CMSC424: Database Design
SQL

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Today's Plan

- Project 1 discussion
- Entity-Relationship Model Details
- Anatomy of a Web Application
  - Project 2
- Converting from E/R Model to Relational Schema

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Entity-Relationship Model

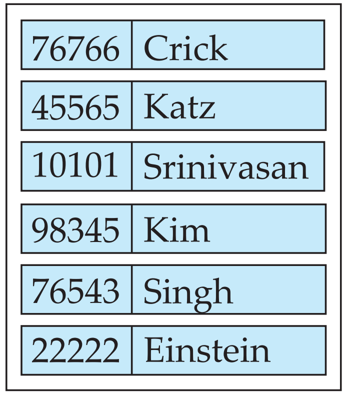
- Two key concepts
  - *Entities*:
    - An object that *exists* and is *distinguishable* from other objects
      - Examples: Bob Smith, BofA, CMSC424
    - Have *attributes* (people have names and addresses)
    - Form *entity sets* with other entities of the same type that share the same properties
      - Set of all people, set of all classes
    - Entity sets may overlap
      - Customers and Employees

Entity-Relationship Model

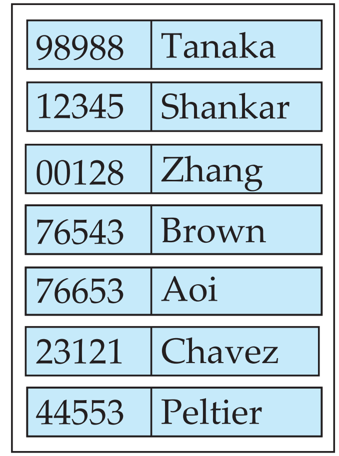
- Two key concepts
  - *Relationships*:
    - Relate 2 or more entities
      - E.g. Bob Smith *has account at* College Park Branch
    - Form *relationship sets* with other relationships of the same type that share the same properties
      - Customers *have accounts at* Branches
    - Can have attributes:
      - *has account at* may have an attribute *start-date*
    - Can involve more than 2 entities
      - Employee *works at* Branch *at* Job

Entities and relationships

Two Entity Sets

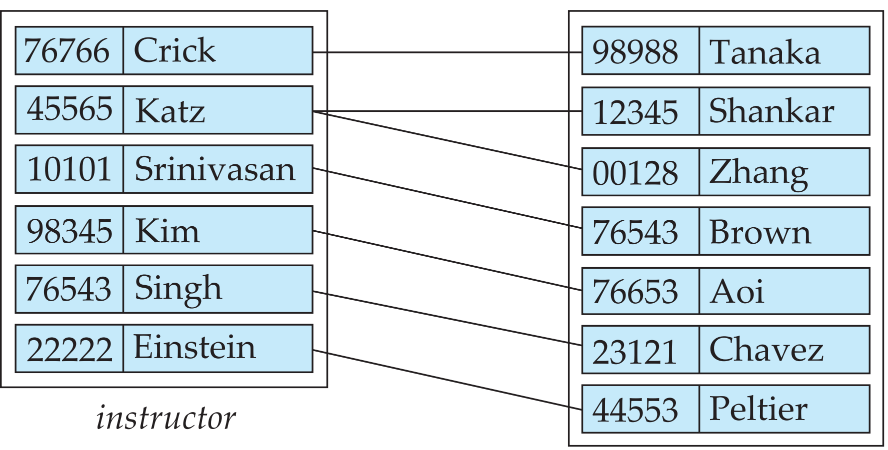


instructor

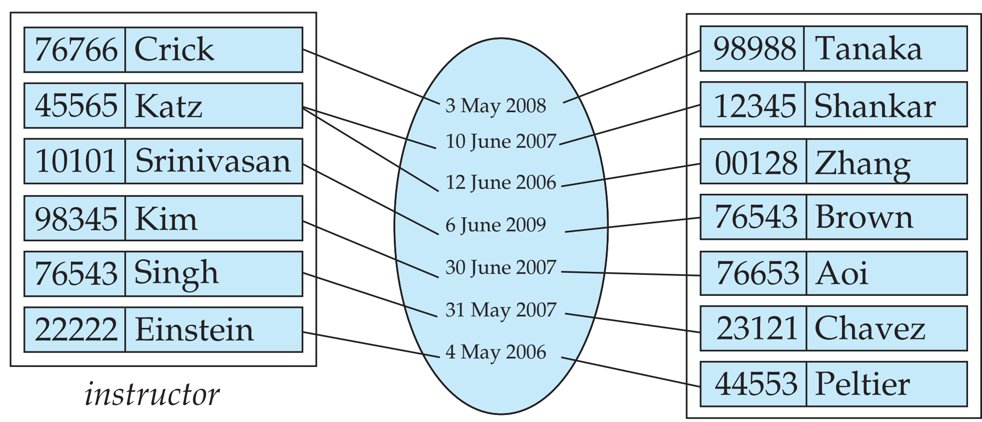


student

Advisor Relationship, with and without attributes

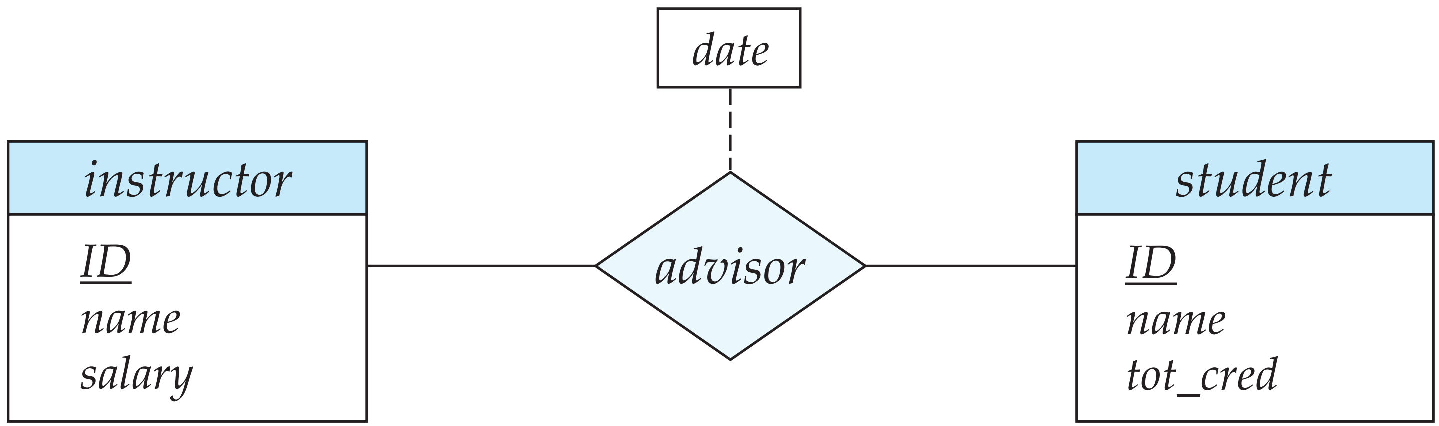


instructor *student*

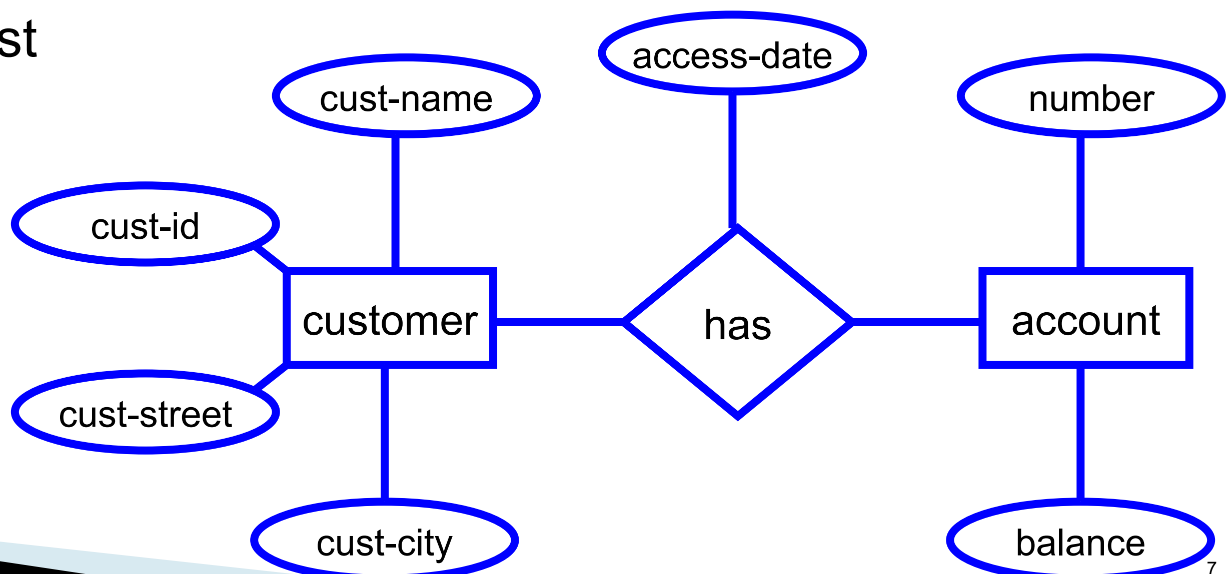


instructor *student*

ER Diagram



Alternative representation, used in the book in the past



Both notations used commonly

Rest of the class

- Details of the ER Model
  - How to represent various types of constraints/semantic information etc.

- Design issues

- A detailed example

Next: Relationship Cardinalities

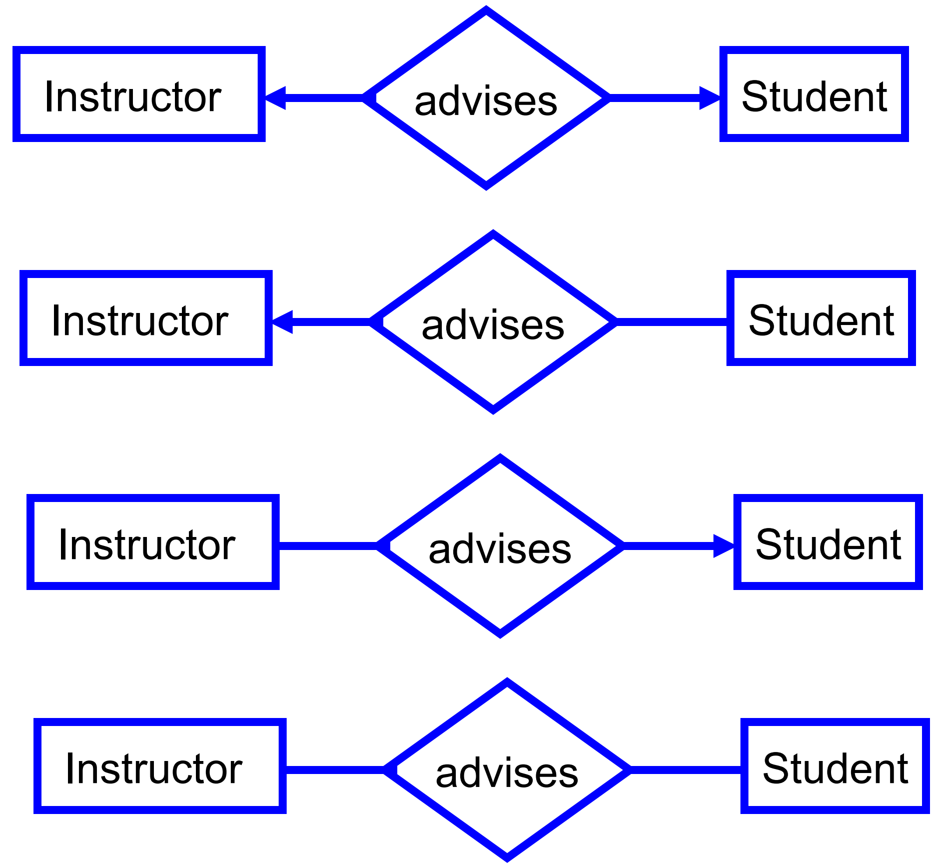
- We may know:
  - One customer can only open one account
  - OR
  - One customer can open multiple accounts
- Representing this is important
- Why ?
  - Better manipulation of data
    - If former, can store the account info in the customer table
  - Can enforce such a constraint
    - Application logic will have to do it; NOT GOOD
  - Remember: If not represented in conceptual model, the domain knowledge may be lost

Mapping Cardinalities

- Express the number of entities to which another entity can be associated via a relationship set
- Most useful in describing binary relationship sets

Mapping Cardinalities

- One-to-One
- One-to-Many
- Many-to-One
- Many-to-Many



Mapping Cardinalities

- Express the number of entities to which another entity can be associated via a relationship set

- Most useful in describing binary relationship sets

- N-ary relationships ?
  - More complicated
  - Details in the book

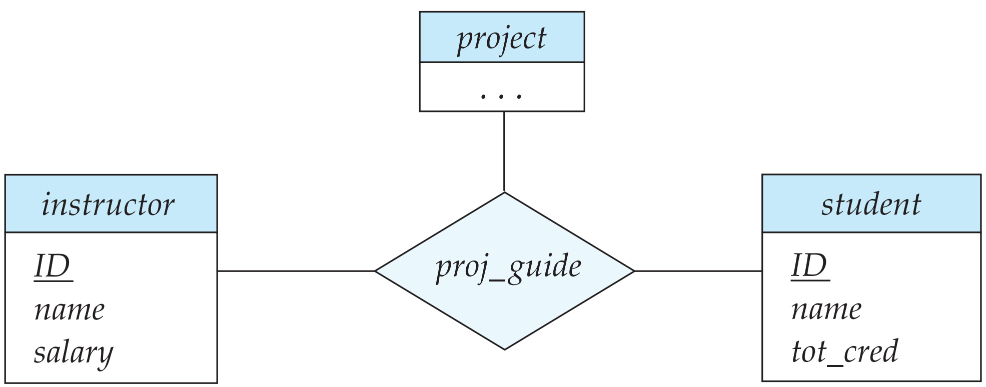


Figure 7.13 E-R diagram with a ternary relationship.

Next: Types of Attributes

- Simple vs Composite
  - Single value per attribute ?
- Single-valued vs Multi-valued
  - E.g. Phone numbers are multi-valued
- Derived
  - If date-of-birth is present, age can be derived
  - Can help in avoiding redundancy, enforcing constraints etc…

Types of Attributes

Primary key underlined

Composite

Multi-valued

Derived

instructor

- <u>*ID*</u>
- *name*
  - *first_name*
  - *middle_initial*
  - *last_name*
- *address*
  - *street*
    - *street_number*
    - *street_name*
    - *apt_number*
  - *city*
  - *state*
  - *zip*
- *{ phone_number }*
- *date_of_birth*
- *age ( )*

Relationship Set Keys

- What attributes are needed to represent a relationship completely and uniquely ?
  - Union of primary keys of the entities involved, and relationship attributes

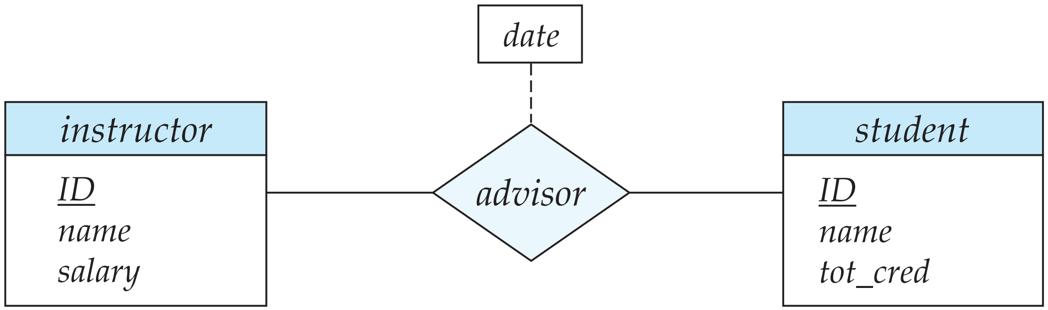


Figure 7.8 E-R diagram with an attribute attached to a relationship set.

  - {instructor.ID, date, student.ID} describes a relationship completely

Relationship Set Keys

- Is *{student_id, date, instructor_id}* a candidate key ?
  - No. Attribute *date* can be removed from this set without losing key-ness
  - In fact, union of primary keys of associated entities is always a superkey

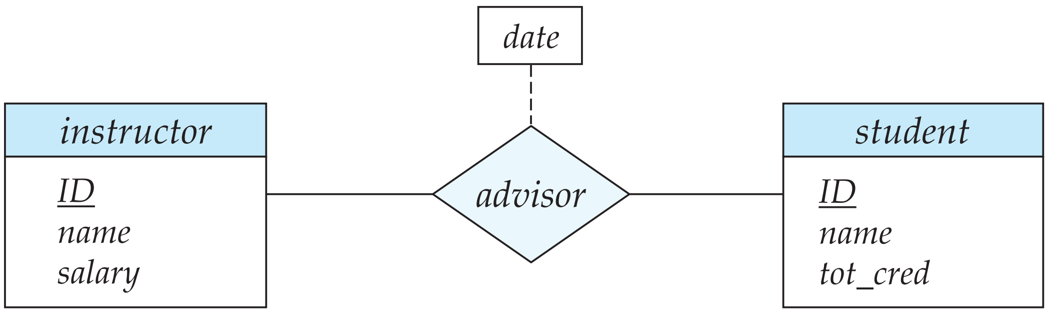
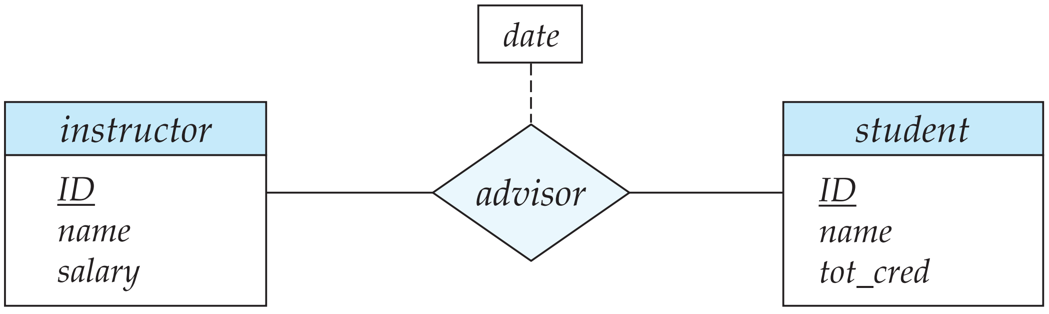


Figure 7.8 E-R diagram with an attribute attached to a relationship set.

Relationship Set Keys

- Is {student_id, instructor_id} a candidate key ?
  - Depends



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Relationship Set Keys

- Is {student_id, instructor_id} a candidate key ?
  - Depends

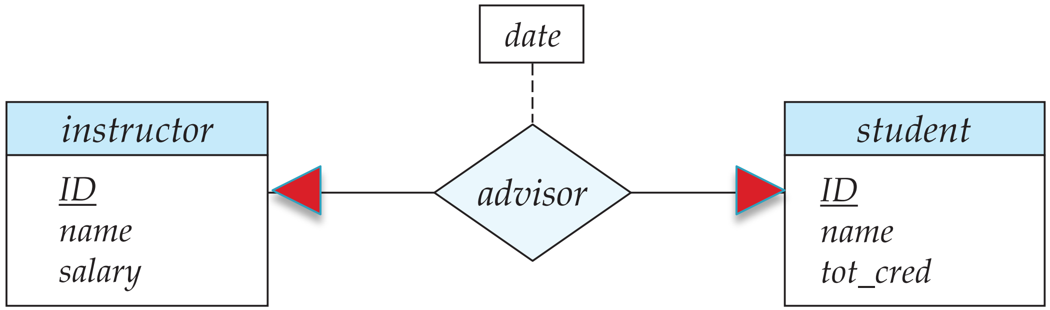


Figure 7.8 E-R diagram with an attribute attached to a relationship set.

- If one-to-one relationship, either *{instructor_id}* or *{student_id}* sufficient
  - Since a given *instructor* can only have one *advisee*, an instructor entity can only participate in one relationship
  - Ditto *student*

Relationship Set Keys

- Is {student_id, instructor_id} a candidate key ?
  - Depends

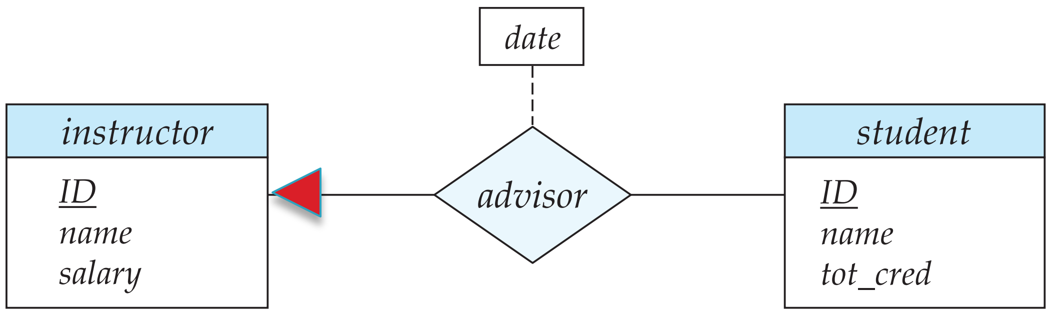


Figure 7.8 E-R diagram with an attribute attached to a relationship set.

- If one-to-many relationship (as shown), *{student_id}* is a candidate key
  - A given instructor can have many advisees, but at most one advisor per student allowed

Relationship Set Keys

- General rule for binary relationships
  - one-to-one: primary key of either entity set
  - one-to-many: primary key of the entity set on the many side
  - many-to-many: union of primary keys of the associate entity sets

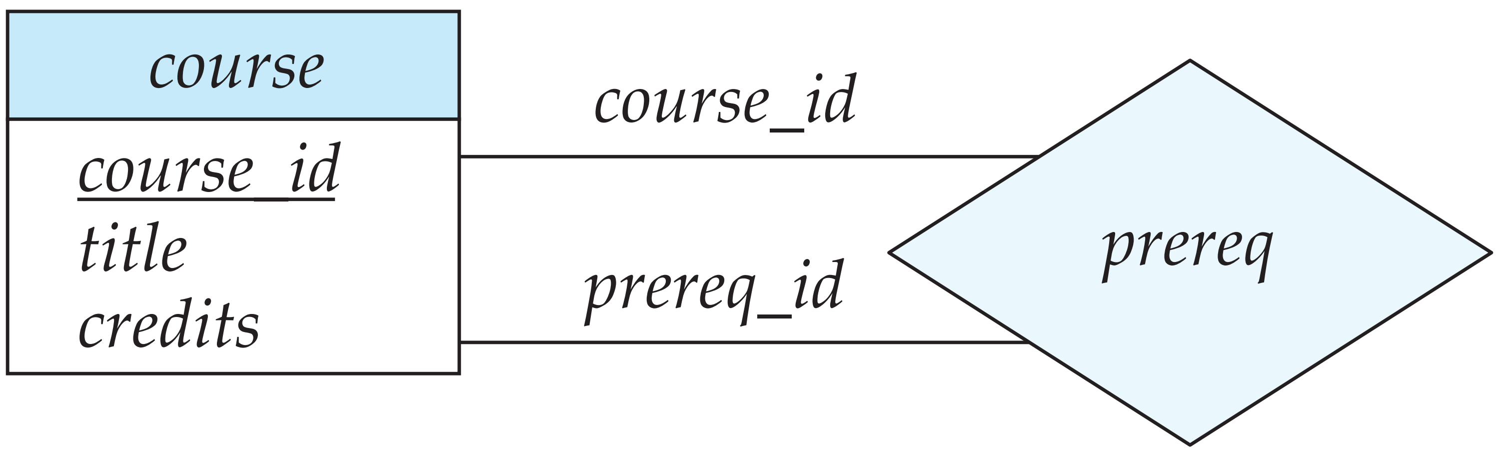
- n-ary relationships
  - More complicated rules

…

- What have we been doing
- Why ?
- Understanding this is important
  - Rest are details !!
  - That’s what books/manuals are for.

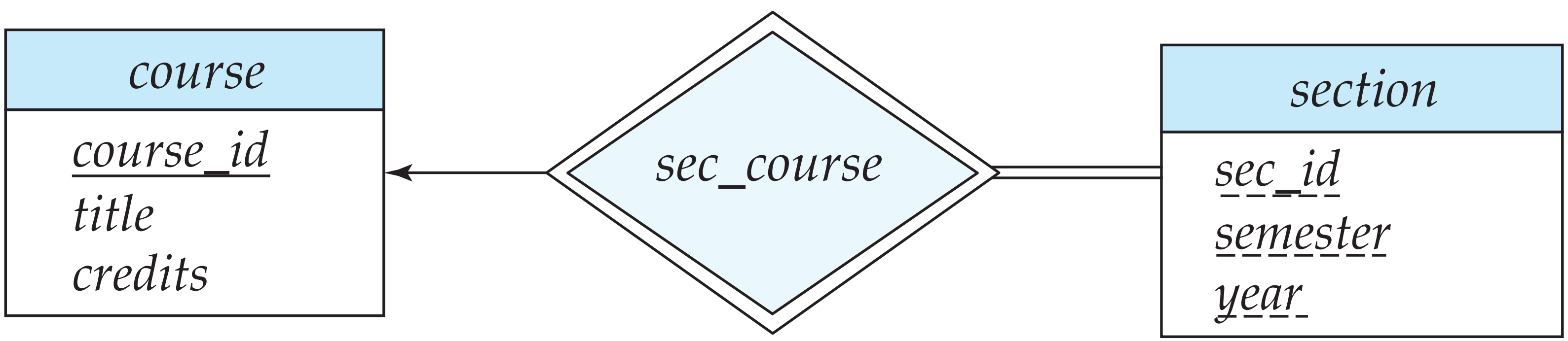
Recursive Relationships

- Sometimes a relationship associates an entity set to itself
- Need "roles" to distinguish



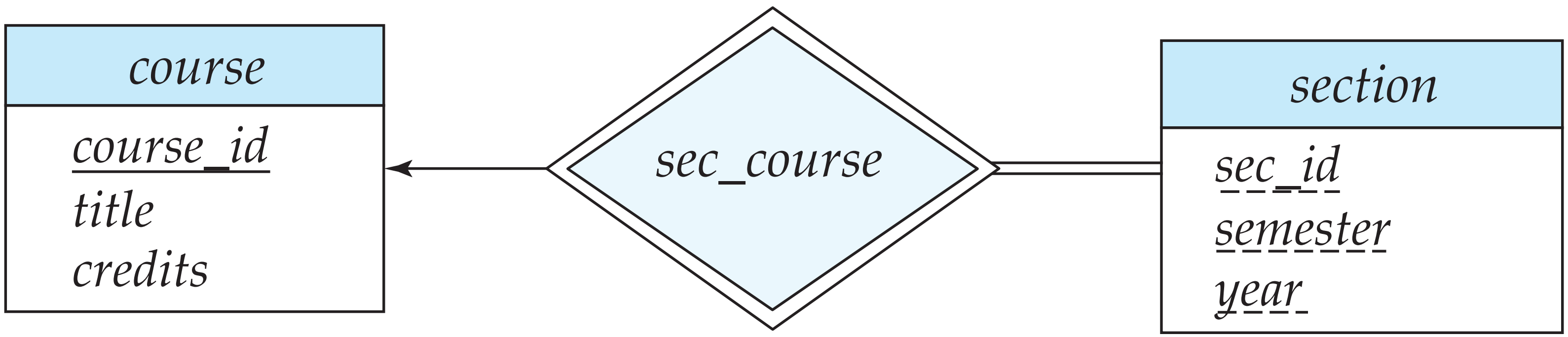
Weak Entity Sets

- An entity set without enough attributes to have a primary key
- E.g. Section Entity
- Still need to be able to distinguish between weak entities
  - Called “discriminator attributes”: dashed underline



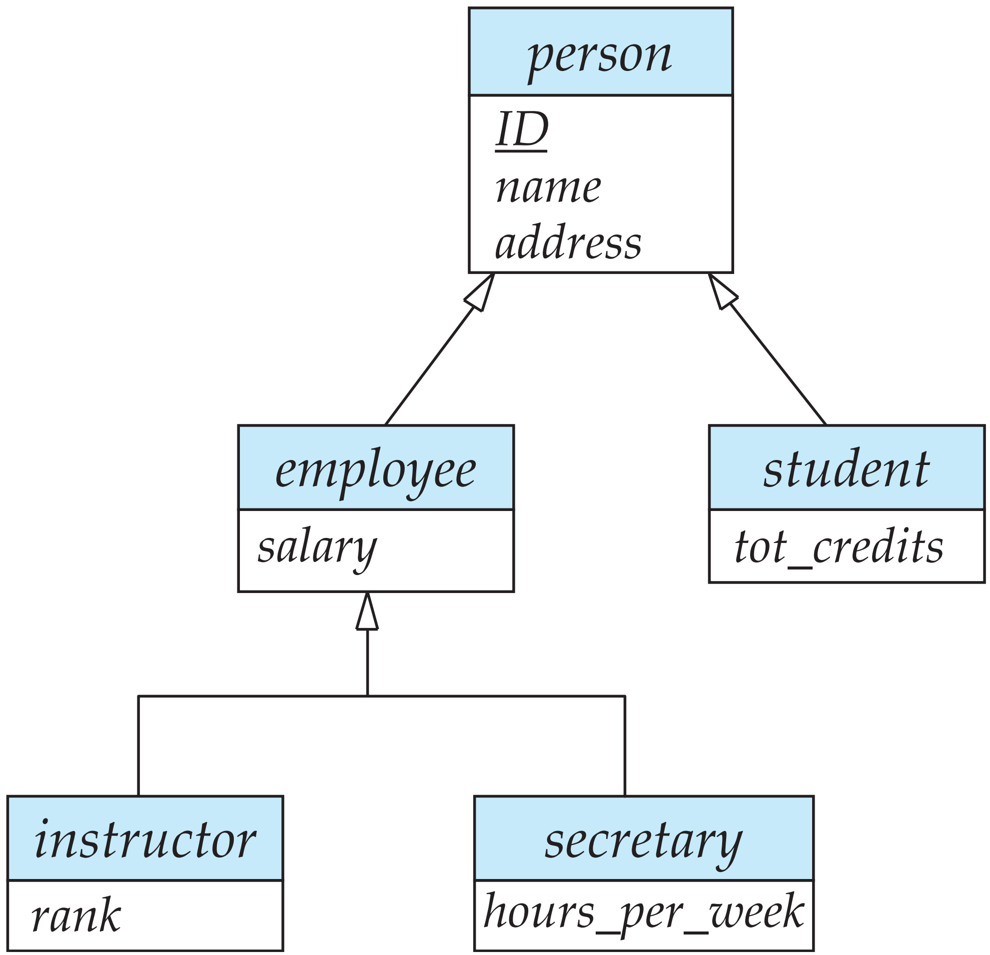
Participation Constraints

- Sometimes a relationship associates an entity set to itself
- Need “roles” to distinguish



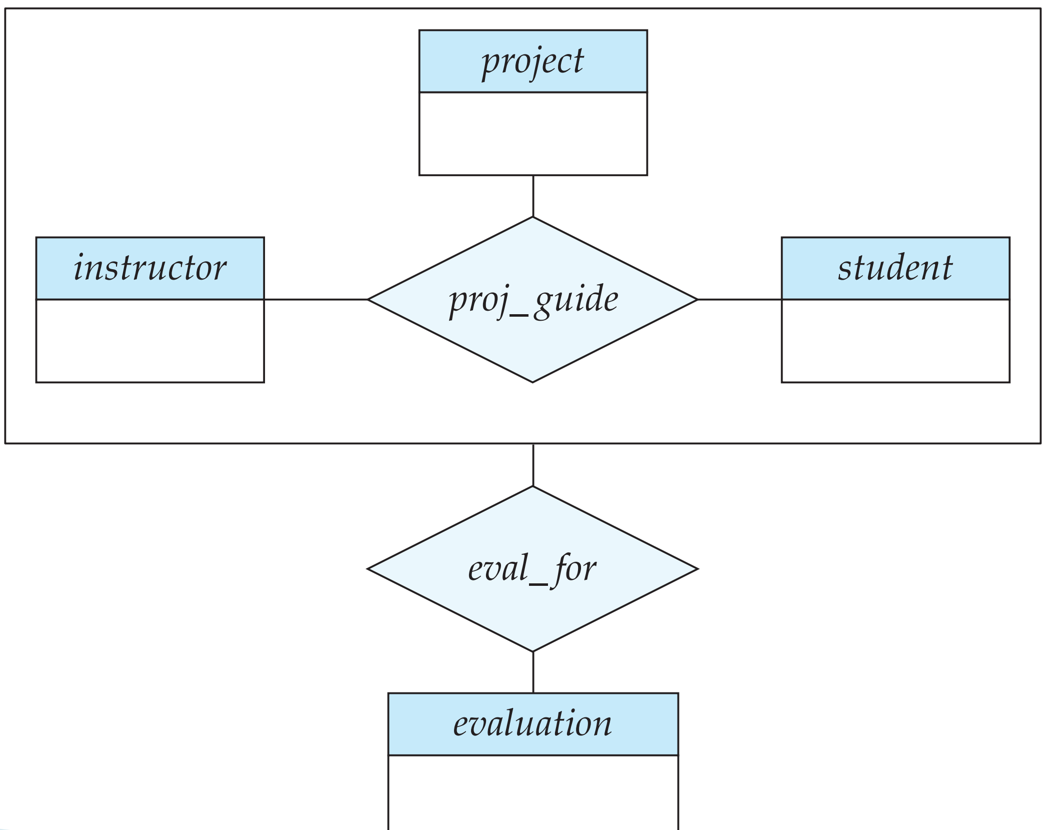
Specialization/Generalization

Similar to object-oriented programming: allows inheritance etc.



Aggregation

- No relationships allowed between relationships
- Suppose we want to record evaluations of a student by a guide on a project



Thoughts…

- Nothing about actual data
  - How is it stored ?
- No talk about the query languages
  - How do we access the data ?
- Semantic vs Syntactic Data Models
  - Remember: E/R Model is used for conceptual modeling
  - Many conceptual models have the same properties
- They are much more about representing the knowledge than about database storage/querying

Thoughts…

- Basic design principles
  - Faithful
    - Must make sense
  - Satisfies the application requirements
  - Models the requisite domain knowledge
    - If not modeled, lost afterwards
  - Avoid redundancy
    - Potential for inconsistencies
  - Go for simplicity
- Typically an iterative process that goes back and forth

Design Issues

- Entity sets vs attributes
  - Depends on the semantics of the application
  - Consider *telephone*
- Entity sets vs Relationsihp sets
  - Consider *loan*
- N-ary vs binary relationships
  - Possible to avoid n-ary relationships, but there are some cases where it is advantageous to use them
- It is not an exact science !!

Recap

- Entity-relationship Model
  - Intuitive diagram-based representation of domain knowledge, data properties etc…
  - Two key concepts:
    - Entities
    - Relationships
  - We also looked at:
    - Relationship cardinalities
    - Keys
    - Weak entity sets
    - …

Recap

- Entity-relationship Model
  - No standardized model (as far as I know)
    - You will see different types of symbols/constructs
  - Easy to reason about/understand/construct
  - Not as easy to implement
    - Came after the relational model, so no real implementation was ever done
    - Mainly used in the design phase

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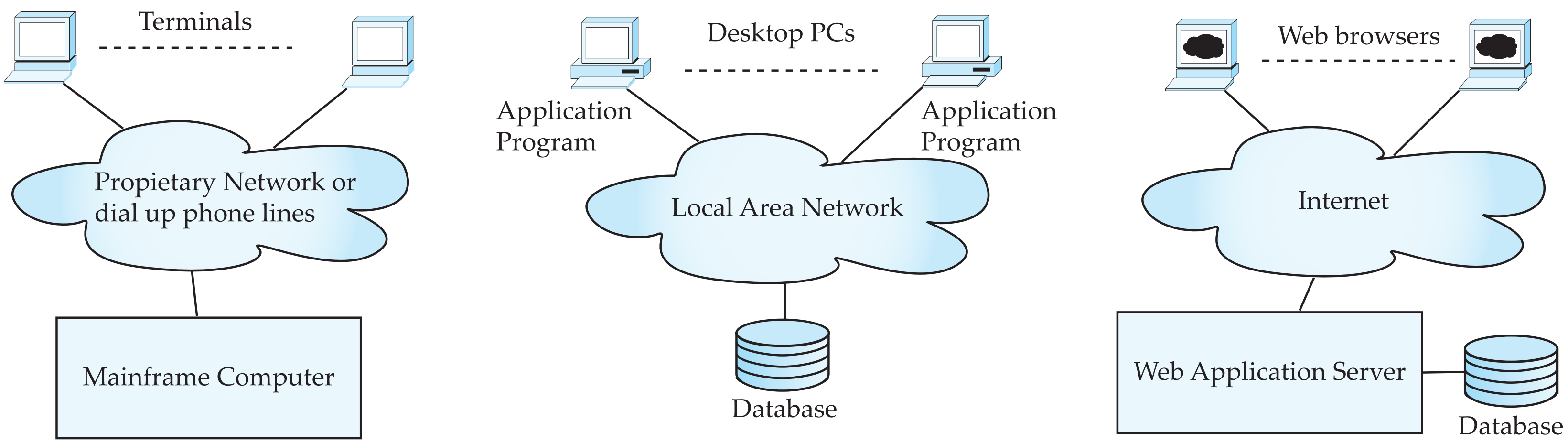
Application Architecture Evolution

- Three distinct eras of application architecture
  - Mainframe (1960’s and 70’s)
  - Personal computer era (1980’ s)
  - Web era (mid 1990’ s onwards)
  - Web and Smartphone era (2010 onwards)

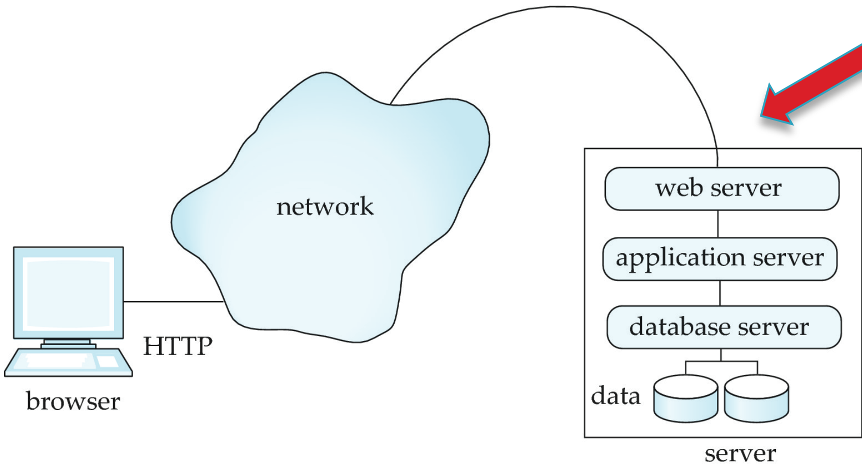


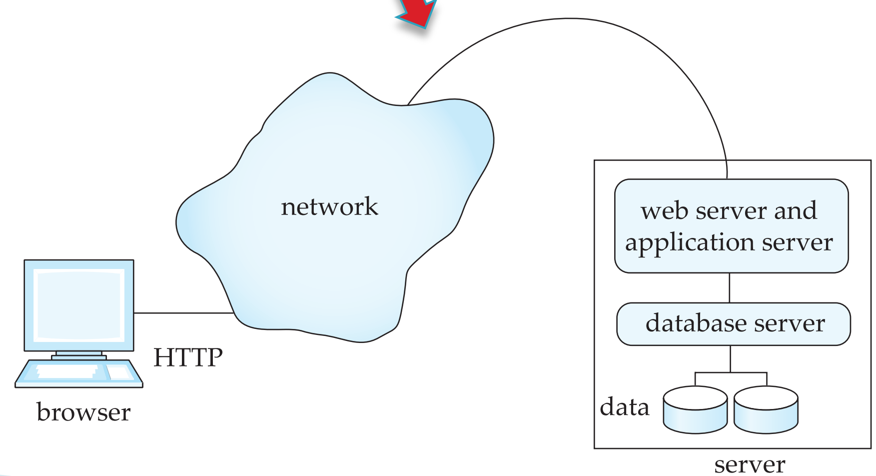
(a) Mainframe Era (b) Personal Computer Era (c) Web era

Web or Mobile Applications

- Web browsers and mobile applications have become de facto standard user interface
  - Wide cross-platform accessibility
  - No need to download something

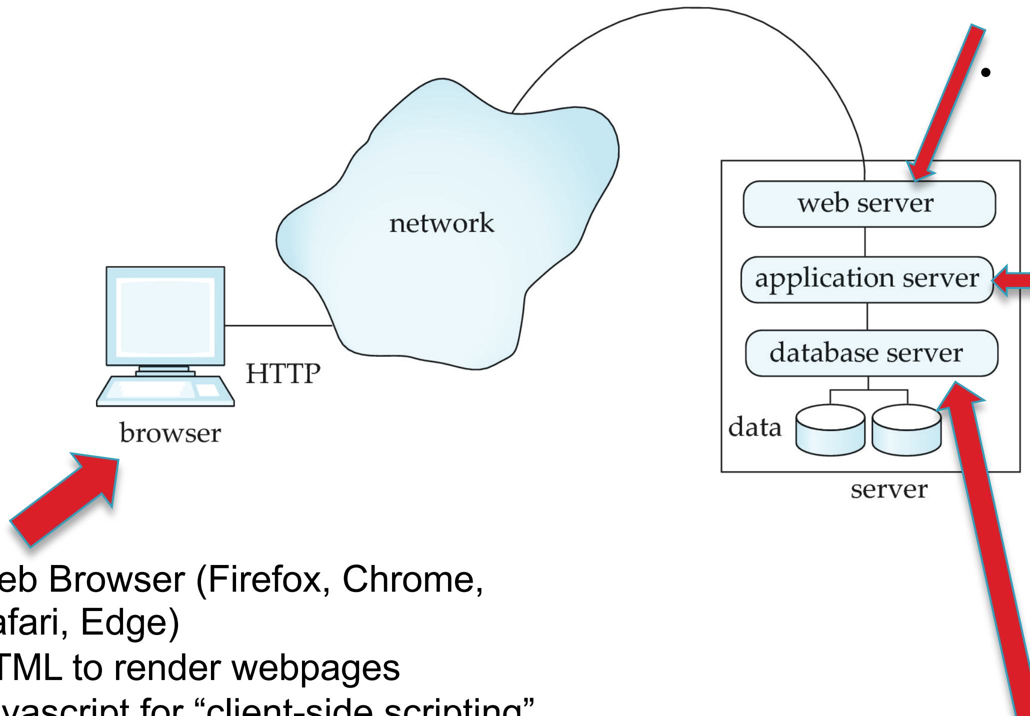
Three Tier or Two Tier Architectures





What runs where?

- Flask, Django, Tomcat, Node.js, and others
- Accept requests from the client and pass to the application server
- Pass application server response back to the client
- Support HTTP and HTTPS connections



- Encapsulates business logic
- Needs to support different user flows
- Needs to handle all of the rendering and visualization
- Ruby-on-rails, Django, Flask, Angular, React, PHP, and many others

1. Web Browser (Firefox, Chrome, Safari, Edge)
2. HTML to render webpages
3. Javascript for “client-side scripting” (running code in your browser without contacting the server)
4. Flash (not supported much – too much security risk)
5. Java “applets” – less common today

- PostgreSQL, Oracle, SQL Server, Amazon RDS (Relational Databases)
- MongoDB (Document/JSON databases)
- SQLite --- not typically for production environments
- Pretty much any database can be used…

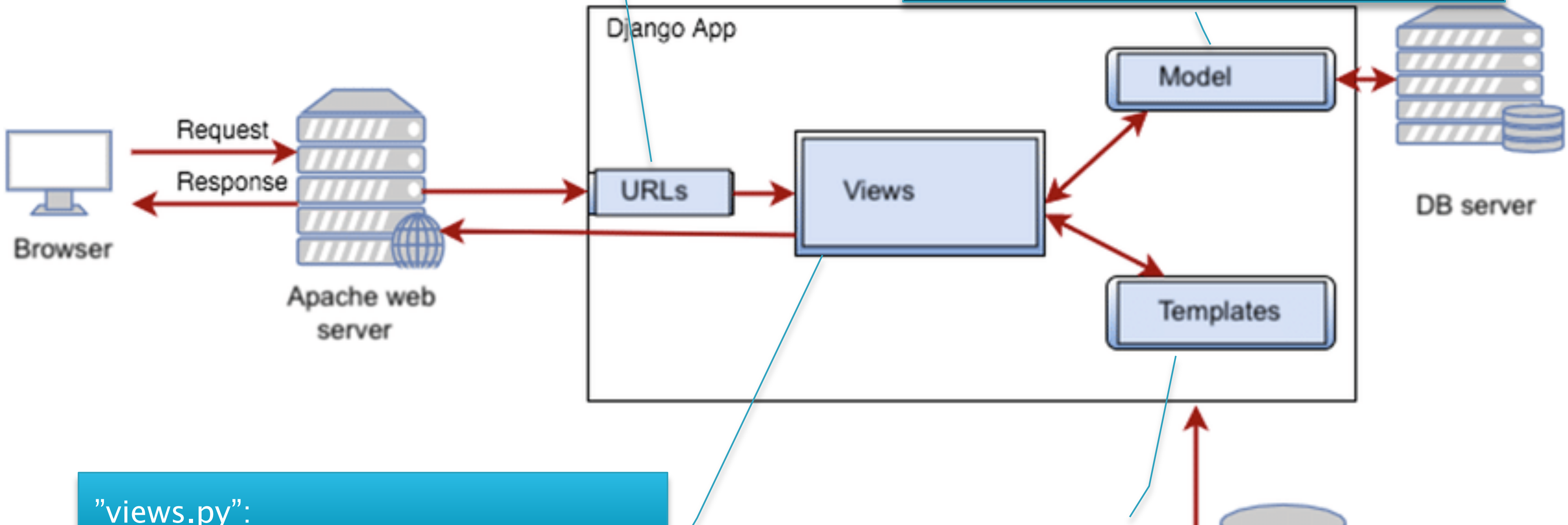
Application Server

- Fair amount of complexity in here
- Need to deal with “user flows”
  - Different types of actions user can take
  - Typically multi-step flows across screens
  - What happens when a user clicks this vs that
- Need to interface with the database
  - To look up the information needed to show to a user
  - To save updates made by the user
- Need to deal with rendering of the information
  - Generating the HTML to show the information to the user
  - Handling the “forms” for when a user makes changes

Django Architecture

"urls.py":
- Map incoming URLs to Views

"models.py":
- Define the different types of entities and relationships
- Think E/R Model more than Relational
- Entities map to classes – relationships may be implicit or explicit
- Django takes care of creating the RDBMS schema



"views.py":
- Fetch data from DB through models
- Do computations, create new objects, etc.
- Send data to "template"

templates directory:
- Create dynamic HTML using the data sent by "view.py"
- A mix of HTML and embedded Django code

Figure from: https://www.researchgate.net/figure/Specific-Django-architecture_fig1_332023947

Project 2: “urls.py”

```
from django.conf.urls import url

from . import views

urlpatterns = [
        url(r'^$', views.mainindex, name='mainindex'),

        url(r'^user/(?P<user_id>[0-9]+)/$', views.userindex, name='userindex'),

        url(r'^event/(?P<event_id>[0-9]+)/$', views.eventindex, name='eventindex'),

        url(r'^calendar/(?P<calendar_id>[0-9]+)/$', views.calendarindex, name='calendarindex'),

        url(r'^user/(?P<user_id>[0-9]+)/createevent$', views.createevent, name='createevent'),

        url(r'^user/(?P<user_id>[0-9]+)/submitcreateevent/$', views.submitcreateevent, name='submitcreateever

        url(r'^user/(?P<user_id>[0-9]+)/createdevent/(?P<event_id>[0-9]+)/$', views.createdevent, name='creat

        url(r'^waiting/user/(?P<user_id>[0-9]+)/calendar/(?P<calendar_id>[0-9]+)/$', views.waiting, name='wai

        url(r'^summary$', views.summary, name='summary'),
]
```

Project 2: “views.py”

```
def eventindex(request, event_id):
        event = Event.objects.get(pk=event_id)
        statuses = [(c.title, BelongsTo.Status(BelongsTo.objects.get(event=event, calendar=c).status)) for c in event.calendars.
        context = {'event': event, 'statuses': statuses}
        return render(request, 'mycalendar/eventindex.html', context)
```

- Get the event object from the database
- Get all the “status” associated with it
- Create the “context” object
- Pass it to “eventindex” template

Project 2: “eventindex.html”

Django command – pulls the title from the “event” object passed by views.py

```
{% if event %}
    <h3> Event Information </h3>
    <b> Event Title: </b> {{ event.title }} <br>
    <b> Start Time: </b> {{ event.start_time }} <br>
    <b> End Time: </b> {{ event.end_time }} <br>
    <h4> Invited Calendars: </h4>
    <table style="border:2px solid black; padding: 10px; border-collapse: collapse">
     <tr> <th style="border:2px solid black"> Calendar Name </th> <th style="border:2px solid black">  Status </th>  </tr>
    {% for x, y in statuses %}
     <tr> <td style="border:2px solid black"> {{ x }} </td> <td style="border:2px solid black">  {{ y.label }}</td>  </tr>
    {% endfor %}
    </table>

{% endif %}
```

You can do for loops and conditionals, but not arbitrary python (that’s for “views.py”

Project 2: "models.py"

```
class Event(models.Model):
        title = models.CharField(max_length=50)
        start_time = models.DateTimeField()
        end_time = models.DateTimeField()
        calendars = models.ManyToManyField(Calendar, through='BelongsTo')
        created_by = models.ForeignKey(User, on_delete=models.CASCADE)
        def __str__(self):
                return self.title
```

Maps to a table in the backend (SQLite3) Database

```
sqlite> .schema mycalendar_event

CREATE TABLE IF NOT EXISTS "mycalendar_event"
    (    "id" integer NOT NULL PRIMARY KEY AUTOINCREMENT,
         "start_time" datetime NOT NULL,
         "end_time" datetime NOT NULL,
         "created_by_id" integer NOT NULL REFERENCES "mycalendar_user" ("id")
DEFERRABLE INITIALLY DEFERRED,
         "title" varchar(50) NOT NULL);
```