Introduction to Database Systems - Indexes

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- Introduction
- What is an index?
- What is an appropriate index?

Introduction

- Until now we was mostly working on a conceptual level of a database system:
  - Relational data model
  - SQL
  - Normal forms
- Today we will look closer under the hood of physical representation of the data


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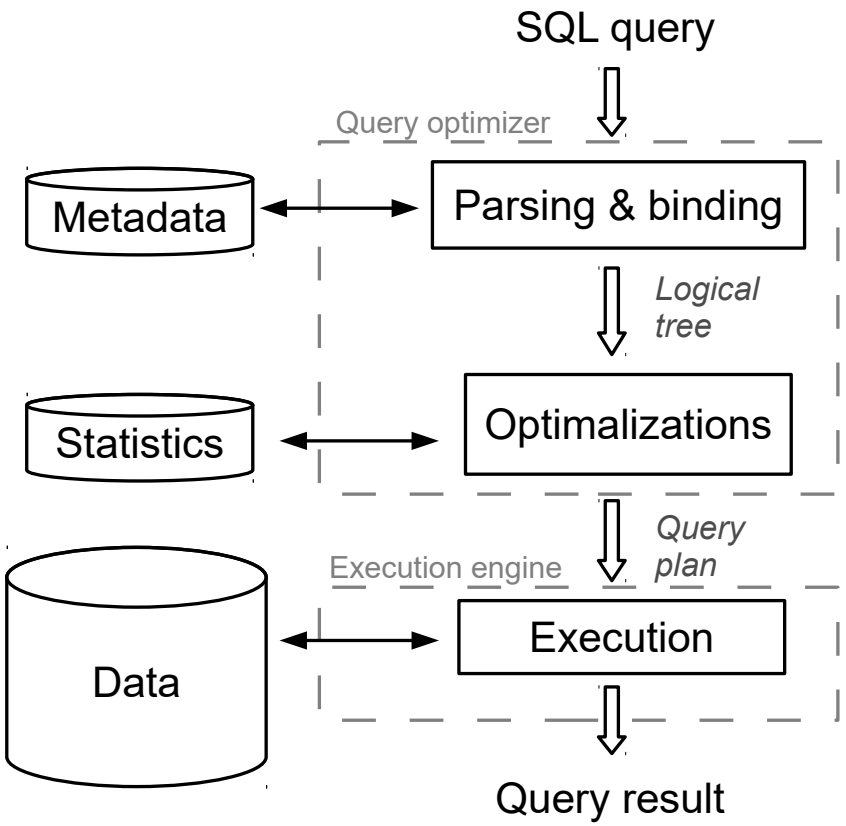
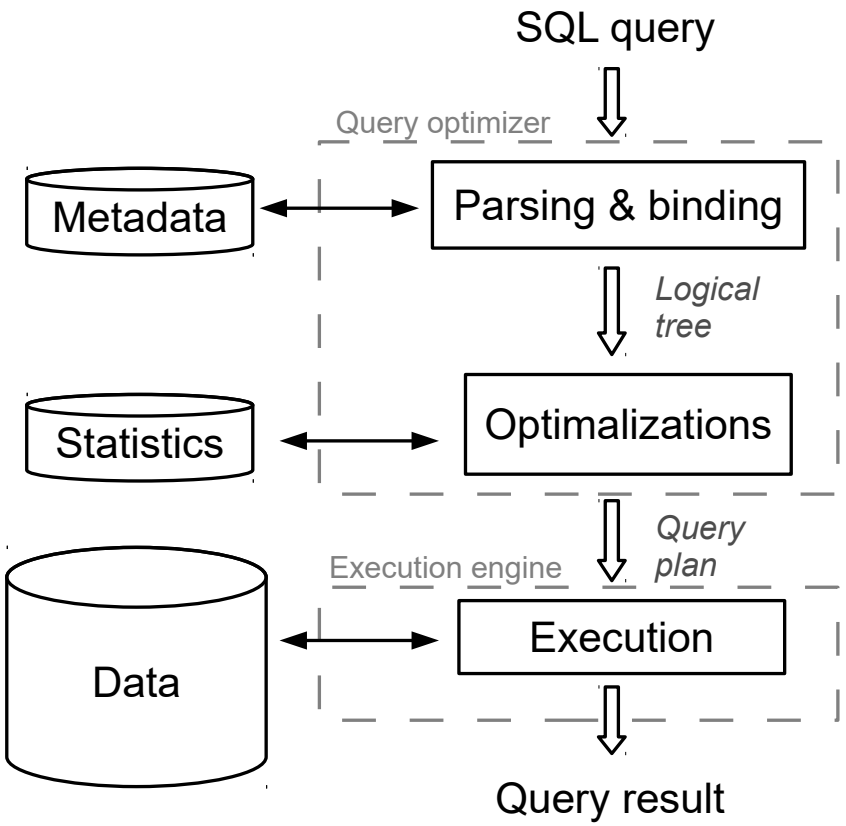
SQL Query Compilation - Remainder



- SQL query optimization is a process which takes a SQL and output an query plan
- The process of plan creation should be deterministic
- If there are appropriate index then the optimizer uses it

SQL Query Compilation - Remainder



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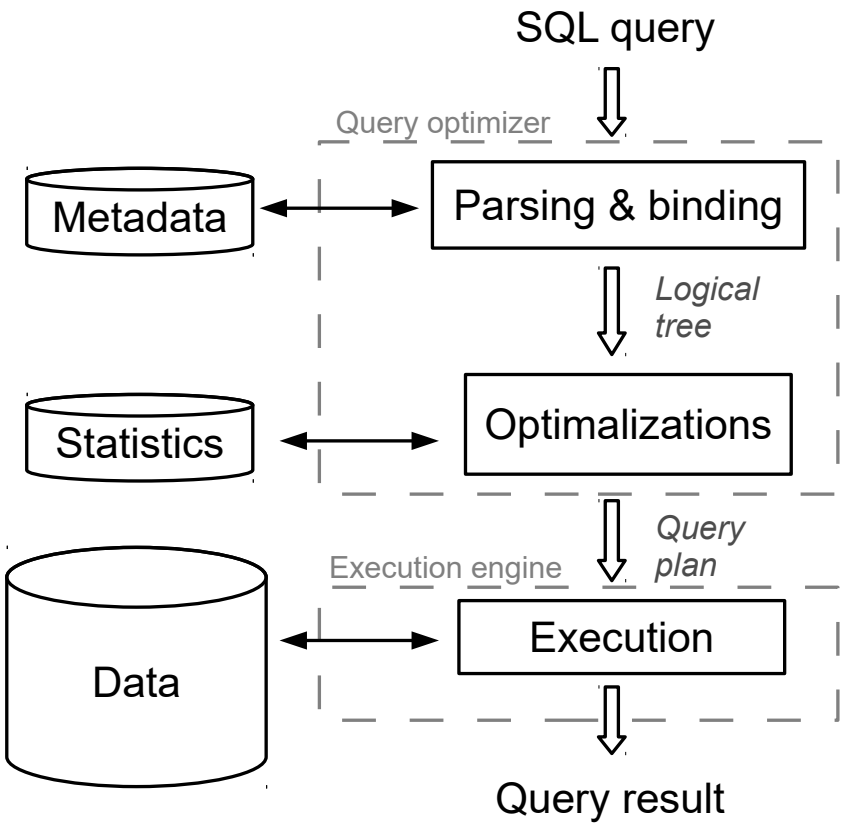

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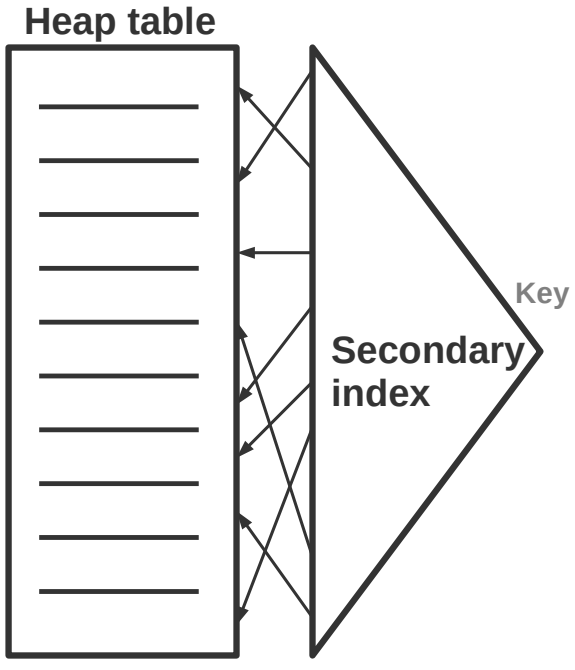
But what is an index and what is an appropriate index?

What is an Index?

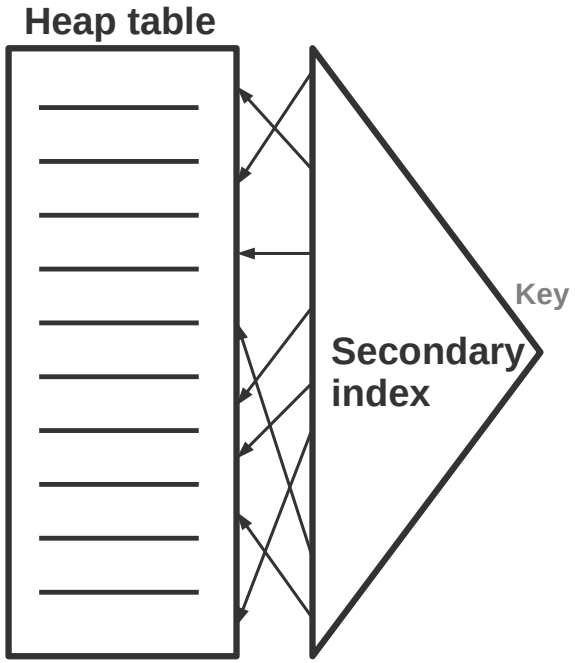
- Index allows fast search of a **value** according to a **key**
- It is data structure in a database system that can be created or dropped (see Lecture 6)
- The most typical data structure used in all database systems is a B+tree



Why B+tree?

It has a following properties

- Search of an value according to a key in $log(n)$ time
- Reasonably fast of writes into the index (insert/update/delete)
- It support range scan in leaf nodes
- Data are organized into pages

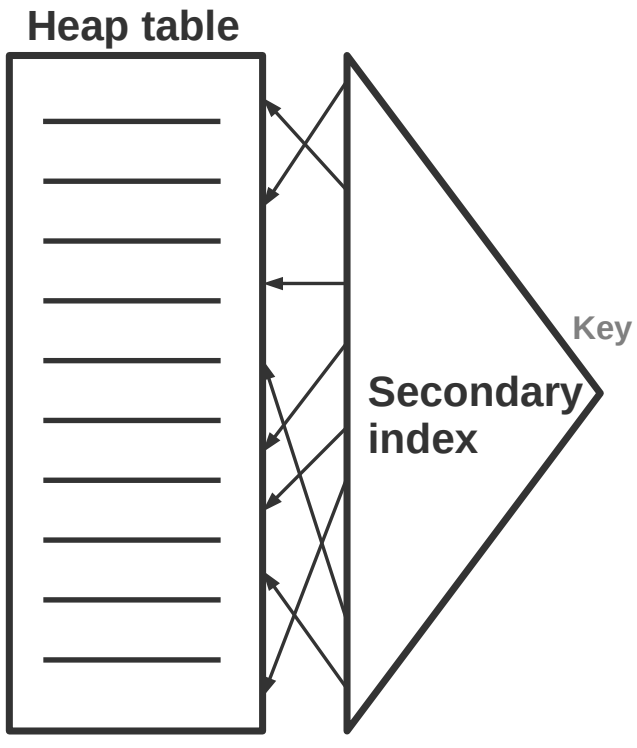


Other Data Structures

- We may use other data structures if it is appropriate:
  - R*tree - fast spatial search
  - Hash table - fast single record lookup
  - Skip list - lock free data structure
- It depends on a availability in a database system
- However, `CREATE INDEX` creates a B+tree in most database systems

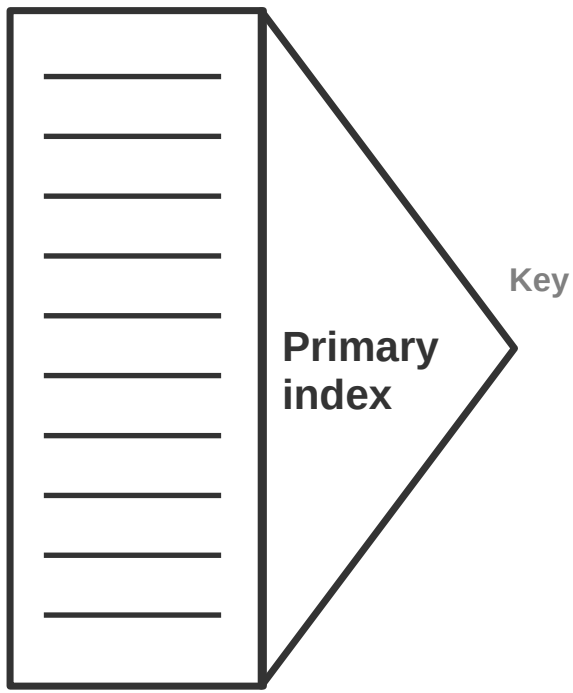
Types of Indexes

- Secondary index - value is a pointer to a table



Types of Indexes

- Primary index - value is a record of a table
- Database can contains just one such index



Primary Index

- It has different names:
  - Clustered index (SQL Server, MySQL)
  - Index organized table (Oracle)
- It is not available in all database systems (PostgreSQL)

When we Need an Index?

- Do we need an index for a table where only insert data and perform a query
  `SELECT * FROM table`?
- Definitely not
- Index helps us to process the predicates of a query more quickly
- The important observation:

The index is always connected to a SQL query (or a set of queries)

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How to Create an Index

```
SELECT * FROM table WHERE atribut = hodnota
```

↓

```
CREATE INDEX ix_table_atr ON table(atribut)
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- We create indexes according to the predicate in a query

Example - SQL Server

- `SELECT * FROM Actor WHERE first_name = 'johnny'` → Search using a sequential scan throuh the `actor` table

Example - SQL Server

- `SELECT * FROM Actor`
  `WHERE first_name = 'johnny'`
- Now lets create an index ?
- `CREATE INDEX`
  `ix_actor_firstname`
  `ON Actor(first_name)`

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Example - SQL Server

- `SELECT * FROM Actor`
  `WHERE first_name = 'johnny'`
- Now lets create an index
- `CREATE INDEX`
  `ix_actor_firstname`
  `ON Actor(first_name)`

→

The index is not used

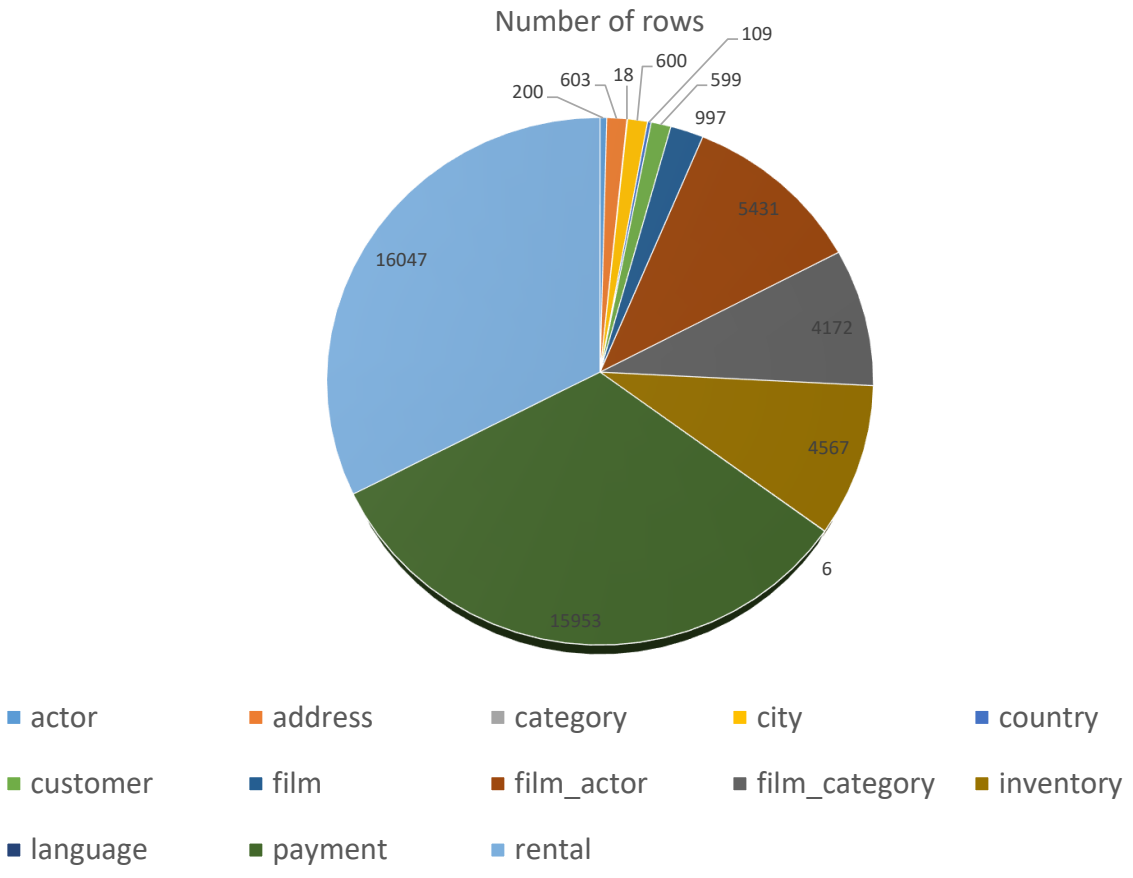
Lesson 1:

Always check the query plan after an index creation to see whether the index is used or not

Index Usage

- We need to inspect the query plan (if possible)
- There are two major types of query plan representations:
  - Graphical
  - Text
- Each database system has its own proprietary way how to display a query plan
- The query plan should contain the newly created index name

Table Statisitcs of Sakila DB



Lesson 2:

Do not bother with indexing of small tables

SARGable Predicate

- ```
  SELECT * FROM rental
  WHERE YEAR(rental_date) = 2005
     and MONTH(rendal_date) = 10
  ```
- ```
  CREATE INDEX ix_uq ON
  rental(rental_date, inventory_id, customer_id)
  ```

SARGable Predicate

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  CREATE INDEX ix_uq ON
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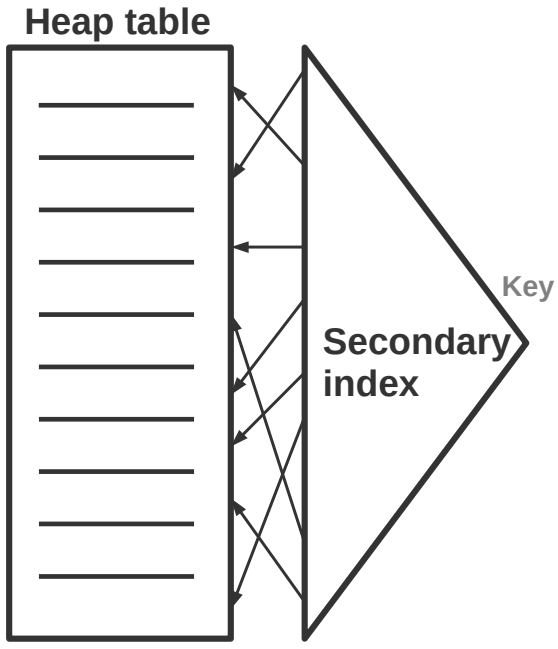
  ```
- The table is scanned despite the index
- Database systems requires no attribute manipulation in the predicate in order to use an index
- We need to rewrite the query

Lesson 3:

Do not manipulate the attributes in predicates if possible

Asterix

- ```
  SELECT * FROM rental
  WHERE YEAR(rental_date) = 2005
     and MONTH(rendal_date) = 10
  ```
- We may observe that the query plan consists from two data accesses:
  - Secondary index seek
  - Heap table access
- What if we are interested just in few atributes
- ```
  SELECT rental_date, customer_id
  FROM ...
  ```



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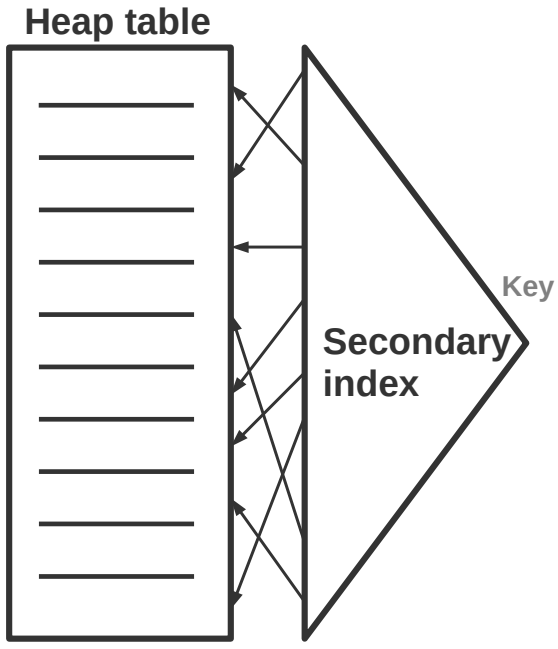

Lesson 4:

Do not use an asterix in the production

Covering Indexes

- We avoid table access completely in the previous example
- We use only data in `idx_uq`
- We say that such index *cover* the query
- Having an index with more attributes you are more likely to witness the index to be used during a scan (not during a seek)
- `SELECT rental_date, inventory_id, customer_id FROM rental WHERE inventory_id < 100`

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Index Scan vs. Index Seek

```
SELECT rental_date, inventory_id, customer_id
FROM rental
WHERE rental_date >= '2005-10-01'
   and rental_date <= '2005-10-31'
```

rental_date	inventory_id	customer_id
2005-01-02	1	1
2005-01-02	1	50
2005-01-02	200	1
2005-10-02	1	1
2005-10-02	200	1
2005-11-05	99	3
2005-11-05	100	2
2005-11-06	1	1

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SELECT rental_date, inventory_id, customer_id
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Insert/Update/Delete and Indexes

- Now lets try an `INSERT` into rental table:

```
INSERT INTO rental
VALUES ('2005-05-26 22:50:00', 367, 130,
     '2005-05-26 22:04:31', 1,
     '2006-02-15 21:30:50')
```

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```

- The database ensures referential integrity during the write operations
- Due to this we should never miss:
  - Indexes on primary keys
  - Indexes on foreign keys

Lesson 5:

Indexes on PK and FK are important to `INSERT`, `UPDATE` and `DELETE` operations (therefore, not only to `SELECT`)

Inteligent Physical Design

- Sometimes it may take a time to come up with inteligent physical design that:
  - supports critical queries
  - do not significantly slow down the insert/update/deletes

Falkirk Wheel

Falkirk Wheel

- It lift 550 tons with 22.5 kW

References

- Course home pages `http://dbedu.cs.vsb.cz`