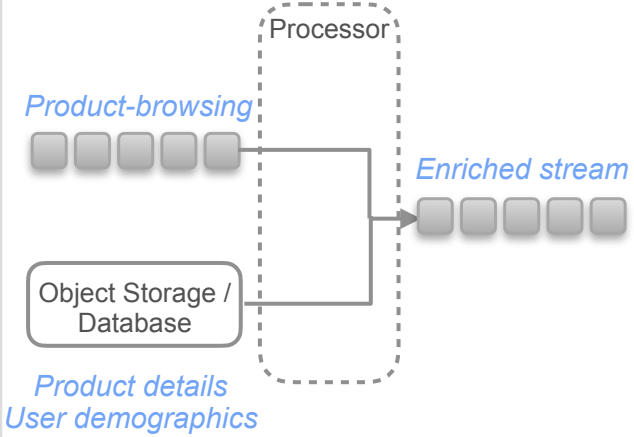
Conventional Way



Stream-to-Stream



Enrich with batch data



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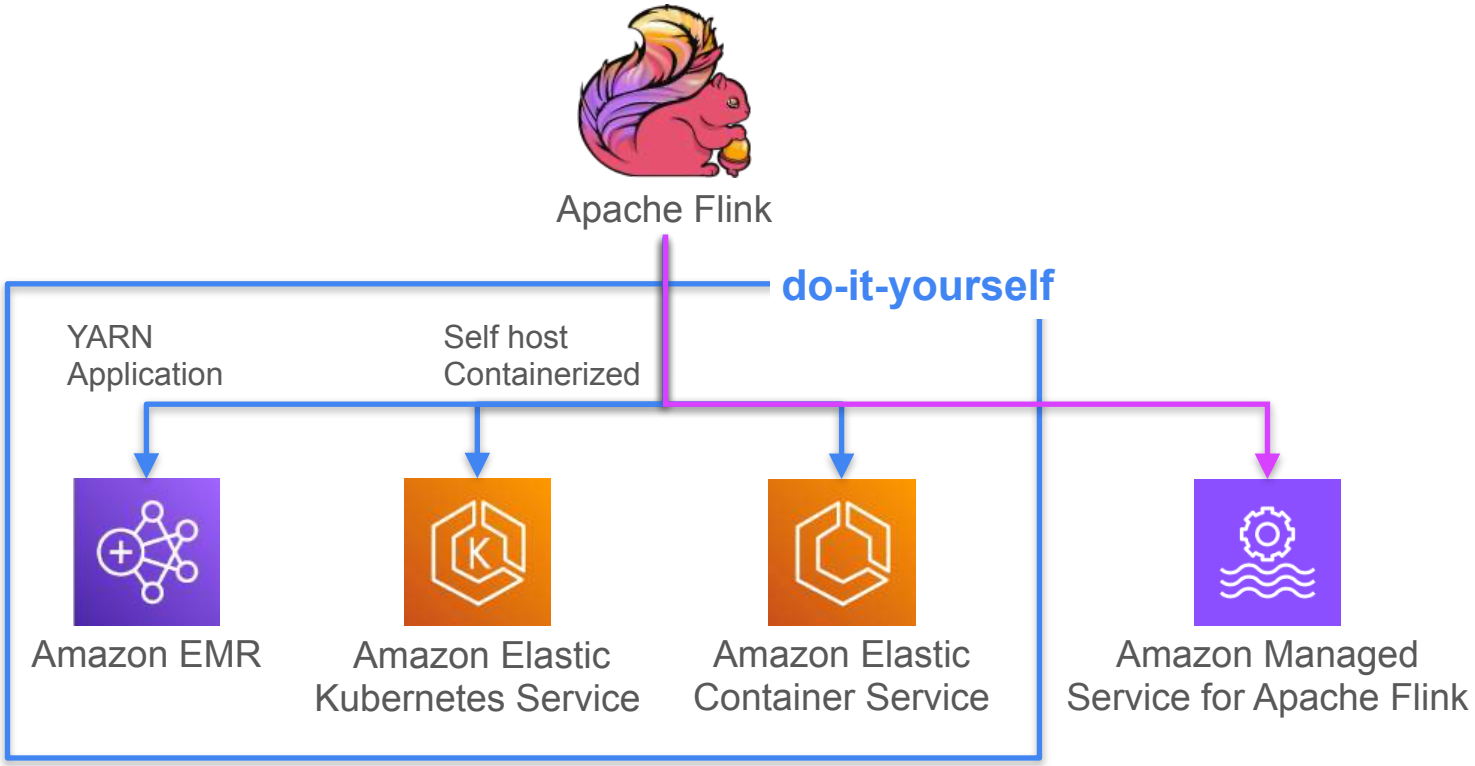
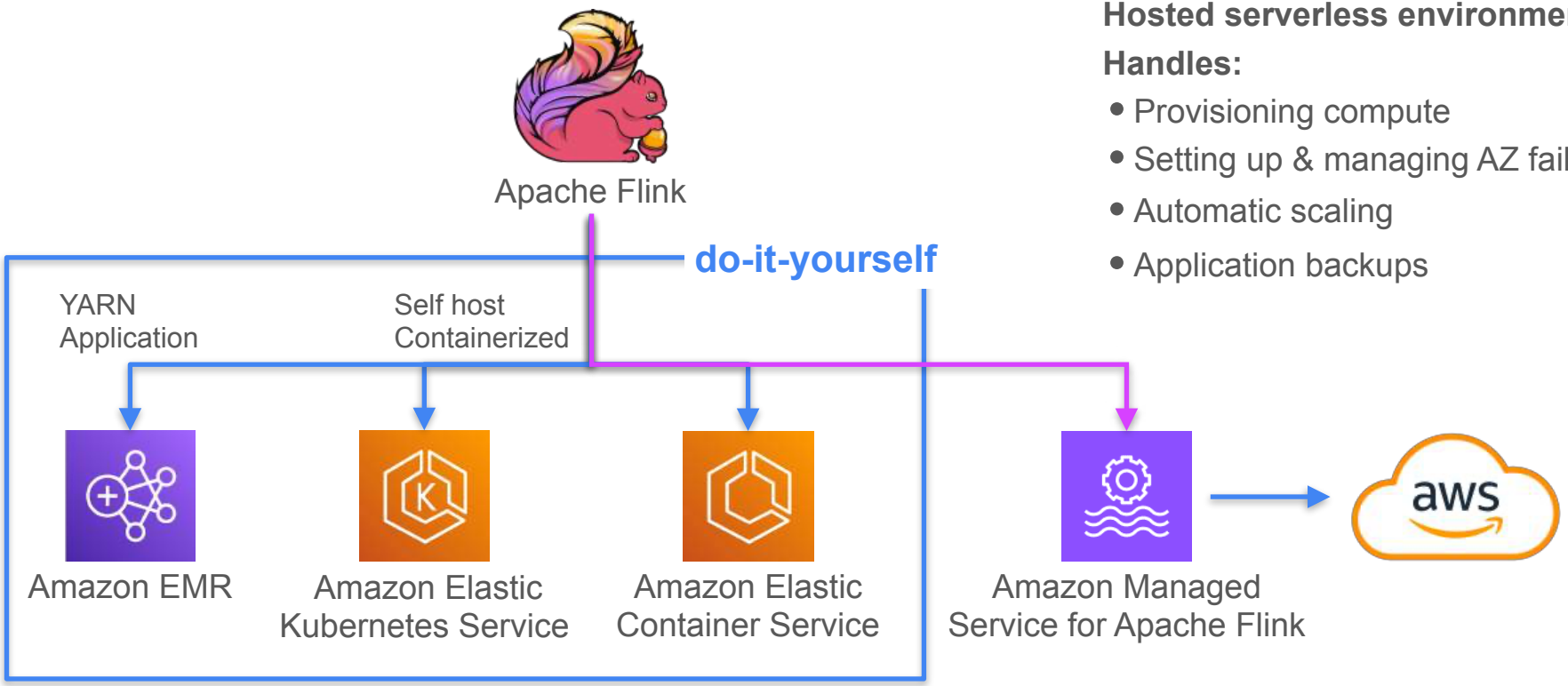
Queries

Deploying an Application with Amazon Managed Service for Apache Flink

Amazon Managed Service for Apache Flink



Amazon Managed Service for Apache Flink



Hosted serverless environment

Handles:

- Provisioning compute
- Setting up & managing AZ failover
- Automatic scaling
- Application backups

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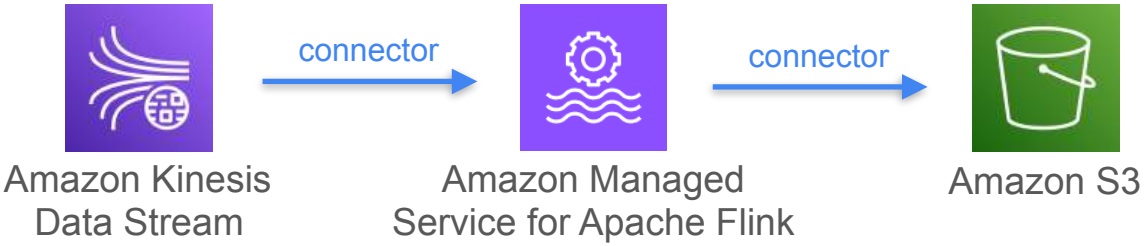
Queries

Deploying a Studio Notebook with Amazon Managed Service for Apache Flink

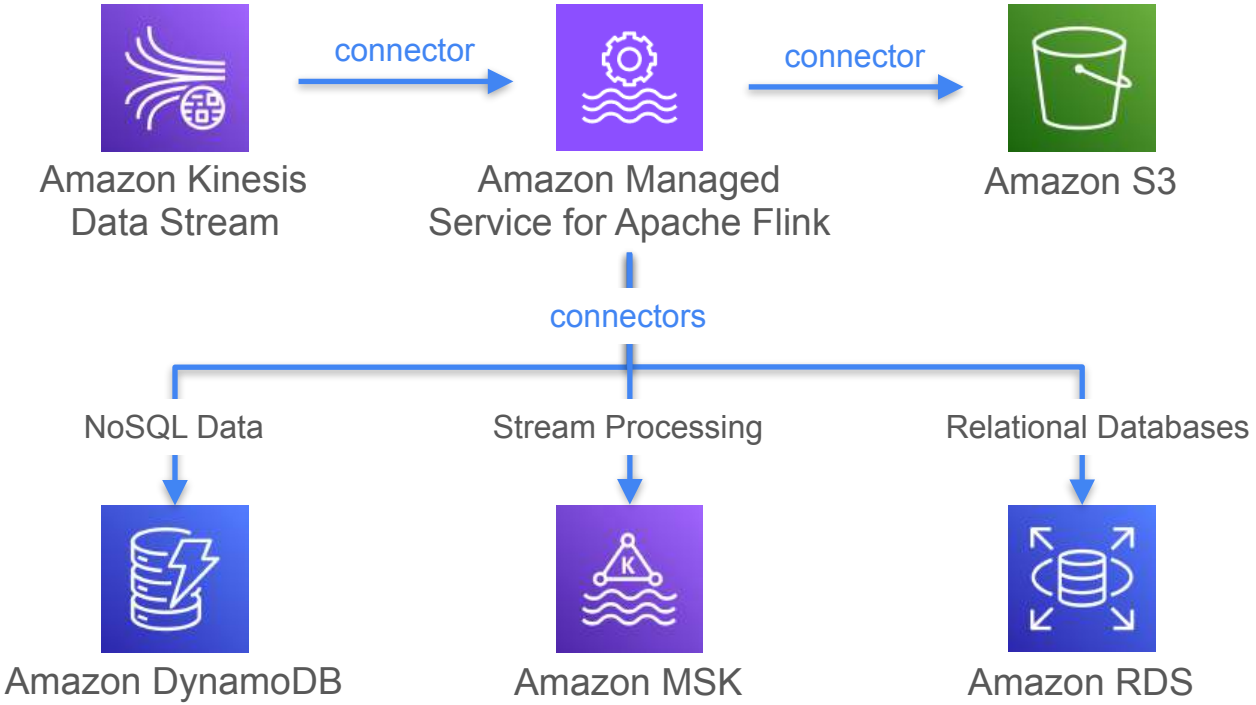
Amazon Managed Service for Apache Flink



Connectors provide code for Interfacing with:

- Databases
- Message queues
- Cloud storage services

Amazon Managed Service for Apache Flink



Connectors provide code for Interfacing with:

- Databases
- Message queues
- Cloud storage services

AWS Glue database

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Queries

Course 3 Summary

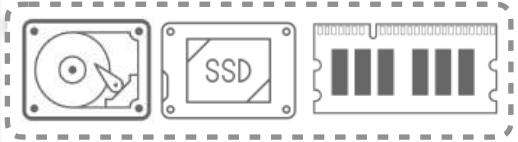
Week 1

Storage Abstractions

Storage Systems

Raw Ingredients

Physical components



Processes

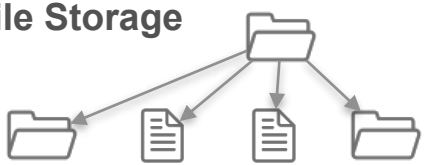
Networking Serialization

CPU

Compression Caching

Labs

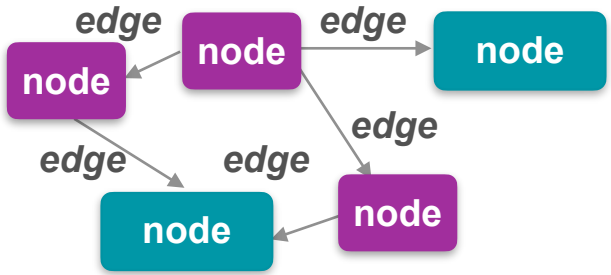
File Storage



Block Storage

Object Storage

Graph Databases



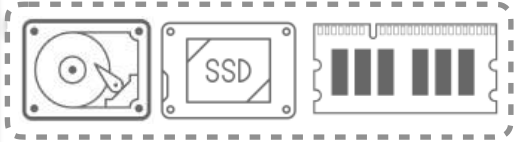
Week 2

Storage Abstractions

Storage Systems

Raw Ingredients

Physical components



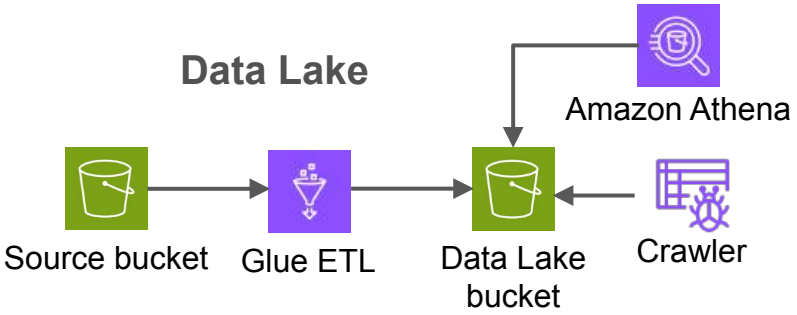
Processes

Networking Serialization

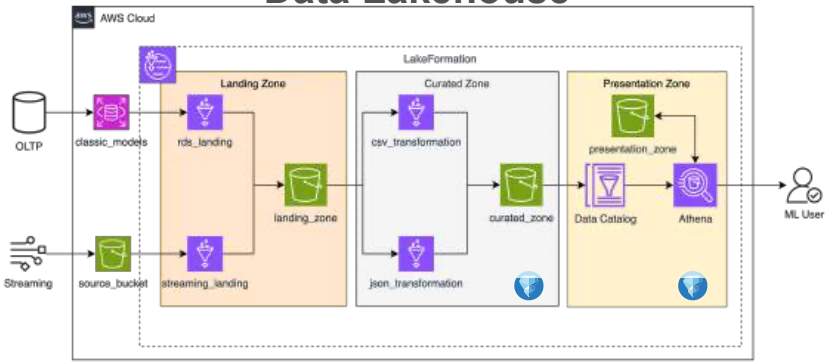
CPU

Compression Caching

Labs

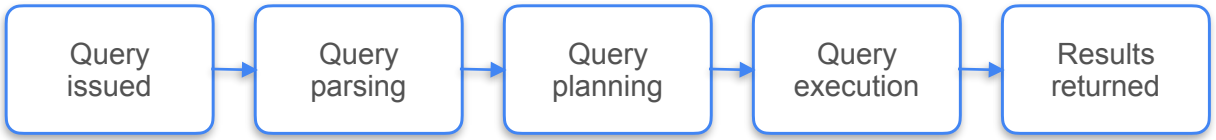


Data Lakehouse



Week 3

- Life of a query



- Processing of filtering, joining and aggregating queries

Labs

- Advanced SQL statements
- Execution time of an analytical query on a row versus columnar storage
- Time-based windowed query on streaming data

Amazon Managed Service for Apache Flink