College of Information Studies

University of Maryland Hornbake Library Building College Park, MD 20742-4345

Data Modeling

Session 12

INST 301

Introduction to Information Science

Databases

- Database
  - Collection of data, organized to support access
  - Models some aspects of reality
- DataBase Management System (DBMS)
  - Software to create and access databases
- Relational Algebra
  - Special-purpose programming language

Structured Information

- Field An “atomic” unit of data
  - number, string, true/false, …
- Record A collection of related fields
- Table A collection of related records
  - Each record is one row in the table
  - Each field is one column in the table
- Primary Key The field that identifies a record
  - Values of a primary key must be unique
- Database A collection of tables

A Simple Example

primary key

Membership Plans file

Membership Code	Membership Name	Monthly Fee
L	Late Shift	$20.25
M	Matinee	$25.75
P	Prime Time	$45.50
R	Round the Clock	$55.50
W	Weekender	$39.50

field names

records

fields

Characteristics of Membership Code field

Field Size	1
Format	
Input Mask	
Caption	Membership Code
Default Value	
Validation Rule	"L" Or "M" Or "P" Or "R" Or "W"
Validation Text	Please enter valid membership code.
Required	Yes
Allow Zero Length	No
Indexed	Yes (No Duplicates)

maximum characters in Membership Code field

Registrar Example

- Which students are in which courses?

- What do we need to know about the students?
  - first name, last name, email, department

- What do we need to know about the courses?
  - course ID, description, enrolled students, grades

A “Flat File” Solution

Student ID	Last Name	First Name	Department ID	Departmen	Course ID	Course description	Grades	email
1	Arrows	John	EE	EE	lbsc690	Information Technology	90	jarrows@wam
1	Arrows	John	EE	Elec Engin	ee750	Communication	95	ja_2002@yahoo
2	Peters	Kathy	HIST	HIST	lbsc690	Informatino Technology	95	kpeters2@wam
2	Peters	Kathy	HIST	history	hist405	American History	80	kpeters2@wma
3	Smith	Chris	HIST	history	hist405	American History	90	smith2002@glue
4	Smith	John	CLIS	Info Sci	lbsc690	Information Technology	98	js03@wam

Discussion Topic

Why is this a bad approach?

Goals of “Normalization”

- Save space
  - Save each fact only once
- More rapid updates
  - Every fact only needs to be updated once
- More rapid search
  - Finding something once is good enough
- Avoid inconsistency
  - Changing data once changes it everywhere

Relational Algebra

- Tables represent "relations"
  - Course, course description
  - Name, email address, department
- Named fields represent "attributes"
- Each row in the table is called a "tuple"
  - The order of the rows is not important
- Queries specify desired conditions
  - The DBMS then finds data that satisfies them

A Normalized Relational Database

Student Table

Student ID	Last Name	First Name	Department ID	email
1	Arrows	John	EE	jarrows@wam
2	Peters	Kathy	HIST	kpeters2@wam
3	Smith	Chris	HIST	smith2002@glue
4	Smith	John	CLIS	js03@wam

Department Table

Department ID	Department
EE	Electronic Engineering
HIST	History
CLIS	Information Stuides

Course Table

Course ID	Course Description
lbsc690	Information Technology
ee750	Communication
hist405	American History

Enrollment Table

Student ID	Course ID	Grades
1	lbsc690	90
1	ee750	95
2	lbsc690	95
2	hist405	80
3	hist405	90
4	lbsc690	98

Approaches to Normalization

- For simple problems
  - Start with "binary relationships"
    - Pairs of fields that are related
  - Group together wherever possible
  - Add keys where necessary
- For more complicated problems
  - Entity relationship modeling

Example of Join

Student Table

Student ID	Last Name	First Name	Department ID	email
1	Arrows	John	EE	jarrows@wam
2	Peters	Kathy	HIST	kpeters2@wam
3	Smith	Chris	HIST	smith2002@glue
4	Smith	John	CLIS	js03@wam

Department Table

Department ID	Department
EE	Electronic Engineering
HIST	History
CLIS	Information Stuides

"Joined" Table

Student ID	Last Name	First Name	Department ID	Department	email
1	Arrows	John	EE	Electronic Engineering	jarrows@wam
2	Peters	Kathy	HIST	History	kpeters2@wam
3	Smith	Chris	HIST	History	smith2002@glue
4	Smith	John	CLIS	Information Stuides	js03@wam

Problems with Join

- Data modeling for join is complex
  - Useful to start with E-R modeling
- Join are expensive to compute
  - Both in time and storage space
- But it’s joins that make databases relational
  - Projection and restriction also used in flat files

Some Lingo

- “Primary Key” uniquely identifies a record
  - e.g. student ID in the student table
- “Compound” primary key
  - Synthesize a primary key with a combination of fields
  - e.g., Student ID + Course ID in the enrollment table
- “Foreign Key” is primary key in the <u>other</u> table
  - Note: it need not be unique in <u>this</u> table

Project

New Table

Student ID	Last Name	First Name	Department ID	Department	email
1	Arrows	John	EE	Electronic Engineering	jarrows@wam
2	Peters	Kathy	HIST	History	kpeters2@wam
3	Smith	Chris	HIST	History	smith2002@glue
4	Smith	John	CLIS	Information Stuides	js03@wam

SELECT Student ID, Department

Student ID	Department
1	Electronic Engineering
2	History
3	History
4	Information Stuides

Restrict

New Table

Student ID	Last Name	First Name	Department ID	Department	email
1	Arrows	John	EE	Electronic Engineering	jarrows@wam
2	Peters	Kathy	HIST	History	kpeters2@wam
3	Smith	Chris	HIST	History	smith2002@glue
4	Smith	John	CLIS	Information Stuides	js03@wam

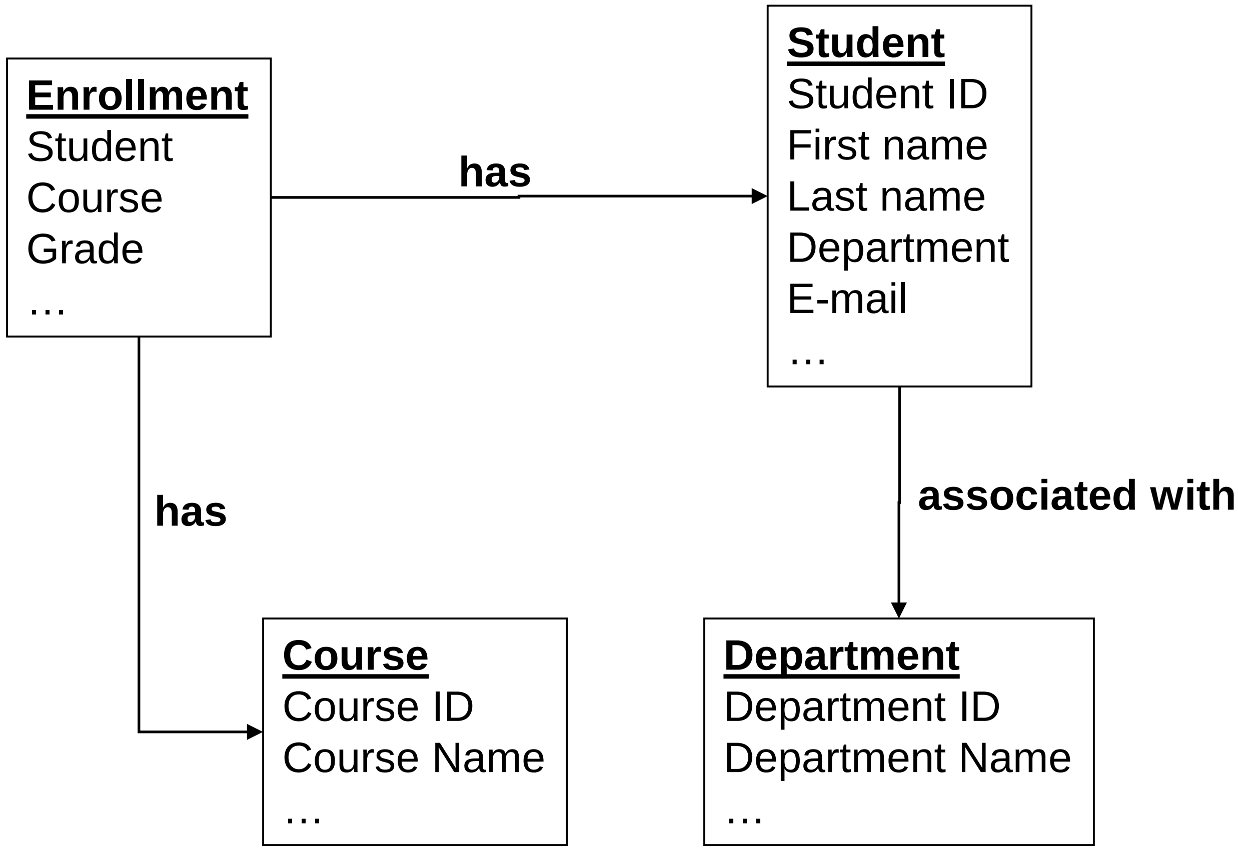
WHERE Department ID = “HIST”

Student ID	Last Name	First Name	Department ID	Department	email
2	Peters	Kathy	HIST	History	kpeters2@wam
3	Smith	Chris	HIST	History	smith2002@glue

Entity-Relationship Diagrams

- Graphical visualization of the data model
- Entities are captured in boxes
- Relationships are captured using arrows

Registrar ER Diagram



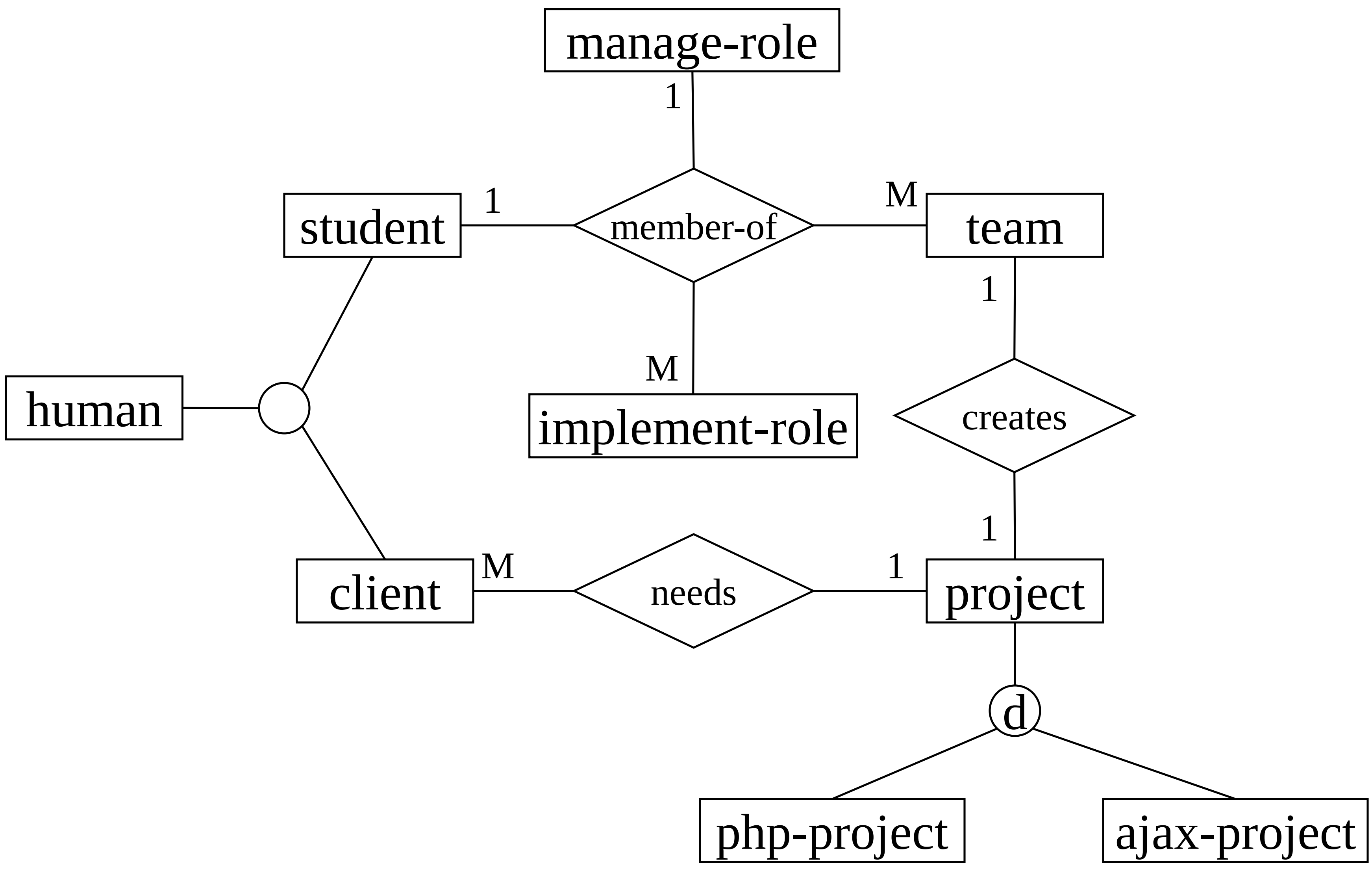
Getting Started with E-R Modeling

- What **<u>questions</u>** must you answer?

- What **<u>data</u>** is needed to generate the answers?
  - Entities
    - Attributes of those entities
  - Relationships
    - Nature of those relationships

- How will the user interact with the system?
  - Relating the question to the available data
  - Expressing the answer in a useful form

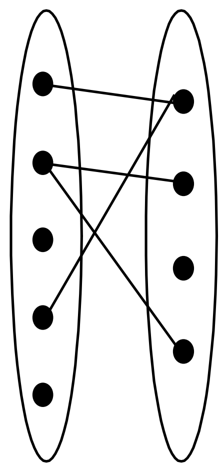
“Project Team” E-R Example



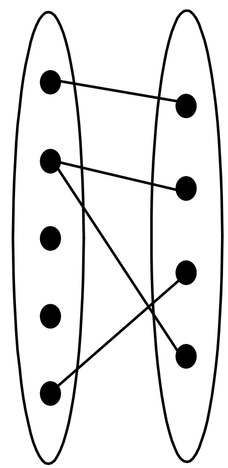
Components of E-R Diagrams

- Entities
  - Types
    - Subtypes (disjoint / overlapping)
  - Attributes
    - Mandatory / optional
  - Identifier
- Relationships
  - Cardinality
  - Existence
  - Degree

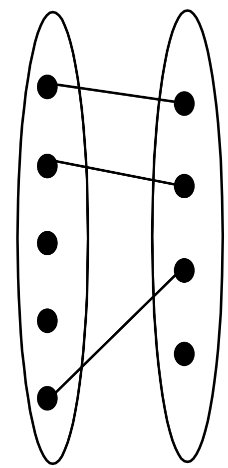
Types of Relationships



Many-to-Many



1-to-Many



1-to-1

Making Tables from E-R Diagrams

- Pick a primary key for each entity
- Build the tables
  - One per entity
  - Plus one per M:M relationship
  - Choose terse but memorable table and field names
- Check for parsimonious representation
  - Relational “normalization”
  - Redundant storage of computable values
- Implement using a DBMS

- 1NF: Single-valued indivisible (atomic) attributes
  - Split “Doug Oard” to two attributes as (“Doug”, “Oard”)
  - Model M:M implement-role relationship with a table

- 2NF: Attributes depend on complete primary key
  - (id, impl-role, name)->(id, name)+(id, impl-role)

- 3NF: Attributes depend directly on primary key
  - (id, addr, city, state, zip)->(id, addr, zip)+(zip, city, state)

- 4NF: Divide independent M:M tables
  - (id, role, courses) -> (id, role) + (id, courses)

- 5NF: Don’t enumerate derivable combinations

Normalized Table Structure

- Persons: id, fname, lname, userid, password
- Contacts: id, ctype, cstring
- Ctlabels: ctype, string
- Students: id, team, mrole
- Iroles: id, irole
- Rlabels: role, string
- Projects: team, client, pstring

Database Integrity

- Registrar database must be internally consistent
  - Enrolled students must have an entry in student table
  - Courses must have a name
- What happens:
  - When a student withdraws from the university?
  - When a course is taken off the books?

Integrity Constraints

- Conditions that must always be true
  - Specified when the database is designed
  - Checked when the database is modified
- RDBMS ensures integrity constraints are respected
  - So database contents remain faithful to real world
  - Helps avoid data entry errors

Referential Integrity

- Foreign key values must exist in other table
  - If not, those records cannot be joined
- Can be enforced when data is added
  - Associate a primary key with each foreign key
- Helps avoid erroneous data
  - Only need to ensure data quality for primary keys

Concurrency

- Thought experiment: You and your project partner are editing the same file…
  - Scenario 1: you both save it at the same time
  - Scenario 2: you save first, but before it's done saving, your partner saves

Whose changes survive?
A) Yours B) Partner's C) neither D) both E) ???

Concurrency Example

- Possible actions on a checking account
  - Deposit check (read balance, write new balance)
  - Cash check (read balance, write new balance)
- Scenario:
  - Current balance: $500
  - You try to deposit a $50 check and someone tries to cash a $100 check at the same time
  - Possible sequences: (what happens in each case?)

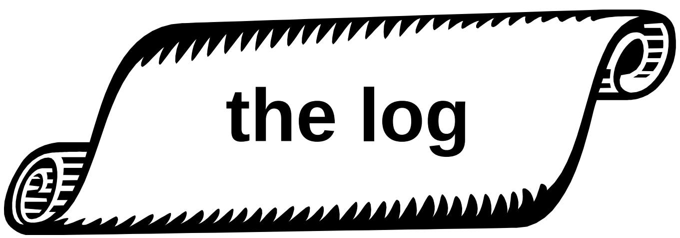
Deposit: read balance	**Deposit: read balance**	**Deposit: read balance**
Deposit: write balance	**Cash: read balance**	**Cash: read balance**
Cash: read balance	**Cash: write balance**	**Deposit: write balance**
Cash: write balance	**Deposit: write balance**	**Cash: write balance**

Database Transactions

- Transaction: sequence of grouped database actions
  - e.g., transfer $500 from checking to savings
- "ACID" properties
  - **Atomicity**
    - All-or-nothing
  - **Consistency**
    - Each transaction must take the DB between consistent states.
  - **Isolation:**
    - Concurrent transactions must appear to run in isolation
  - **Durability**
    - Results of transactions must survive even if systems crash

Making Transactions

- Idea: keep a log (history) of all actions carried out while executing transactions
  - Before a change is made to the database, the corresponding log entry is forced to a safe location



- Recovering from a crash:
  - Effects of partially executed transactions are undone
  - Effects of committed transactions are redone

Key Ideas

- Databases are a good choice when you have
  - Lots of data
  - A problem that contains inherent <u>relationships</u>
- Join is the most important concept
  - Project and restrict just remove undesired stuff
- Design before you implement
  - Managing complexity is important

Before You Go

On a sheet of paper, answer the following (ungraded) question (no names, please):

What was the muddiest point in today's class?