Tutorial 11
Coarse Review

CSCI3170 Tutorial

What’s Important

- Why Database: Files vs. DBMS
- Database Modeling: Entity-relationship Model
- How it Works: Relational Algebra and SQL-based Application
- Make it Faster: Schema Refinement
- The Underlying: Storage vs. Memory, Indexes, and B+ Tree
- More: Hashing, Concurrency Control, and Recovery

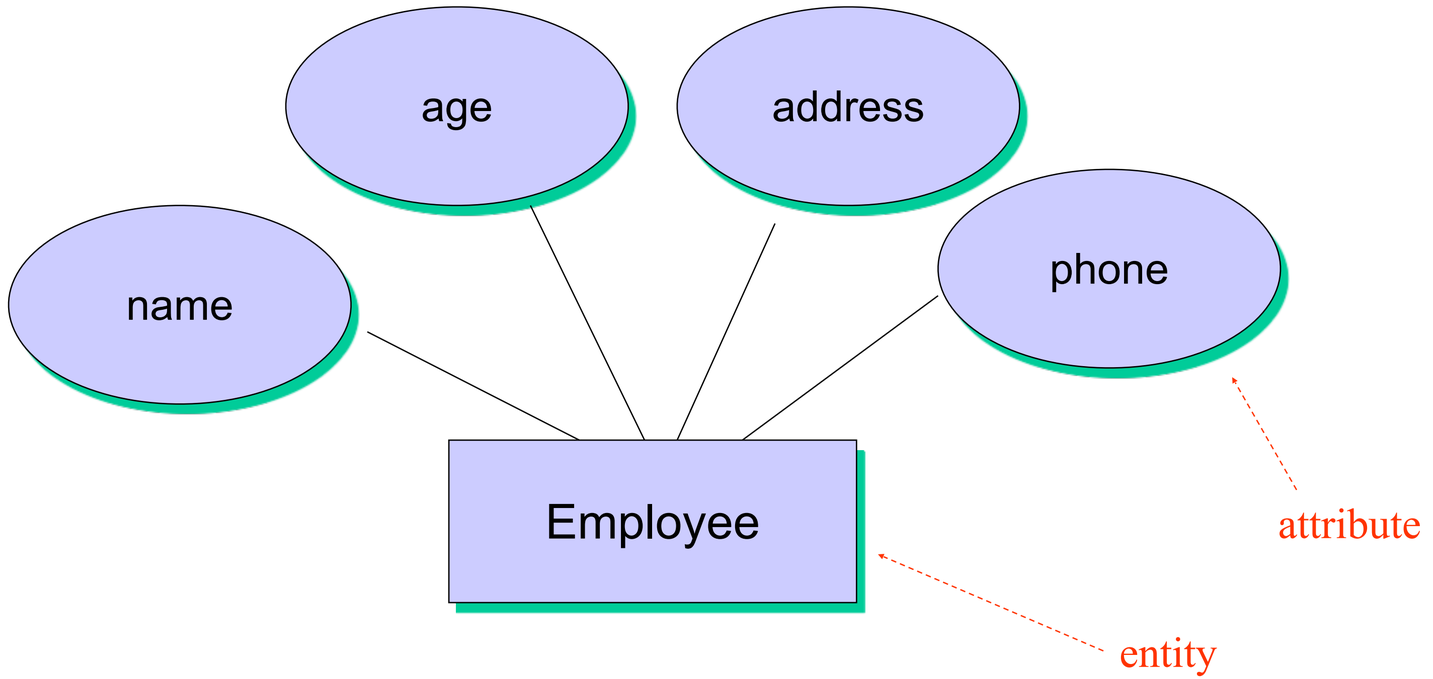
- (Note: This short slide aims to help you organize what you’ve learned, please don’t forget to review the more comprehensive lecture slide.)

Files vs. DBMS

- Suppose a company try to handle a large amount of data in files.
    - Application must have to handle large amount of data between main memory and secondary storage. Problems include: Buffering; Page-oriented access; Address handling
    - Special programs to answer different queries.
    - Must protect data from inconsistency due to multiple concurrent users.
    - Handle crash recovery.
    - Restore the system to a consistent state after a crash.
    - Security and access control.
- DBMS is a piece of software designed to make the above tasks easier.
- We can use the features of a DBMS to manage the data in a robust and efficient manner.

Entity-Relationship diagram (E-R diagram)

- The E-R model can be presented graphically by an E-R diagram.



Relational data model

- Most DBMS today are based on the relational data model.
- Relation
  - the central data description construct in this model.
  - It can be thought of as a set of records.
  - A table with rows and columns.
    - Row – a record
    - Column – field, attribute.

Relational data model

sid	name	login	age	gpa
53666	Jones	Jones@cs	18	3.4
53688	Smith	Smith@ee	18	3.2
53650	Smith	Smith@math	19	3.8
53831	Madayan	Madayan@music	11	1.8
53832	Guldu	guldu@music	12	2.0

An example of a student relation

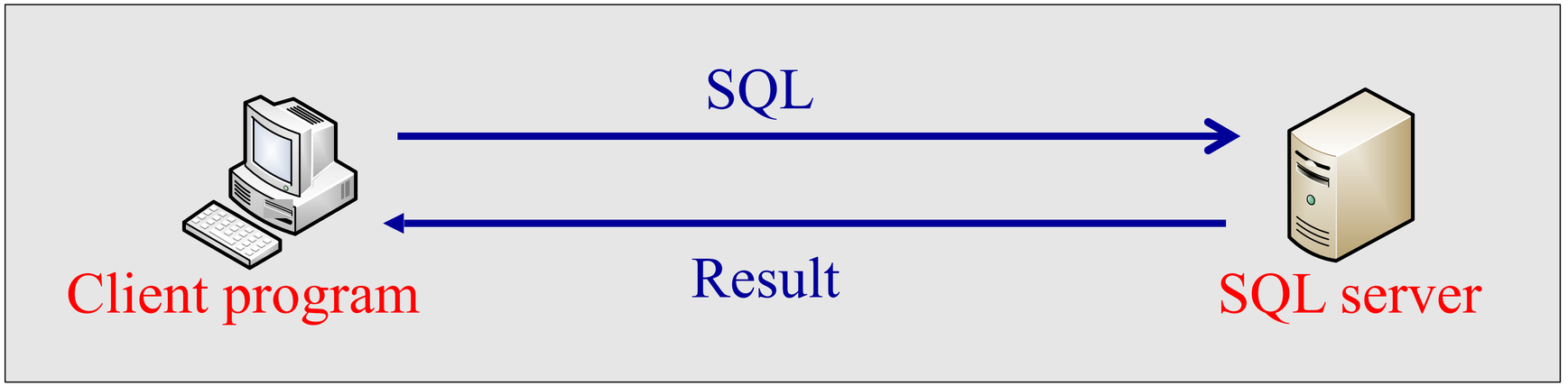
- A description of data in terms of a data model is called a schema.
- The schema of the above table is

  Students(*sid*: string, *name*: string, *login*: string,
  age: integer, *gpa*: real)

Basic Operators

- There are six basic operators in relation algebra:
  - select (σ)
  - project (Π)
  - union (U)
  - set different (-)
  - Cartesian product (x)
  - rename (ρ)

Client-server Model



- The program running on the client machine sends SQL statements to the database server.
- The results of the SQL statements will be returned to the client.

Motivation Example

Id	name	age	rating	Hourly_wages	Hours_worked
123-22-3666	Peter	48	8	10	40
231-31-5368	Paul	22	8	10	30
131-24-3650	Mary	35	5	7	30
434-26-3751	David	35	5	7	32
612-67-4134	Ada	35	8	10	40

- Redundant Storage
  - The rating value 8 corresponds to the hourly wage 10, and this association is repeated three times.
  - Storage is not used efficiently.

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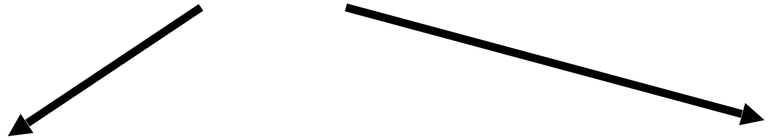

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rating	Hourly_wages
8	10
5	7

Functional dependency:
- rating determines Hourly_wages

A decomposition of a relation schema R consists of replacing the relation schema by two (or more) relation schemas that each contains a subset of attributes of R and together include all attributes in R

Disks and Files

- DBMS stores information on ("hard") disks.
  - A disk is a sequence of bytes, each has a ***disk address***.
  - READ: transfer data from disk to main memory (RAM).
  - WRITE: transfer data from RAM to disk.
  - Both are high-cost, relative to in-memory operations.
- Data are stored and retrieved in units called *disk blocks* or *pages*.
  - Each page has a fixed size, say 512 bytes. It contains a sequence of ***records***.
  - In many (not always) cases, records in a page have the same size, say 100 bytes.
  - In many (not always) cases, records implement relational tuples.

Why Not Store Everything in Main Memory?

- *Costs too much.* Ram is much more expensive than disk.
- *Main memory is volatile.* We want data to be saved between runs. (Obviously!)
- Typical storage hierarchy:
  - Main memory (RAM) for currently used data.
  - Disk for the main database (secondary storage).
  - Tapes for archiving older versions of the data (tertiary storage).

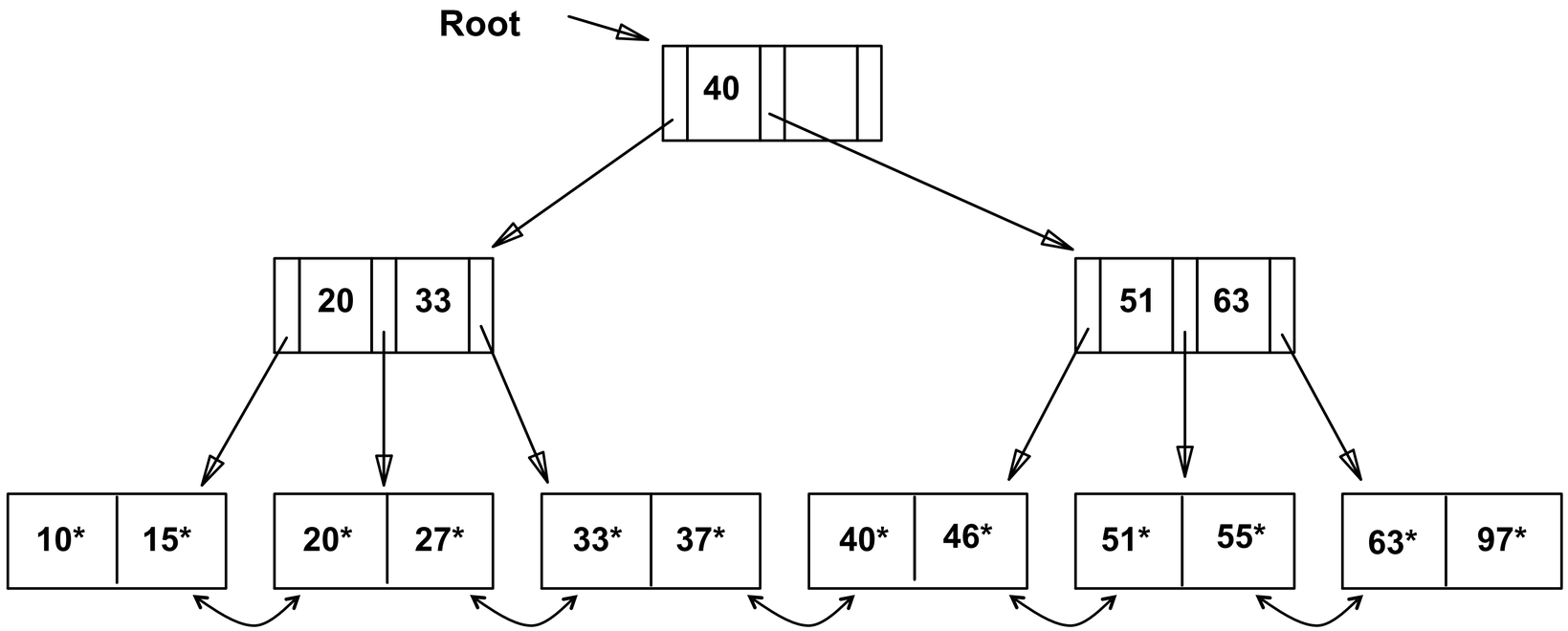
Indexes

- An *index* on a file speeds up selections on the *search key fields* for the index.
  - Any subset of the fields of a relation can be the search key for an index on the relation.
  - *Search key* is not the same as *key* (minimal set of fields that uniquely identify a record in a relation).
- An index contains a collection of *data entries*
- A data entry is denoted as **k***, where **k** is a search key value and * tells where to find the record containing **k**
- Index must support efficient retrieval of all data entries **k*** with a given key value **k**
- Structure of data entry in more detail

Index Classification

- *Primary* vs. *secondary*: If search key contains primary key, then called primary index, otherwise secondary.
  - *Unique* index: Search key contains a candidate key.
- *Clustered* vs. *unclustered*: If order of data records is the same as, or `close to', order of data entries, then called clustered index.
  - A file can be clustered on at most one search key.
  - Cost of retrieving data records through index varies *greatly* based on whether index is clustered or not!

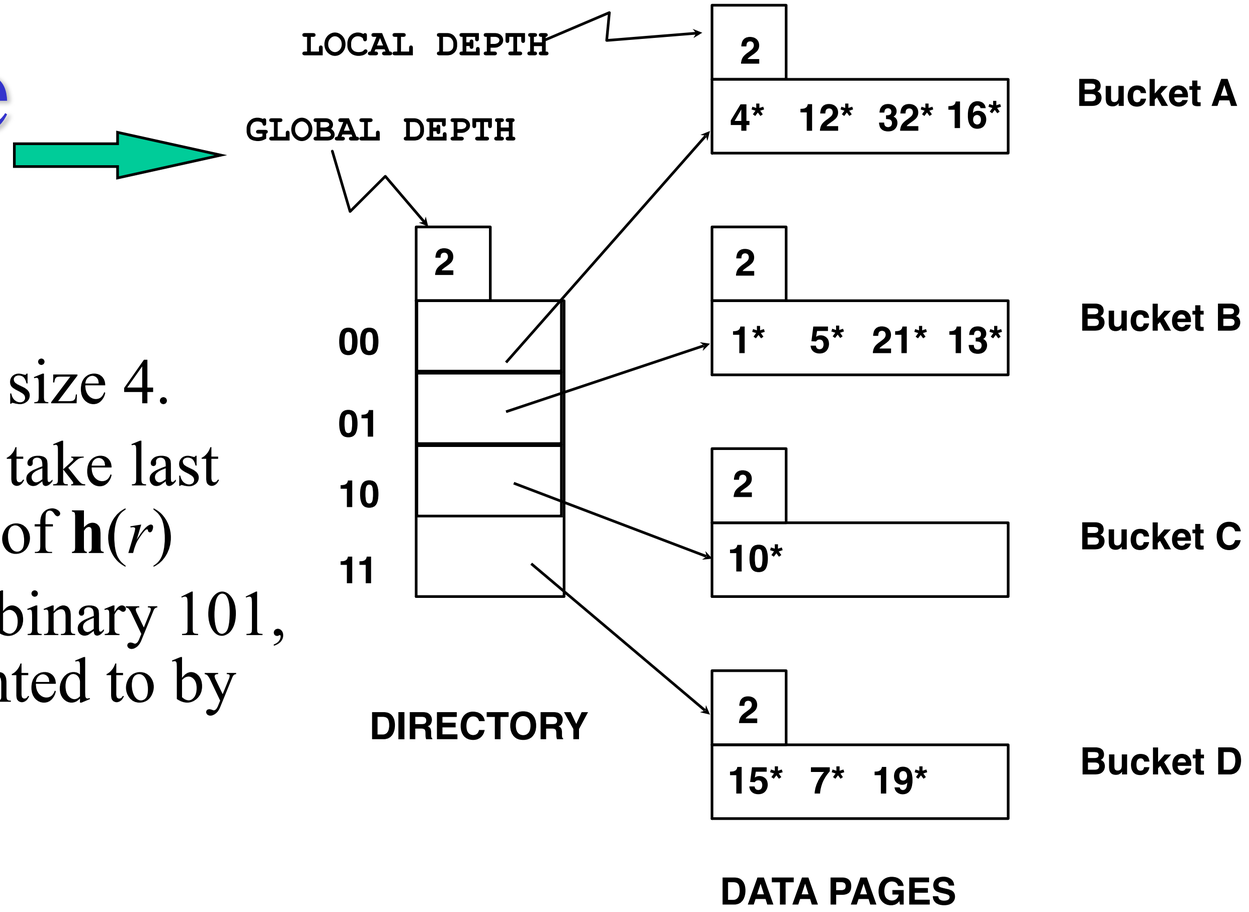
An example of a B+ tree



Extendible Hashing

- Situation: Bucket (primary page) becomes full. Why not re-organize file by *doubling* # of buckets?
  - Must re-hash all data entries to the right buckets
  - Example: assume hash function h(k) = k mod M
    - For M = 4, entries 3* and 7* both in bucket 3 (3 mod 4 = 7 mod 4 = 3)
    - But for M = 8, entry 7* will be in bucket 7
  - Can we only re-hash those values that have changed addresses?
    - Difficulties: without re-hashing all the values, we don't know which values keep the old addresses and which get new addresses
  - Reading and writing all pages are expensive!
  - Question: how do we add more buckets, but only re-hash a few data entries?
  - Answer: use a level of indirection, ***directory of pointers to buckets***

Example



- **h**(*r*) = *r mod 32*
- Directory is array of size 4.
- To find bucket for *r*, take last `*global depth*' # bits of **h**(*r*)
  - If *r* = 5, **h**(*r*) = 5 = binary 101, 5* is in bucket pointed to by 01.

❖ **Insert**: If bucket is full, *split* it (*allocate new page, re-distribute*).

❖ *If necessary*, double the directory. (As we will see, splitting a bucket does not always require doubling; we can tell by comparing *global depth* with *local depth* for the split bucket.)

Concurrency

- Multiple users.
- Concurrent accesses.
- Problems could arise if there is no control.
- Example:
  - Transaction 1 (T1): withdraw $500 from account A.
  - Transaction 2 (T2): deposit $800 to account A.

T_1	T_2
Read(A)	Read(A)
A = A – 500	A = A + 800
Write(A)	Write(A)

Transactions

- A *transaction* is a sequence of read/write operations.
- A transaction is *atomic*.
  - Either all or none of the operations are executed.
  - No transaction can observe partial effect of other transactions.

Recoverable

- Transactions may be aborted due to logical failure. e.g. deadlock
- Recoverability is required to ensure that aborting a transaction does not change the semantics of committed transaction's operations.
- Example
  - $Write_1(x,2)$; $Read_2(x)$; $Write_2(y,3)$; $Commit_2$
  - Not recoverable.
  - T_2 has committed before T_1 commits.
  - The problem is: what can we do if T_1 abort?
  - Delaying the commitment of T_2 can avoid this problem
- A schedule *H* is called *recoverable* (RC) if, whenever T_i reads from T_j. ($i \neq j$) in *H* and $c_i \in H$, $c_j < c_i$.
- Intuitively, a history is recoverable if each transaction commits after the commitment of all transactions (other than itself) from which it reads.