Lecture 2
Entity-Relationship Model

Eugene Wu

Steps for a New Application

Requirements

- what are you going to build?

Conceptual Database Design

- pen-and-pencil description

Logical Design

- formal database schema

Schema Refinement:

- fix potential problems, normalization

Physical Database Design

- use sample of queries to optimize for speed/storage

App/Security Design

- prevent security problems

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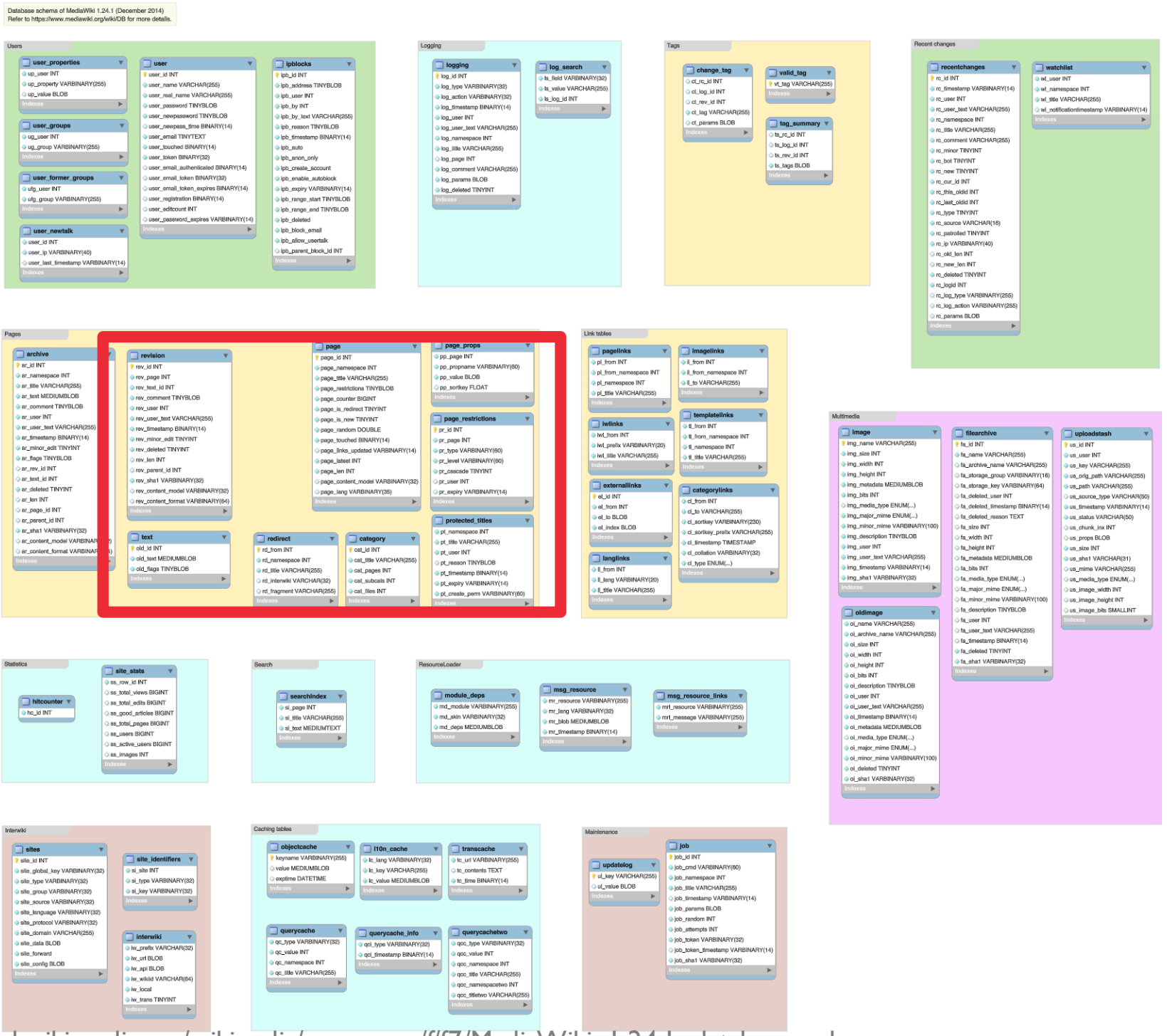
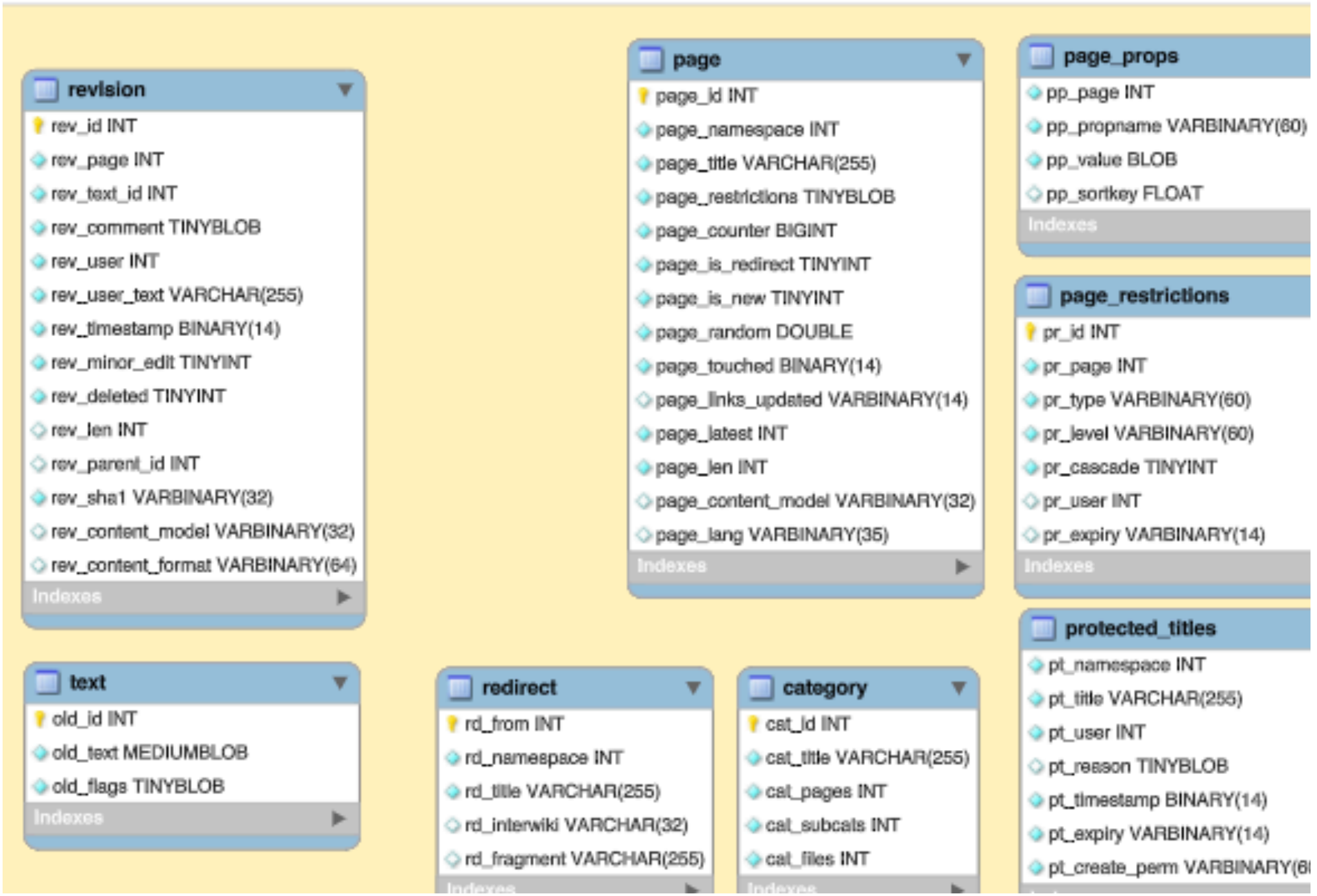
Database Apps Are Complicated

Typical Fortune 100 Company

- ~10k different information (data) systems
- 90% relational databases (DBMSes)
- Typical database has >100 tables
- Typical table has 50 – 200 attributes



https://upload.wikimedia.org/wikipedia/commons/f/f7/MediaWiki_1.24.1_database_schema.svg



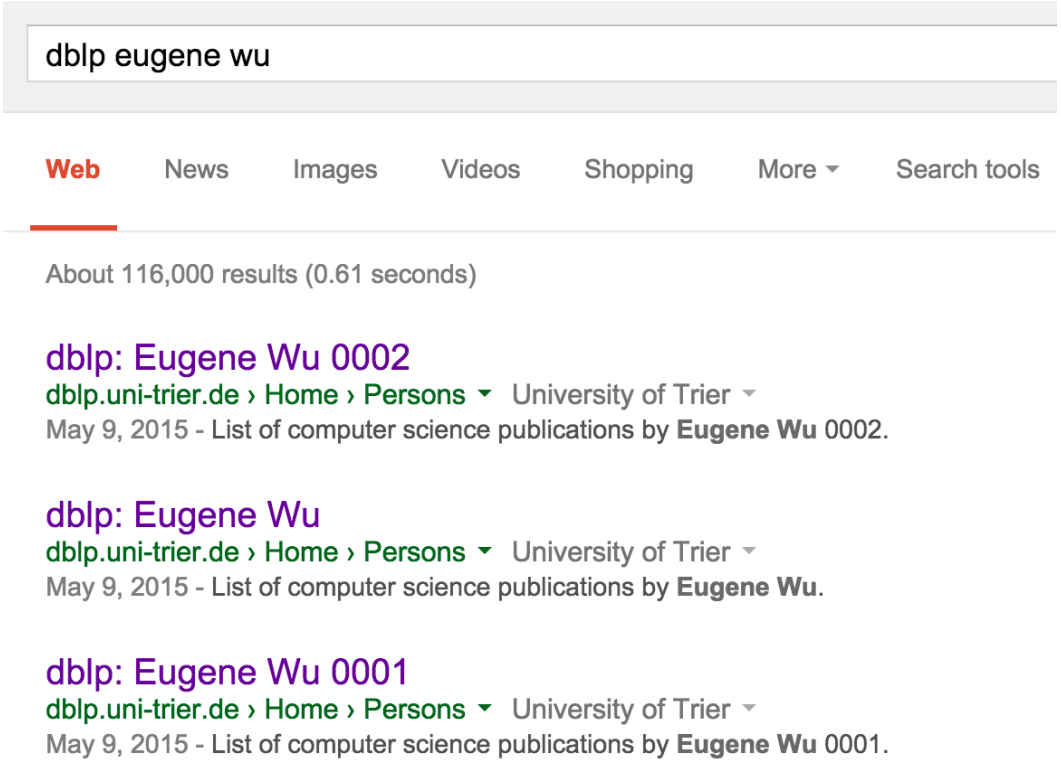
https://upload.wikimedia.org/wikipedia/commons/f/f7/MediaWiki_1.24.1_database_schema.svg

Inconsistencies/Constraint Violations

Huge amount of effort to avoid inconsistencies

Can data model help us avoid automatically?

DBLP is *the* site for computer science publications



Inconsistencies/Constraint Violations

[–] **2010 – today** [+] **Refine list**

2014

[j8] Eugene Wu, Leilani Battle, Samuel R. Madden:
The Case for Data Visualization Management Systems. PVLDB 7(10): 903-906 (2014)

[j7] Alekh Jindal, Praynaa Rawlani, Eugene Wu, Samuel Madden, Amol Deshpande, Mike Stonebraker:
VERTEXICA: Your Relational Friend for Graph Analytics! PVLDB 7(13): 1669-1672 (2014)

≠

[–] **1990 – 1999** [+] **Refine list**

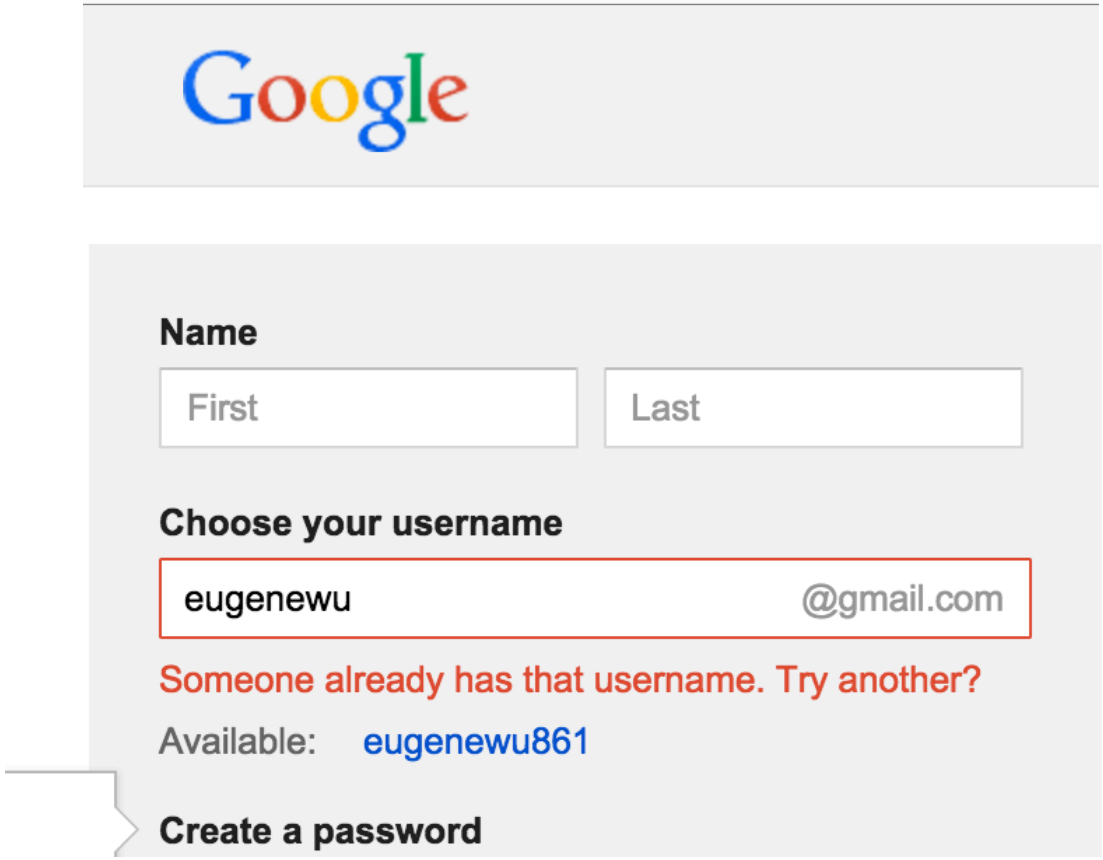
1994

[c2] James Hwang, Eugene Wu, Alan Bell, Andy Cordell, LeBarian Stokes, Scott Hankins:
Design of a SPDM-Like Robotic Manipulator System for Space Station on Orbit Replaceable Unit Ground Testing - An Overview of the System Architecture. ICRA 1994: 1286-1291

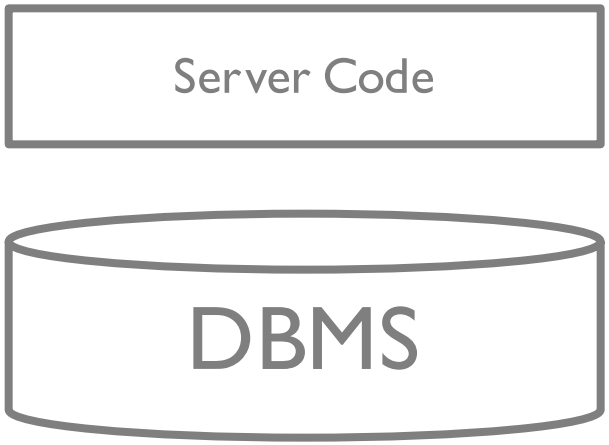
[c1] Eugene Wu, James Hwang, Scott Hankins:
Design of the Control System for a Robotic Manipulator for Space Station On-Orbit Replaceable Unit Ground Testing. ICRA 1994: 1415-1420

Inconsistencies/Constraint Violations

Giving me eugenewu@gmail would violate constraints



It is Hard to Design Applications



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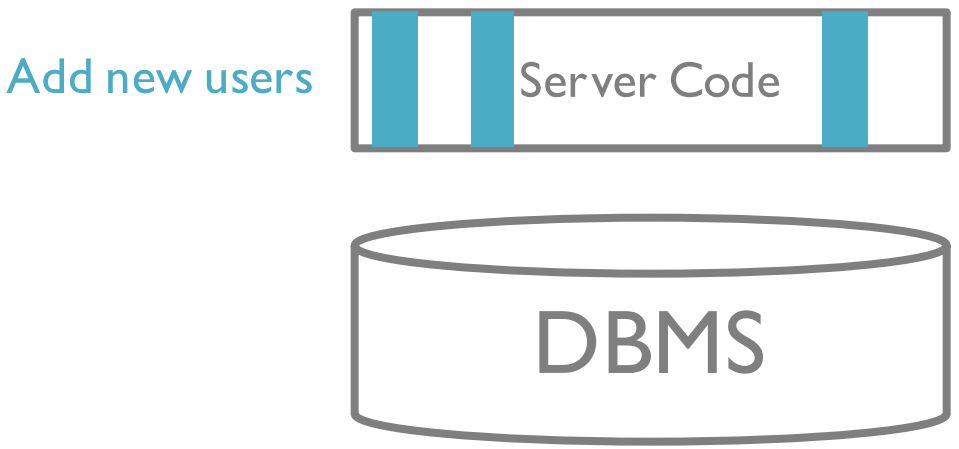

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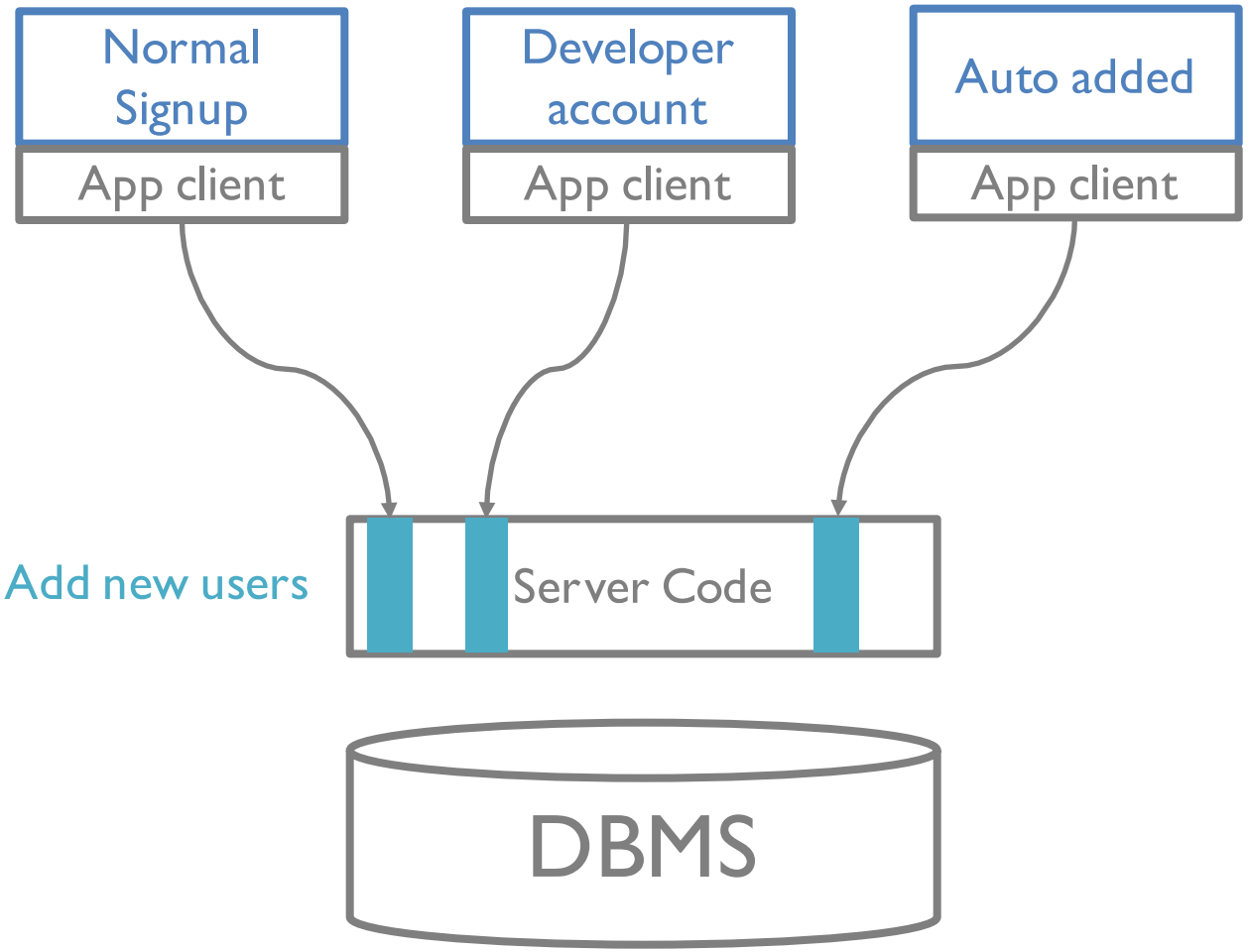

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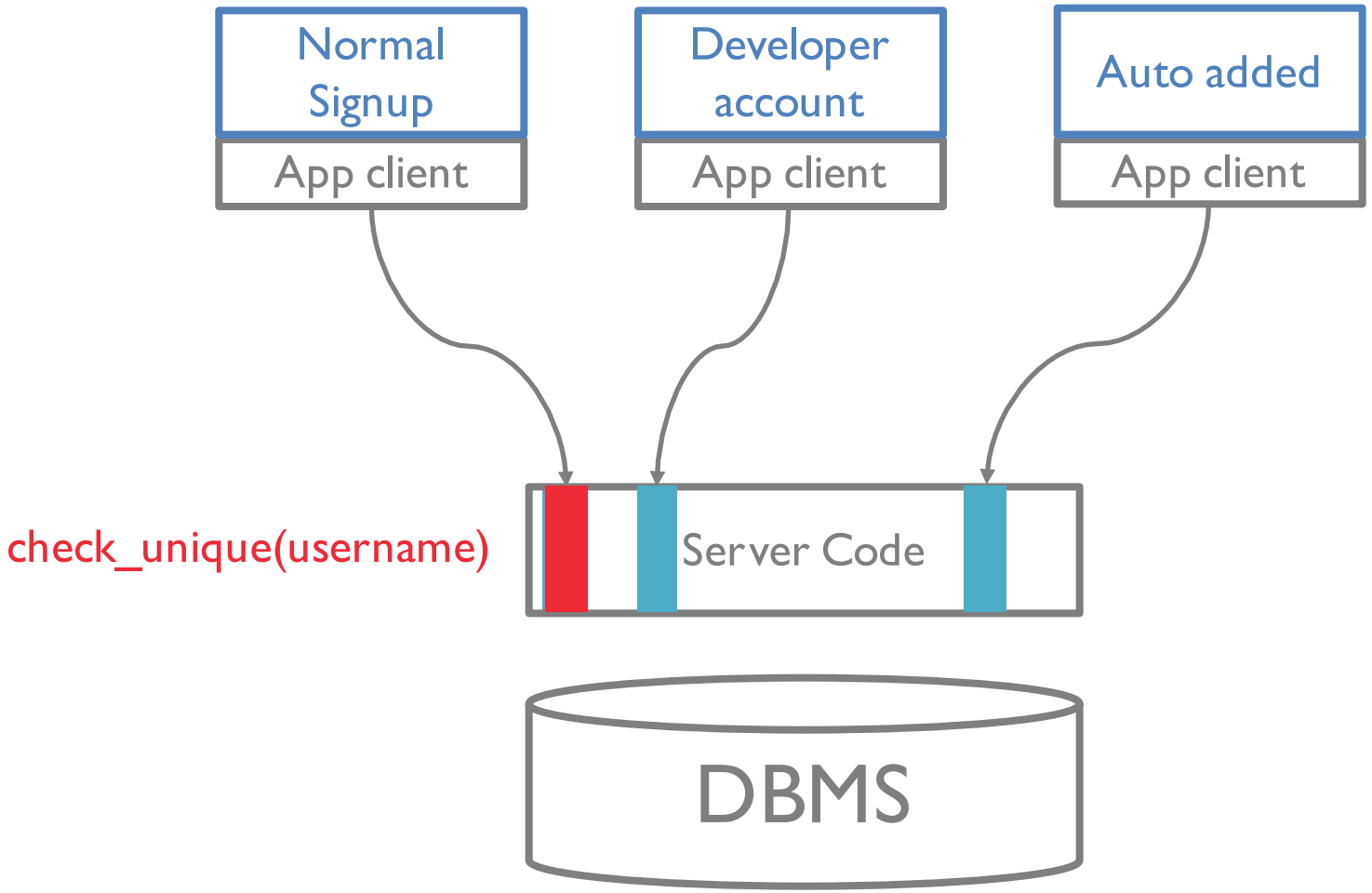
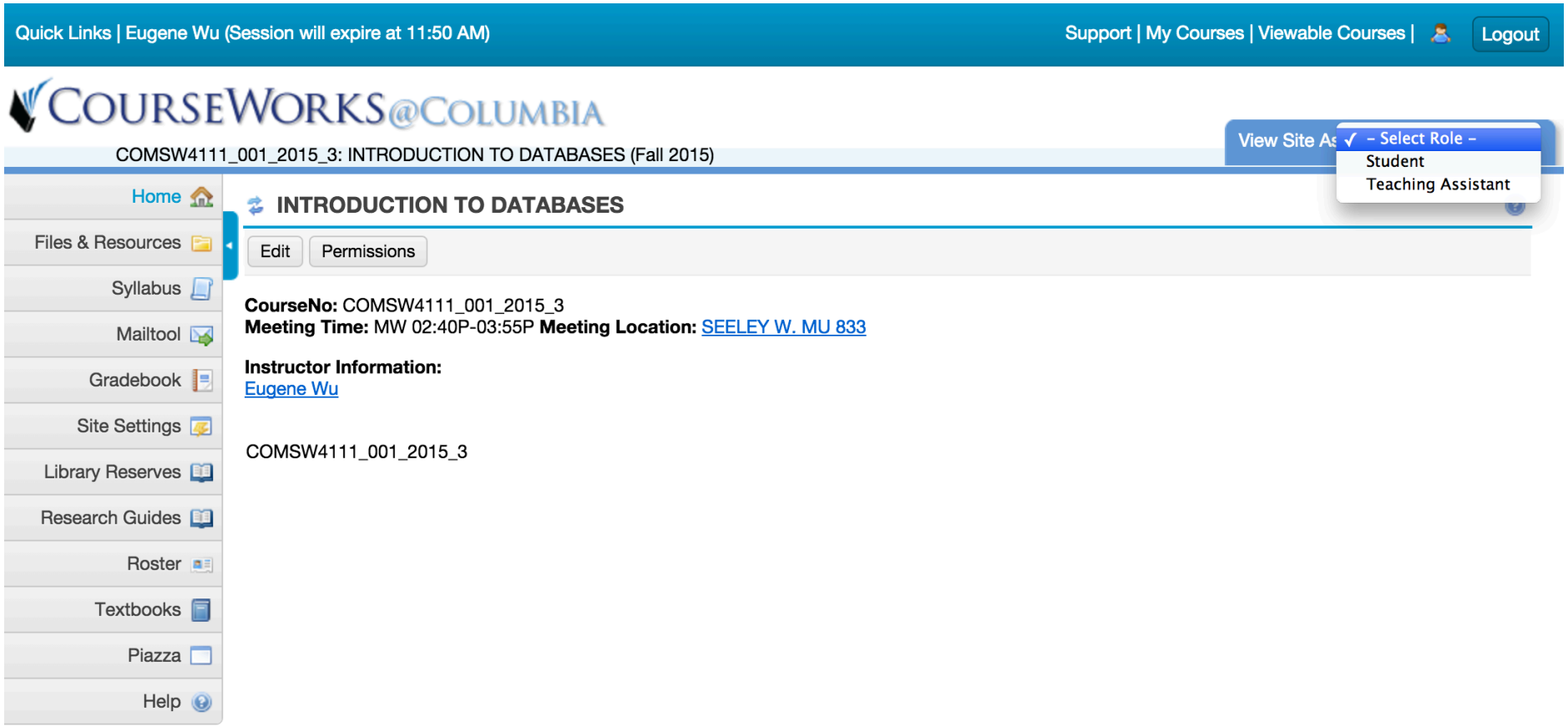


Let's make ~~a webapp~~ $$$

live exercise time


Quick Links | Eugene Wu (Session will expire at 11:50 AM)
Support | My Courses | Viewable Courses |
Logout
COURSEWORKS@COLUMBIA
COMSW4111_001_2015_3: INTRODUCTION TO DATABASES (Fall 2015)
View Site As
– Select Role –
Student
Teaching Assistant
Home
Files & Resources
Syllabus
Mailtool
Gradebook
Site Settings
Library Reserves
Research Guides
Roster
Textbooks
Piazza
Help
INTRODUCTION TO DATABASES
Edit
Permissions
CourseNo: COMSW4111_001_2015_3
Meeting Time: MW 02:40P-03:55P Meeting Location: SEELEY W. MU 833
Instructor Information:
Eugene Wu
COMSW4111_001_2015_3

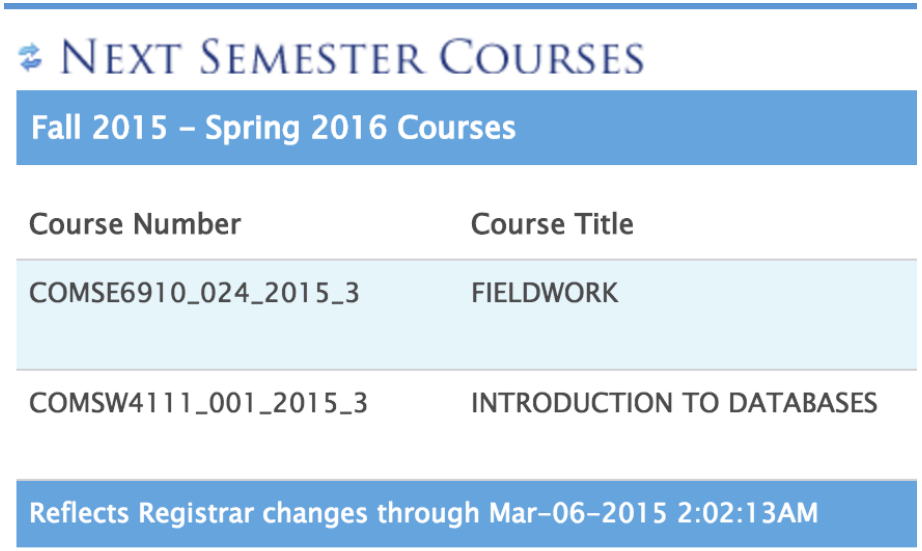
Entity-Relationship Modeling

Entities (objects) to store and their attributes

Relationships between entities and their attrs.

Integrity constraints & business rules

Visually modeled, easy to turn into DB schema



NEXT SEMESTER COURSES

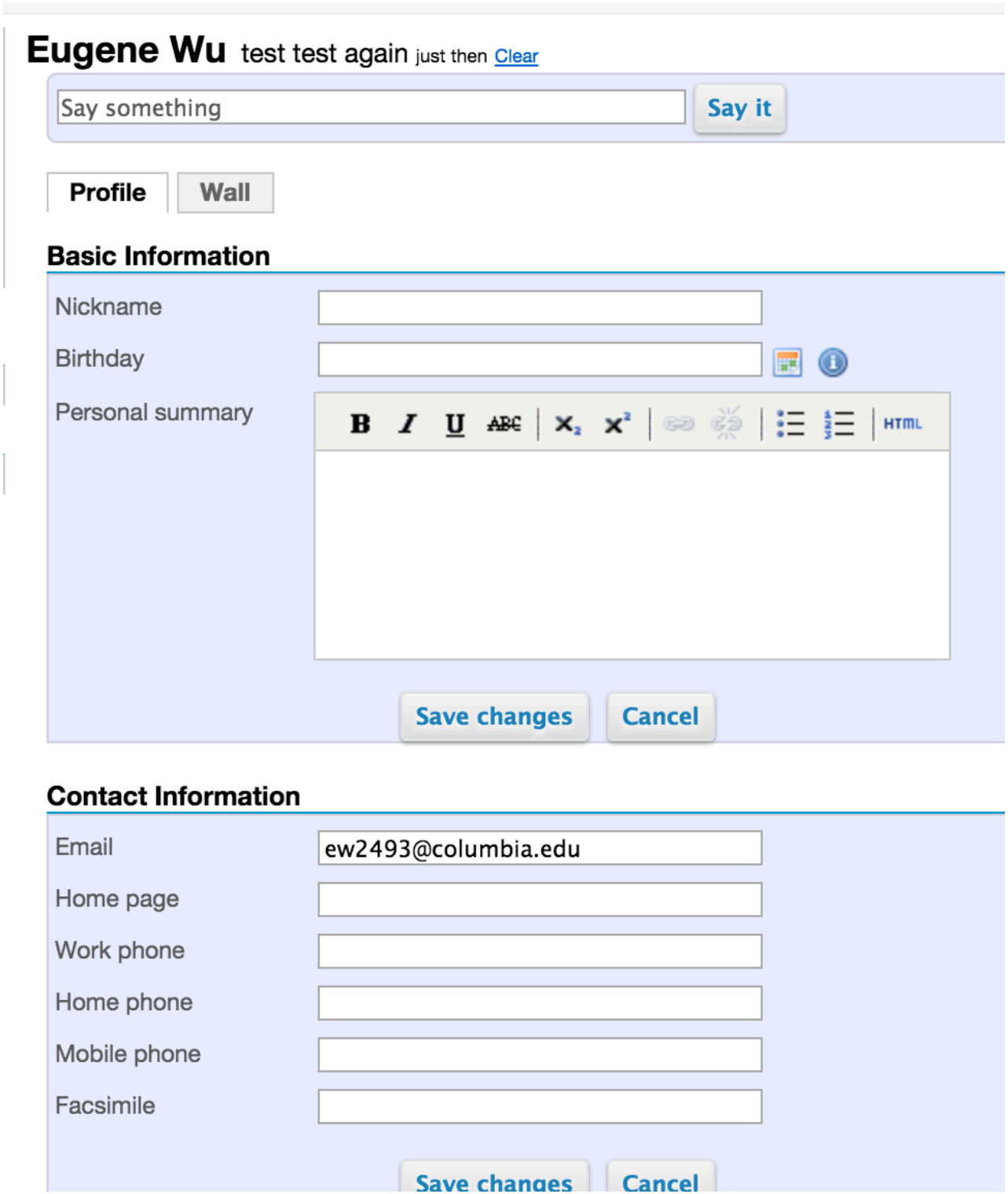
Fall 2015 – Spring 2016 Courses

Course Number	Course Title
COMSE6910_024_2015_3	FIELDWORK
COMSW4111_001_2015_3	INTRODUCTION TO DATABASES

Reflects Registrar changes through Mar-06-2015 2:02:13AM

Courses

- Course Number
- Course Title
- Year
- Semester



Users

- Nickname
- Name
- Birthday
- Summary
- Email
- …

Basics: Entities

Entity e.g., intro to databases

- real-world object distinguishable from other objects
- described as set of attributes & the values
- (think one record)

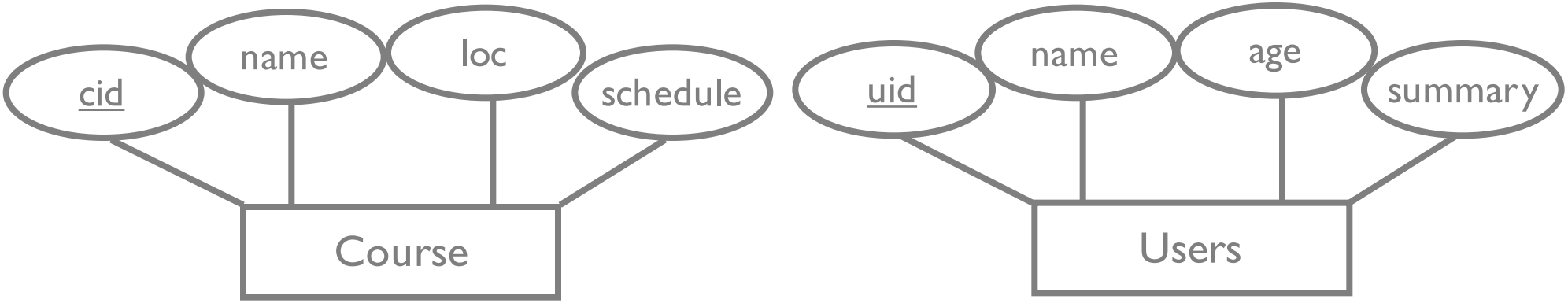
Entity Set e.g., all courses

- collection of similar entities
- all entities have same attributes (unless Is-A)
- must have one or more keys
- attributes have domains
- ≈ table

Example: Entity

Keys (cid, uid) are underlined

- Values must be unique
- (think: can use as hashtable key to lookup in table)



Basics: Relationships

Relationship: association between 2 or more entities

e.g., alice is taking Introduction to DBs

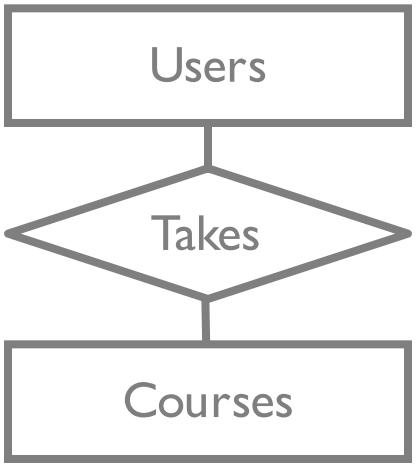
Relationship Set: collection of similar relationships

N-ary relationship set R relates N entity sets $E_1 \ldots E_n$

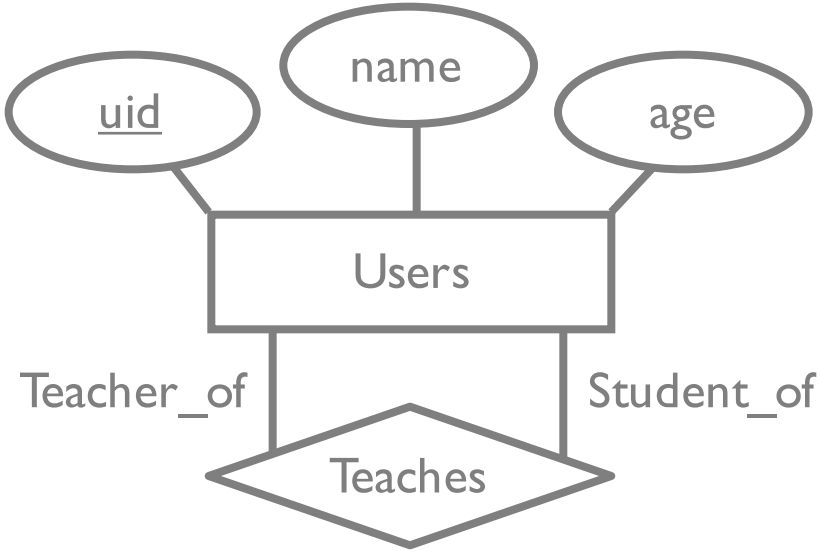
Each $r \in R$ involves entities $e_1 \ldots e_n$

An E_i can be part of diff. relationship sets or diff. roles in same set

Basics: Relationships



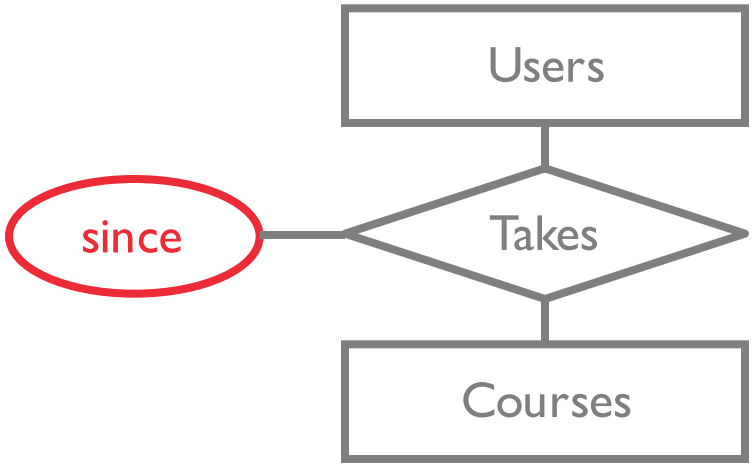
Users takes diff roles in same relationships set



Basics: Relationships

Relationships sets can have descriptive attributes

e.g., the *since* attribute of Instructs

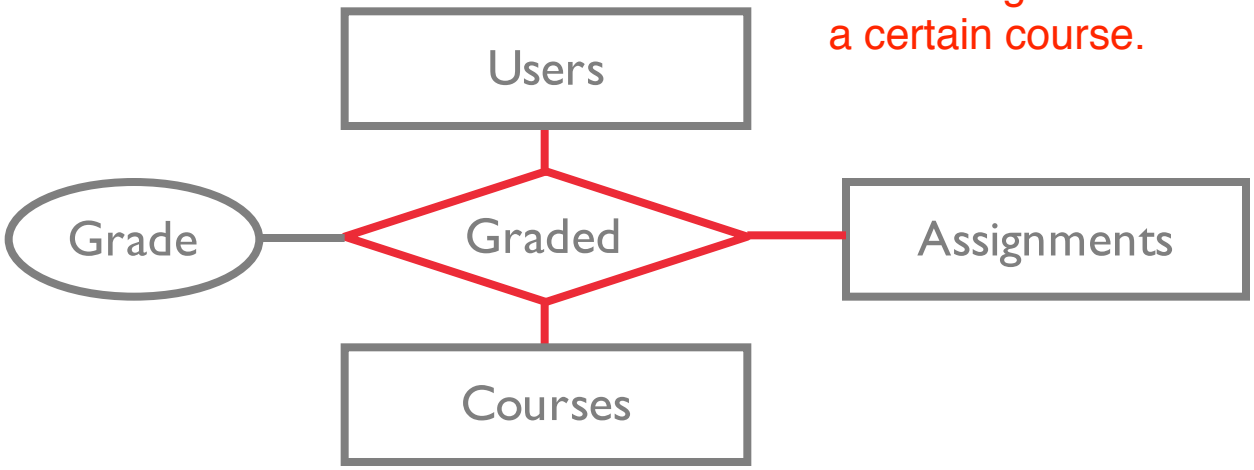


Basics: Ternary Relationships

Connects three entities

N-ary relationships possible too.

same user cannot submit assignments multiple times.
a user is graded for an assignment for a certain course.



Constraints

Help avoid corruption, inconsistencies

- Key constraints
- Participation constraints
- Weak entities
- Overlap and covering constraints

Key Constraints

Defines cardinality requirements on relationships

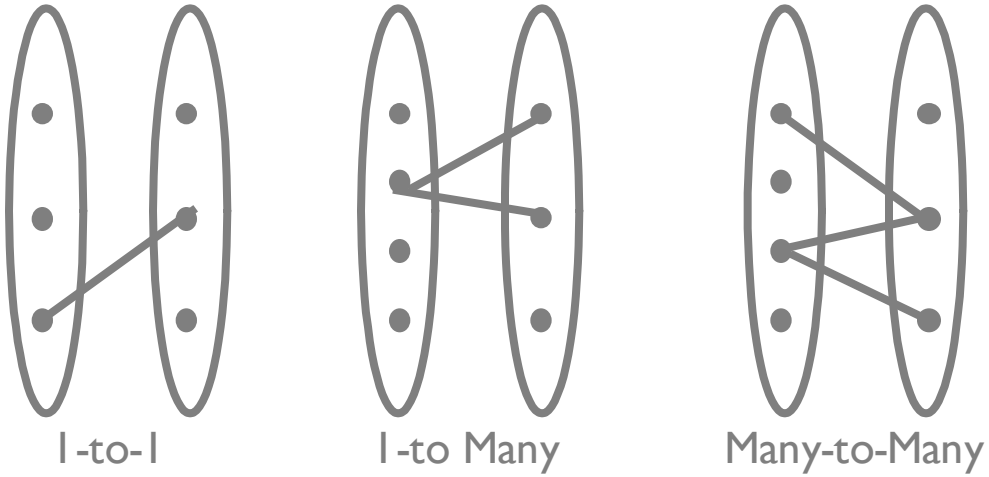
Many to many e.g., consider *Takes*

a user can take many courses

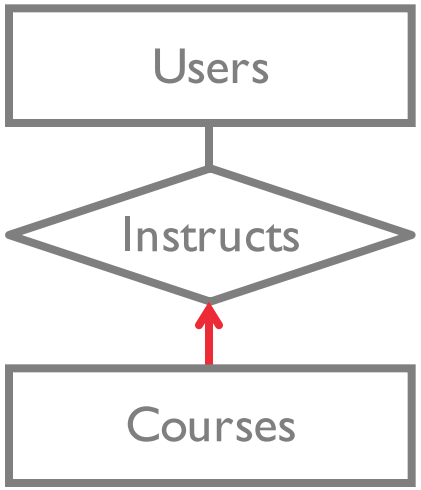
a course can have many users that take the course

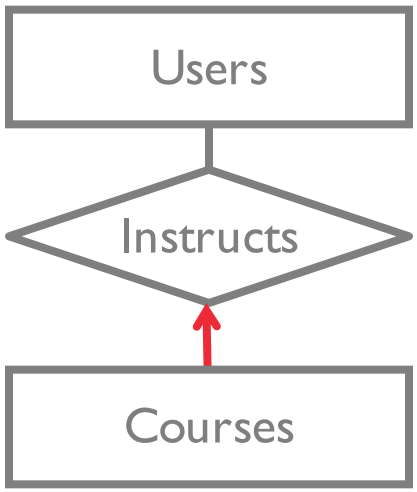
One to Many e.g., consider *Instructs*

a course has at most one instructor

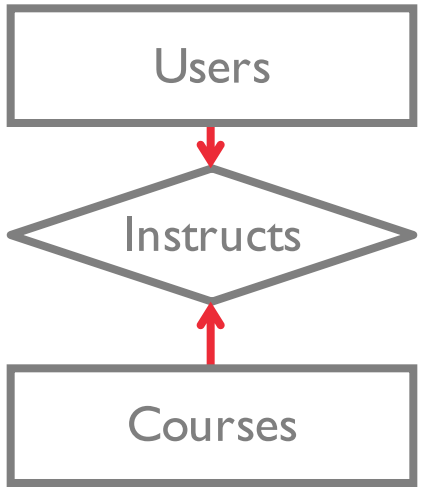


constraint between courses and users





A course has at most one instructor



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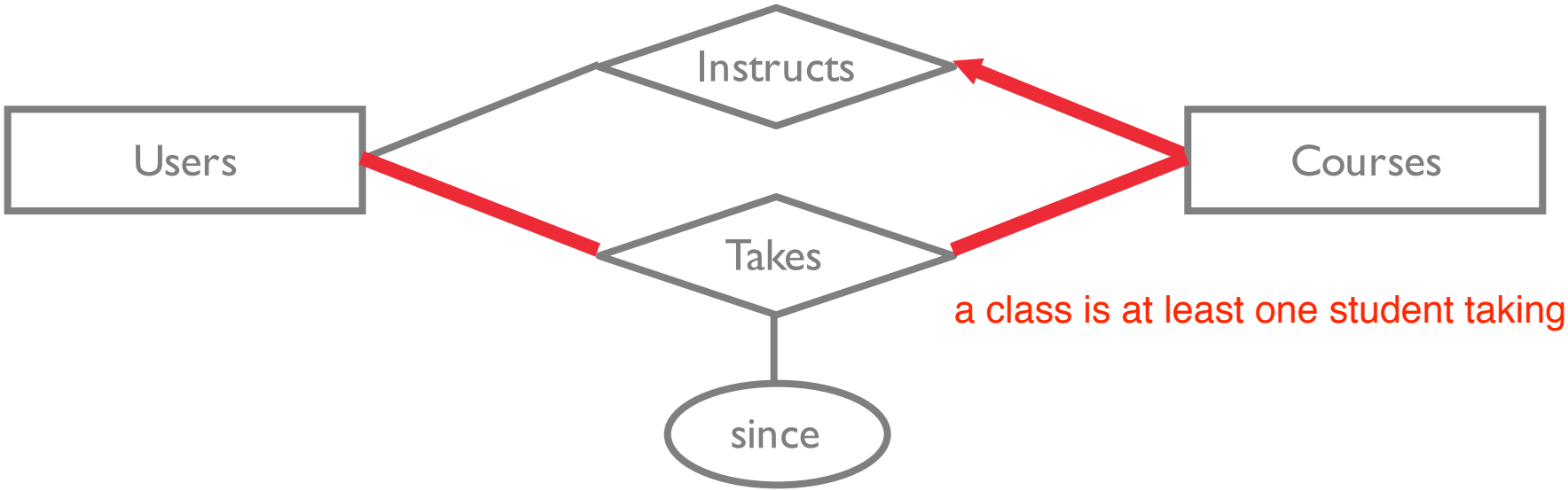
Participation Constraints

Does every course need an instructor?

If yes, it's a participation constraint

e.g., participation of Courses in instructs is *Total*

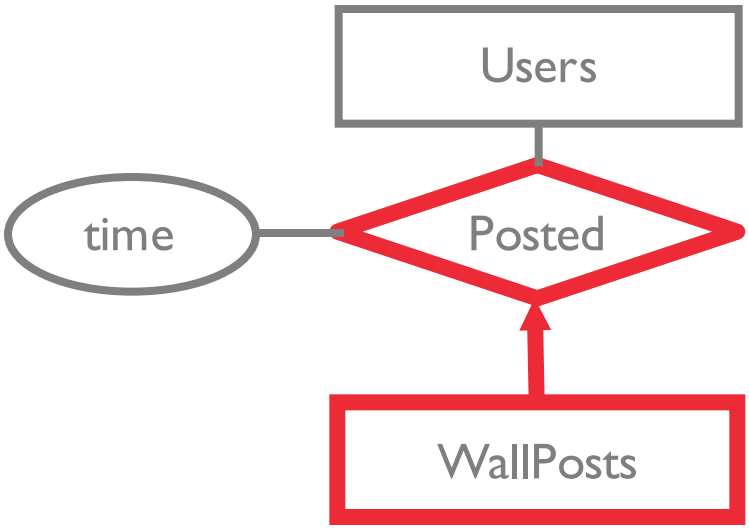
Otherwise, *partial* participation constraint



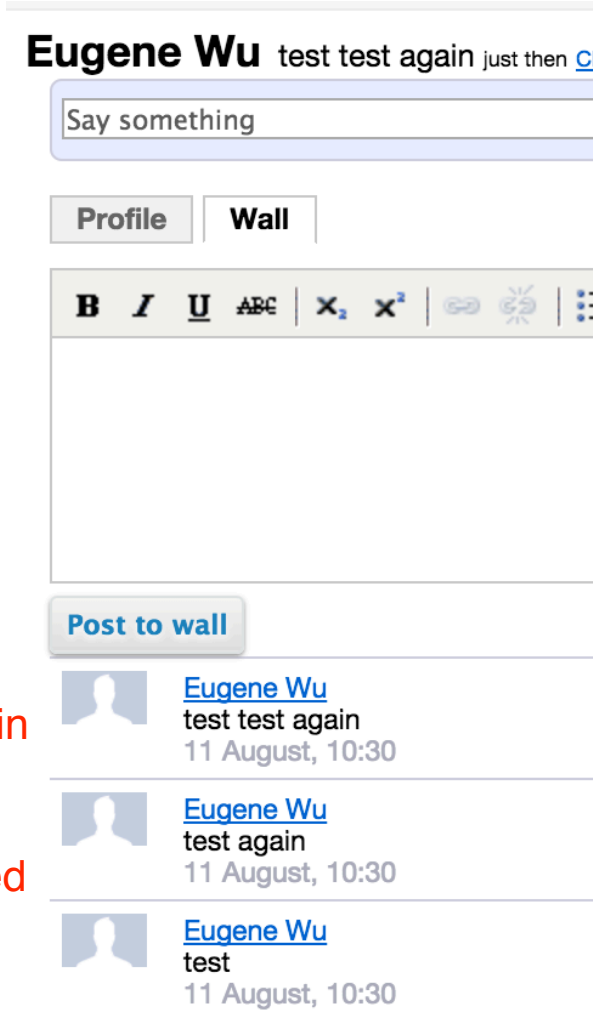
Weak Entities

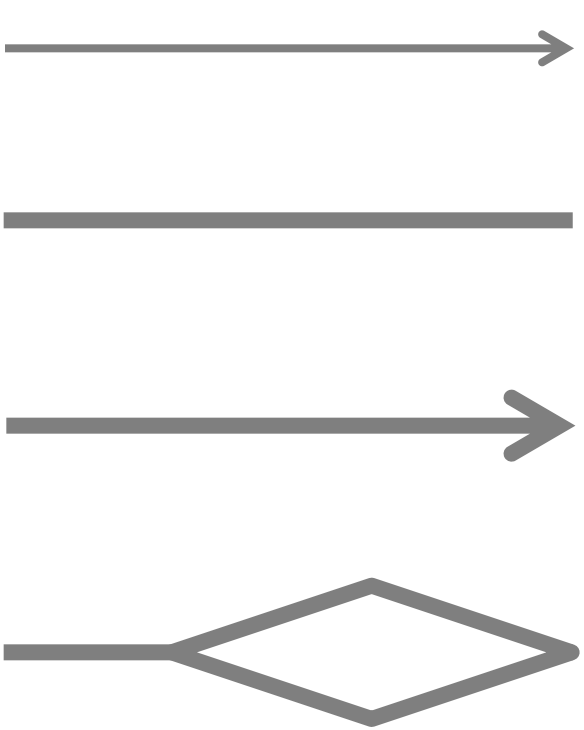
A *weak entity* can only be uniquely identified by using the primary key of its owner entity

- Owner and weak entity sets must be in one to many relationship set
- Weak entity set must have total participation in this *identifying* relationships set



A weak entity is one that can only exist when owned by another one. For example: a ROOM can only exist in a BUILDING. On the other hand, a TIRE might be considered as a strong entity because it also can exist without being attached to a CAR.




At most one
At least one
Exactly one
Weak Entity

ISA (is a) Hierarchies

Inheritance rules similar to programming languages

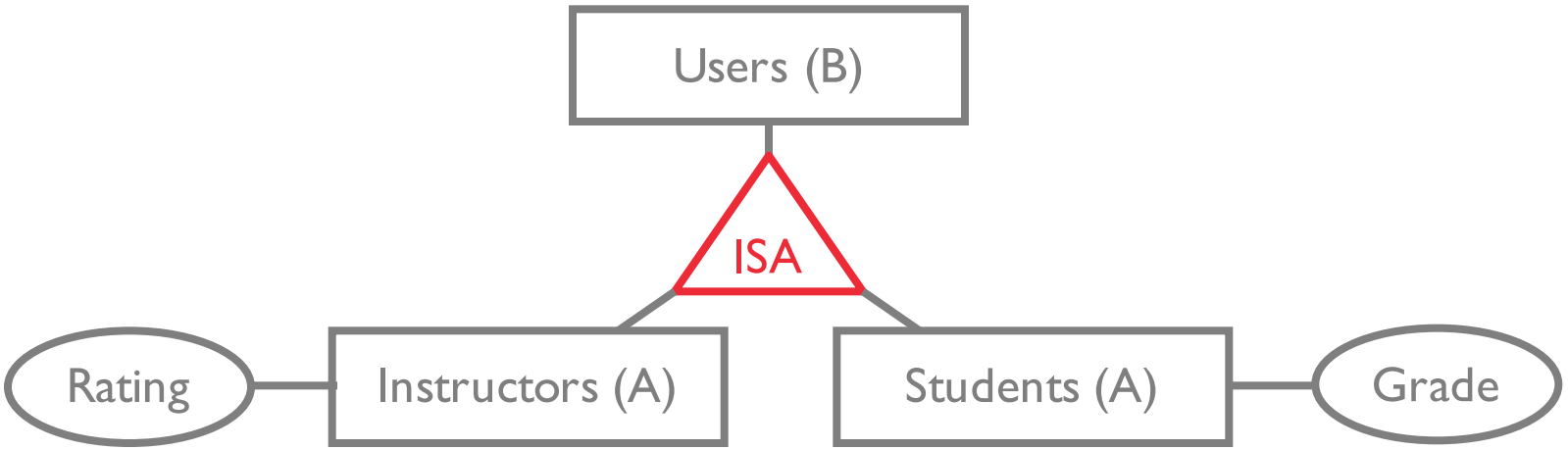
A ISA B → every A also considered a B

When querying for Bs, must consider As (unlike e.g., C++)

Why use ISA?

add descriptive attributes specific to a subclass e.g., grade

identify entities that participate in a relationship



ISA (is a) Hierarchies

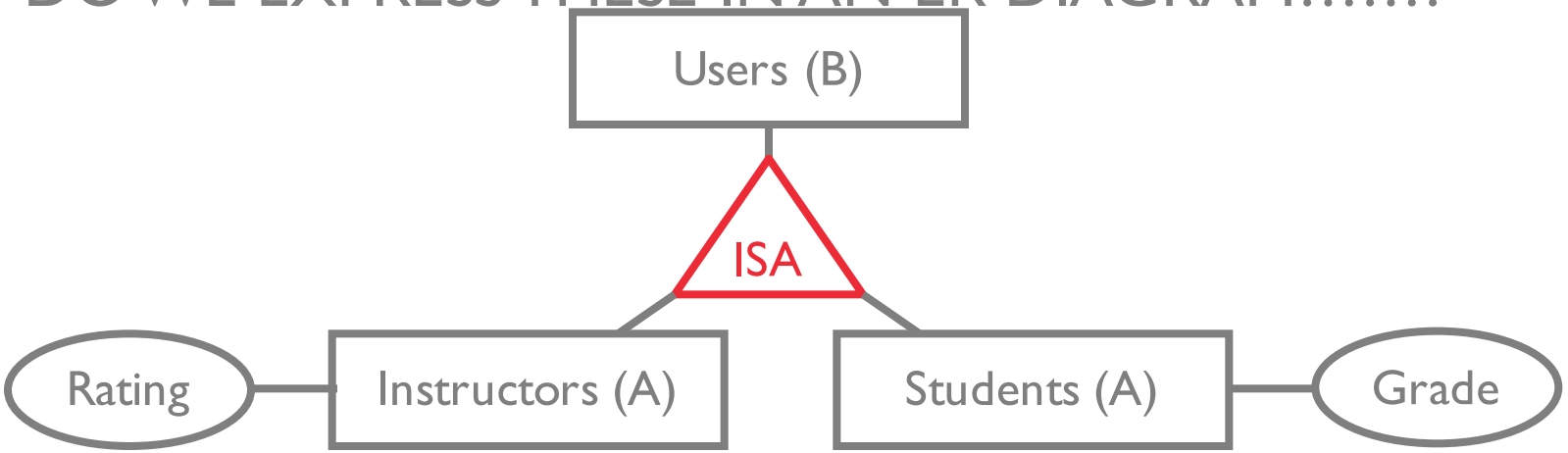
Overlap Constraint

can eugene be an instructor and a student? (allow/disallow)

Covering Constraint

must every user be an instructor or student? (yes/no)

HOW DO WE EXPRESS THESE IN AN ER DIAGRAM???????

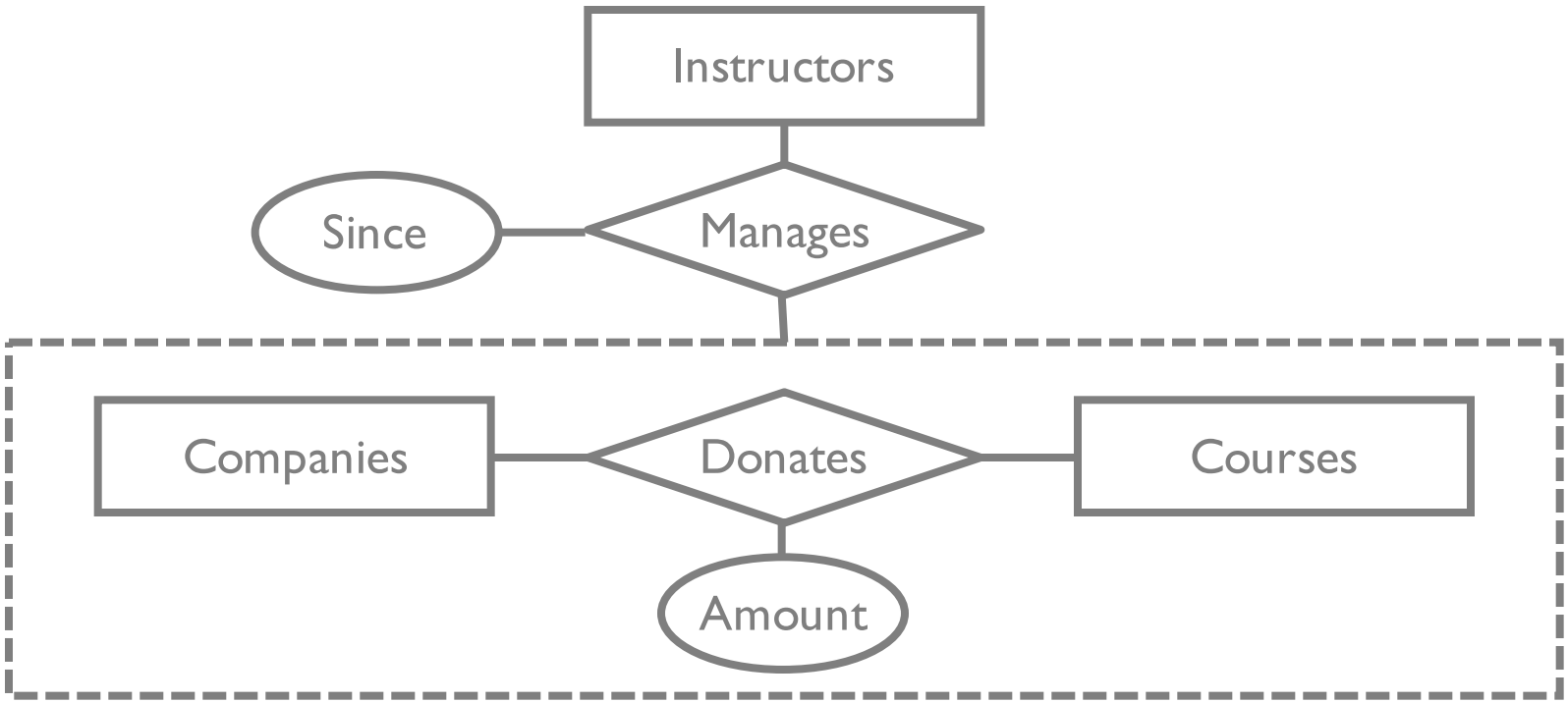


Aggregation

Relationships between (entities – relationships)

Lets us treat a Relationship Set like an Entity Set

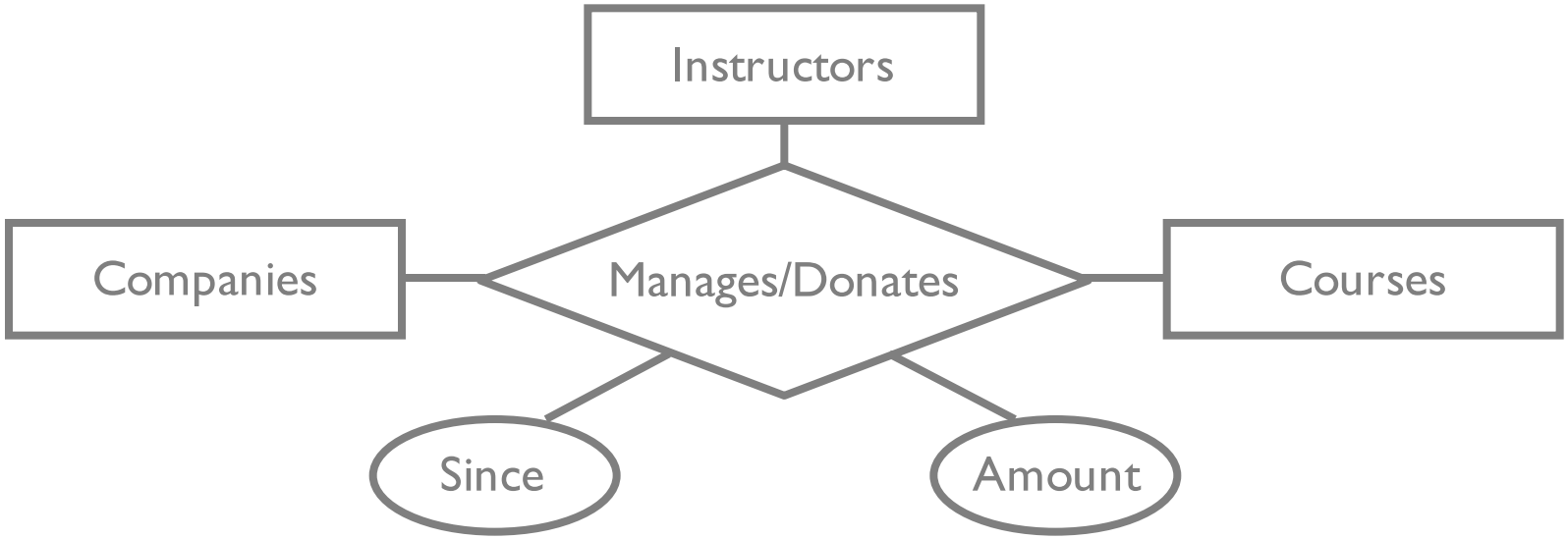
so it can participate in other relationships



Aggregation vs Ternary Relationships

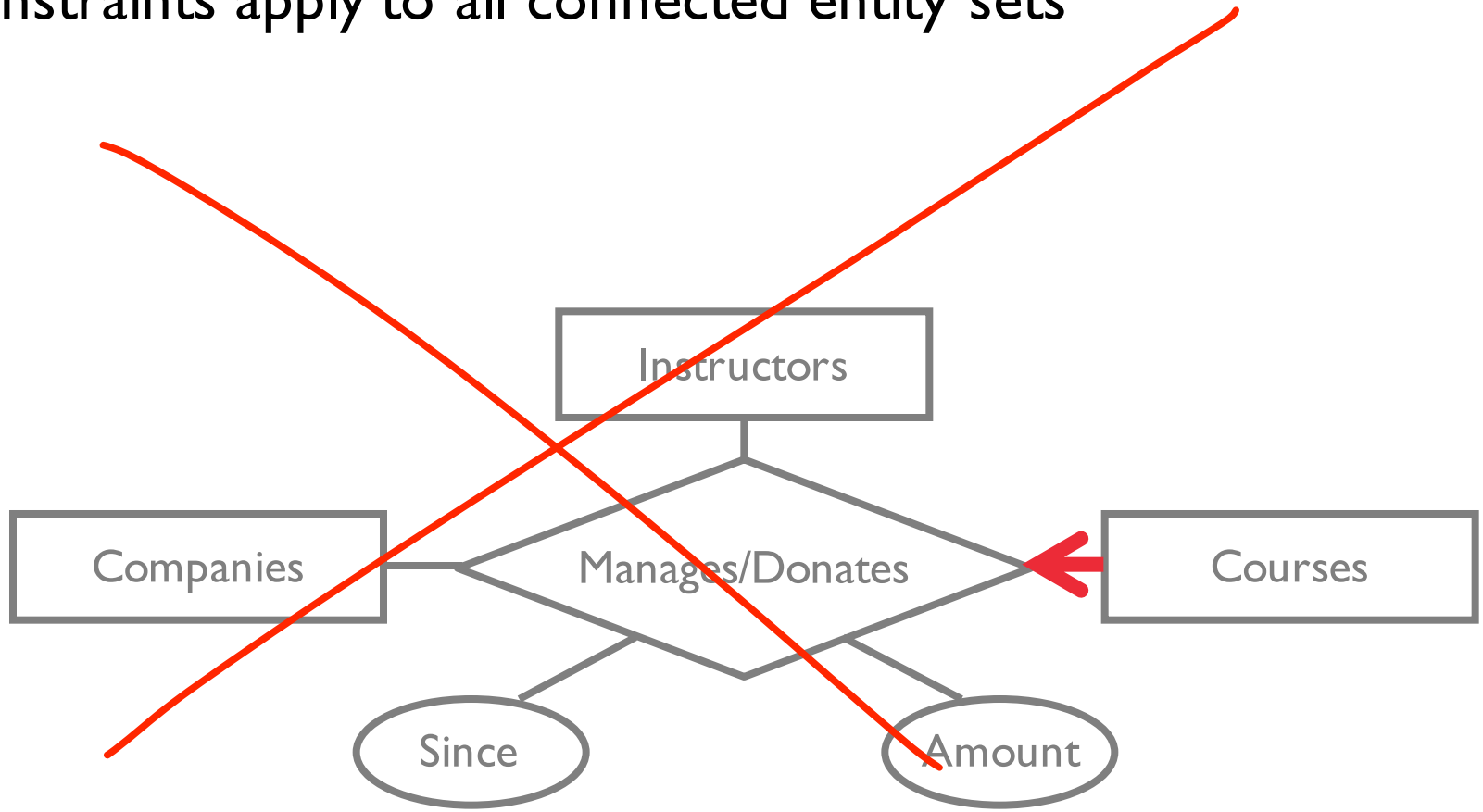
Why use aggregation?

- Manages and Donates are distinct relationships with own attrs
- Can define constraints on relationship sets
  - e.g., a donation can be managed by at most one instructor



Aggregation vs Ternary Relationships

Constraints apply to all connected entity sets



Using the ER Model

Design Choices for a concept

- Entity or Attribute?
- Entity or Relationship?
- Binary or Ternary relationship?
- Aggregation or Ternary relationship?

Entity or Attribute?

Is users.address an attribute of Users or an entity connected to Users by a relationship?

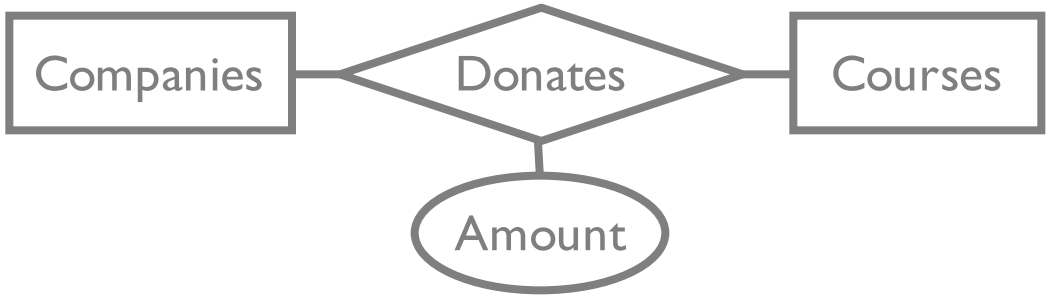
Depends (and may change over time!)

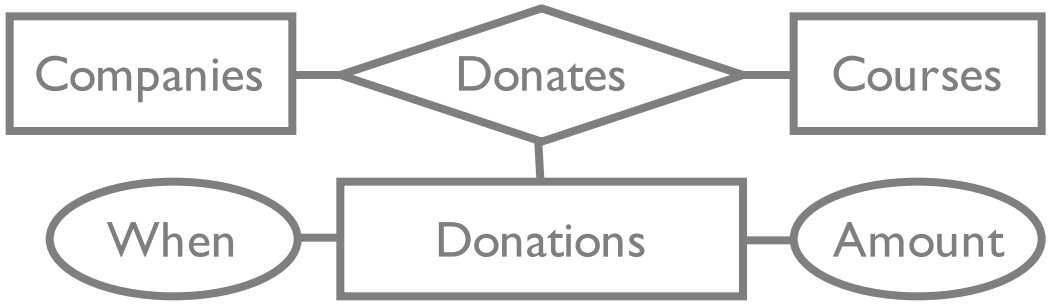
- If a user has >1 addresses, must be an entity
- If an address has attrs (structure), must be entity
  - e.g., want to search for users by city, state, or zip

Entity or Attribute?

A company can't donate multiple amounts (top fig)

Use ternary relationship (bottom fig)



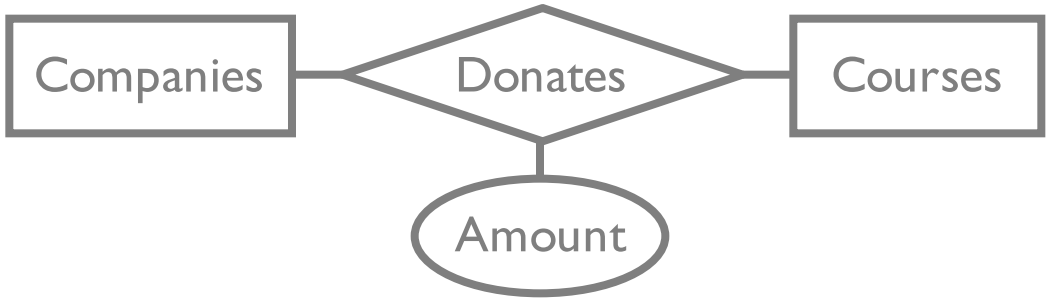


Entity or Relationship?

OK if company donates to courses individually

What if company donates to school for all data-related courses?

- Redundancy of *amount*, need to remember to update every one
- Misleading implies *amount* tied to *each* donation individually



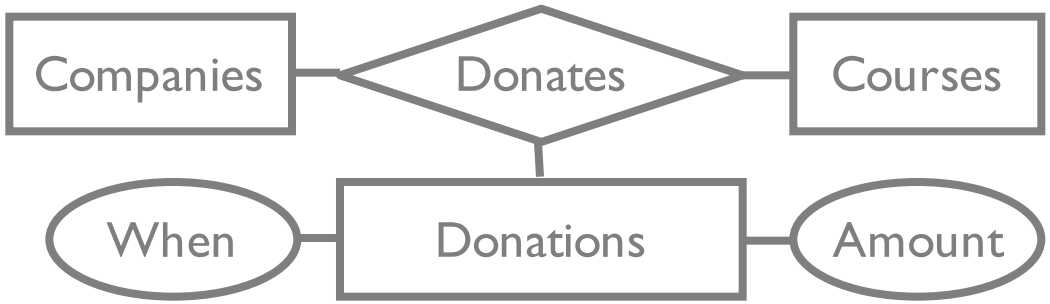
Company	Course	Amount
Amazon	4111	2000
Amazon	4112	2000
Amazon	5111	2000

These amounts are logically the same (redundant)!

Entity or Relationship?

If company donates once to school for data related courses.

Refactor amount into an entity



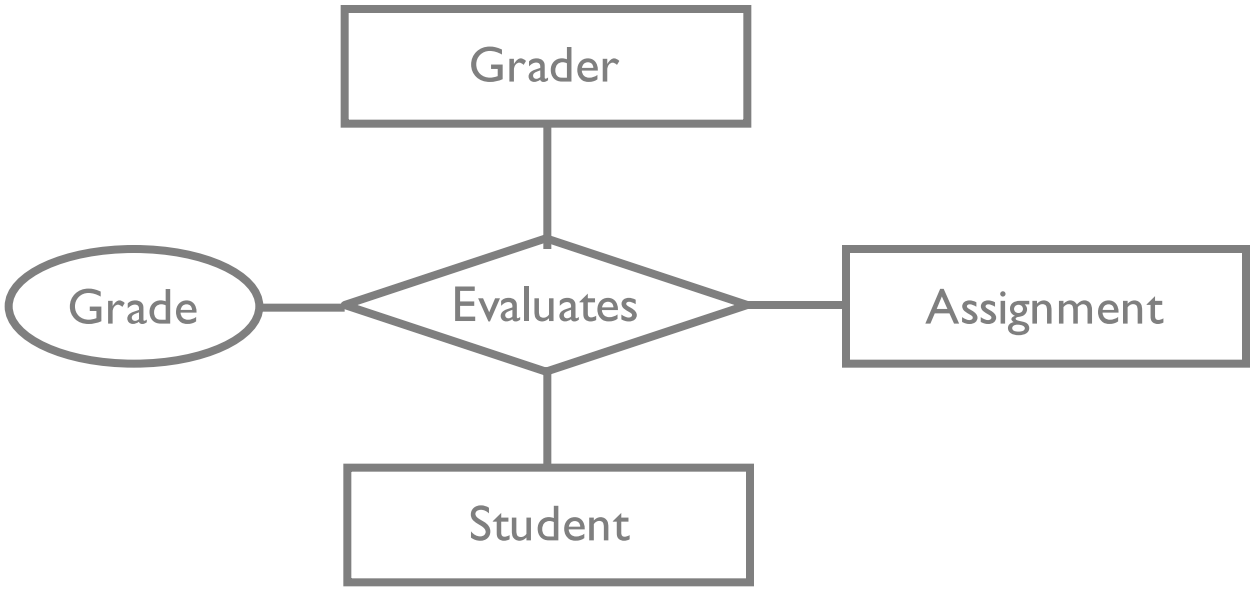
Company	Course	Donation
Amazon	4111	1
Amazon	4112	1
Amazon	5111	1

KEY

Donation	When	Amount
1	Today	2000

Binary or Ternary Relationship?

What if assignments have at most one grader?

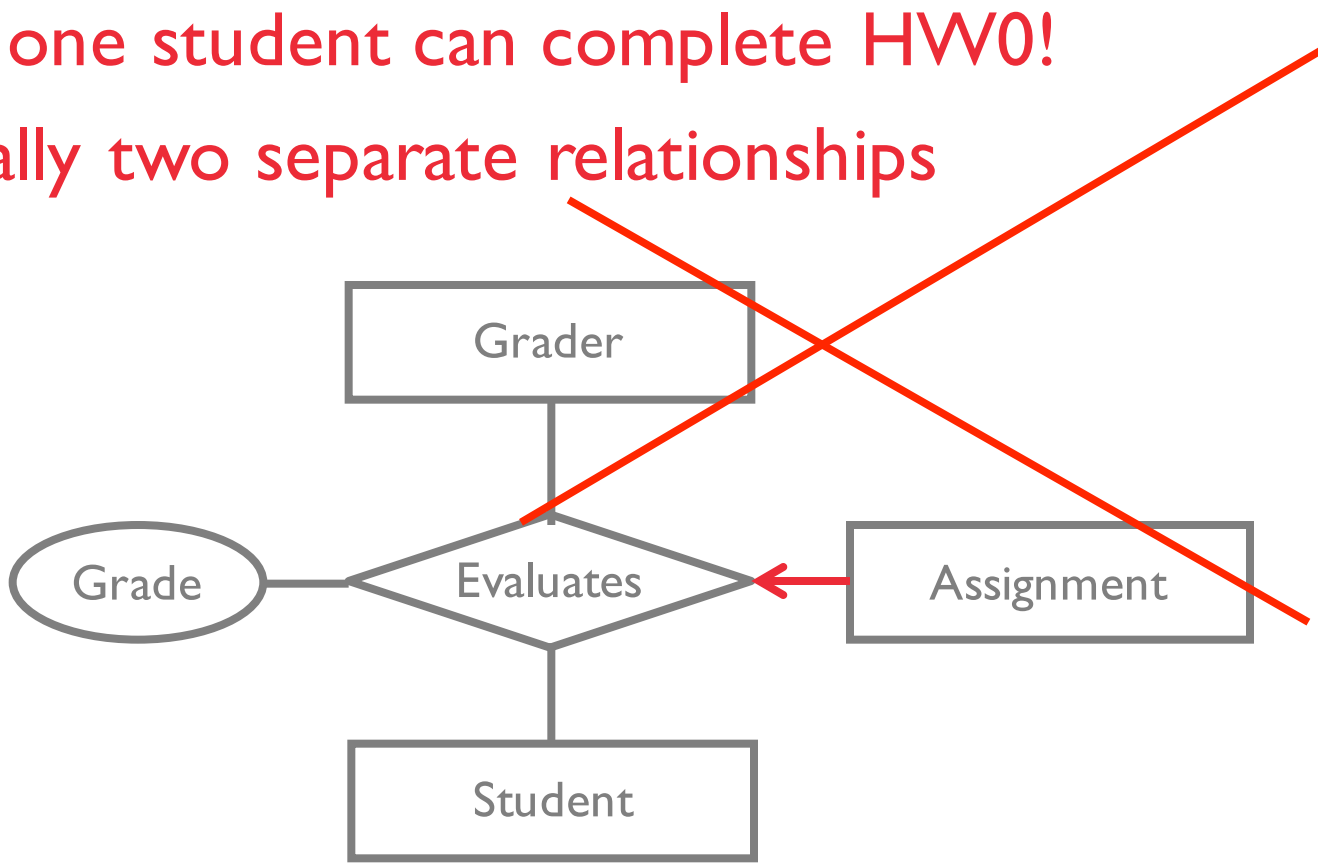


Binary or Ternary Relationship?

What if assignments have at most one grader?

Only one student can complete HW0!

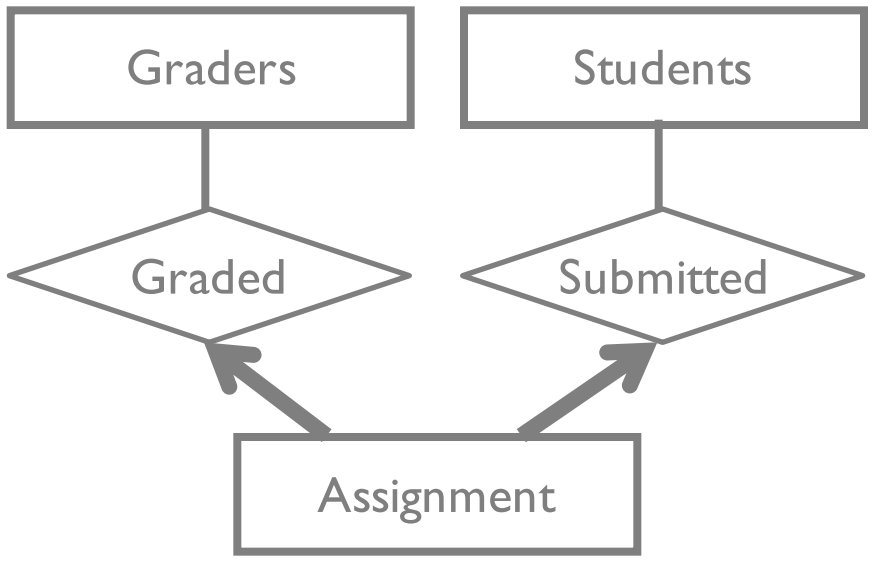
Actually two separate relationships



Binary or Ternary Relationship?

Binary relationships allows additional constraints

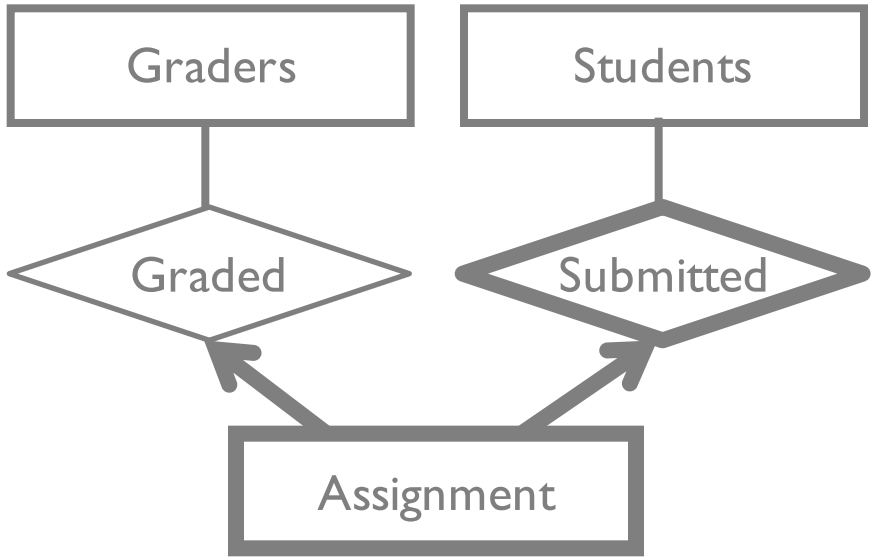
What should happen if a student drops the class? (see next slide)



Binary or Ternary Relationship?

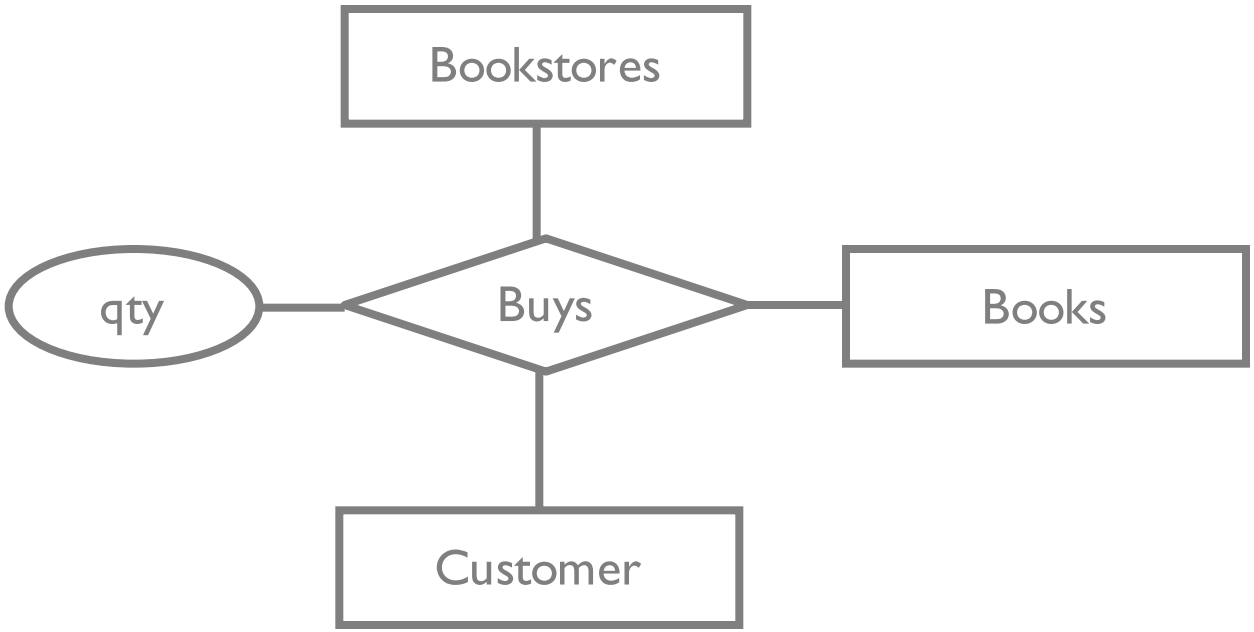
Binary relationships allows additional constraints

What should happen if a student drops the class? The previous ER diagram is sufficient.
This is wrong! You don't need a weak entity to express this.
In fact, this would mean that if Jane completed HW0 and then dropped the class, then the entire HW0 (not just her submission) would disappear.



Binary or Ternary Relationship?

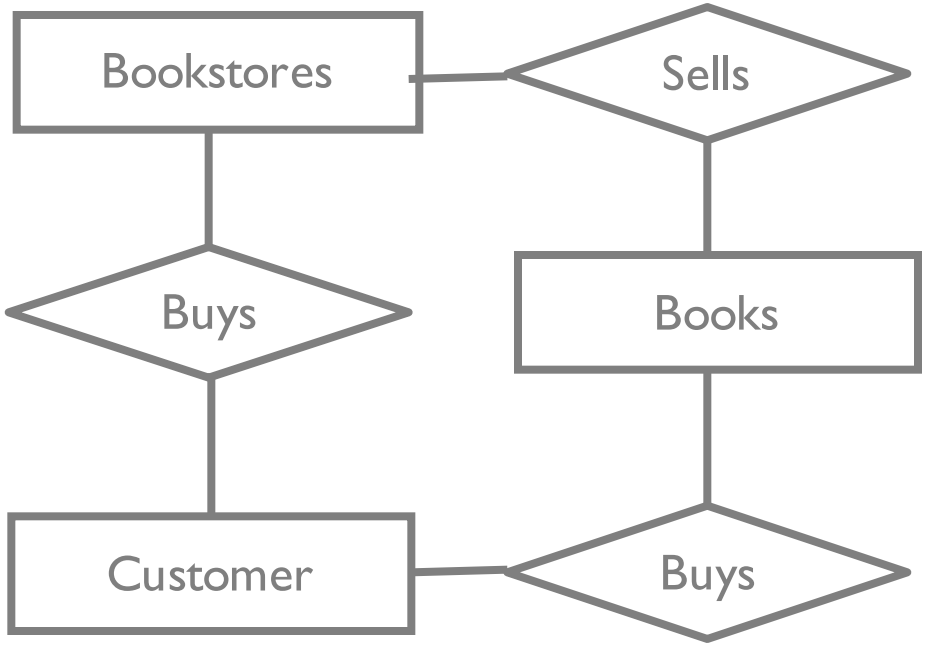
Sometimes have true ternary relationship that is defined by all three entities.



Binary or Ternary Relationship?

Sometimes have true ternary relationship that is defined by all three entities.

Doesn't Really Work



Using ER Modeling

Constraints in ER Modeling

- Many types of data semantics can be captured using ER
- Some constraints not captured (discuss limitations later)

Need further schema refinement

- ER Model is still subjective, need further refinement after translated into relational schema

Summary

Requirements
- what are you going to build?

Conceptual Database Design
- pen-and-pencil description

(Today) ER Modeling

Logical Design
- formal database schema

Schema Refinement:
- fix potential problems, normalization

Physical Database Design
- use sample of queries to optimize for speed/storage

App/Security Design
- prevent security problems

Summary

Conceptual design follows *requirements analysis*

ER model helpful for conceptual design

- constraints are expressive
- matches how we often think about applications

Core constructs

- entity, relationship, attribute
- weak entities, ISA, aggregation

Many variations beyond today's discussion

Summary

ER design is subjective based on usage+needs

- Today we saw multiple ways to model same idea

ER design is not complete/perfect

- Developed in an enterprise-oriented world (ER First)
- Doesn't capture semantics (what does "instructor" *mean?)*
- Doesn't capture e.g., processes/state machines
- How to combine multiple ER models automatically?
- Limitation of imagination when designing application
- Open problems!

ER design is a useful way to think

Next Time

Relational Model: de-facto DBMS standard

Set up for ER diagrams → Relational models