Lecture 2
Entity-Relationship Model

Eugene Wu

Fall 2015

HW0: Why the different results?

Result: 69

```
import csv
file = open('iowa-liquor-sample.csv')
file_reader = csv.reader(file)
n = 0
for row in file_reader:
  for el in row:
  if "single malt scotch" in el.lower():
    n += 1
print n
```

Result: 51

```
file = open('iowa-liquor-sample.csv','r')
n = 0
for line in file:
  temp = line.lower()
  if 'single malt scotch' in temp:
    n += 1
print n
```

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

Steps for a New Application

Requirements
  what are you going to build?

Conceptual Database Design   ER Modeling
  pen-and-pencil description

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  formal database schema

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  fix potential problems, normalization

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

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  prevent security problems

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

Database schema of MediaWiki 1.24.1 (December 2014)
Refer to https://www.mediawiki.org/wiki/DB for more details.

Users

user_properties
- up_user INT
- up_property VARBINARY(255)
- up_value BLOB
- Indexes

user_groups
- ug_user INT
- ug_group VARBINARY(255)
- Indexes

user_former_groups
- ufg_user INT
- ufg_group VARBINARY(255)
- Indexes

user_newtalk
- user_id INT
- user_ip VARBINARY(40)
- user_last_timestamp VARBINARY(14)
- Indexes

user
- user_id INT
- user_name VARCHAR(255)
- user_real_name VARCHAR(255)
- user_password TINYBLOB
- user_newpassword TINYBLOB
- user_newpass_time BINARY(14)
- user_email TINYTEXT
- user_touched BINARY(14)
- user_token BINARY(32)
- user_email_authenticated BINARY(14)
- user_email_token BINARY(32)
- user_email_token_expires BINARY(14)
- user_registration BINARY(14)
- user_editcount INT
- user_password_expires VARBINARY(14)
- Indexes

ipblocks
- ipb_id INT
- ipb_address TINYBLOB
- ipb_user INT
- ipb_by INT
- ipb_by_text VARCHAR(255)
- ipb_reason TINYBLOB
- ipb_timestamp BINARY(14)
- ipb_auto
- ipb_anon_only
- ipb_create_account
- ipb_enable_autoblock
- ipb_expiry VARBINARY(14)
- ipb_range_start TINYBLOB
- ipb_range_end TINYBLOB
- ipb_deleted
- ipb_block_email
- ipb_allow_usertalk
- ipb_parent_block_id INT
- Indexes

Logging

logging
- log_id INT
- log_type VARBINARY(32)
- log_action VARBINARY(32)
- log_timestamp BINARY(14)
- log_user INT
- log_user_text VARCHAR(255)
- log_namespace INT
- log_title VARCHAR(255)
- log_page INT
- log_comment VARCHAR(255)
- log_params BLOB
- log_deleted TINYINT
- Indexes

log_search
- ls_field VARBINARY(32)
- ls_value VARCHAR(255)
- ls_log_id INT
- Indexes

Tags

change_tag
- ct_rc_id INT
- ct_log_id INT
- ct_rev_id INT
- ct_tag VARCHAR(255)
- ct_params BLOB
- Indexes

valid_tag
- vt_tag VARCHAR(255)
- Indexes

tag_summary
- ts_rc_id INT
- ts_log_id INT
- ts_rev_id INT
- ts_tags BLOB
- Indexes

Recent changes

recentchanges
- rc_id INT
- rc_timestamp VARBINARY(14)
- rc_user INT
- rc_user_text VARCHAR(255)
- rc_namespace INT
- rc_title VARCHAR(255)
- rc_comment VARCHAR(255)
- rc_minor TINYINT
- rc_bot TINYINT
- rc_new TINYINT
- rc_cur_id INT
- rc_this_oldid INT
- rc_last_oldid INT
- rc_type TINYINT
- rc_source VARCHAR(16)
- rc_patrolled TINYINT
- rc_ip VARBINARY(40)
- rc_old_len INT
- rc_new_len INT
- rc_deleted TINYINT
- rc_logid INT
- rc_log_type VARBINARY(255)
- rc_log_action VARBINARY(255)
- rc_params BLOB
- Indexes

watchlist
- wl_user INT
- wl_namespace INT
- wl_title VARCHAR(255)
- wl_notificationtimestamp VARBINARY(14)
- Indexes

Pages

archive
- ar_id INT
- ar_namespace INT
- ar_title VARCHAR(255)
- ar_text MEDIUMBLOB
- ar_comment TINYBLOB
- ar_user INT
- ar_user_text VARCHAR(255)
- ar_timestamp BINARY(14)
- ar_minor_edit TINYINT
- ar_flags TINYBLOB
- ar_rev_id INT
- ar_text_id INT
- ar_deleted TINYINT
- ar_len INT
- ar_page_id INT
- ar_parent_id INT
- ar_sha1 VARBINARY(32)
- ar_content_model VARBINARY(32)
- ar_content_format VARBINARY(64)
- Indexes

revision
- rev_id INT
- rev_page INT
- rev_text_id INT
- rev_comment TINYBLOB
- rev_user INT
- rev_user_text VARCHAR(255)
- rev_timestamp BINARY(14)
- rev_minor_edit TINYINT
- rev_deleted TINYINT
- rev_len INT
- rev_parent_id INT
- rev_sha1 VARBINARY(32)
- rev_content_model VARBINARY(32)
- rev_content_format VARBINARY(64)
- Indexes

text
- old_id INT
- old_text MEDIUMBLOB
- old_flags TINYBLOB
- Indexes

redirect
- rd_from INT
- rd_namespace INT
- rd_title VARCHAR(255)
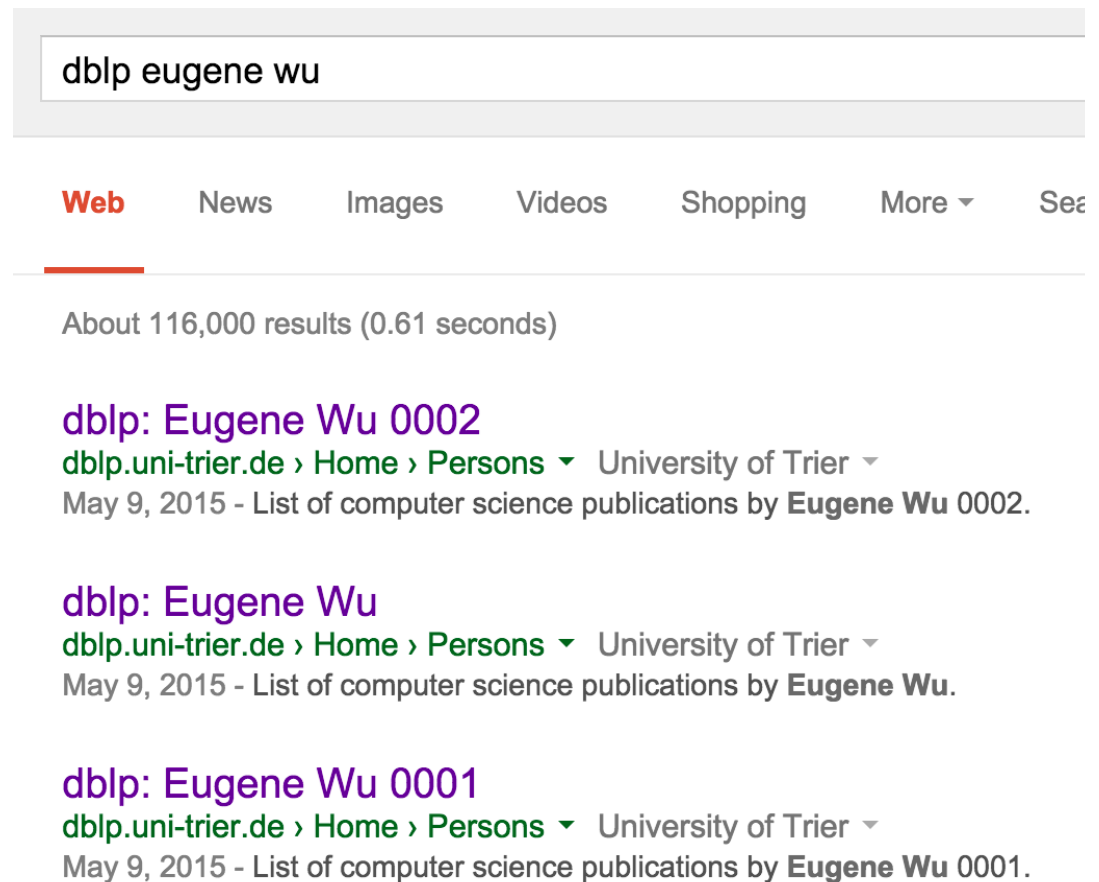- rd_interwiki VARCHAR(32)
- rd_fragment VARCHAR(255)
- Indexes

page
- page_id INT
- page_namespace INT
- page_title VARCHAR(255)
- page_restrictions TINYBLOB
- page_counter BIGINT
- page_is_redirect TINYINT
- page_is_new TINYINT
- page_random DOUBLE
- page_touched BINARY(14)
- page_links_updated VARBINARY(14)
- page_latest INT
- page_len INT
- page_content_model VARBINARY(32)
- page_lang VARBINARY(35)
- Indexes

category
- cat_id INT
- cat_title VARCHAR(255)
- cat_pages INT
- cat_subcats INT
- cat_files INT
- Indexes

page_props
- pp_page INT
- pp_propname VARBINARY(60)
- pp_value BLOB
- pp_sortkey FLOAT
- Indexes

page_restrictions
- pr_id INT
- pr_page INT
- pr_type VARBINARY(60)
- pr_level VARBINARY(60)
- pr_cascade TINYINT
- pr_user INT
- pr_expiry VARBINARY(14)
- Indexes

protected_titles
- pt_namespace INT
- pt_title VARCHAR(255)
- pt_user INT
- pt_reason TINYBLOB
- pt_timestamp BINARY(14)
- pt_expiry VARBINARY(14)
- pt_create_perm VARBINARY(60)
- Indexes

Link tables

pagelinks
- pl_from INT
- pl_from_namespace INT
- pl_namespace INT
- pl_title VARCHAR(255)
- Indexes

iwlinks
- iwl_from INT
- iwl_prefix VARBINARY(20)
- iwl_title VARCHAR(255)
- Indexes

externallinks
- el_id INT
- el_from INT
- el_to BLOB
- el_index BLOB
- Indexes

langlinks
- ll_from INT
- ll_lang VARBINARY(20)
- ll_title VARCHAR(255)
- Indexes

imagelinks
- il_from INT
- il_from_namespace INT
- il_to VARCHAR(255)
- Indexes

templatelinks
- tl_from INT
- tl_from_namespace INT
- tl_namespace INT
- tl_title VARCHAR(255)
- Indexes

categorylinks
- cl_from INT
- cl_to VARCHAR(255)
- cl_sortkey VARBINARY(230)
- cl_sortkey_prefix VARCHAR(255)
- cl_timestamp TIMESTAMP
- cl_collation VARBINARY(32)
- cl_type ENUM(...)
- Indexes

Multimedia

image
- img_name VARCHAR(255)
- img_size INT
- img_width INT
- img_height INT
- img_metadata MEDIUMBLOB
- img_bits INT
- img_media_type ENUM(...)
- img_major_mime ENUM(...)
- img_minor_mime VARBINARY(100)
- img_description TINYBLOB
- img_user INT
- img_user_text VARCHAR(255)
- img_timestamp VARBINARY(14)
- img_sha1 VARBINARY(32)
- Indexes

oldimage
- oi_name VARCHAR(255)
- oi_archive_name VARCHAR(255)
- oi_size INT
- oi_width INT
- oi_height INT
- oi_bits INT
- oi_description TINYBLOB
- oi_user INT
- oi_user_text VARCHAR(255)
- oi_timestamp BINARY(14)
- oi_metadata MEDIUMBLOB
- oi_media_type ENUM(...)
- oi_major_mime ENUM(...)
- oi_minor_mime VARBINARY(100)
- oi_deleted TINYINT
- oi_sha1 VARBINARY(32)
- Indexes

filearchive
- fa_id INT
- fa_name VARCHAR(255)
- fa_archive_name VARCHAR(255)
- fa_storage_group VARBINARY(16)
- fa_storage_key VARBINARY(64)
- fa_deleted_user INT
- fa_deleted_timestamp BINARY(14)
- fa_deleted_reason TEXT
- fa_size INT
- fa_width INT
- fa_height INT
- fa_metadata MEDIUMBLOB
- fa_bits INT
- fa_media_type ENUM(...)
- fa_major_mime ENUM(...)
- fa_minor_mime VARBINARY(100)
- fa_description TINYBLOB
- fa_user INT
- fa_user_text VARCHAR(255)
- fa_timestamp BINARY(14)
- fa_deleted TINYINT
- fa_sha1 VARBINARY(32)
- Indexes

uploadstash
- us_id INT
- us_user INT
- us_key VARCHAR(255)
- us_orig_path VARCHAR(255)
- us_path VARCHAR(255)
- us_source_type VARCHAR(50)
- us_timestamp VARBINARY(14)
- us_status VARCHAR(50)
- us_chunk_inx INT
- us_props BLOB
- us_size INT
- us_sha1 VARBINARY(31)
- us_mime VARCHAR(255)
- us_media_type ENUM(...)
- us_image_width INT
- us_image_height INT
- us_image_bits SMALLINT
- Indexes

Statistics

hitcounter
- hc_id INT

site_stats
- ss_row_id INT
- ss_total_views BIGINT
- ss_total_edits BIGINT
- ss_good_articles BIGINT
- ss_total_pages BIGINT
- ss_users BIGINT
- ss_active_users BIGINT
- ss_images INT
- Indexes

Search

searchindex
- si_page INT
- si_title VARCHAR(255)
- si_text MEDIUMTEXT
- Indexes

ResourceLoader

module_deps
- md_module VARBINARY(255)
- md_skin VARBINARY(32)
- md_deps MEDIUMBLOB
- Indexes

msg_resource
- mr_resource VARBINARY(255)
- mr_lang VARBINARY(32)
- mr_blob MEDIUMBLOB
- mr_timestamp BINARY(14)
- Indexes

msg_resource_links
- mrl_resource VARBINARY(255)
- mrl_message VARBINARY(255)
- Indexes

Interwiki

sites
- site_id INT
- site_global_key VARBINARY(32)
- site_type VARBINARY(32)
- site_group VARBINARY(32)
- site_source VARBINARY(32)
- site_language VARBINARY(32)
- site_protocol VARBINARY(32)
- site_domain VARCHAR(255)
- site_data BLOB
- site_forward
- site_config BLOB
- Indexes

site_identifiers
- si_site INT
- si_type VARBINARY(32)
- si_key VARBINARY(32)
- Indexes

interwiki
- iw_prefix VARCHAR(32)
- iw_url BLOB
- iw_api BLOB
- iw_wikiid VARCHAR(64)
- iw_local
- iw_trans TINYINT

Caching tables

objectcache
- keyname VARBINARY(255)
- value MEDIUMBLOB
- exptime DATETIME
- Indexes

l10n_cache
- lc_lang VARBINARY(32)
- lc_key VARCHAR(255)
- lc_value MEDIUMBLOB
- Indexes

transcache
- tc_url VARBINARY(255)
- tc_contents TEXT
- tc_time BINARY(14)
- Indexes

querycache
- qc_type VARBINARY(32)
- qc_value INT
- qc_namespace INT
- qc_title VARCHAR(255)
- Indexes

querycache_info
- qci_type VARBINARY(32)
- qci_timestamp BINARY(14)
- Indexes

querycachetwo
- qcc_type VARBINARY(32)
- qcc_value INT
- qcc_namespace INT
- qcc_title VARCHAR(255)
- qcc_namespacetwo INT
- qcc_titletwo VARCHAR(255)
- Indexes

Maintenance

updatelog
- ul_key VARBINARY(255)
- ul_value BLOB
- Indexes

job
- job_id INT
- job_cmd VARBINARY(60)
- job_namespace INT
- job_title VARCHAR(255)
- job_timestamp VARBINARY(14)
- job_params BLOB
- job_random INT
- job_attempts INT
- job_token VARBINARY(32)
- job_token_timestamp VARBINARY(14)
- job_sha1 VARBINARY(32)
- Indexes

revision
- rev_id INT
- rev_page INT
- rev_text_id INT
- rev_comment TINYBLOB
- rev_user INT
- rev_user_text VARCHAR(255)
- rev_timestamp BINARY(14)
- rev_minor_edit TINYINT
- rev_deleted TINYINT
- rev_len INT
- rev_parent_id INT
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- rev_content_model VARBINARY(32)
- rev_content_format VARBINARY(64)

Indexes

page
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- page_namespace INT
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- page_restrictions TINYBLOB
- page_counter BIGINT
- page_is_redirect TINYINT
- page_is_new TINYINT
- page_random DOUBLE
- page_touched BINARY(14)
- page_links_updated VARBINARY(14)
- page_latest INT
- page_len INT
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- page_lang VARBINARY(35)

Indexes

page_props
- pp_page INT
- pp_propname VARBINARY(60)
- pp_value BLOB
- pp_sortkey FLOAT

Indexes

page_restrictions
- pr_id INT
- pr_page INT
- pr_type VARBINARY(60)
- pr_level VARBINARY(60)
- pr_cascade TINYINT
- pr_user INT
- pr_expiry VARBINARY(14)

Indexes

protected_titles
- pt_namespace INT
- pt_title VARCHAR(255)
- pt_user INT
- pt_reason TINYBLOB
- pt_timestamp BINARY(14)
- pt_expiry VARBINARY(14)
- pt_create_perm VARBINARY(6...)

text
- old_id INT
- old_text MEDIUMBLOB
- old_flags TINYBLOB

Indexes

redirect
- rd_from INT
- rd_namespace INT
- rd_title VARCHAR(255)
- rd_interwiki VARCHAR(32)
- rd_fragment VARCHAR(255)

Indexes

category
- cat_id INT
- cat_title VARCHAR(255)
- cat_pages INT
- cat_subcats INT
- cat_files INT

Indexes

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

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)

$$\neq$$

[−] **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

App Server

DBMS

It is Hard to Design Applications

Add new users   App Server

DBMS

It is Hard to Design Applications

Normal Signup	Developer account	Auto added
App client	App client	App client

Add new users → App Server

DBMS
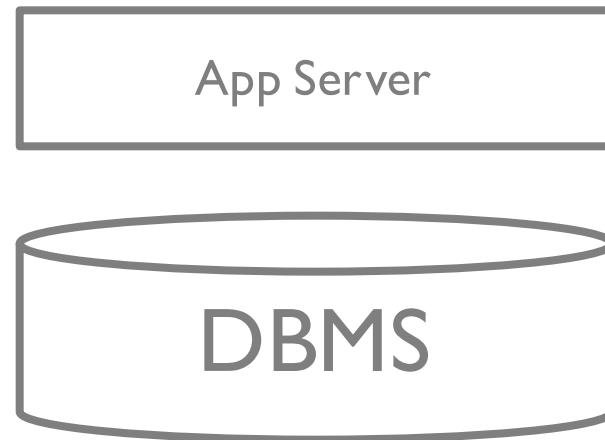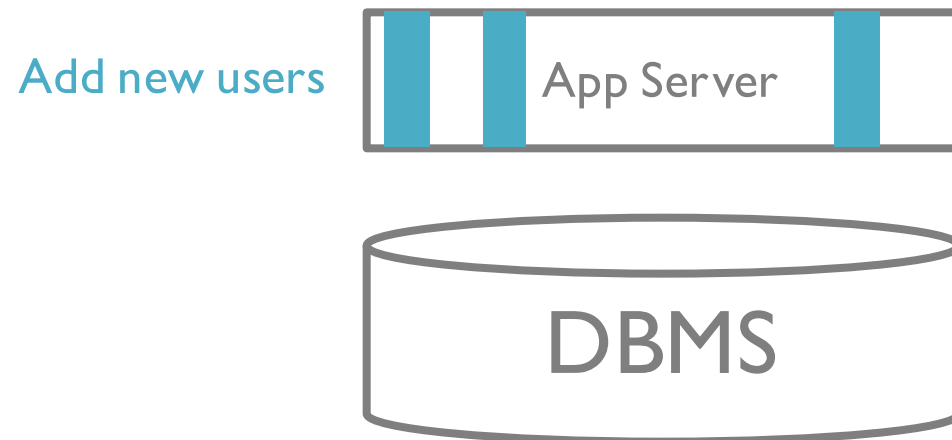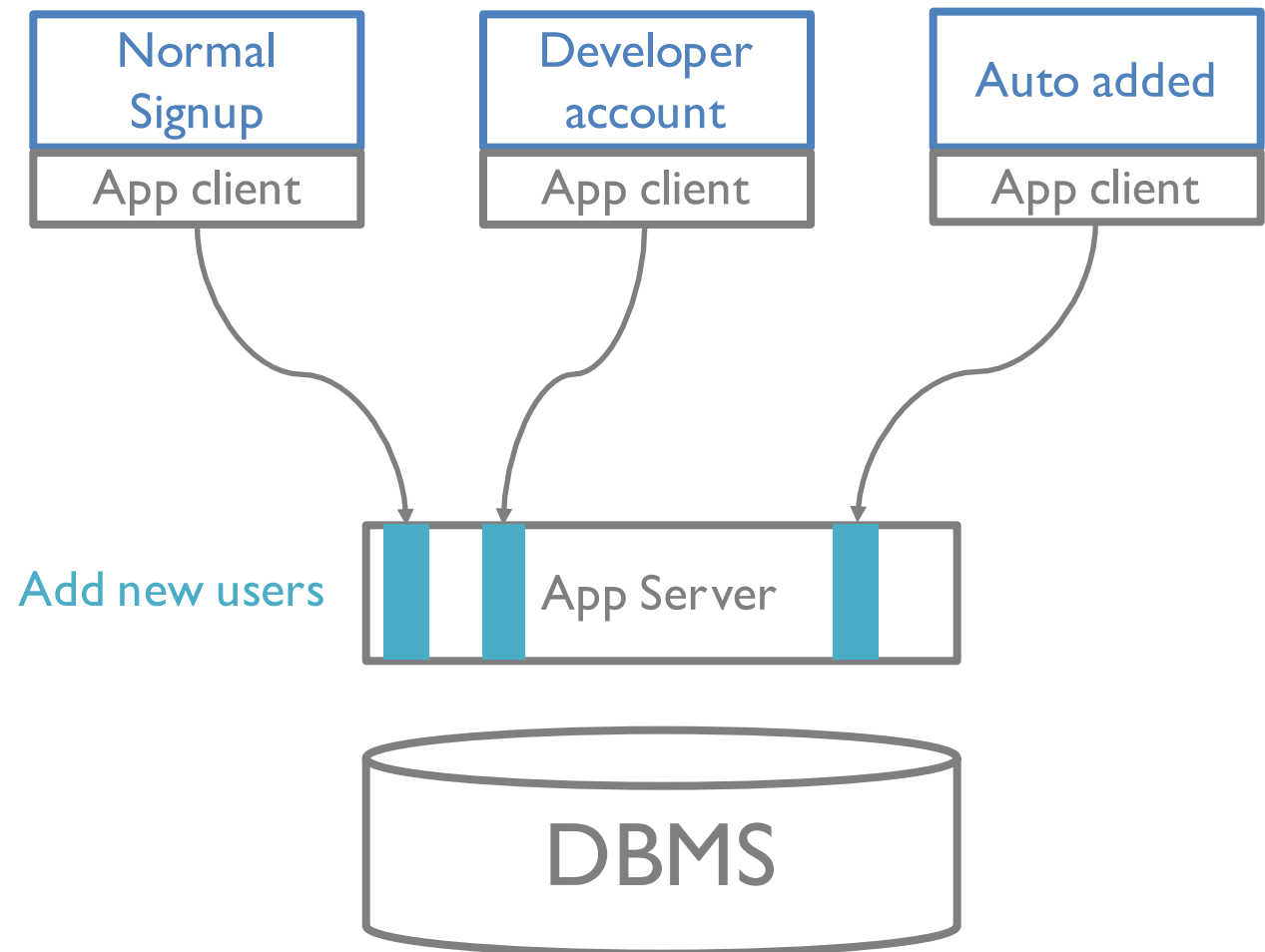
It is Hard to Design Applications
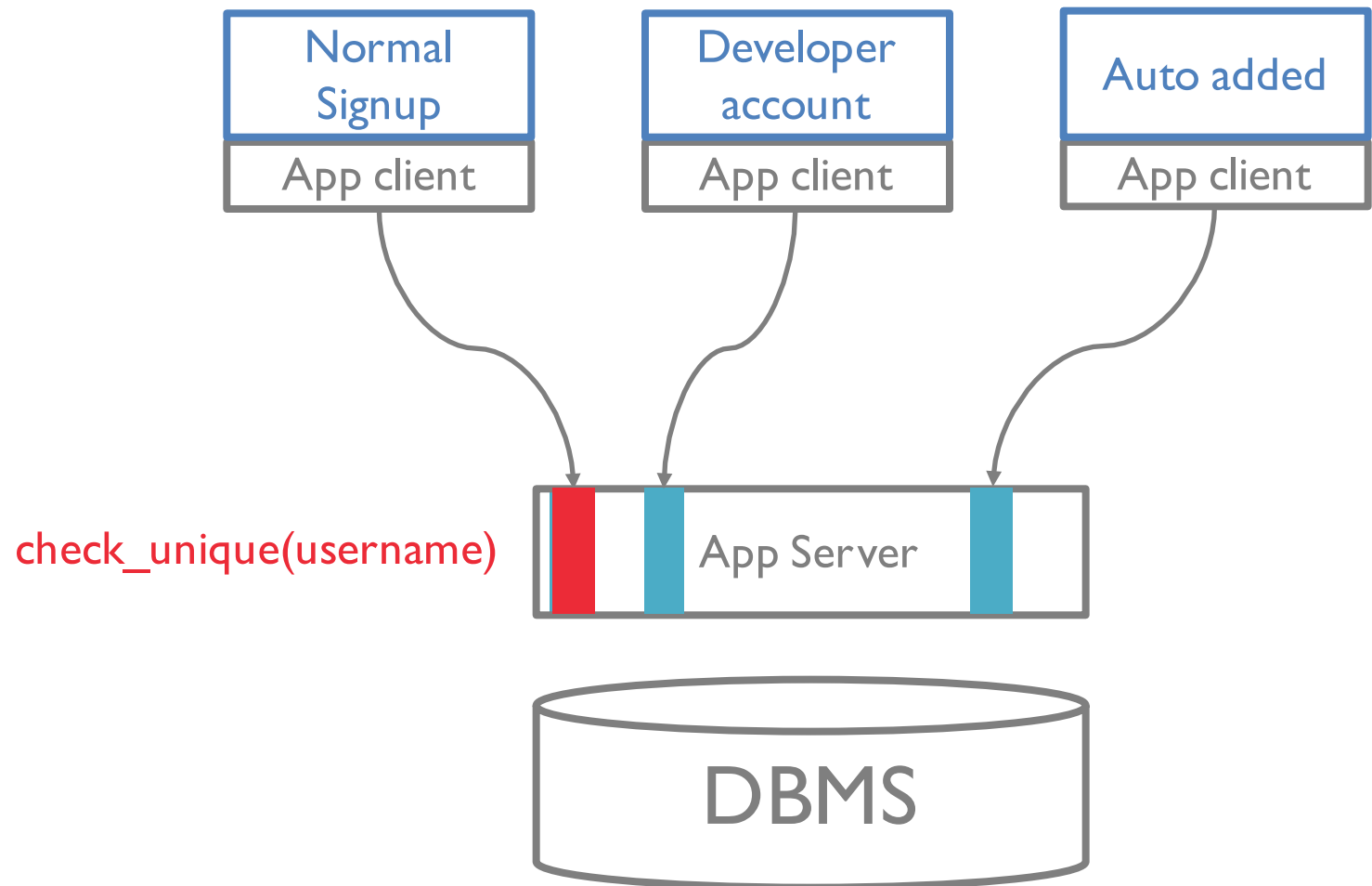
Let's make ~~a webapp~~ $$$

live exercise time

COURSEWORKS@COLUMBIA

COMSW4111_001_2015_3: INTRODUCTION TO DATABASES (Fall 2015)

View Site As: | ✓ – Select Role –
| Student
| Teaching Assistant

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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

Eugene Wu test test again just then Clear

Say something | **Say it**

Profile | Wall

Basic Information

Nickname | [   ]

Birthday | [   ]

Personal summary | **B** *I* U ABC X₂ X² | 🔗 | ☰ ☰ | HTML

Save changes | Cancel

Contact Information

Email | ew2493@columbia.edu

Home page | [   ]

Work phone | [   ]

Home phone | [   ]

Mobile phone | [   ]

Facsimile | [   ]

Save changes | Cancel

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 attribute & 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 table)
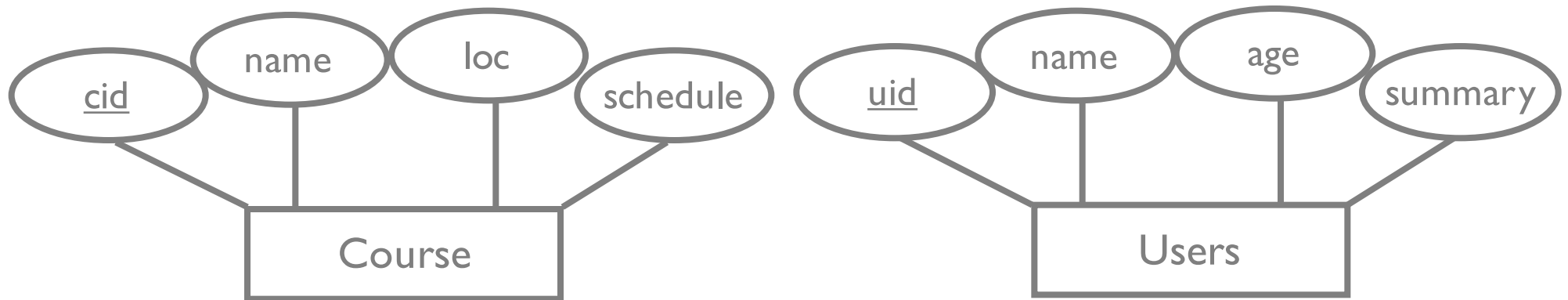
Basics: Relationships

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

Users

Takes

Courses

uid

name

age

Users

Teacher_of   Student_of

Teaches
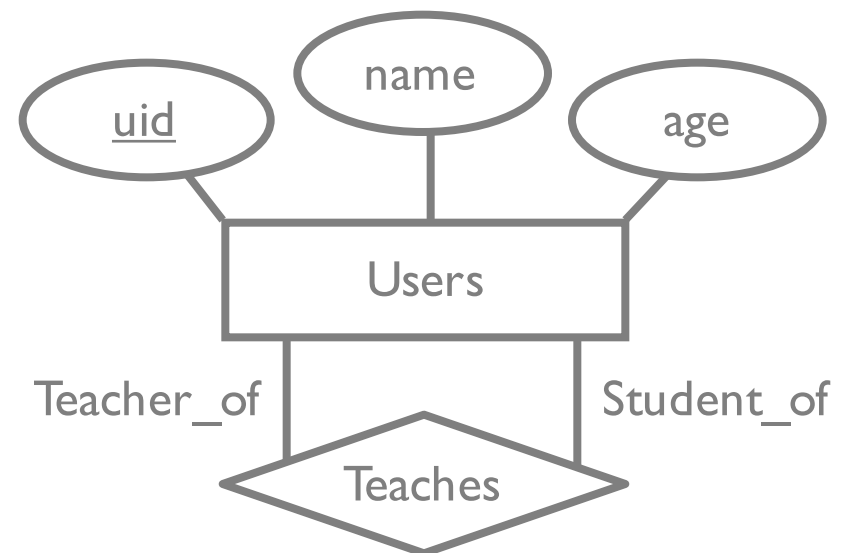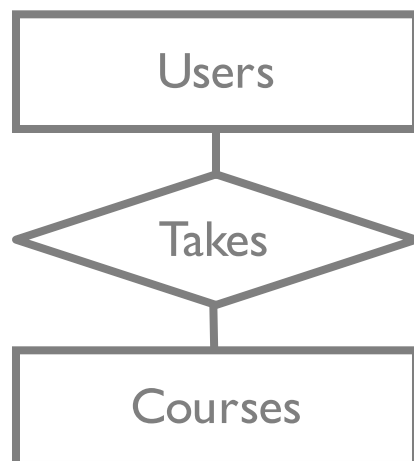
Basics: Relationships

Relationships sets can have descriptive attributes

e.g., the *since* attribute of Instructs
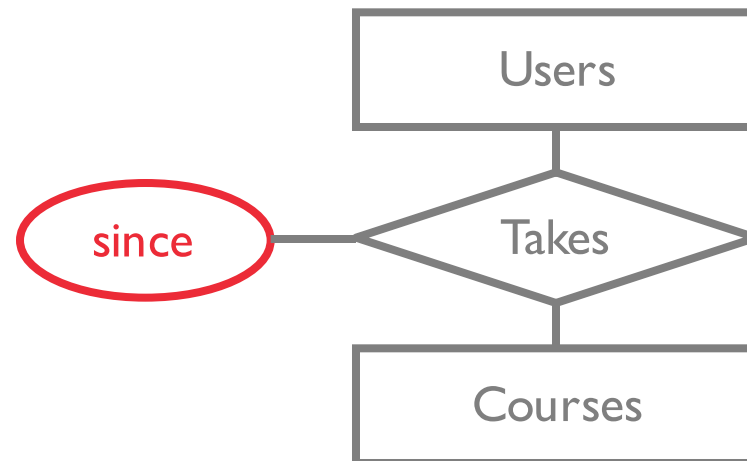
Basics: Ternary Relationships

Connects three entities

N-ary relationships possible too.
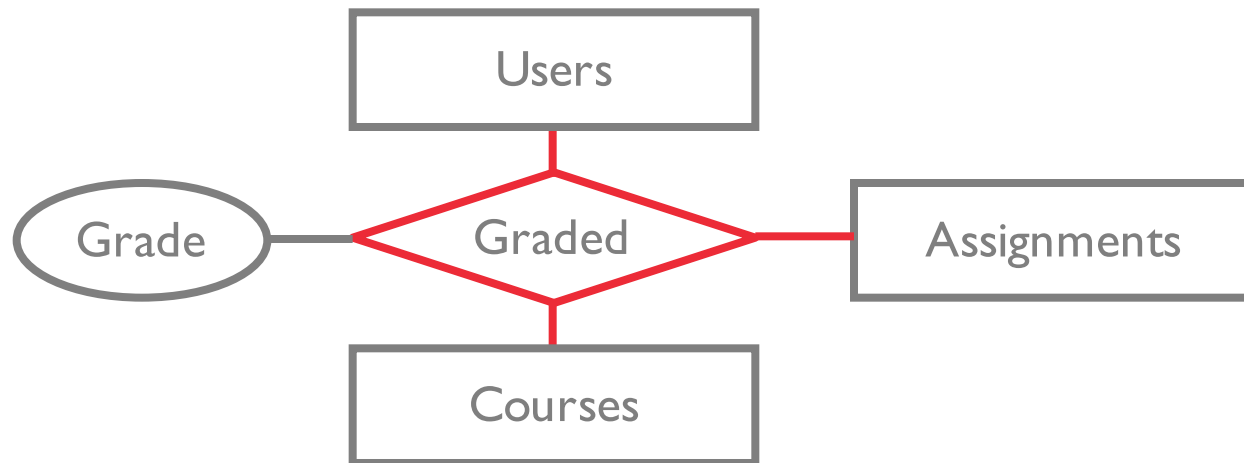
Constraints

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
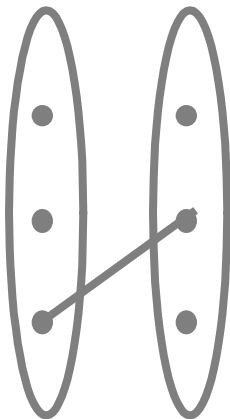
1-to-1   1-to Many   Many-to-Many

Users		Users
Instructs		Instructs
Courses		Courses
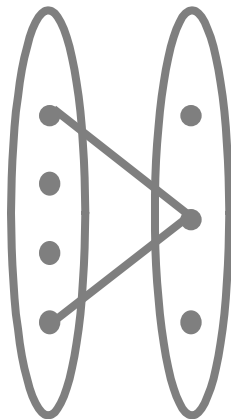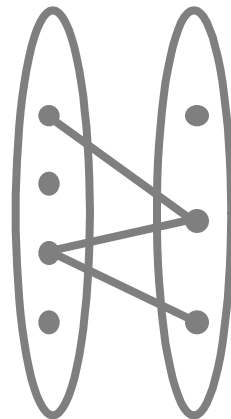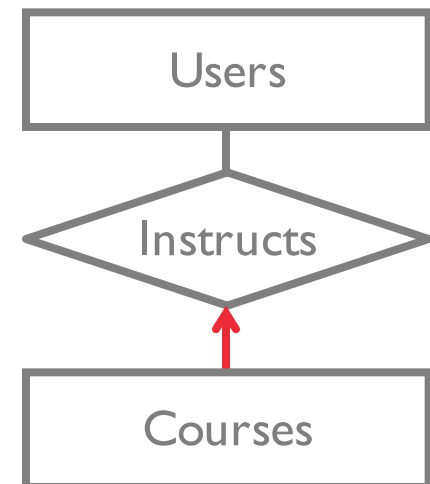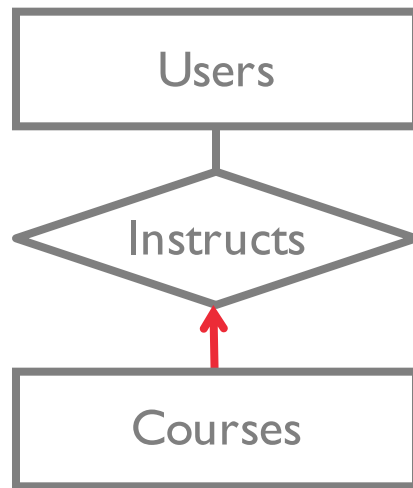
A course has at most
one instructor

???
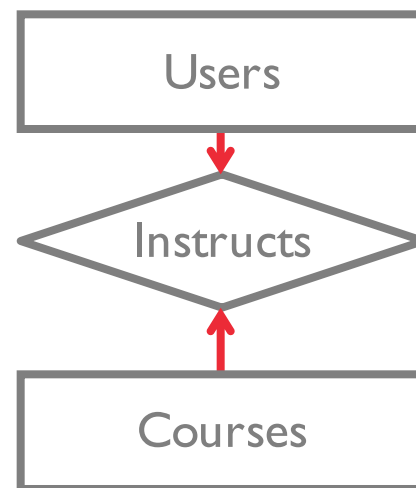
Participation Constraints

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
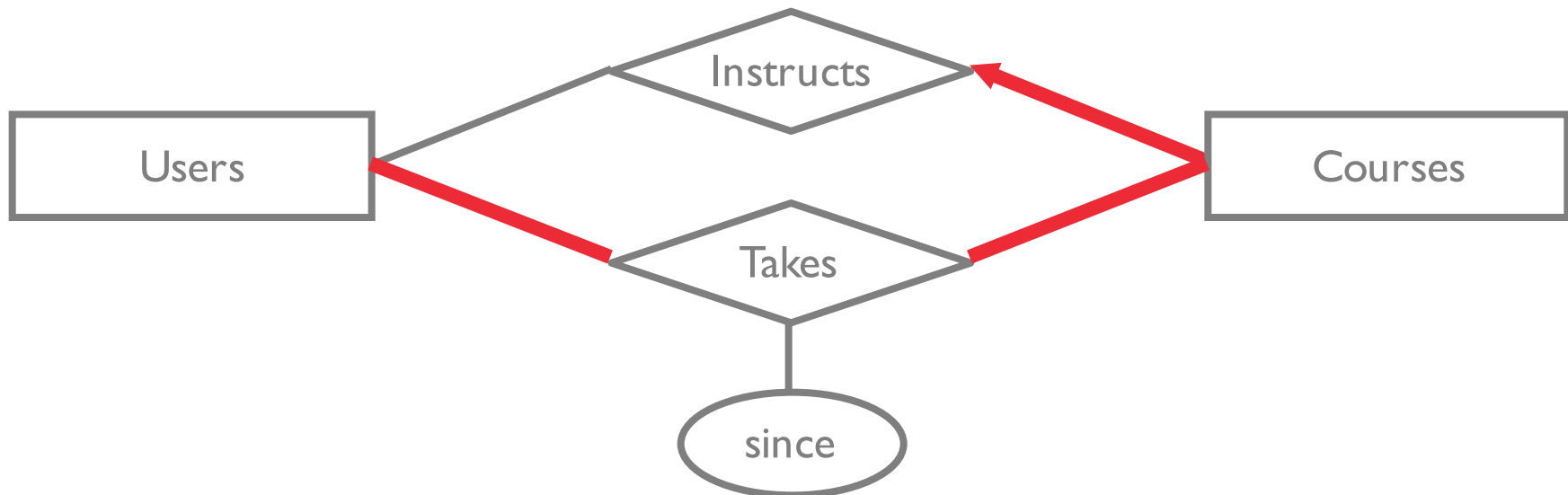
Weak Entities

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
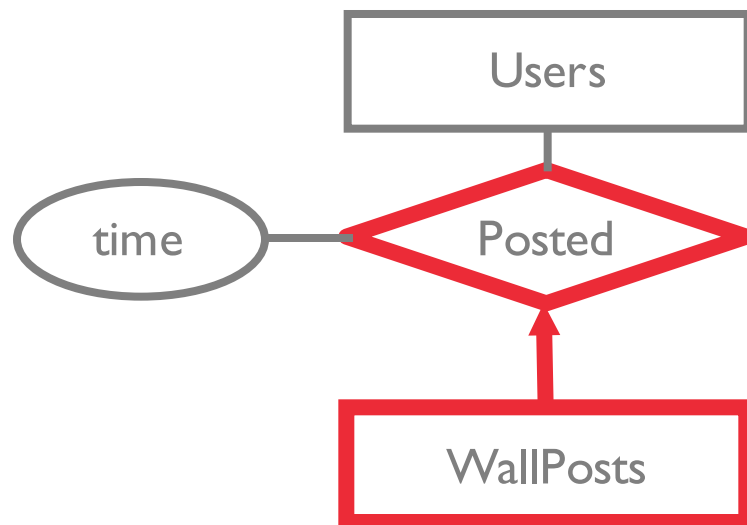
$\longrightarrow$ At most one

$\longrightarrow$ At least one

$\Longrightarrow$ Exactly one
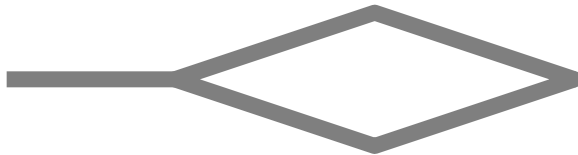
$\longrightarrow\!\Diamond$ Weak Entity

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
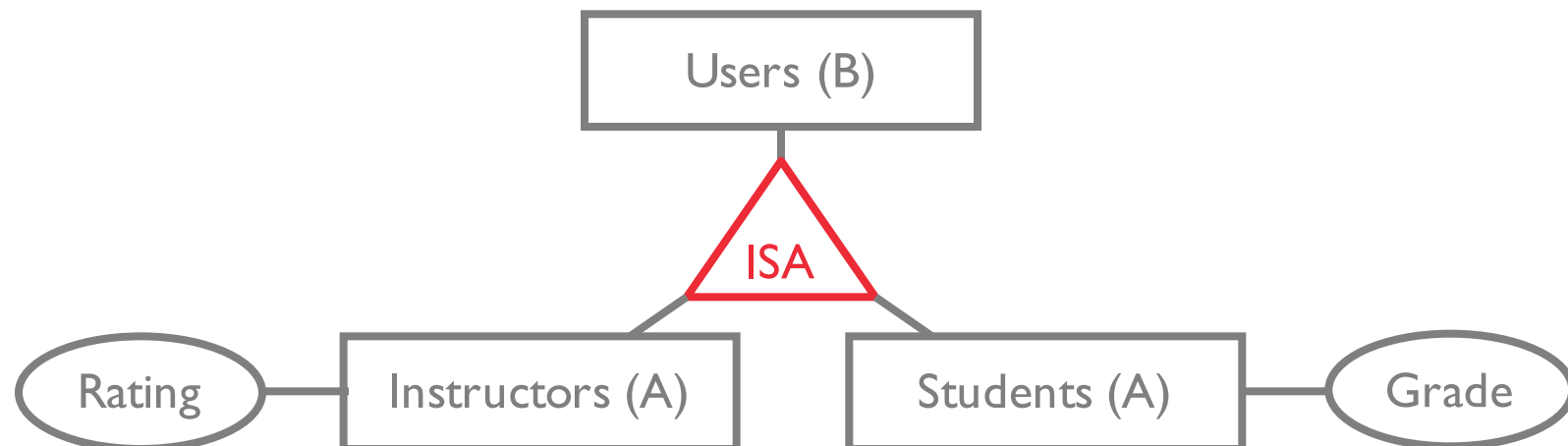
ISA (is a) Hierarchies

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???????
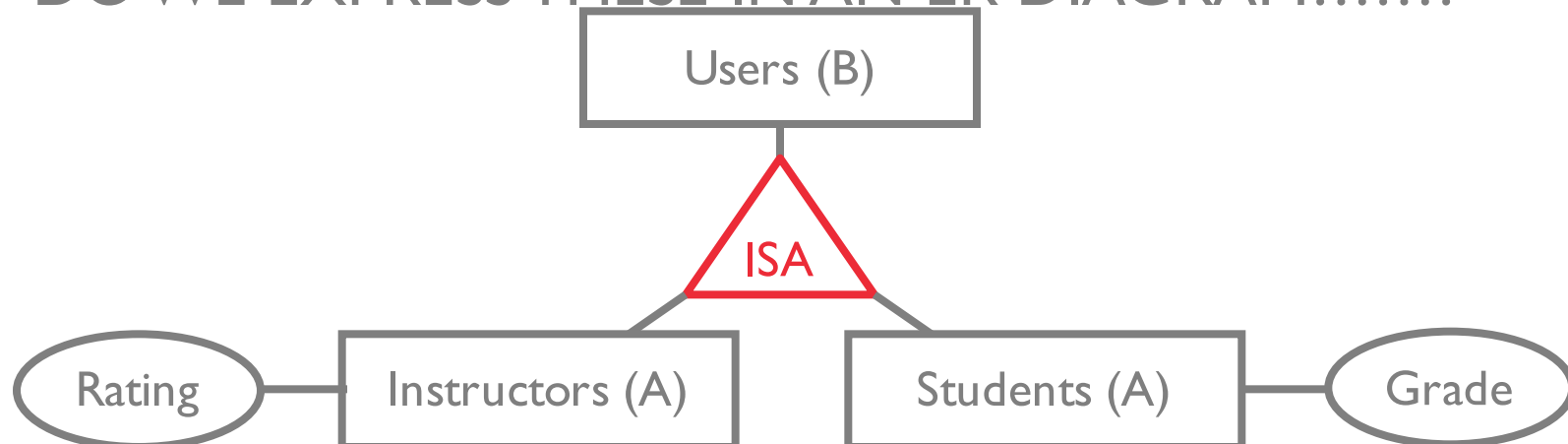
Aggregation

Relationships between (entities – relationships)

Lets us treat a Relationship Set like an Entity Set

so it can participate in other relationships
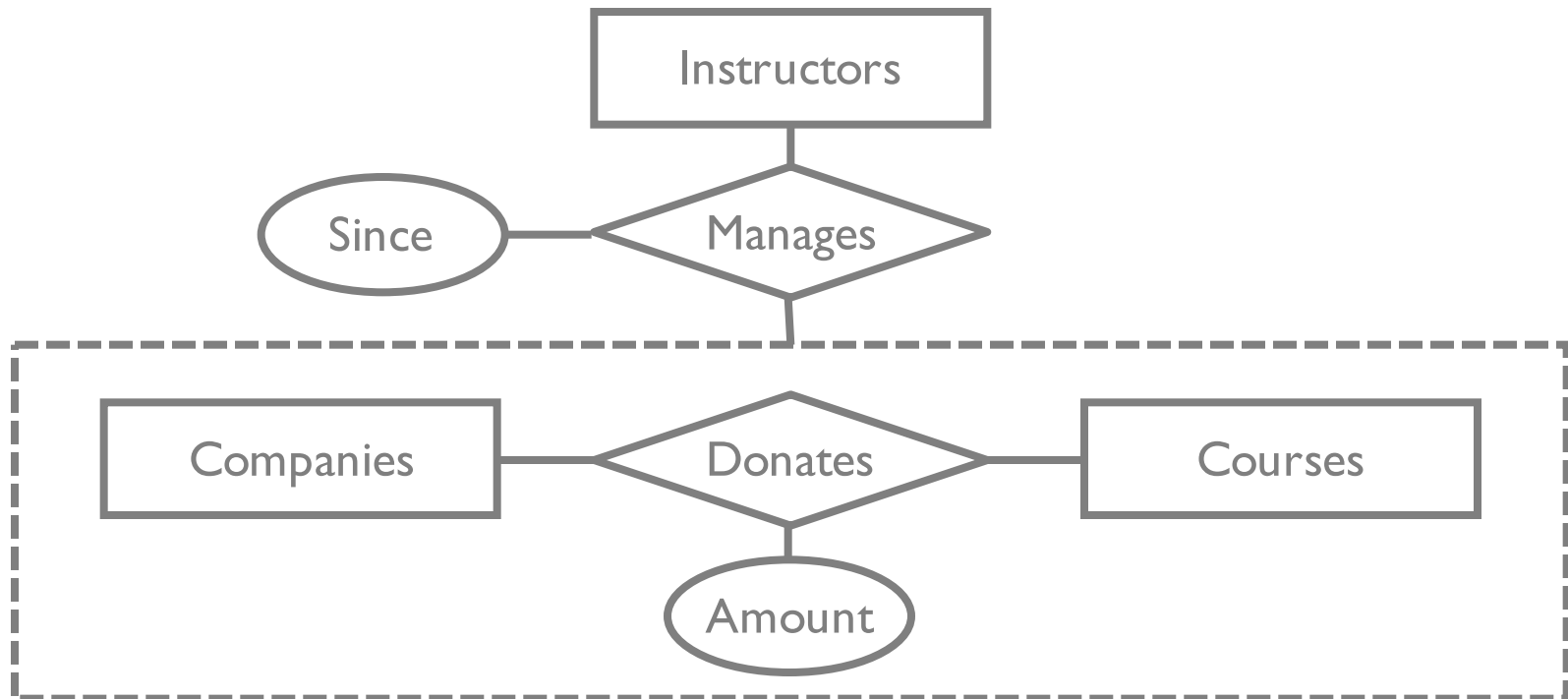
Aggregation vs Ternary Relationships

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
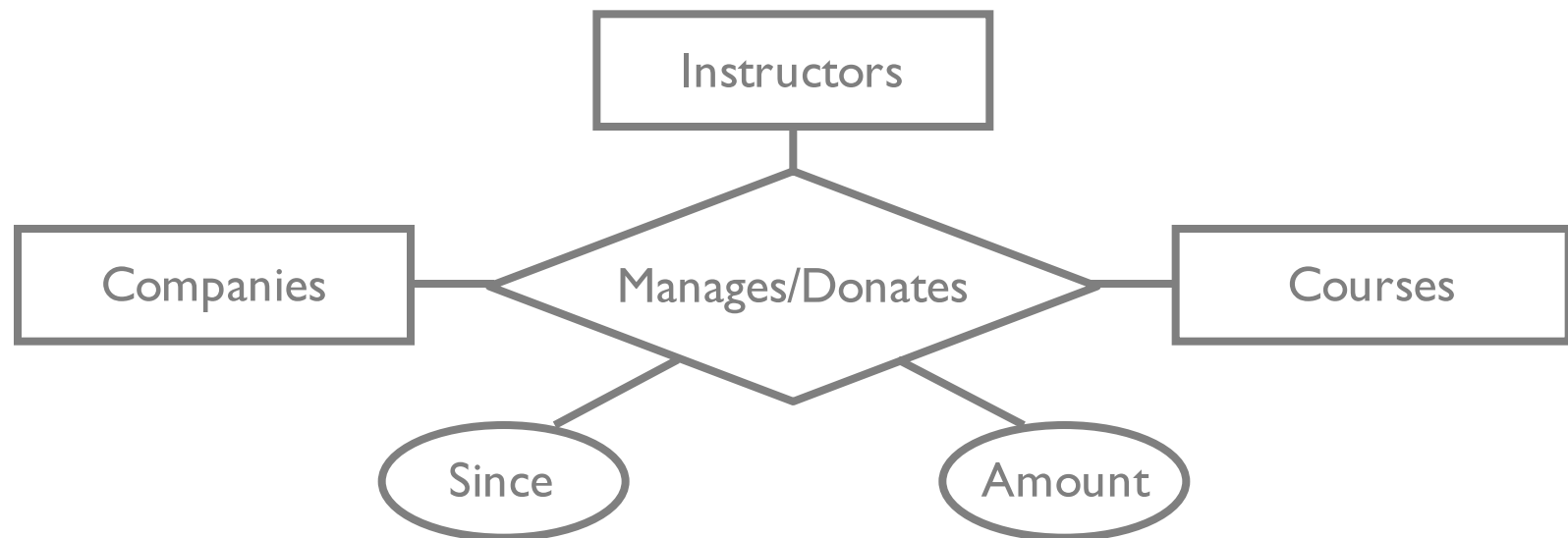
Aggregation vs Ternary Relationships

Constraints apply to all connected entity sets
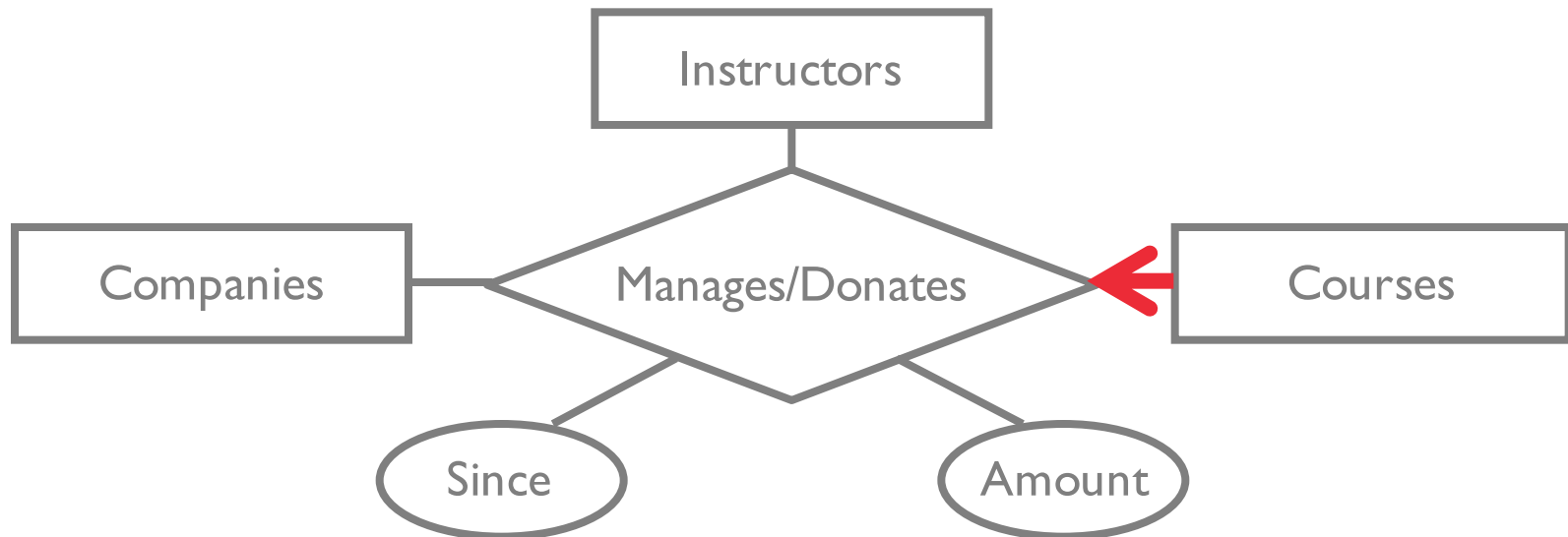
Using the ER Model

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)
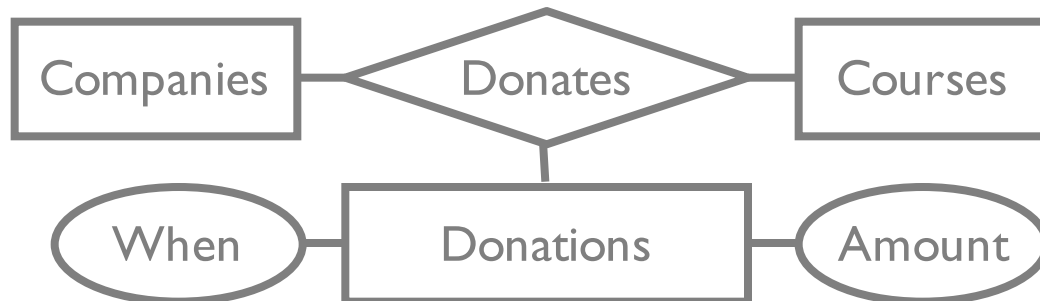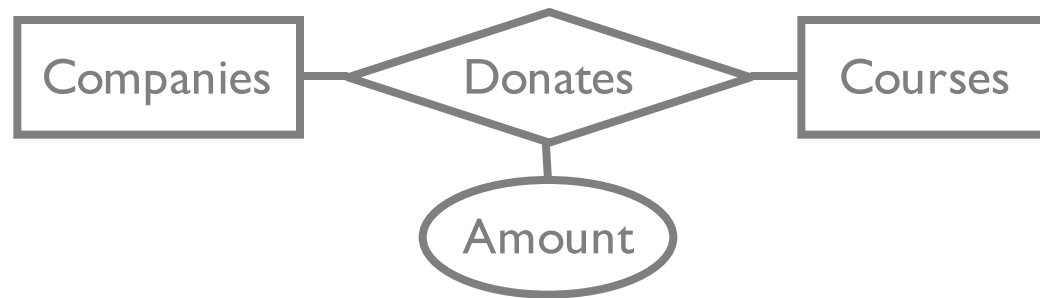
Entity or Relationship?

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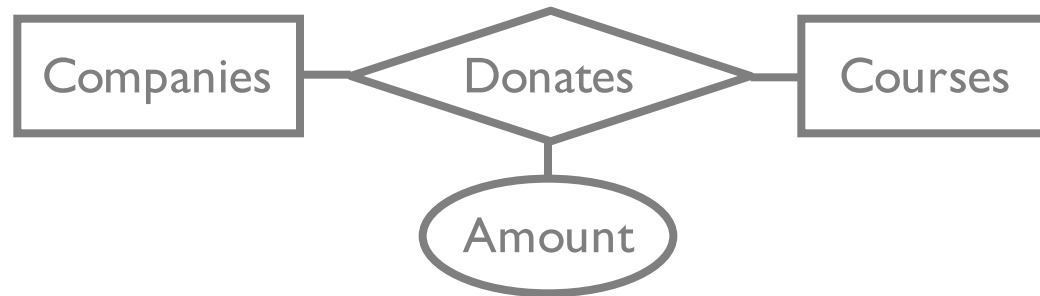
Company	Course	Amount
Amazon	4111	2000
Amazon	4112	2000
Amazon	5111	2000

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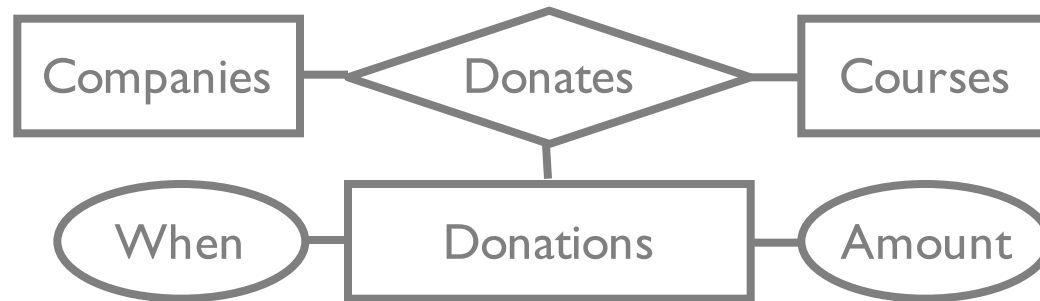
Company	Course	Donation
Amazon	4111	1
Amazon	4112	1
Amazon	5111	1

Donation	When	Amount
1	Today	2000

Binary or Ternary Relationship?

What if assignments have at most one grader?
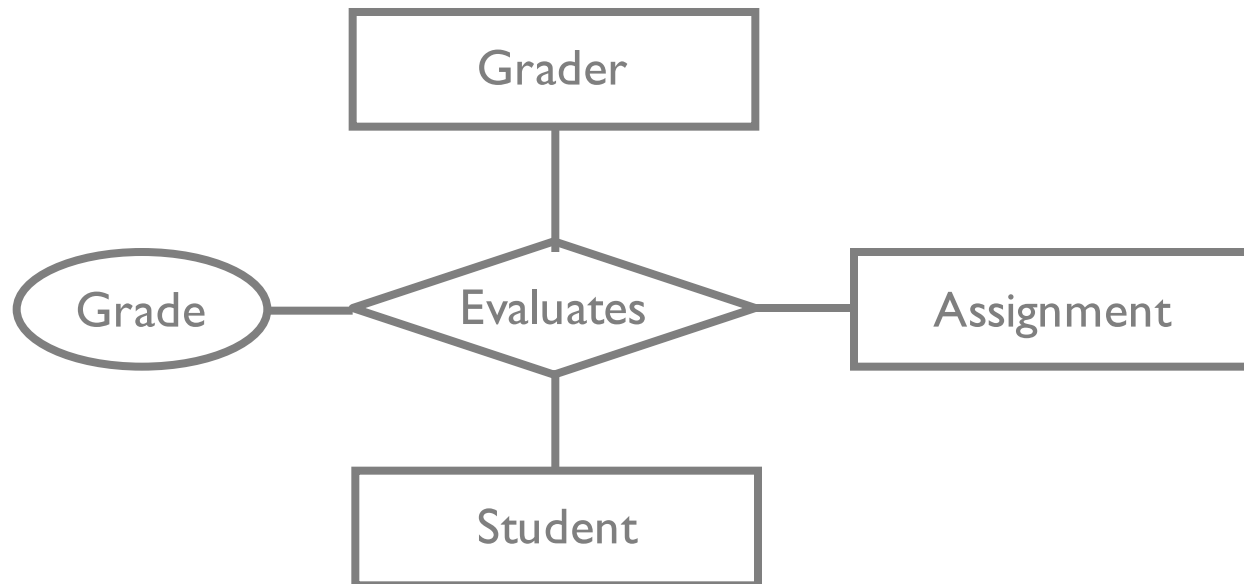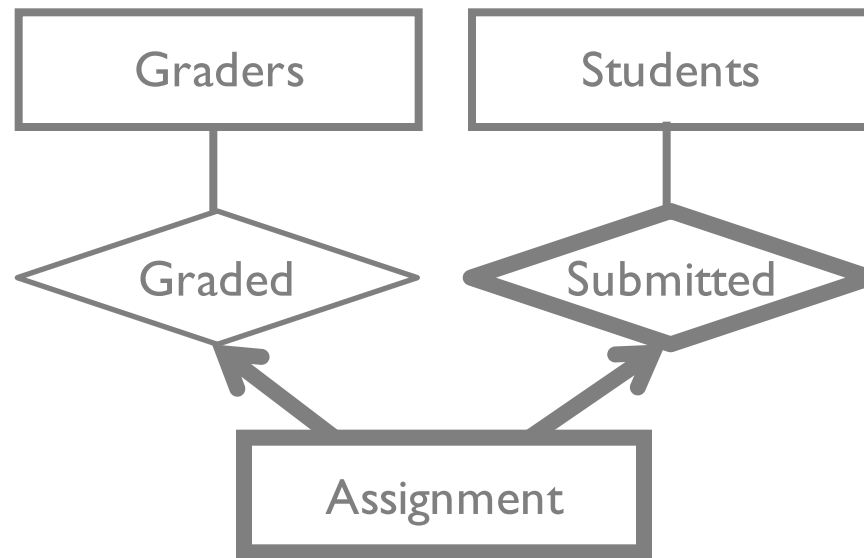
Binary or Ternary Relationship?

What if assignments have at most one grader?

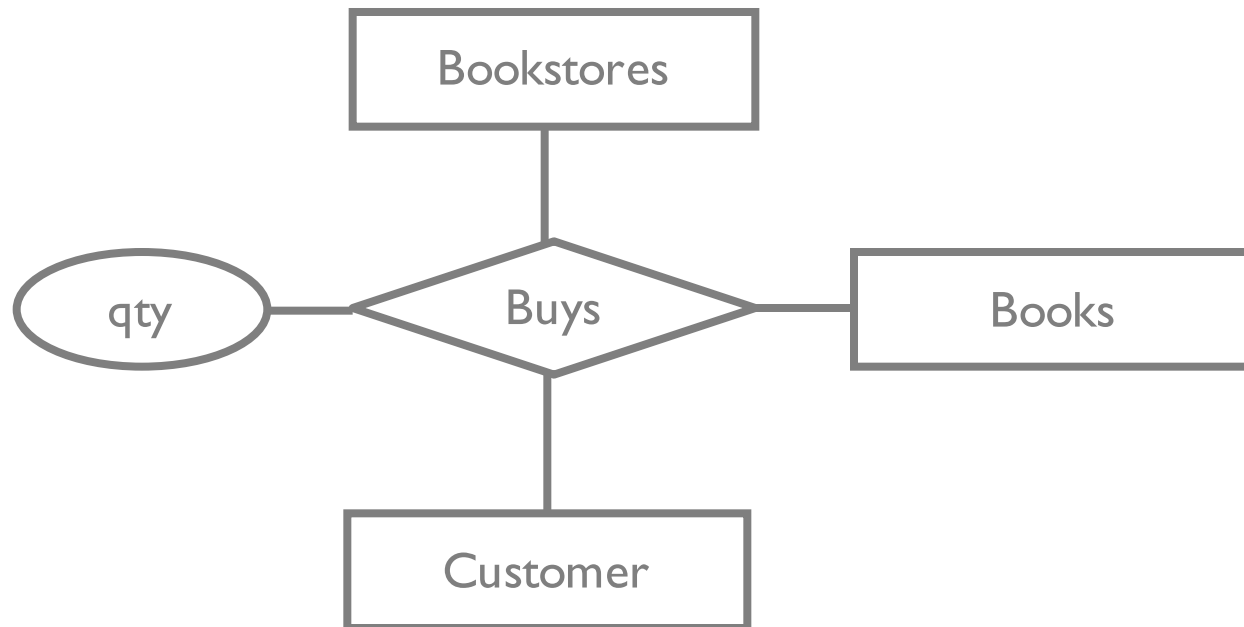Only one student can complete HW0!

Actually two separate relationships
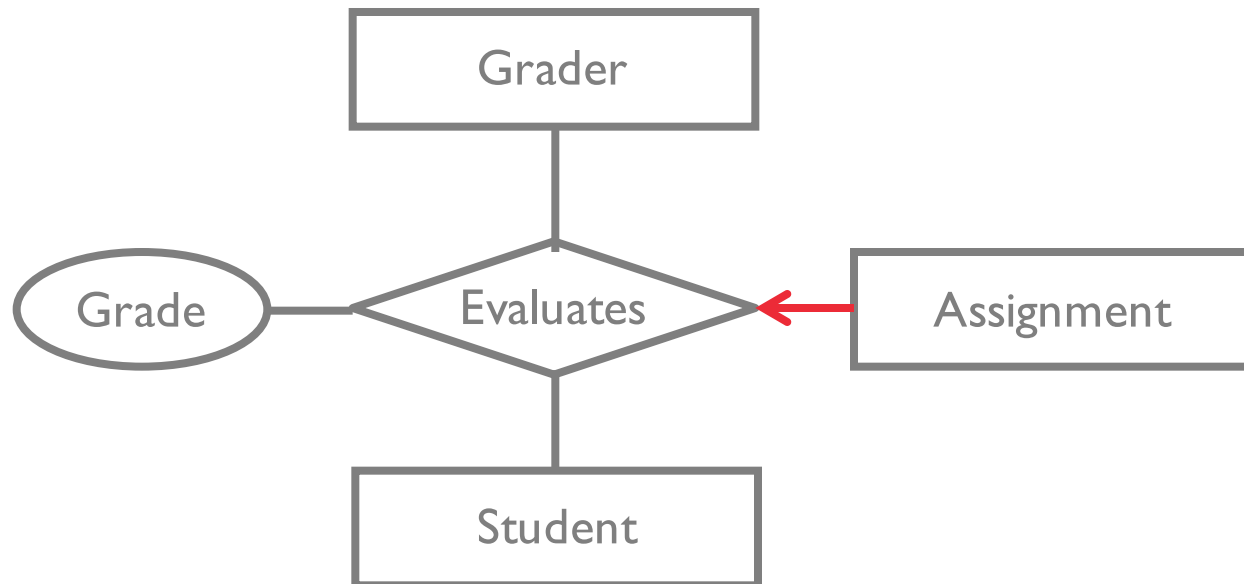
Binary or Ternary Relationship?

Binary relationships allows additional constraints

Binary or Ternary Relationship?

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

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   (Today) ER Modeling
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

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 webapp

 Open problems!

ER design is a useful way of thought

Next Time

Relational Model: de-facto DBMS standard

Set up for ER diagrams → Relational models