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# Unit 1

### Overview

### Ternimalogy :

- **Data** - 50 cats
- **Database**
  - collection of data which can acessed from computer system
  - The data in the same database should relate have "entities" along with "relationships"
- **Database machines** - or back end processer is the hardware for database
- **DBMS** - Database Managment - software package for database

### DBMS Character

- **less redundancy** - the same piece of data store many place
- **data consistency** - accurate and up-to-date across difference system
- **data intergrity** - unsure that data remain intact, uncorrupt
- **data security** - implement strict access rule, encrytion
- **multi-user support** - concurrency control
- **backup & recovery**
- **query language support**
- ***ACID transaction*** (not all DBMS can do all the ACID)
  - **A: Atomicily** - transactions are all or nothing
  - **C: Consistency** - Only valid data will be saved
  - **I: Isolation** - transactions don't affect each others
  - **D: Durabulity** - written data will not be lost
  - How are ACID transactions implemented
    - most via "lock"
    - to guarantee duability use "write-ahead lock"
    - rolled back or continued from the transaction log left off

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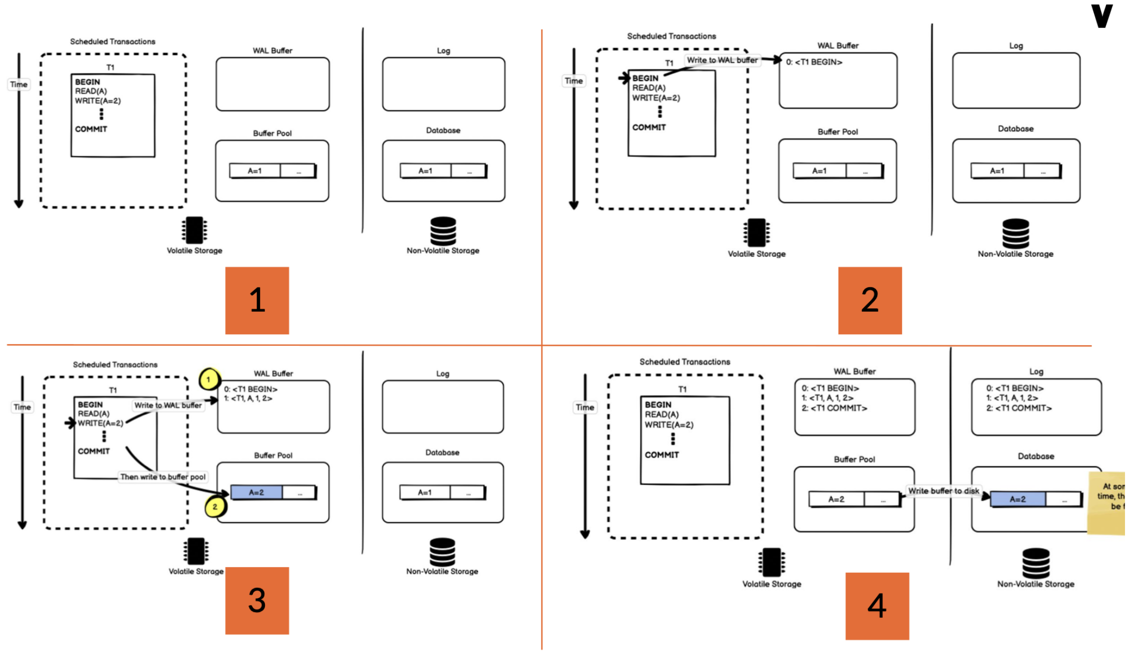
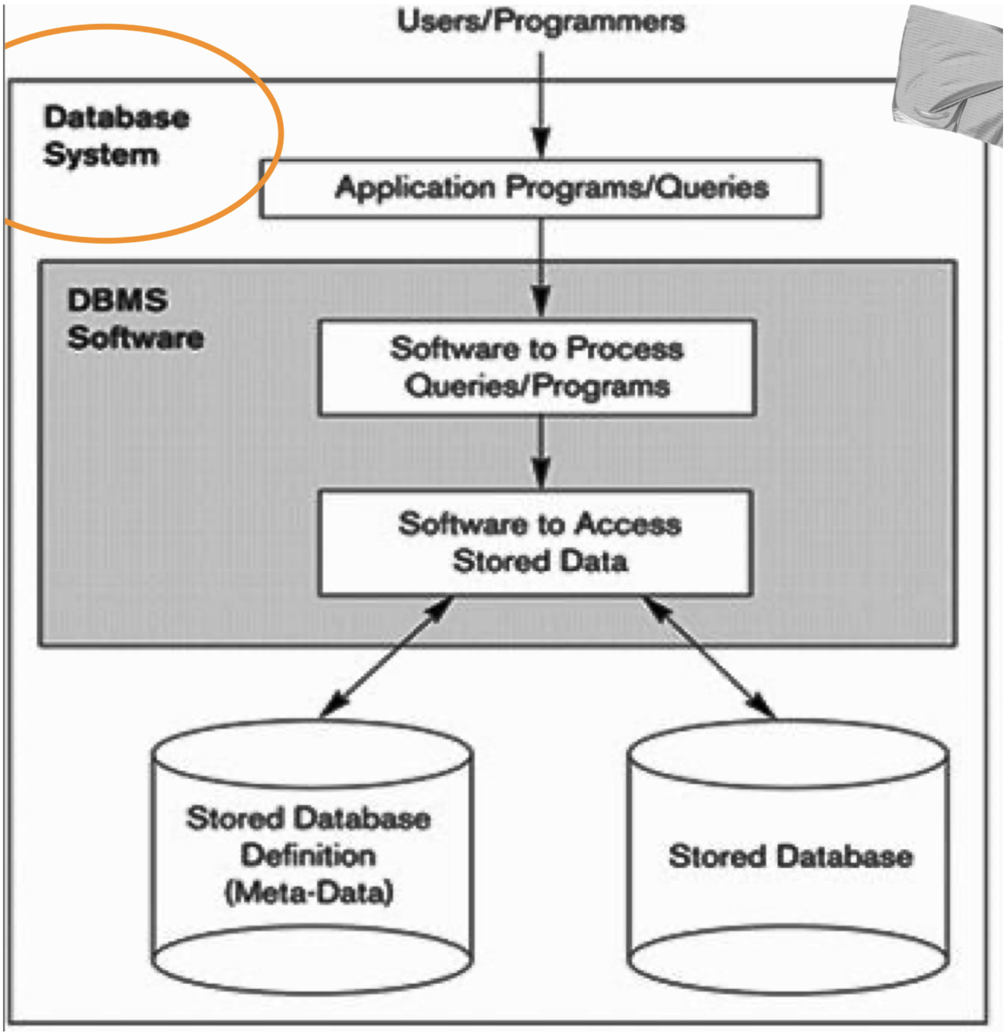
- 


## CAP theorem or Brewer's theorem

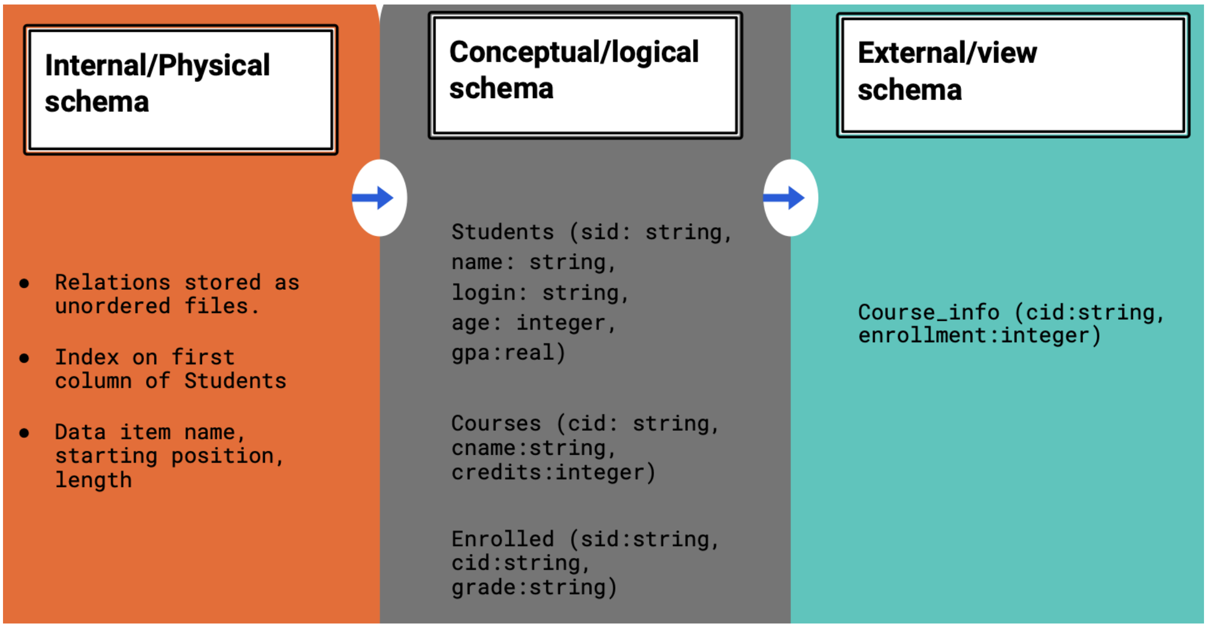
- impossible for a dist data store to simultaneously provide more than two of

1. **Consistency**: when system return info, it is always up-to-date
2. **Availability**: systems always return info, even if state
3. **Partition tolerance**: system continues oparating during a patition

## A Simplified Database System Environment




Level of Abstraction Three Schema Architecture




1. **Internal Level** - low-level data structure
2. **Conceptual Level** - what data to store and what relationships
3. **External Level** - difference view of users

SQL Language

- **DDL** (Data Definition Language)
  - create, drop, comment
- **DML** (Data Manipulation Language)
  - select, update, insert, call
- **DCL** (Data Control Language)
  - grant, revoke
- **TCL** (Transaction Control Language)
  - commit, rollback

> NoSQL = Not Only SQL or Non-SQL NoSQl is non-relational database, compatable with Big data

| | RDBMS | NoSQL |
|---|---|---|
| Type | Realtional | Non-Relational |
| Data Format | Table | JSON(Text) etc. |
| Scaling | Vectical (increase Spec Server) | Horizontal(increase Sever) |
| Schema | Fixed | Flex |
| Ex | Oracle, MySQL, Microsoft SQL | MongoDB |

# Unit 2

## ER-model

- **Entities** are specific objects in the database
- **Attributes** are properties used to describe any entity
  - Type of Attributes
    1. **Simple** - single atomic ex. SSN, Sex
    2. **Composite** - may be composed of several component ex. Address (Apt#, House#, City)
    3. **Single-valued** - ex. age, height
    4. **Multi-valued** - ex. {car}
  - 1. **Stored attributes** - birth date
    2. **Derived attributes** - age
    3. **Null values** - not have applicable value
- **Entity Types and Key Attributes**
  - ex. *EMPLOYEE* entity type and *SSN of EMPLOYEE* is the key attribute
  - the collection of all entities of a paticular entity type at any point in time is called **an entity set**
  - An entity type may hace more than one key
  - A key attribute may be composite

- **Relationships and Relationship Types**

  - A relation ship relates two or more entities with a specific meaning
    - EMPLOYEE John Smith *works on* the ProductX PROJECT
  - Relationships of the same type group into a relationship type

        - EMPLOYEEs WORKS_ON PROJECTs
    - **Degree of Relationship Type** - number of participating entity types
    - More than one relationship type can exist with the same participating entity types
    - can have **recursive** relationship type
        - ex. ManagerID is also EmployeeID
    - A relationship type can have attributes
        - ex. work_on -> start_date

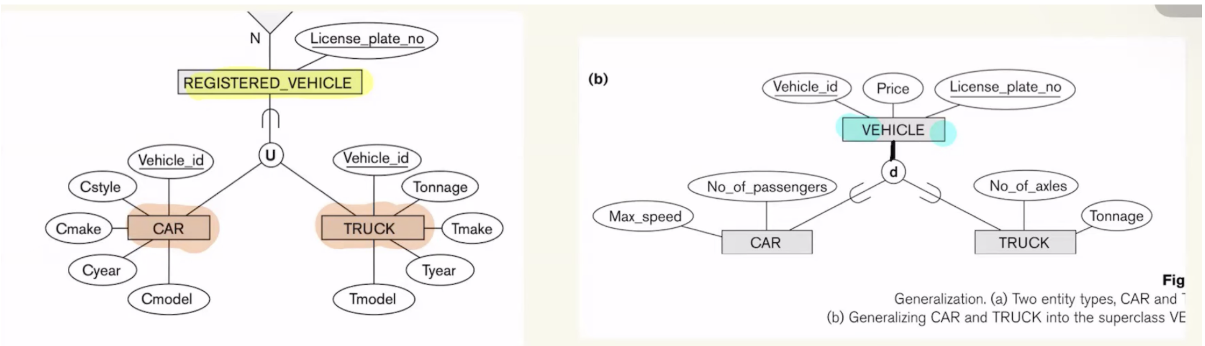
- **Constraints on Relationship**
    - Cardinality Ratios (placing number on the link)
        - 1:1 , 1:N, N:1, M:N
    - Participation constraint
        - total participation (one or more - mandatory): shown by double lining the link
        - partial participation (zero - optional): shown by single lining the link
    - We will refer to the cardinality ratio and participation constraints, taken together, as the **structural constraints** of a relationship type

- **Weak Entity Types** - entity that **doesn't have key attribute**
    - entity that have a key that matching from other entity

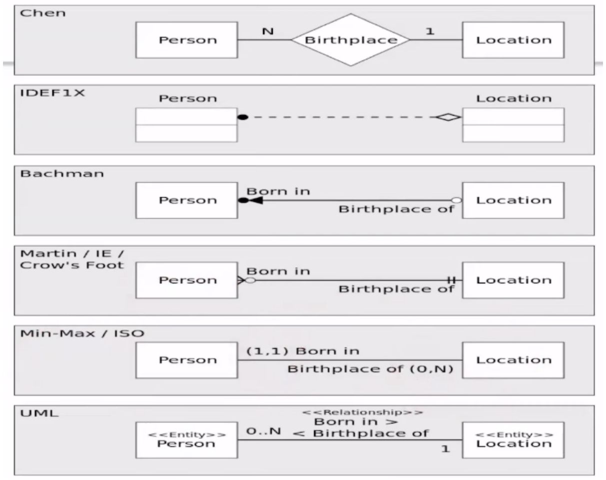
- **Subclasses and Superclasses** - IS-A relationship
    - the same as java
    - use node(d) and line out
    - **Attribute Inherihance**
        - subclass inherits all attribute of superclass, also inherits all relationships
    - **Specialization and Generalization**
        - CAR, TRUCK is a specialization of VEHECLE
        - CAR, TRUCK generalrize intp VEHICLE
        - **Constrains**
            - READTHID
            - **predicate-defined** -?
            - **attribute-defined** -?
            - user-defined -?
            - 2 other conditions apply
                - **Disjointness Constraint**
                    - **disjointed**(d) - an entity can be a member of at most 1 subclass
                    - **overlap** (o) - can be more than one subclass
                - **Completeness Constraint**
                    - **patial** (single line) - every entity in superclass must be a member of some subclass
                    - **total** (double line) - allows an entity not to belong to any subclasses
            - **Insertion and Deletion Rules**
                - **Deleting** an entity form superclass -> auto delete from all subclasses
                - **Inserting** an entity in superclass
                    - *partial* don't have to insert in subclass

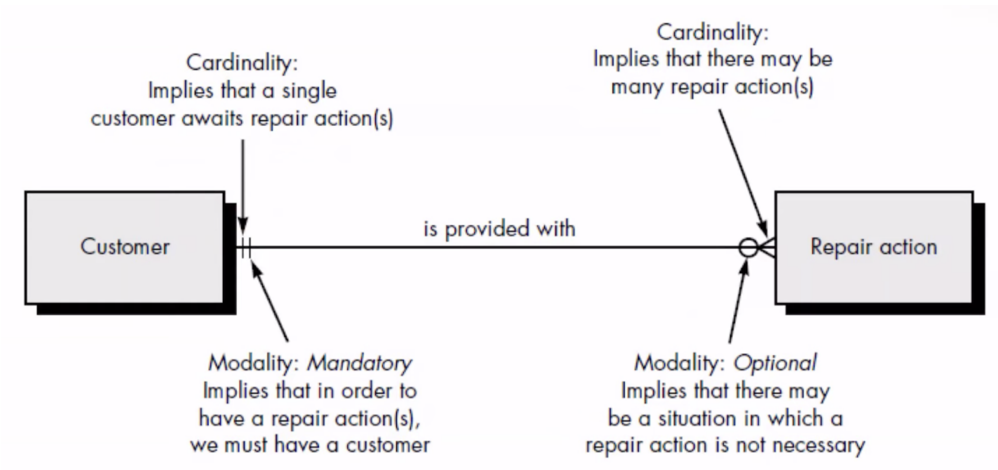
- *total* have to insert into at least one subclass
- **Hierarchies** - only one superclass (single inheritance)
- **Lattice** - can be subclass of more than one superclasses (multiple inheritance)
  - call that subclass "share subclass"

- **Categories (UNION TYPES)**
  - a shared subclass is subclass in more than one distinct superclass/subclass realationships, where each relationships has a single superclass




alt="difference between catagories and share subclass" ไปดู notation




crow's foot notation

# UNIT 3

## The Relational Model and Relational Database Design

> Informally, a relation looks like a *table* of values. typically contains a set of rows. Each *rows* represent certain facts that correspond to a real-world entity or relationship. Each *column* has a header that gives a meaning of the data items.

- **Key of a Relation**
  - each row have a *key* (data item or set of items)
  - sometimes gen a row-id (not a good choice)
- **Formal Definition**
  - R(A1,A2,...An) -> R is name of the relation
  - Relation schema *R* defined over attributes A1, A2, ... An
  - Each Ai is the name of a role played by some **Domain D** and denoted by dom(Ai)
  - the *degree* or *arity* is the number of attributes *n* of its R
  - relation is set of **tuples**(rows), Column called attributes
  - r(R): a specific state of R

| Informal Terms | Formal Term |
| --- | --- |
| table | relation |
| column header | attribute |
| all possible column value | domain |
| row | tuple |
| table definition | schema of a relation |
| populated table | state of the relation |

- **Chatacteristics of Relation**

  - **Ordering of tuples** - the tuple are not considered to be ordered (even they appear to be in the tabular form)
  - **Ordering of attributes** - must be order!
  - **Values in a tuple**
    - all values are **atomic** (indivisible)
    - a *null* value is used to represent value that are unknow or inapplicable

- **Relational Database Constraints**

  - **inherent model-based constrainstd** - no duplication tuple
  - **schema-based constraints** - specify by DDL
    - **Domain constraints**
      - within each tuple, the value of each attribute A must be atomic
      - data types for each attribute
      - a subrange of values, an enumerated type
    - **Key onstraints**
      - all element of a set are distinct
      - denote such the subset by SK (Superkey)
      - SK is a set of attributes that uniquely identifies a row
      - every relation has at least one *defualt superkey* - the set of all its attribute

            - *Key* of R is a superkey which cannot delete any attribute, to still be superkey
            - if a relation has several **candidate key**, choose primary key (underline) -> the left one is alternate key
        - **Entity intergrity onstraints**
            - S is the name of the database -> S = {R1,R1,...Rn}
            - **primary key cannot be null**
        - **Referential integrity onstraints**
            - involving two relation (referencing relation and referenced relation)
            - referencing relation have **FK** (foreign key) that reference the promary key attributes PK of the referenced relation
            - t1[FK] = t2[PK]
        - **other type**
            - Semantic Integrity Constraints
            - Functional Dependency Constraints
    - **application-based constraints**

- **Update Operation**

    - insert: insert tuple
    - delete: delete tuple
    - update or mondify: change value of existing tuple
    - *intergity constraint should bot be violated by this operation*
    - **insert** - can violate
        - domain constraints: if attribute value violates the corresponding constraint
        - key constraints: dup key value
        - entity integrity: new PK is null
        - referential intergrity: refers to a tupple that not exist
    - **delete** - can violate
        - *only* referential intergrity - the tuple being deleted is referenced by the FK
        - incase that happen
            - reject deletion
            - attempt to cascade(propagate) - delete the tuple that reference
            - modify the referencing attribute values
            - execute a user-specified error-correction routine
        - in some case cannot be null, be careful XD
    - **update** - can violate everything TT

# Normal Forms

## First Normal Form (1NF)

- **Atomic values only**
  Each field should contain only one value.
    - ❌ `course_name = "Astrology, Tarot"`
    - ✅ `course_name = "Astrology"`
- **No repeating groups**
  Avoid multiple similar columns for the same attribute (e.g., `phone1`, `phone2`). Use separate rows or

related tables.
- **Unique rows with a Primary Key**
  Each table must have a primary key to uniquely identify each record.

### Second Normal Form (2NF)

- **Must satisfy 1NF**
- **No partial dependency**
  All non-key attributes must be fully functionally dependent on the entire primary key.
  - ❌ `Course_Order(course_id, order_id, course_name)`
    (Here, `course_name` depends only on `course_id`)
  - ✅ Move `course_name` to `Course(course_id, course_name)`
- Applies **only if** the table has a **composite primary key**.

### Third Normal Form (3NF)

- **Must satisfy 2NF**
- **No transitive dependency**
  Non-key attributes should not depend on other non-key attributes.
  - ❌ `Account(account_id, username, email)`
    (If `username → email`, then `email` is transitively dependent)
- **Every non-key attribute must depend directly and only on the primary key**

# Stored Routine

### Stored routines

- a block of code that save in database call when want
- benefit: reuse code, security
- **Stored functions**
  - return something
  - call by their name not from CALL, be part of query
- **Stored procedure**
  - don't return value
  - call by CALL
- **Triggers**
  - automaticly run when something happen(insert, update, delete)
  - 2 level (ex.100 row but in 1 statement)
    - Row-level - call 100 times
    - Statement-level - call 1 time
  - create function(that return trigger) first, then create trigger (binding)
  - we can DROP, or ALTER

### View - Virtual table

- don't make things faster but, easier to call
- reuse query

- update table -> view updated
- usually be read-only
- high query cost, wanna reduce overhead -> materialize view(use more storage)

### EXPLAIN, EXPLAIN ANALYZE

- EXPLAIN shows how a SQL query will be executed (the query plan).
- EXPLAIN ANALYZE actually runs the query and shows the real execution steps and time.

### Transaction

- update data on many places -> atomicity
- commit things ._.

# Windows Function

- ประมวลชุดรายการข้อมูล โดยไม่มีการรวมรายการเหมือน aggregate function

# NoSQL

- in this course we will learn Document database which is **MongoDB**
- it is **schema-less** NoSQL document database, Scale well both data volumn and network traffic
- termminology
  - table -> collection, row -> document, column -> field, table joins -> $lookup
- Document schema - JSON object that define structure in document
- pros and cons **Embedding inside document**
  - **Pros**
    - pull everything in one query
    - link data between collection through &lookup -> decrease overhead
    - ensure atomic
  - **Cons**
    - document may be too big -> overhead
    - MongoDB max at 16MB
- pros and cons **Referencing**
  - **Pros**
    - document size not too big
    - less redundency (not a big deal, if perf ok is ok)
  - **Cons**
    - use more queries or $lookup

### schema design rules

1. use embedding first if possible,and one-to-few case too (one-to-many or call separately better use referencing)
2. use case that need to call separately, make it new collection
3. don't use lookup if not necessary
4. one-to-squillions(1000)(ex.log) -> new document and point back to host

5. many-to-many -> new document, point back and forth

# Storage and Indexing

## Overview

- how does DBMS store and access persistent data?
- minimizing I/O cost
- hash, tree based index?

## External Storage

- Disks
  - Random acess devices
  - retrieve any page at fixed cost
- Tapes
  - Sequential acess device

## Files and access methods layer

- Operation support (insert, delete, scan)
- keep track of pages allocation
- tracks available space
- how is a relation stored?
  - as a file of records, each has a **record id** which use to locate page number
  - iprementby the componect: Files and access methods layer

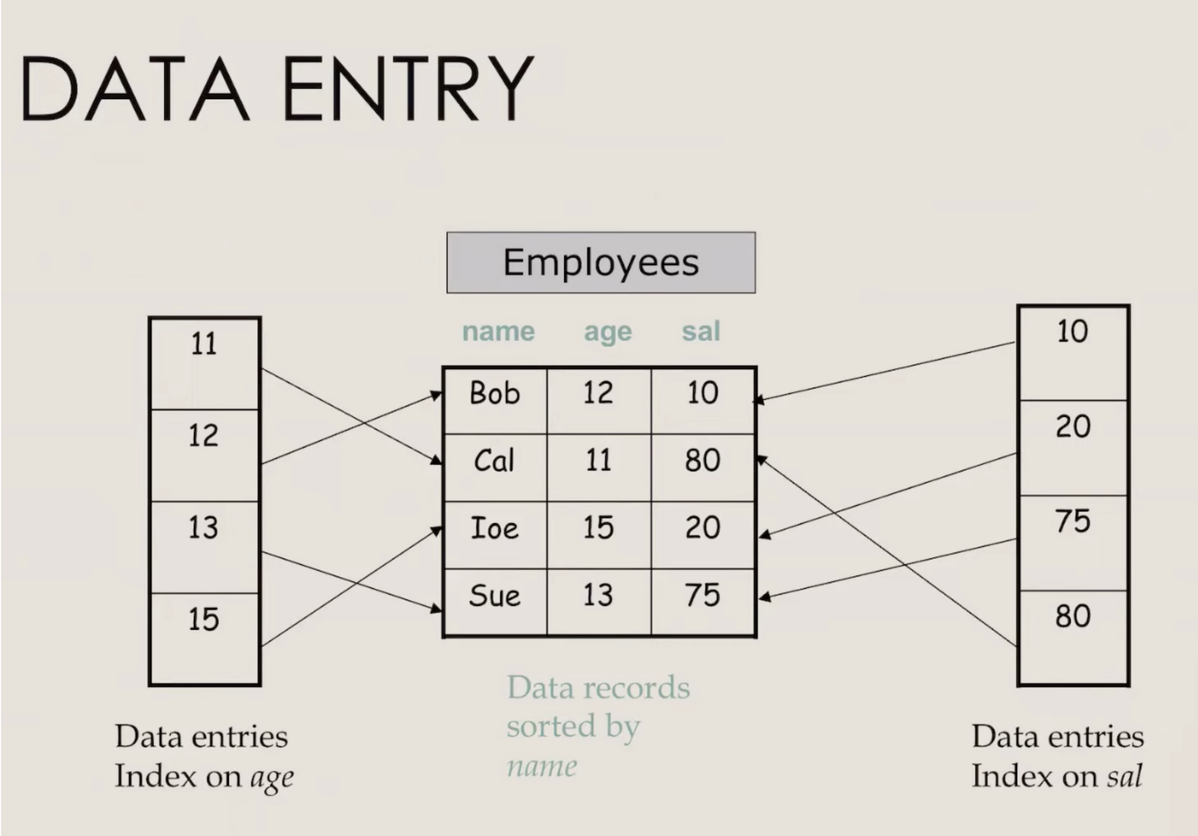
## File Organization

- Alternative file organizations
  - heap (random order)
  - sorted
  - indexes

## Concepts

- **index file** contains a collection of **data entries**(aka. index entries) -> (search-key, pointer)
- Two basic kinds of indices
  - **Ordered indices**

- **Hash indices**




Alternative For Data Entries

- **Alternative 1**
  - data entry k* is an **actual data record**
  - at most 1 index
  - if data is large, # of pages is high
  - indexed file organization
- **Alternative 2**
  - data entry is <k,rid> pair
- **Alternative 3**
  - Data entry is <k,rid-list>
- 2,3 smaller than 1

Index classification

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- **Primary index** - search key contains primary key
  - Sequential scan is efficient
- **Secondary index** - not primary._.
  - must be dense
  - Sequential scan is expensive
- (unique index - search ket contains candidate key)
- primary, secondary when file modified, every index must be update

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- **Clustered index** - order of data recode is close to order of data entries
- **Unclustered index** - not clustered ._.

- **Dense Index Files** - index record appears for every search key value
  - faster
- **Sparse Index Files**
  - only for **Cluster and Primary** index
  - less space ans leass maintenance overhead (insert, delete)

### Index Data Structure

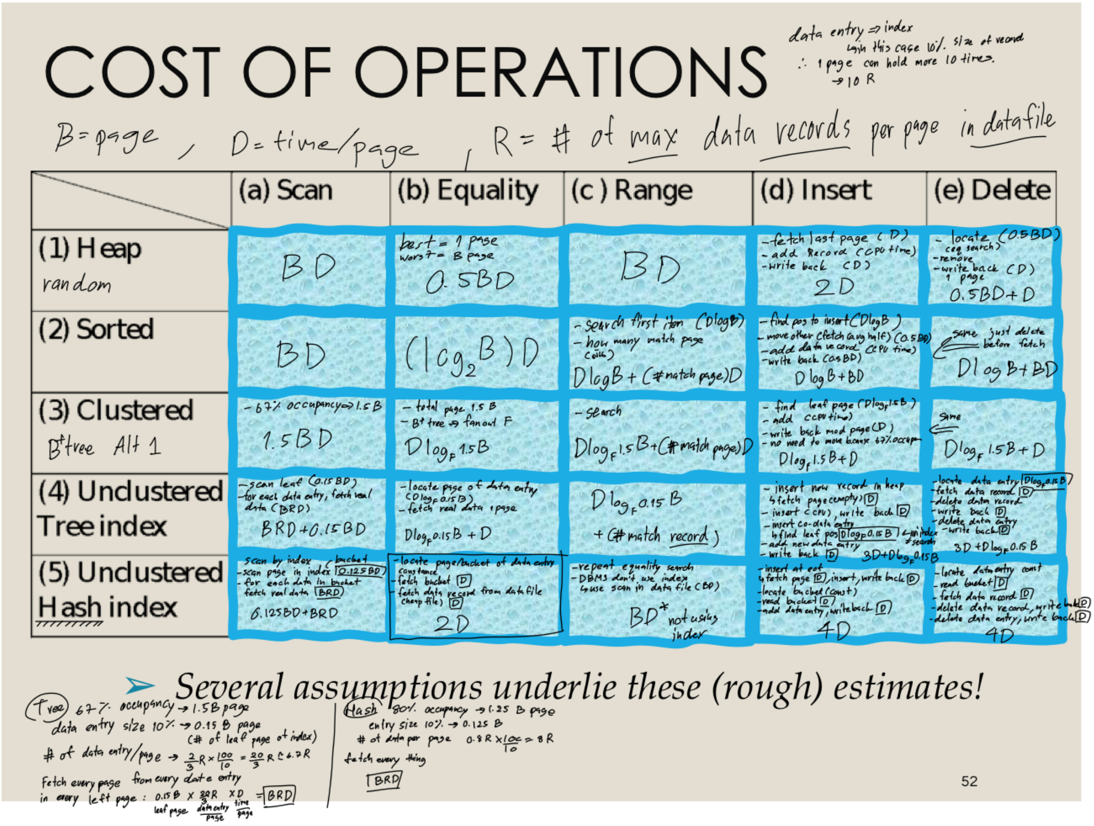
- **HASH-BASE INDEXS**
  - index is a collection of buckets
  - good for equality selection
- **B+ TREE INDEX**
  - 50-100 fanout -> height really short
  - good for range search
  - always balance in height
  - fill factor - min pointer for a node
  - todo: understand how it balance

### Cost Model

In this course we ignore CPU cost, for simplicity (I/O cost dominate), ignore pre-fetching too, use Average-case analysis

- B: The number of data page
- R: Number of data records per page
- D: AVG time to read and write disk page
- **Operations to Compare** - Scan, Equality search, Range selection, Insert selection, Insert a record, Delete a record
- **Compare File Organizations**
  - Heap files(randon order; insert at eof)
  - Sorted files, sored on a search key (no index)
  - Clustered B+ tree file on a search key, Alternative 1
  - Heap file with unclustered B+ tree index Assumtions in our analysis
- Heap files
  - equality selection on key
  - exactly one match
- Sorted files
  - files compact after deletions
- Indexes
  - Alt 2 & 3

        - data entry size = 10% size of record
    - Hash
        - No overflow bucket
        - 80% page occupany -> file size = 1.25 data size
    - Tree
        - 67% occupancy (typical) -> file size = 1.5 data size




- Understanding the Workload

    - more selective, you better index it

- Choice of indexes

    - consider the most important queries in turn
    - trade-off: queries faster, updates slower and require disk space
    - Where clause
        - **Exact match - hash index**
        - **range query - tree index**
            - cluster may help
    - Multi-attribute
        - order of attribute is important for range queries
        - can sometimes enable **index-only strategies** - clustering is not important

- Example

```
SELECT E.dno FROM Emp E WHERE E.age>40
/*
ragne so b+ tree index on
how selective -> if most people age > 40 not that selective so not worth
```

```
is the index cluster?
*/
SELECT E.dno, COUNT(*) FROM Emp E WHERE E.age>10 GROUP BY E.dno
/*
consider the Group by
if many age > 10 -> not selective -> better not create index on age
group by dno, so Cluster E.dno index may be better -> dont even have to
fetch, use only index very fast
*/
SELECT E.dno FROM Emp E WHERE E.hobby='Stamps'
/*
equality search but hobby not uniqe
clustering on E.hobby helps!
*/
```

Indexs with Composite Search Keys

- **in goodnote😭**