CS 4604: Introduction to Database Management Systems

Midterm Review

Virginia Tech CS 4604 Sprint 2021

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Midterm Exam Topics

- Relational Algebra
- Entity-Relationship (E/R)
- SQL
- Storing and Indexing
- Hashing and Sorting
- Query Processing

Relational Algebra

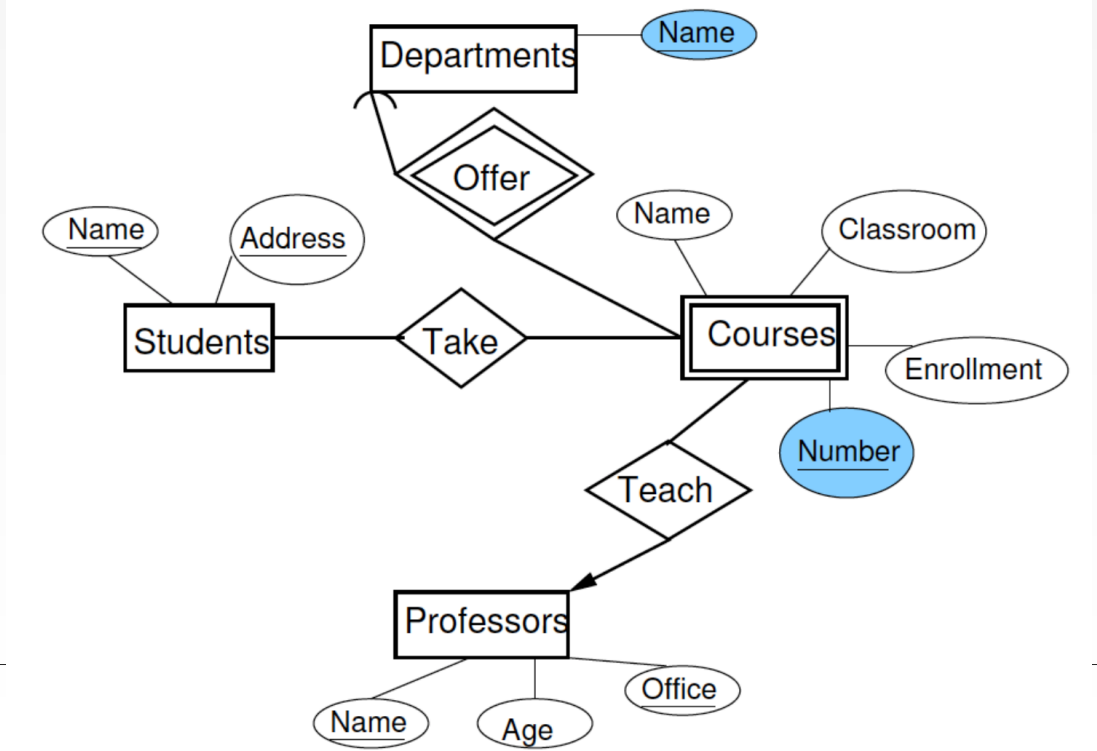
- Selection: $\sigma_{condition}(R)$
- Projection: $\pi_{att-list}(R)$
- Cartesian product: R X S
- Set union: R U S
- Set difference: R - S
- Intersection ∩
- Joins (▷ ◁)
- Rename (ρ)

E/R Diagrams: Relationships

- Show a many-one relationship by an arrow entering the "one" side. Many → One
- Show a one-one relationship by arrows entering both entity sets. One ↔ One
- In some situations, we can also assert "exactly one," i.e., each entity of one set must be related to exactly one entity of the other set. To do so, we use a rounded arrow. Exactly One →)

E/R Example

- Each department teaches multiple courses. Each course has a number.



Converting E/R Diagrams to Relational Designs

- Entity Set → Relation
  - Attribute of Entity Set → Attribute of a Relation
- Relationship → relation whose attributes are
  - Attribute of the relationship itself
  - Key attributes of the connected entity sets
- Several special cases:
  - Weak entity sets
  - Combining relations (especially for many-one relationships)
  - *ISA* relationships and subclasses
- Also note how referential integrity comes in (foreign keys)

Basic SQL Query

SELECT [DISTINCT] target-list
FROM relation-list
WHERE qualification;

- Relation-list: A list of relation names (possibly with range- variable after each name)
- Target-list: A list of attributes of relations in relation-list
- Qualification: conditions on attributes
- DISTINCT: optional keyword for duplicate removal
  - Default = no duplicate removal!
- ORDER BY: for sorting values

Boolean operators

- NOT, AND, and OR

```
SELECT name , num dogs FROM Person
WHERE age >= 18
AND num dogs > 3;
```

NULL

- SELECT name , num dogs FROM Person
  WHERE age <= 20 OR num dogs = 3;

name	age	num_dogs
Ace	20	4
Ada	NULL	3
Ben	NULL	NULL
Cho	27	NULL

Aggregate Functions

- SUM, AVG, MAX, MIN, and COUNT
- The input to an aggregate function is the name of a column, and the output is a single value that summarizes all the data within that column.
- Every aggregate ignores NULL values except for COUNT(*)

MIN(num dogs)
AVG(num dogs)

COUNT(num dogs)
COUNT(*)

name	age	num_dogs
Ace	20	4
Ada	18	3
Ben	7	NULL
Cho	27	3

Group By and Having

- SELECT age, AVG(num dogs) FROM Person
  WHERE age >= 18
  GROUP BY age
  HAVING COUNT(*) > 1;

age	AVG(num_dogs)
20	3.0
18	4.0
27	2.0

name	age	num_dogs
Ace	20	4
Ada	18	3
Ben	7	2
Cho	27	3
Ema	20	2
Ian	20	3
Jay	18	5
Mae	33	8
Rex	27	1

Illegal Queries

- SELECT age, AVG(num dogs) FROM Person;

- SELECT age, num dogs FROM Person
  GROUPBY age;

You Should Already Know

- SELECT <columns>
  FROM <tbl>
  WHERE <predicate>
  GROUP BY <columns>
  HAVING <predicate>
  ORDER BY <columns>
  LIMIT <num>;
- https://github.com/VTCourses/CS4604_Labs/tree/master/2.select
- https://github.com/VTCourses/CS4604_Labs/tree/master/3.more_queries

Other SQL Functions

- DATEDIFF()
- ROUND(), Sum(), min(), max(), count()
- IFNULL()
- IF()
- ABS(), avg()
- MOD()
- Between…and
- CASE…WHEN
- A lot more: https://www.w3schools.com/sql/sql_ref_mysql.asp

Join Variants

- Inner Joins
- Outer Joins
- Natural Join
- https://github.com/VTCourses/CS4604_Labs/tree/master/4.joins

SELECT <*column expression list*>
FROM *table_name*
  [**INNER** | **NATURAL**
 | {**LEFT** |**RIGHT** | **FULL** } {**OUTER**}] JOIN *table_name*
  ON <*qualification_list*>
WHERE …

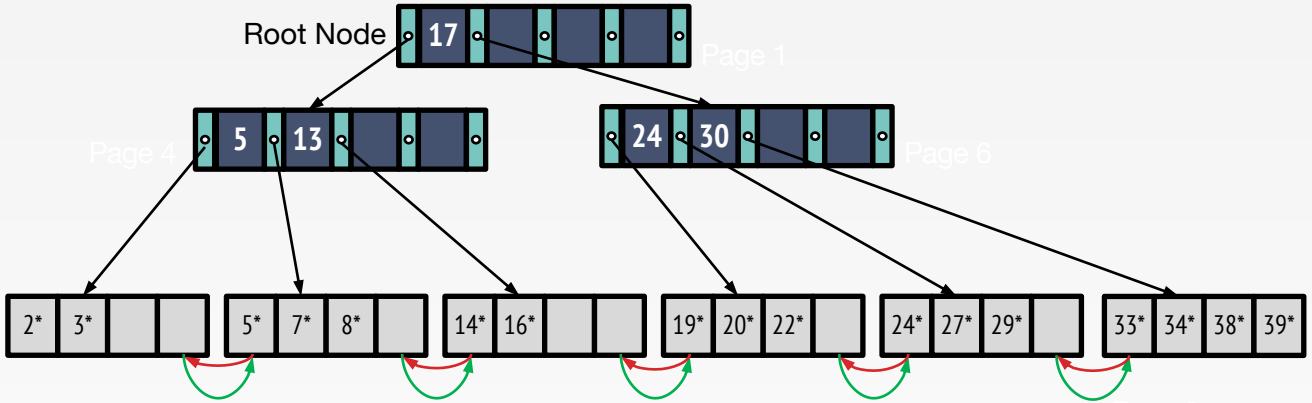
More SQL

- Sub-queries
- Correlated Subqueries
- SQL DDL
- Constraints
- Triggers
- Functions
- Note how referential integrity can be enforced (foreign key; on delete cascade etc.)

Tree Indexes

- B+-Trees
  - **Carefully understand the Definition!**
  - Searching
  - Inserting
  - Deleting

Example: B+ Tree



- Each interior node is at least partially full:
  - d <= #entries <= 2d (* root: 1<= #entries <= 2d)
  - d: order of the tree (max fan-out = 2d + 1)
- Data pages at bottom need not be stored in logical order
  - Next and prev pointers
- Height: the length of a path from the root to a leaf

Hashing/Sorting

- Hashing
  - Static Hashing
  - Extendible Hashing
  - Linear Hashing
- Sorting
  - Two-way merge sort
  - External merge sort
  - B+ trees for sorting
- How to search and build, internalize the structure
- Understand the process, how to cost it, how many passes it takes etc.

Hashing Summary

- B-trees and variants: in all DBMSs
- Hash indices: in some DBMSs
  - Hashing is useful for joins
- Hashing performs well on exact match queries
- B+ tree performs well on:
  - Search:
    - exact match queries
    - range queries
    - nearest-neighbor queries
  - Insertion and deletion
  - Smooth growing and shrinking

Sorting Summary

- External sorting is important
- External merge sort minimizes disk I/O cost:
  - Pass 0: Produces sorted ***runs*** of size ***B*** (# buffer pages)
  - Later passes: ***merge*** runs.
- Clustered B+ tree is good for sorting
- Unclustered B+ tree is usually very bad

Join techniques

- Nested-loops join
  - Simple Nested Loop Join
  - Page Nested Loop Join
  - Block Nested Loop Join
- Index-nested loops join
- Sort-merge join
- Hash join
  - Naive Hash Join
  - Grace Hash Join

Reading and Next Class

- Midterm Review
- Next: Project Interim presentation