Introduction to Relational Databases

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BIPG 540/740

Overview

- DBMS vs. Flat Files
- The Relational Model
- Relations
- Schemas
- Primary Keys
- Relationships
- Relationships Examples
- Derived Attributes, Views

DBMS

- Database Management Systems (DBMSs) are software systems that facilitate management and access of data

- A relational DBMS (RDBMS) is database system that uses the relational data model

- Other data models include hierarchical, network, object-oriented, and object-relational

- The relational model is the most popular

DBMS vs. Flat Files

- Why use a DBMS rather than storing everything in flat files?
- Ultimately, it depends on the task at a hand
- DBMSs take care of data storage and access details
- Is this useful or an inconvenience?

Flat Files: Cons

- Must write a custom program every time a new search is needed
  - Searches are limited by structure of files
  - Alternatively, could write code library of access routines, but this is more work and flexibility must be considered
- Need to consider concurrent access details
  - Multiple people editing records
  - Accessing a record that is being deleted by another person
- Need to consider access/security issues
  - Who can access which parts of the database
  - How will access be managed?

DBMS: Pros

- Data storage/access abstraction
  - Don't have to worry about how/where data stored
  - Implementation of low-level access routines not required
- Efficient searching/updating
  - DBMSs use sophisticated, semi-optimized access routines
  - Further optimization available
- Data integrity check mechanisms available
  - e.g. to avoid adding a record that already exists
  - Or to make sure data entered conforms to certain specifications

DBMS: Pros Cont'd

- Access/security management built-in
- Concurrent access details taken care of
- Reduced application development time
- Convenient, powerful stand-alone access tool
- Uniform, consistent access methods

DBMS: Cons

- In certain cases, data access can be slower
  - It’s faster to read from disk than a DBMS
  - Highly specialized searches may be completed more quickly by custom programs
  - Data manipulation facilities may be inconvenient
- May need to retrieve data in a way not supported
  - e.g. complex text manipulation
  - Operation that works on multiple rows
- Still limited by structure of database
  - Must conform data/tasks to database structure
  - How long will it take to conform your data for loading?

Flat Files vs. DBMS

- Depends on task
  - How long will database be used?
  - Who needs to be able to access data, and how?
  - How complex is data?
  - How complex are searches?

- Both types of databases will require sufficient planning for future needs

The Relational Model

- The central concept in the relational model is the **relation**

- Think of a relation as a collection of “things”
  - collection of students
  - collection of genes

- These “things” are called **records** or **tuples**

The Relation

- Each relation has one or more characteristics, known as **attributes** or **fields**
  - Student: address, GPA, phone number, …
  - Gene: sequence, function, chromosome, …
- Each record in a relation has these attributes
  - They have different values, of course
  - Attribute values can be missing/empty (more on this in later lectures)

Schemas

- A <u>description</u> of a relation is called a **schema**
- Schemas consist of:
  - The <u>name</u> of the relation
  - A <u>list</u> of the attributes in a relation
  - The <u>type</u> or **domain** of each attribute
    - Number (integer, real, etc.)
    - Character (single character, string of characters, etc.)
    - Logical (True/False)

Student Relation Schema

- Relation: *Student*

- Attributes:
  - **Name** - *character string*
  - **Age** - *integer*
  - **Phone number** - *character string*
  - **G.P.A.** - *real number*

Gene Relation Schema

- Relation: *Gene*

- Attributes:
  - **Name** - *character string*
  - **Sequence** - *character string*
  - **Function** - *character string*
  - **Chromosome** - *integer*

Schema Diagrams

- Often you will see schemas in box diagrams:

GENE
Gene ID - *serial*
Name - *varchar*
Sequence - *varchar*
Function - *varchar*
Chromosome - *integer*

- Although the format may differ
- More on “Gene ID” later

Relations and Tables

- An instance of a relation is <u>table</u>

- Tables have:
  - Rows
    - each row is a record
    - student 1, student 2, etc.
  - Columns
    - each column is an attribute
    - name, phone number, age, G.P.A., etc.

- Think of a relation as the abstract idea and a table as an actual set of records

Student Table

Name	Age	Phone Number	GPA
John Smith	19	419-383-2879	3.4
Sarah Jones	21	419-383-3120	3.1
Tim Roberts	20	419-383-4560	2.5

Gene Table

Name	Sequence	Function	Chromosome
abc	ATGGCCAA…	oxidize fat	2
efg	TGGACTTA..	transport Ca^{2+}	13
hij	CTAGATCA…	structural	6

Primary Keys

- Each record must be uniquely identifiable
- Otherwise there is no way to differentiate records
- A set of one or more attributes that uniquely identifies a record is called a **candidate key** or just **key**
- If more than one key exists, one of these is chosen, and is called the **primary key**

Primary Keys

- Usually, primary keys are created by adding a new attribute, which has type “serial”
  - A sequential set of unique numbers
  - 1, 2, 3, …
- Alternatively, the primary key can be a set of existing attributes:
  - (name, age, phone number)
  - As long as the record is uniquely identified, any combination of attributes is acceptable

Student Table Primary Key

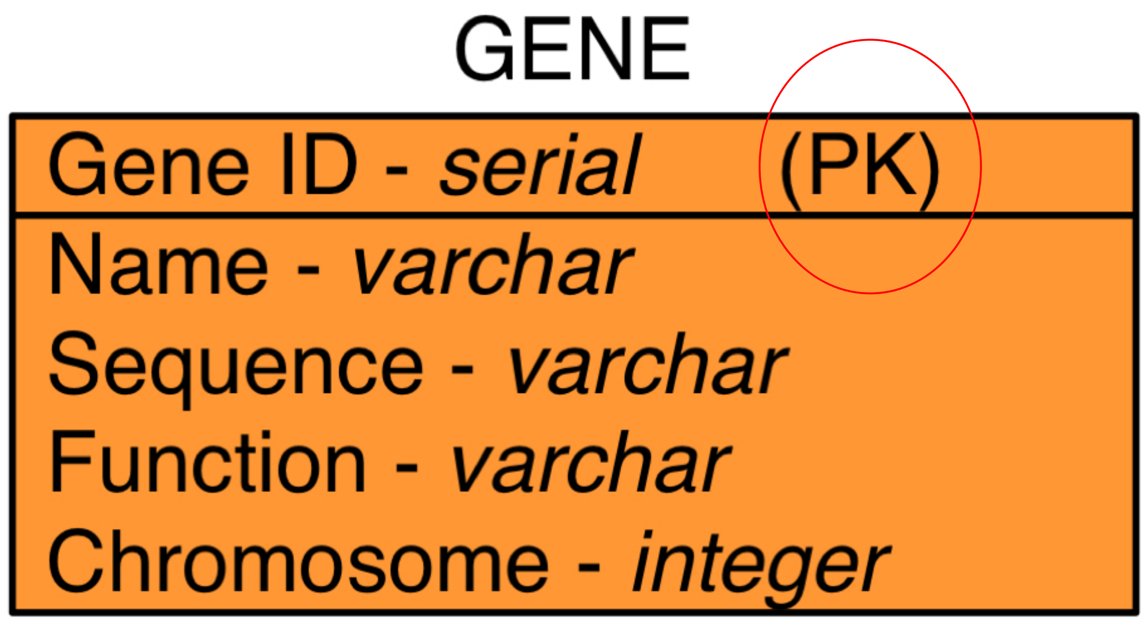
Student ID	Name	Age	Phone Number	GPA
101	John Smith	19	419-383-2879	3.4
312	Sarah Jones	21	419-383-3120	3.1
057	Tim Roberts	20	419-383-4560	2.5

Gene Table Primary Key

Gene ID	Name	Sequence	Function	Chromosome
1	abc	ATGGCCAA…	oxidize fat	2
2	efg	TGGACTTA..	transport Ca2+	13
3	hij	CTAGATCA…	structural	6

Gene Table Schema

- In schema diagrams, the primary key is usually annotated



Multiple Relations

- More often than not your database will have multiple relations
  - Student, college, residence hall, course, …
  - Gene, chromosome, genome, organism, …

- The utility of the relational model is being able to link these various relations

Multiple Relations

- What do I mean by “linking relations”?
  => **Relationships**

- Students
  - Belong to a college
  - Live in a residence hall
  - Enroll in several courses
- Genes
  - Are located in a chromosome
  - Exist in an organism

Relationships

- Relationships can be:
  - One-to-one
    - One bed per student
    - One genome per organism
    - These could be in the same relation
  - One-to-many
    - One college for many students
    - One chromosome for many genes
  - Many-to-many
    - Many students take many courses
    - Many genes exist in many organisms

Relationships Example

- Students in a College

STUDENT

Student ID - *integer* (PK)
Name - *varchar* Age - *integer* Phone Number - *varchar* G.P.A. - *real*

COLLEGE

College ID - *integer* (PK)
Name - *varchar* Building Location - *varchar* Office Phone Number - *varchar*

Students in a College

- How do we model this relationship?
- The relations must be linked by a common attribute
- They likely don’t have any naturally common attributes
  - Students and Colleges
  - Apple and Oranges

Students in a College

- To model this relationship, we'll <u>put one or more attributes from one relation into the other relation</u>
  - So, we are adding another attribute(s) to one of the relations
  - Which attribute(s)?

- We need to be able to uniquely associate the 2 relations
  - We'll use primary keys
  - But, do we use the student's PK or the college's PK?

Students in a College

- Well, what kind of a relationship is this?
  - One-to-many
  - One College for many Students

- Two options:
  - Add the student’s PK to the college relation
  - Add the college’s PK to the student relation

Students in a College

- What if we store each student in the college table?

College ID	Name	Building Location	Office Phone Number	Student ID
5	Engineering	Main Street	419-383-1234	1
5	Engineering	Main Street	419-383-1234	2
5	Engineering	Main Street	419-383-1234	3

.		.
.		.
.		.

Students in a College

- Since there are many students per college, it would be cumbersome and redundant to store each student in the college table
- Instead, we'll store the college's PK in the student table

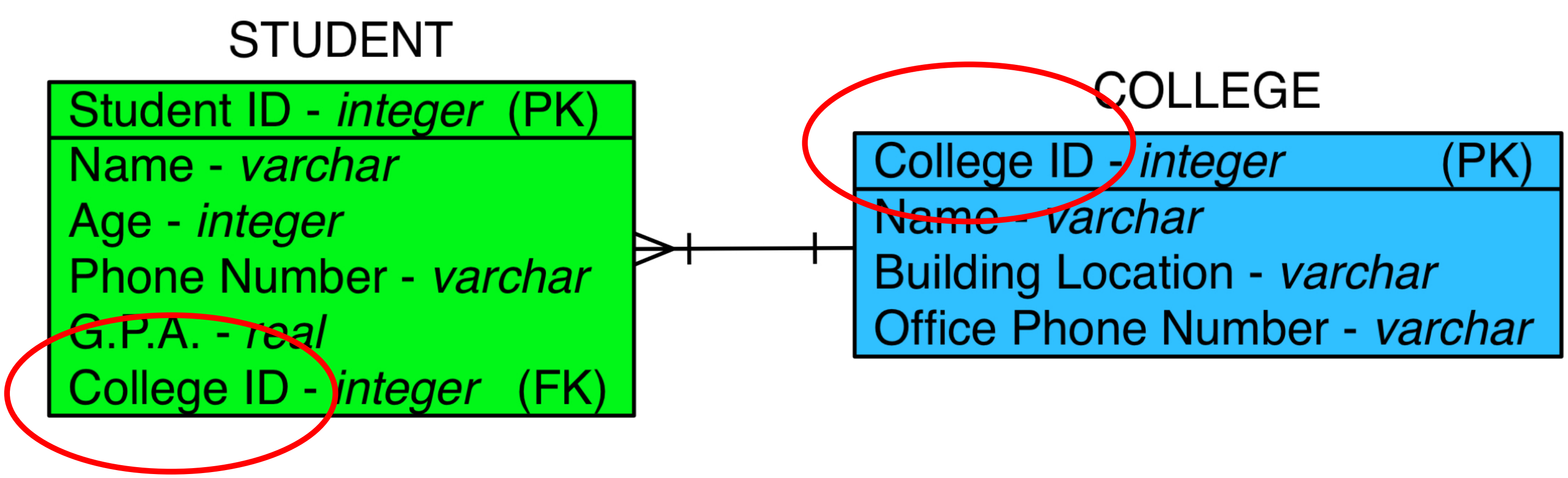
Student ID	Name	Age	Phone Number	GPA	College ID
1	John Smith	19	419-383-2879	3.4	5
2	Sarah Jones	21	419-383-3120	3.1	5
3	Tim Roberts	20	419-383-4560	2.5	5

Students in a College

- Storing the College ID in the Student table is much less redundant
- As an aside, redundancy can be prone to errors
  - Typing errors during data entry
  - Mistyped entries would be interpreted as distinct

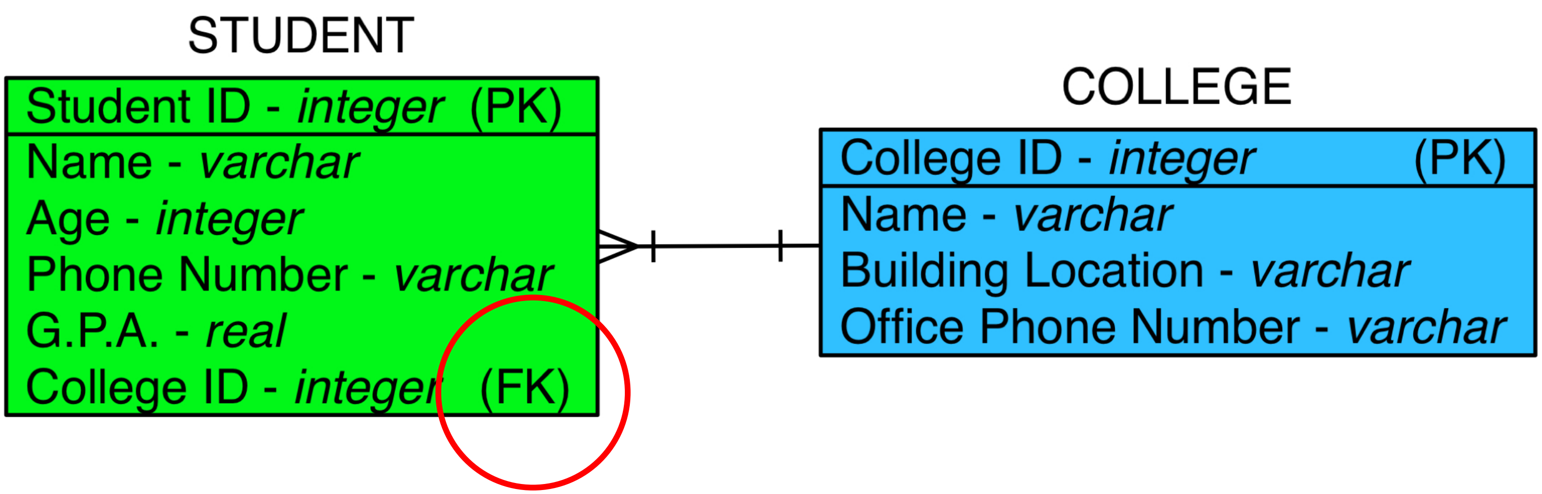
Student-College Schema

- To model relationships, the primary key of one relation is an attribute in another relation



Foreign Keys

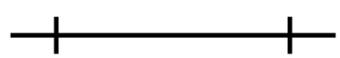
- A primary key from one relation stored in another is a **foreign key**

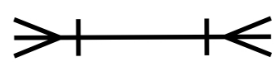


Relationship Schema Symbols

- What about *THAT*

- This symbol can be used to indicate the type of relationship
  - In this case, many-to-one
  - Think of the 3 legs on the left end as “many” vs. the one leg on the other end, “one”
  - Accordingly, one-to-one and many-to-many symbols can also be used:





Relational Database

- A relational database is a collection of one or more relations
- Each relation is linked to the others by primary keys, directly or indirectly
- Indirectly?
  - student => college => college faculty member
  - gene => chromosome => genome

Derived vs. Stored Attributes

- So far all of the attributes we have seen are stored directly in the database

- Can also <u>derive</u> attributes from others stored in database
  - Calculate age from D.O.B.
  - Compile full name from first and last name attributes

Derived Attributes

- Age from D.O.B.
  - Find absolute DOB age in years
  - Find today's absolute age in years
  - Subtract the DOB age from today's age and divide by 365.25 (accounting for leap years)

- Average gene length for a chromosome
  - Sum gene lengths for chromosome
  - Divide by total number of genes on chromosome

Views

- Views are derived relations
- A collection of attributes can be derived from one or more relations and “stored” in a view
- A view is thereafter accessible, just as you would access any other table
- Updating views may or may not be allowed, depending on the database system you are using

Views

- Why use a view?

- Views are persistent (until database is shutdown)
  - So if you are constantly creating certain derived attributes, a view would be useful
  - Alternative would be to store redundant information, which isn't recommended
    - Added consistency task
    - Waste of space
    - Views are more flexible

Reference

- Database Management Systems, Third Edition, by Ramakrishnan and Gehrke

What Now?

- We have a few in-class challenge problems
- Any questions before then?