Relational Model

COURSE 2: Databases

Relational model

Relational model

- Database = collection of RELATIONS
  - relation in relational model ≠ relationship in ERD.

- Relation Schema: A relation schema represents the name of the relation with its attributes.

- Attribute domain – Each attribute has some pre-defined values.

Relational model

- Codd rules 1985 → Is DBMS relational? If yes, to what degree?

https://computing.derby.ac.uk/c/codds-twelve-rules/

Relational Integrity constraints

RELATIONS

OPERATORS

Relational Integrity constraints

RELATIONS

OPERATORS

- Domain constraints
  - the value of each attribute must be unique, specified data types integers, real numbers, characters, Booleans, variable length strings etc.
- Key constraint
  - Unique + not null PK
- Referential integrity constraints
  - the value of a FK is null or it coresponds to the value of a PK.

Relational Integrity constraints

RELATIONS

OPERATORS

- Relational shema $R(A_1, A_2, \ldots, A_n)$

- $R \subset D_1 \times D_2 \times \cdots \times D_n$, D_i $domain$

Relational Integrity constraints

RELATIONS

OPERATORS

- UNION, INTERSECT, PRODUCT, DIFFERENCE

- PROJECT
- SELECT
- JOIN
- DIVISION

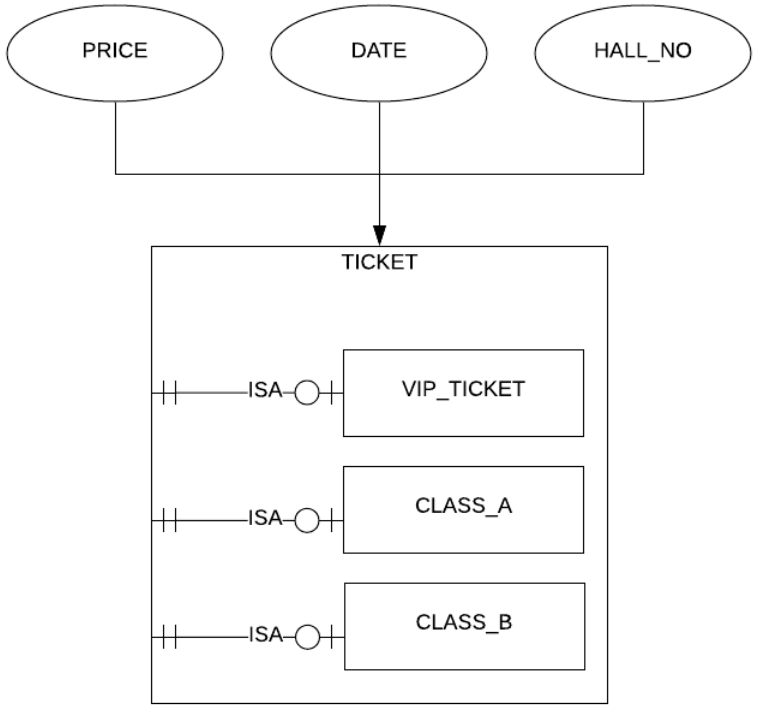
Converting ER into RM

Rules for entities

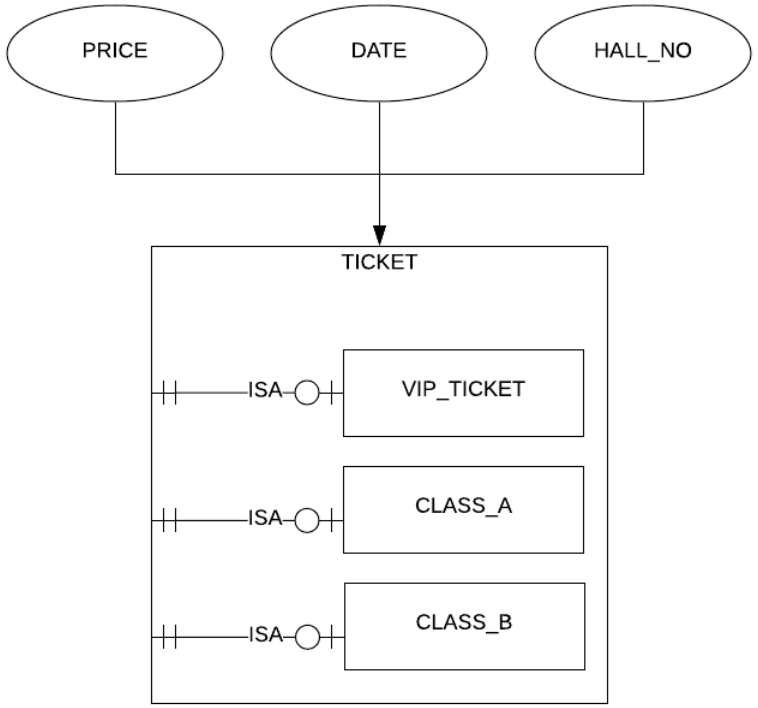
- Strong entities → independent tables
  - PK doesn’t contain foreign keys.
- Weak entities → table
  - PK contains the key of the related strong entity and or more key attributes.
- Sub-entities → one ore more tables, Boolean attribute, type_attribute
  - PK may also represent a FK.

Rules for entities strong – weak entity

Rules for entities ISA

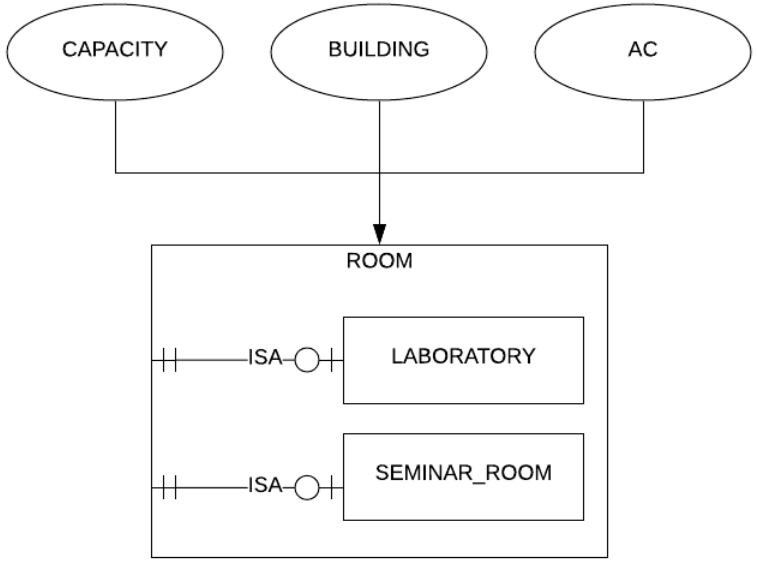


Rules for entities ISA

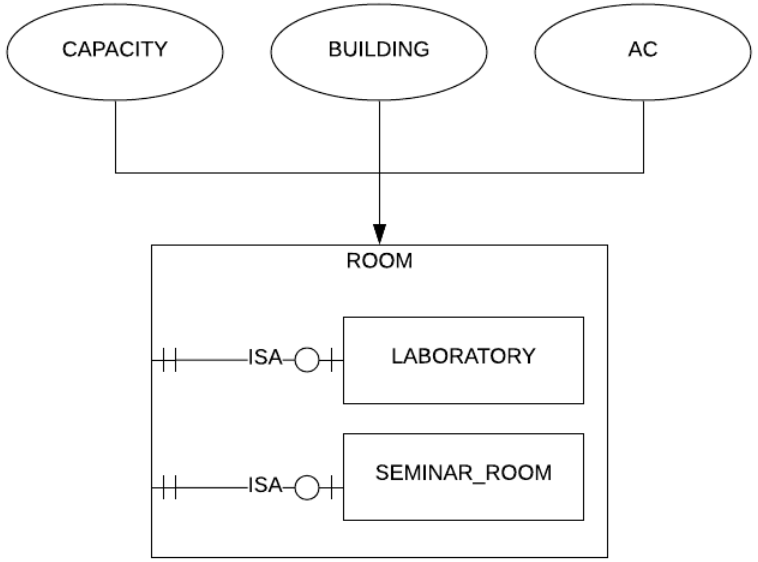


TICKET_ID	PRICE	HALL_NO	DATE	TYPE
1	200	Coliseum	08/03/20	VIP
2	150	Lyttelton	14/04/20	A
3	140	Olivier	01/05/20	A
4	90	Coliseum	04/06/20	B
5	220	Lyttelton	08/03/20	VIP
6	95	Olivier	14/04/20	B
7	210	Coliseum	20/03/20	VIP

Rules for entities ISA

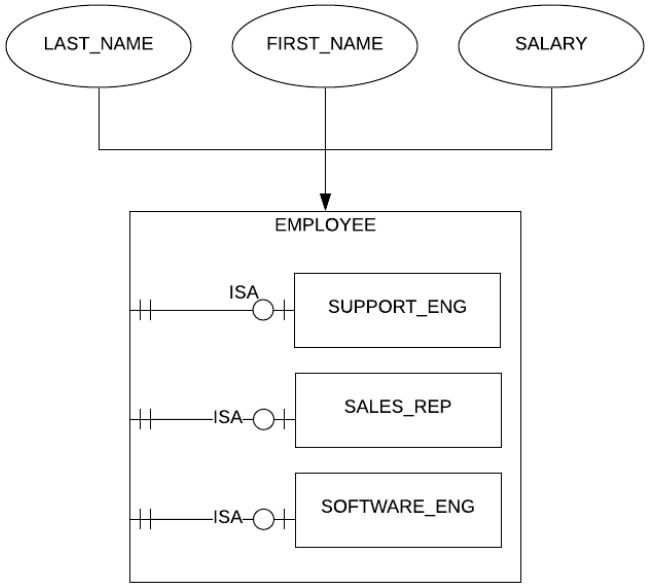


Rules for entities ISA

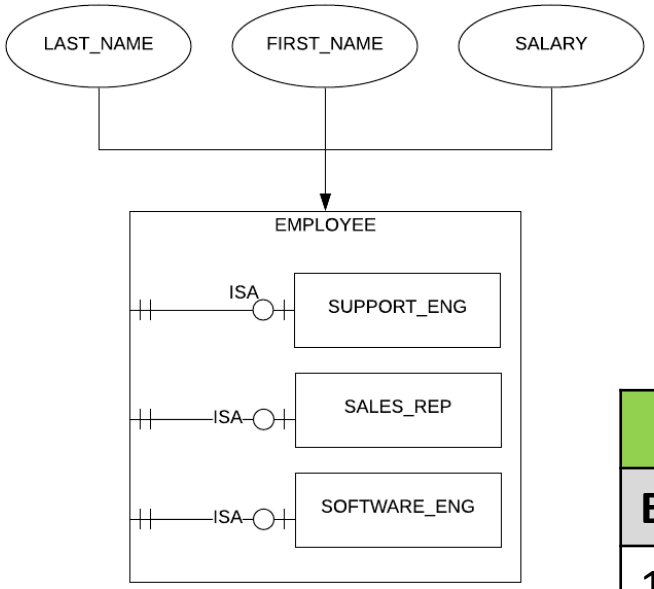


ROOM_ID	CAPACITY	BUILDING	LAB	SEM
1	40	FMI	1	1
2	45	Magurele	1	0
3	30	Geografie	0	0
4	90	FMI	1	0
5	80	FMI	1	0
6	95	Drept	0	1
7	20	FMI	1	1

Rules for entities ISA



Rules for entities ISA



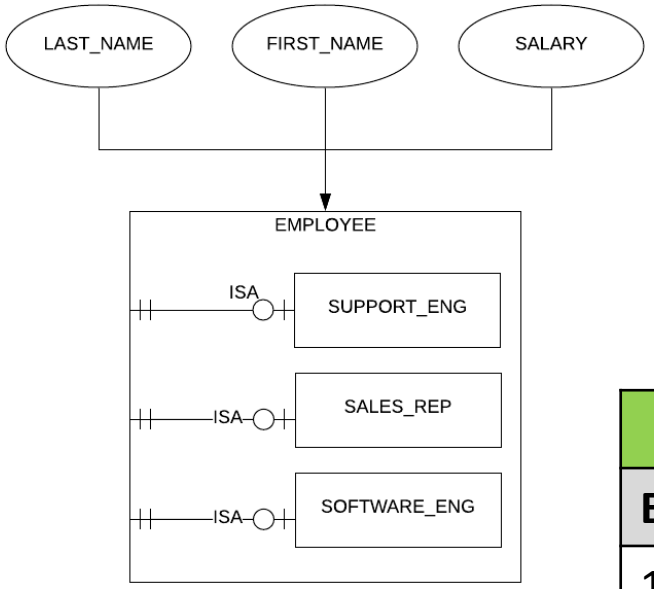
EMPLOYEES			
EMP_ID	**LAST_NAME**	**FIRST_NAME**	**SALARY**
1	Smith	John	2500
2	Grant	Anne	2700
3	Brown	Gregory	2300
…			

SUPPORT_ENG	
EMP_ID	**LEVEL**
1	3
…	…

SALES_REP	
EMP_ID	**TARGET**
2	25
…	…

SOFTWARE_ENG	
EMP_ID	**TEEM**
3	
…	…

Rules for entities ISA



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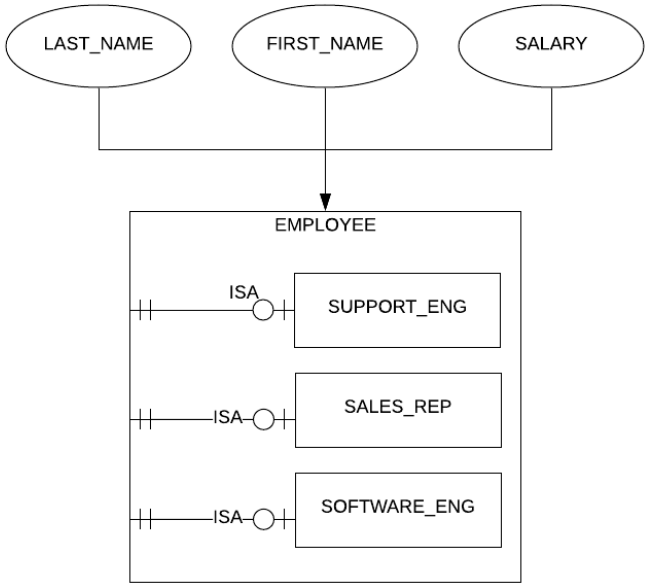
…	…

Rules for entities ISA



SUPPORT_ENG				
EMP_ID	**LEVEL**	**LAST_NAME**	**FIRST_NAME**	**SALARY**
1	3	Smith	John	2500
…	…			

SALES_REP				
EMP_ID	**TARGET**	**LAST_NAME**	**FIRST_NAME**	**SALARY**
2	25	Grant	Anee	2700
…	…			

SOFTWARE_ENG				
EMP_ID	**TEEM**	**LAST_NAME**	**FIRST_NAME**	**SALARY**
3	3	Brown	Gregory	2300
…	…			

Rules for relationships

- 1 to 1 & 1 to M → foreign keys.
  - 1 (PK) to M (FK)
  - Usually in 1 to 1 relationships the FK is placed in the tables with fewer rows.

- M to M → associative table.
  - PK contains FKs and additional column.

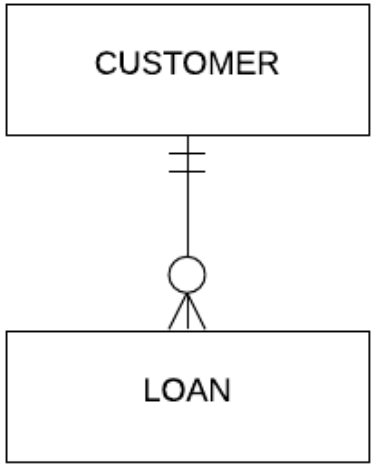
- Ternary relationships → associative table.
  - PK contains FKs and additional column.

One to One

ACCOUNT			
ACCOUNT_ID	**LAST_NAME**	**FIRST_NAME**	**DATE**
10	Snow	John	08/03/20
22	Grant	Anee	14/04/20
300	Brown	Gregory	01/05/20
…	…	…	…

CARD			
CARD_ID	**ACCOUNT_ID**	**CVN**	**DATE**
16897	10	125	18/04/21
24789	22	987	14/04/22
34597	300	875	03/05/21
…	…	…	…

One to Many

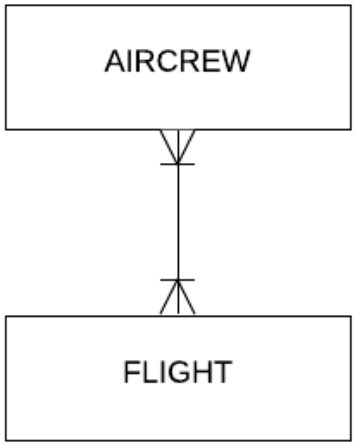


CUSTOMER			
CUSTOMER_ID	**LAST_NAME**	**FIRST_NAME**	**….**
10	Snow	John	….
22	Grant	Anee	….
300	Brown	Gregory	….
…	…	…	…

LOAN			
LOAN_ID	**CUSTOMER_ID**	**VALUES**	**DATE**
16897	10	125000	18/04/21
24789	22	987000	14/04/22
34597	300	87500	03/05/21
…	…	…	…

Many to Many

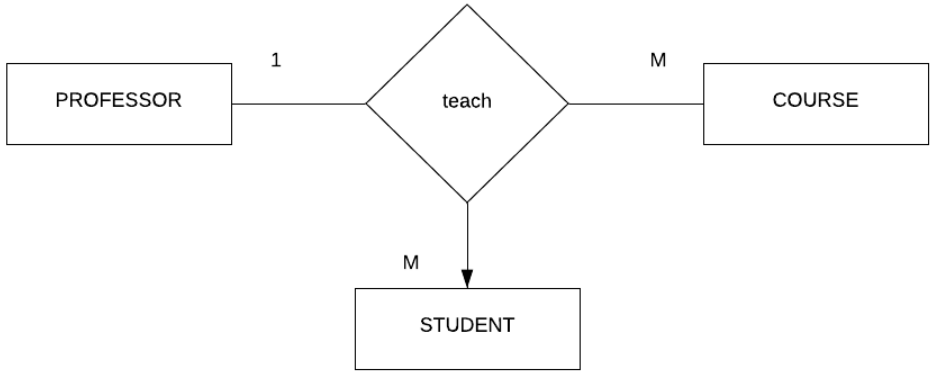
FLIGHT			
FLIGHT_ID	**DEP_AIRPORT**	**DATE**	**….**
1	Gatwick Airport	20/04/21	….
2	Grant	14/05/20	….
…	…	…	…



FLIGHT_CREW		
CREW_ID	**FLIGHT_ID**	**OBSERVATIONS**
10	1	…
22	1	…
10	2	…

AIRCREW			
CREW_ID	**LAST_NAME**	**FIRST_NAME**	**JOB_ID**
10	Snow	John	captain
22	Grant	Anee	first_officer
…	…	…	…

Ternary Relationships

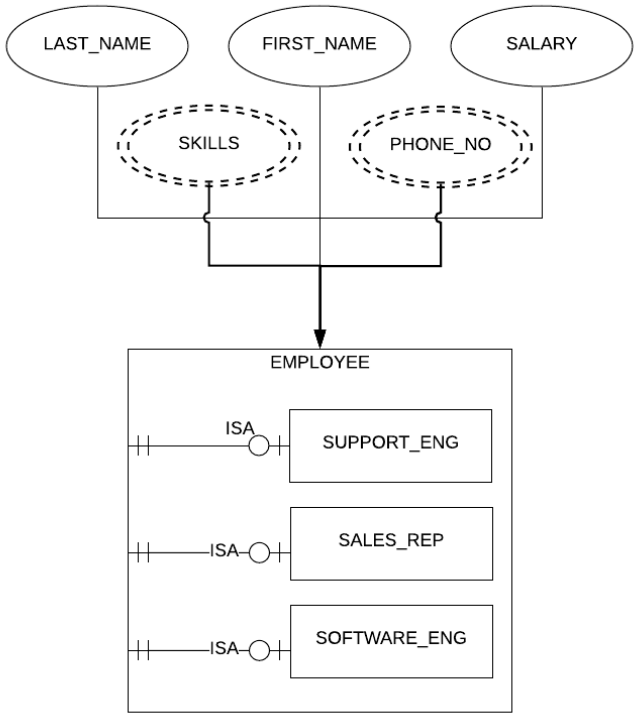


TEACH			
PROFESSOR_ID	**COURSE_ID**	**STUDENT_ID**	**GRADE**
1	BD	1001	9
1	SGBD	1002	10
1	BD	1002	8
2	TAP	1001	8
2	TAP	1002	10
2	AG	1001	5
….	….	….	….

Rules for attributes

- Simple attribute → column
- Multivalued attributes → weak entity → table
  → set of columns

Rules for entities ISA



EMPLOYEES					
EMP_ID	**LAST_NAME**	**FIRST_NAME**	**SALARY**	**PHONE1**	**PHONE2**
1	Smith	John	2500	0745…	0720…
2	Grant	Anne	2700	07497…	NULL
3	Brown	Gregory	2300	NULL	07458..
…	…	…	…	…	…

EMP_SKILL		
EMP_ID	**SKILL**	**LEVEL**
1	Python	3
1	C++	2
1	NoSql	3
2	SQL	1

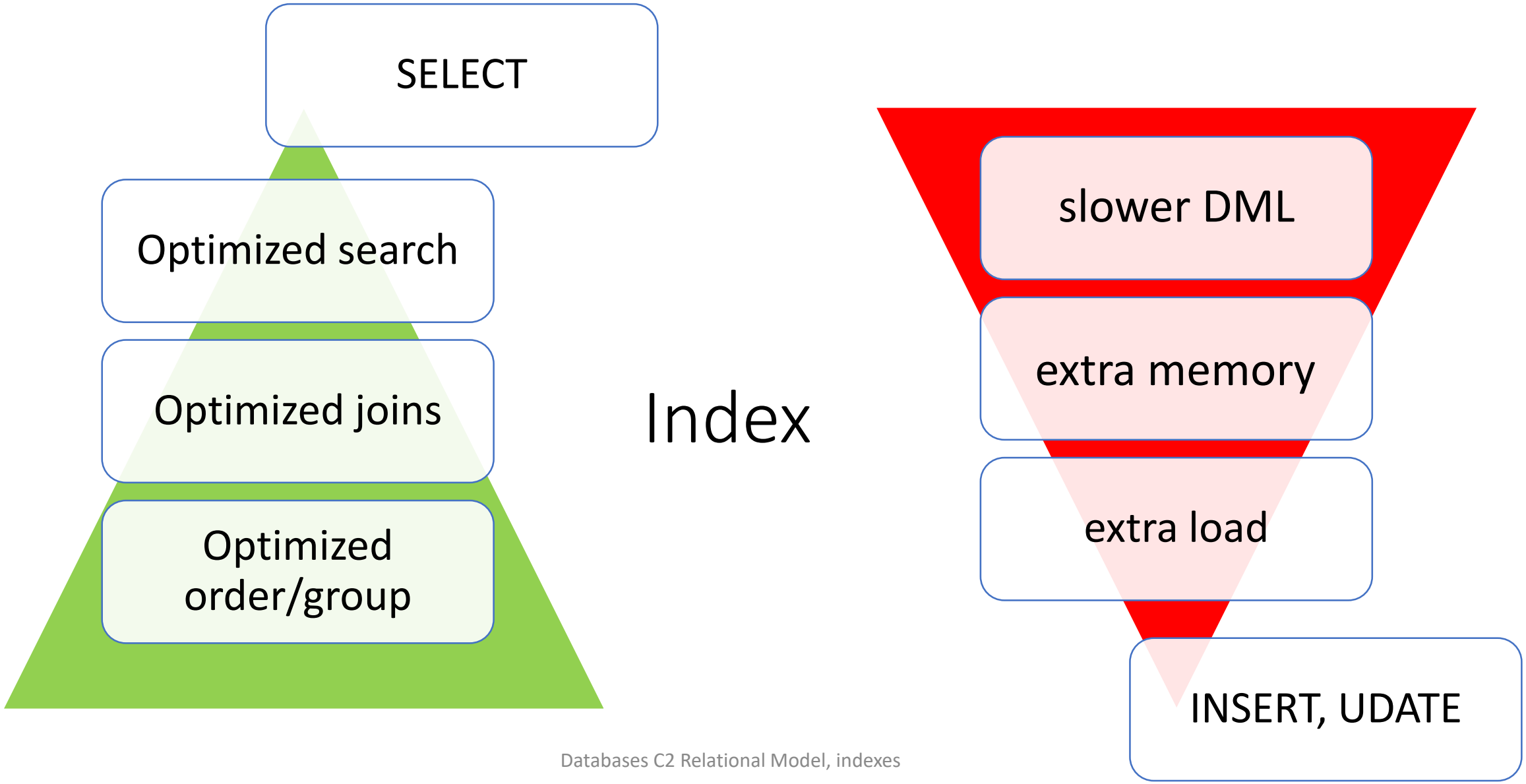
Indexes

Indexes

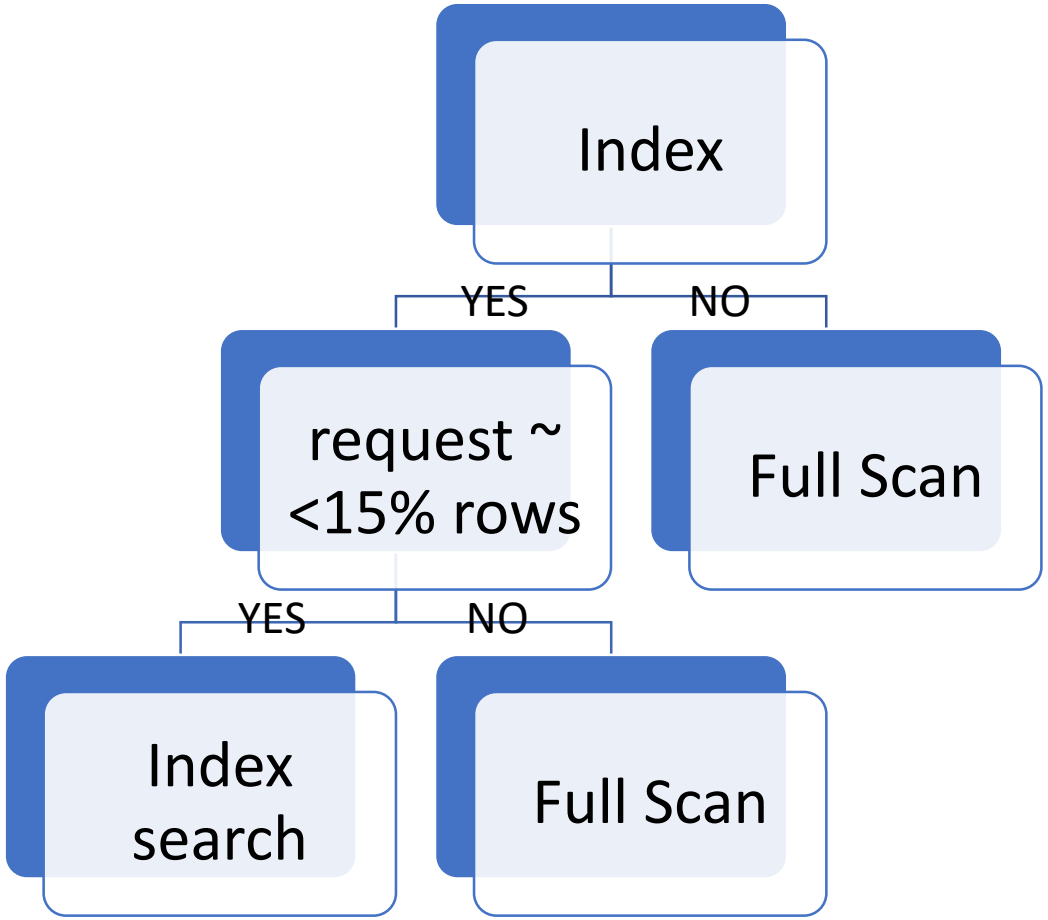
- Maps search key to data using specific data structures.

- Optimized search.
- Optimized joins (lookup in more than one table)
- Optimized order/group

- slower DML (insert and update operations).
- extra memory


SELECT
Optimized search
Optimized joins
Optimized order/group
Index
slower DML
extra memory
extra load
INSERT, UDATE

Sql Optimizer



Autogenerated columns

- MySQL auto-generated index (key):
  - DB_ROW_ID increases monotonically as new rows are inserted.
  - DB_ROLL_PTR roll pointer, points to log record.
  - DB_TRX_ID last transaction that updated or inserted the row.

- Oracle rowid:
  - Pseudo column 18 characters = 10 + 4 + 4 (block, row, file).
  - Store and return row address in hexadecimal format (string).
  - Unique identifier for each row.
  - Immutable.

Autogenerated columns

- Oracle rowid:
  - Used in where clause to select/update/delete a row.
- Oracle rownum:
  - Sequential number in which oracle has fetched the row, before ordering the result
  - Temporary generated along with a select statement.
- Mongo
  - ObjectID (timestamp 4Bytes + random 5Bytes + Count 3Bytes.

Index

- Data structure that optimize search.
- Automatically created when a PK/unique constraint is defined.

Primay key

- Constraint imposed on insert/update behavior.
- NotNull & Unique.

MySQL

```
SHOW EXTENDED INDEX FROM index_test;
```

MySQL

```
select * from  information_schema.statistics
where table_name = 'index_test1'
        and index_name = 'primary';
```

Oracle

```
select * from user_indexes
where table_name = 'INDEX_TEST';
```

Oracle

```
select * from user_constraints
where table_name = 'INDEX_TEST';
```

Index types

Clustered index (SqlServer, MySql)

- Defines the order in which data is physically stored in a table. (index on column semester)
- Only one clustered index on a table (data can be stored in only one order)
- A cluster index is created automatically when a primary key is defined.
- No second data structure for the table

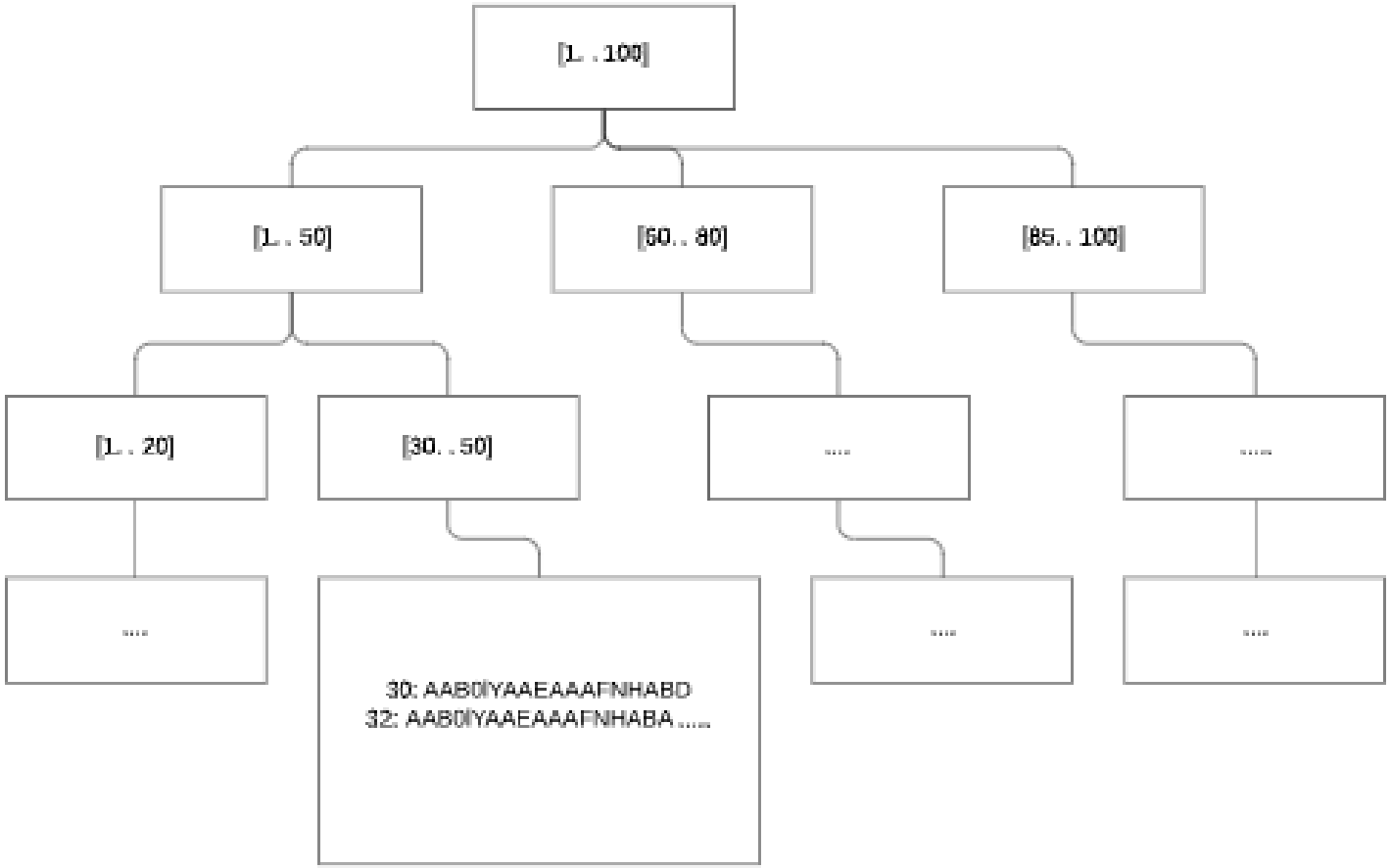
- Oracle: IOT index organized tables. Table is stored in a B-tree structure. (key and non-keys column are stored in leafs)

B – Tree

- B -- Balanced tree.
- Default index type in Oracle.
- Two types of nodes: branch blocks and leaf blocks.
- Branch blocks pointers to lower levels.
- Leaf blocks contain rowids/physical address.
- The number of blocks traversed in order to reach a leaf block is the same for each leaf block.

B – Tree

- create index idx_emp_id on employees(employee_id).
  - Divide employee_id values in sorted ranges.
  - Leaves nodes store rowid


[1. . 100]
[1. . 50]
[50. . 80]
[85. . 100]
[1. . 20]
[30. . 50]
....
....
....
....
30: AABDIYAAEAAAFNHABD
32: AABDIYAAEAAAFNHABA ....

Reverse index

- B – tree where keys are in reverse order. Key 4573 is stored 3754.
- Optimized insert operations.
- Key 4573 will be stored in the same block with key 9573
  while 4574 will be stored in a different block.

Bitmap index

- Used for columns with limited number of distinct values.
- Example: language proficiency levels (en)

emp_id	en	fr
1	A1	B1
2	A2	B2
3	C1	A1
4	A1	B1
5	A1	

row_id	A1	A2	B1	B2	C1	C2
AAB0lYAAEAAAFNHABD	1	0	0	0	0	0
AAB0lYAAEAAAFNHABV	0	1	0	0	0	0
AAB0lYAAEAAAFNHABX	0	0	0	0	1	0
AAB0lYAAEAAAFNHAAv	1	0	0	0	0	0
AAB0lYAAEAAAFNHAAV	1	0	0	0	0	0