Web Engineering:
Web application architecture

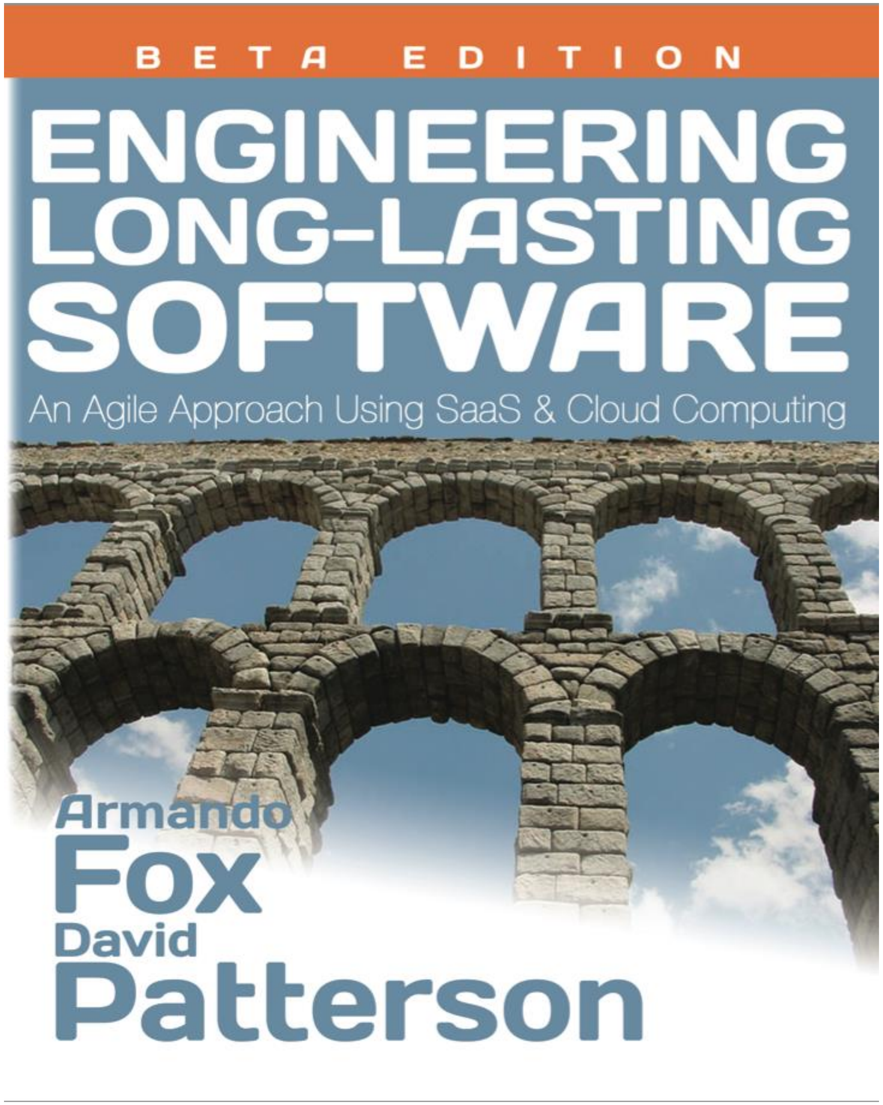
The University of Aizu
Quarter 2, AY 2018

Outline

- Client-server architecture, HTTP, URIs, cookies
- HTML & CSS, XML & XPath
- 3-tier shared-nothing architecture, horizontal scaling
- model-view-controller design pattern
  - Models: ActiveRecord & CRUD
  - Routes, controllers, and REST
  - Template views
- Fallacies & pitfalls, perspectives
- Patterns, architecture, & perspective

Literature

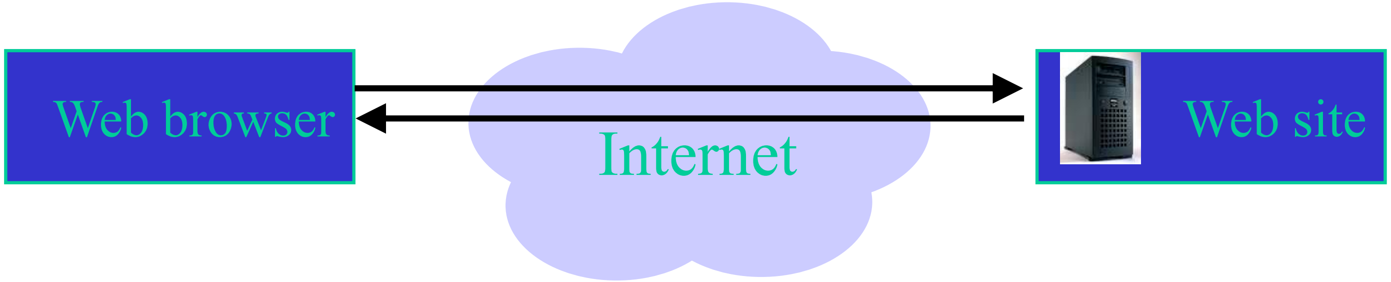
- ❐ http://saasbook.info
- ❐ Beta edition (0.9.0)
- ❐ We apply slides designed to accompany the book
  - ○ Chapter 2

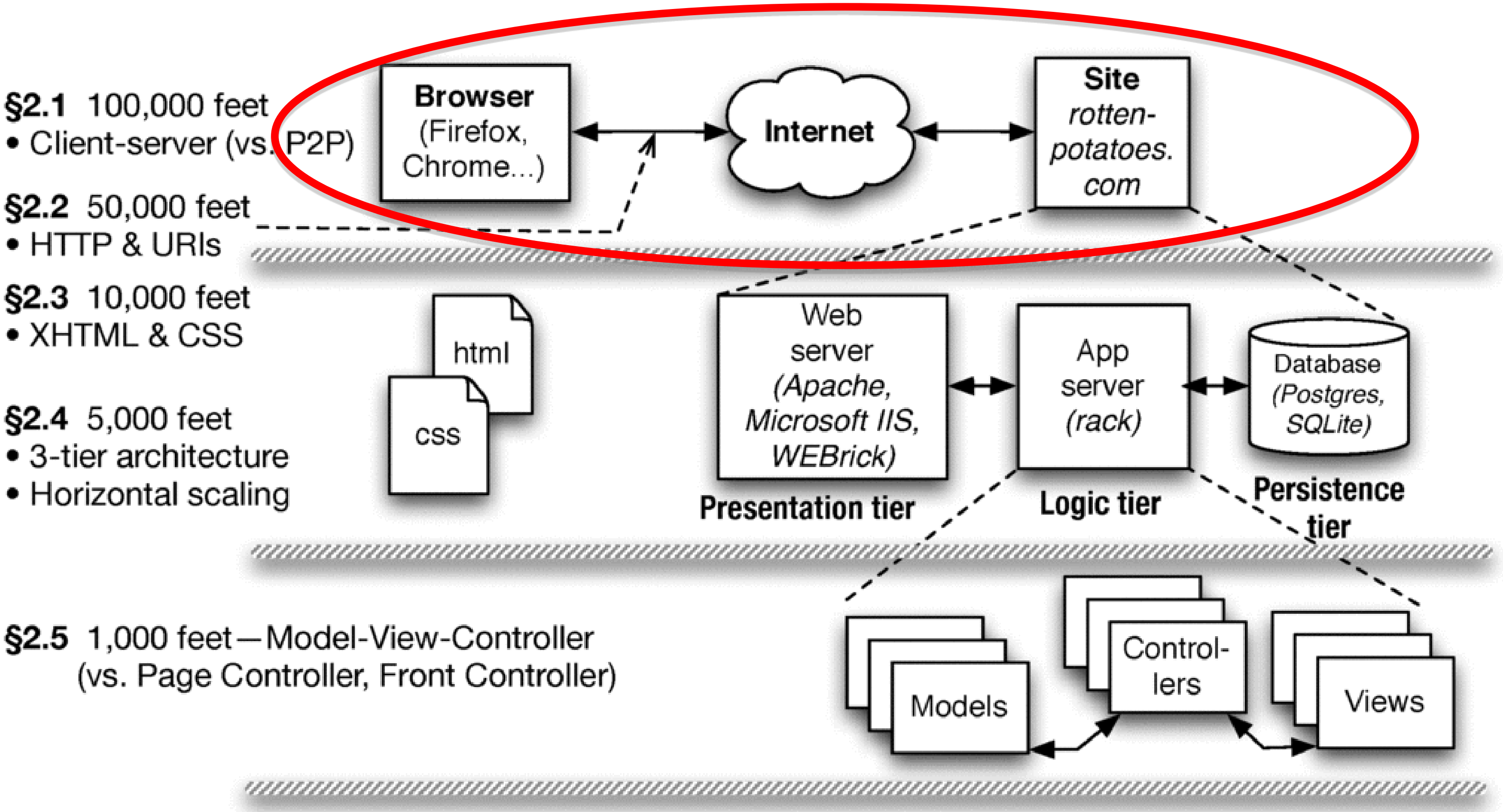

BETA EDITION
ENGINEERING LONG-LASTING SOFTWARE
An Agile Approach Using SaaS & Cloud Computing
Armando Fox
David Patterson

The Web as a Client-Server System; TCP/IP intro

Web at 100,000 feet

- The web has a *client/server* architecture
- It is fundamentally *request/reply oriented*





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- Client-server (vs. P2P)

§2.2 50,000 feet
- HTTP & URIs

§2.3 10,000 feet
- XHTML & CSS

§2.4 5,000 feet
- 3-tier architecture
- Horizontal scaling

§2.5 1,000 feet—Model-View-Controller (vs. Page Controller, Front Controller)

Browser (Firefox, Chrome...)

Internet

Site *rotten-potatoes.com*

html

css

Web server *(Apache, Microsoft IIS, WEBrick)*

Presentation tier

App server *(rack)*

Logic tier

Database *(Postgres, SQLite)*

Persistence tier

Models

Control-lers

Views

§2.6 500 feet: Active Record models (vs. Data Mapper)
§2.7 500 feet: RESTful controllers (Representational State Transfer for self-contained actions)
§2.8 500 feet: Template View (vs. Transform View)

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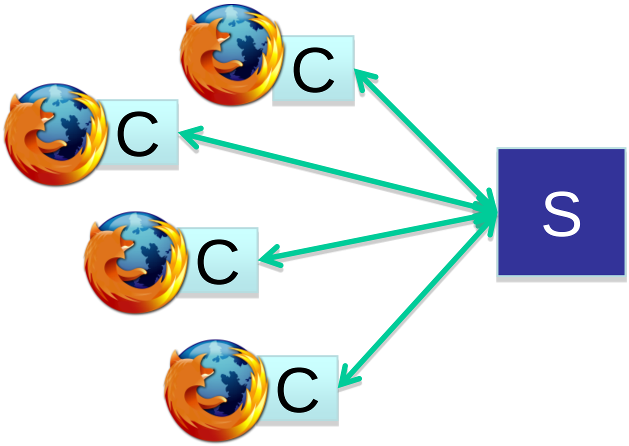
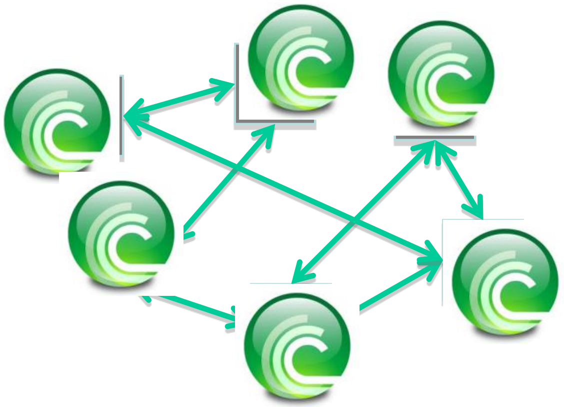
Client-Server vs. Peer-to-Peer

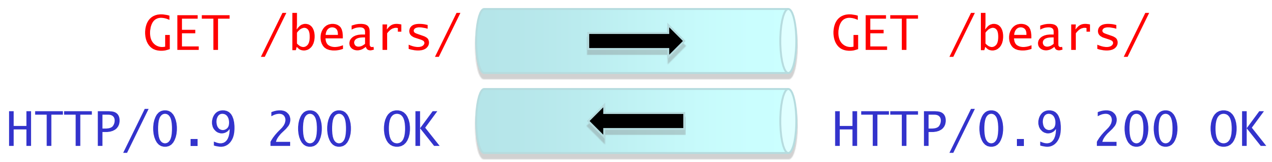




- Client & server each *specialized* for their tasks
  - Client: ask questions on behalf of users
  - Server: wait for & respond to questions, serve many clients
- Design Patterns capture common structural solutions to recurring problems
  - Client-Server is an *architectural pattern*

Nuts and bolts: TCP/IP protocols

- IP (Internet Protocol) *address* identifies a physical network interface with four *octets*, e.g. `128.32.244.172`
  - Special address `127.0.0.1` is "this computer", named `localhost`, even if not connected to the Internet!
- TCP/IP (Transmission Control Protocol/Internet Protocol)
  - IP: no-guarantee, best-effort service that delivers *packets* from one IP address to another
  - TCP: make IP reliable by detecting "dropped" packets, data arriving out of order, transmission errors, slow networks, etc., and respond appropriately
  - TCP *ports* allow multiple TCP apps on same computer
- Vint Cerf & Bob Kahn: 2004 Turing Award for Internet architecture & protocols, incl. TCP/IP



GET /bears/ → GET /bears/

HTTP/0.9 200 OK ← HTTP/0.9 200 OK

Web at 100,000 feet

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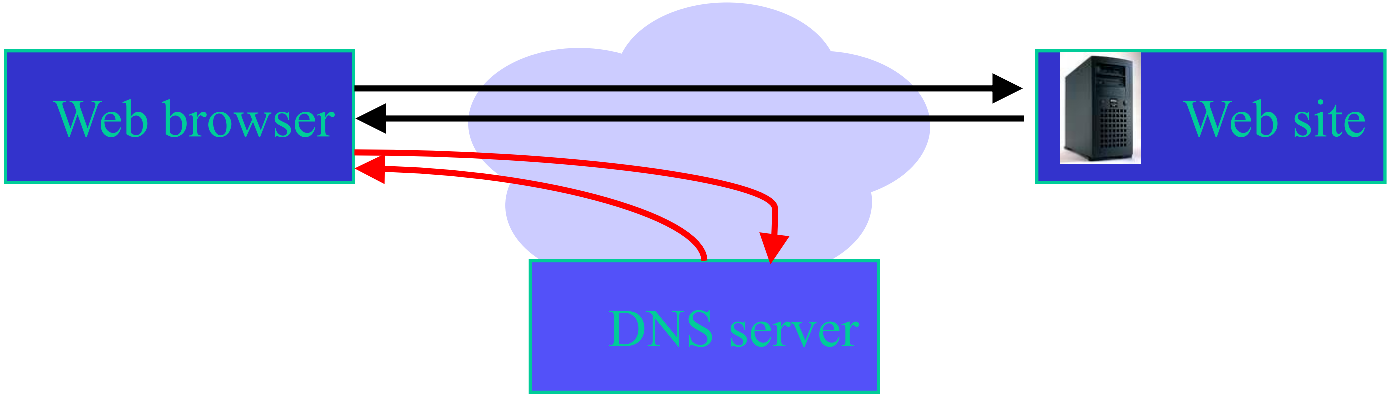
- It is fundamentally *request/reply oriented*
- Domain Name System (DNS) is another kind of server that maps *names* to *IP addresses*



Hypertext Transfer Protocol

- an *ASCII-based request/reply protocol* for transferring information on the Web
- *HTTP request* includes:
  - *request method* (GET, POST, etc.)
  - Uniform Resource Identifier (URI)
  - HTTP protocol version understood by the client
  - *headers*—extra info regarding transfer request
- *HTTP response* from server
  - Protocol version & Status code =>
  - Response headers
  - Response body

HTTP status codes:

2xx — *all is well*

3xx — *resource moved*

4xx — *access problem*

5xx — *server error*

Cookies

- Observation: *HTTP is stateless*
- Early Web 1.0 problem: how to guide a user "through" a flow of pages?
  - use IP address to identify returning user?
    - ✖ public computers, users sharing single IP
  - embed per-user junk into URI query string?
    - ✖ breaks caching
- Quickly replaced by *cookies*
  - Associate the browser with information held on the server corresponding to that user session. The browser responsible for including right cookies with each HTTP request

Uses of cookies

- Most sites quickly realized that the per-user state could be used for lots of things:
  - customization (“My Yahoo”)
  - click tracking/flow tracking
  - *authentication* (logged in or not)
  - *Which of these could be implemented on the client side? Which ones shouldn’t be and why?*
- A golden rule: *don’t trust the client*—cookies must be tamper-evident

HTML+CSS

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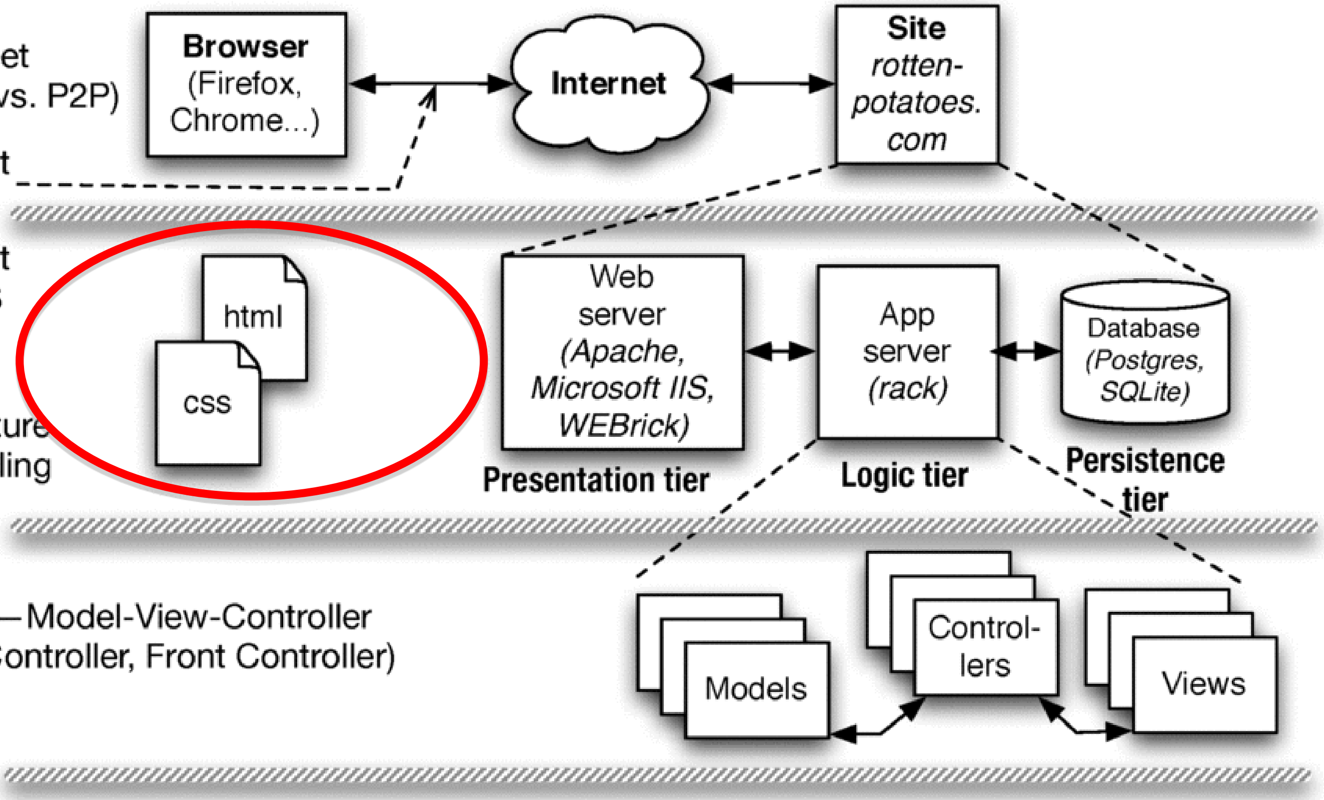

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Introduction

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First, that penguins actually prefer tropical foods such as bananas and pineapple to their traditional diet of fish

Second, that tropical foods give penguins an odor that makes them unattractive to their traditional predators

```
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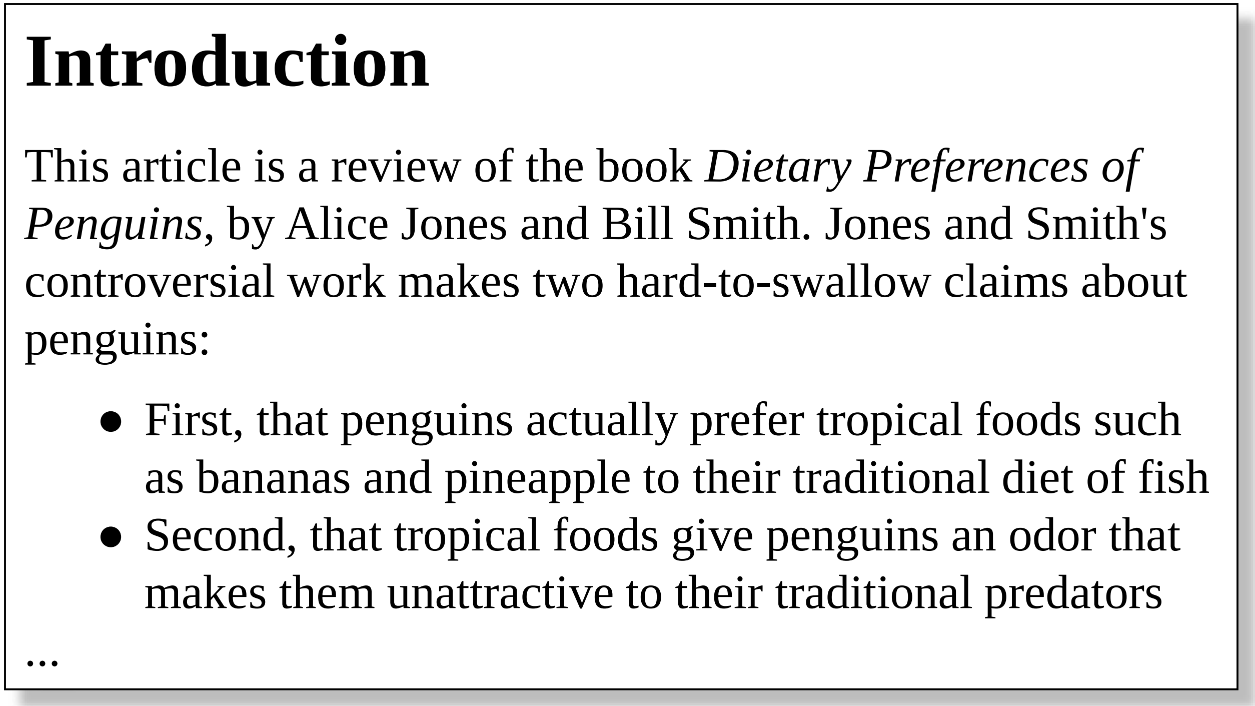

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First, ...
```

HTML ~1.0

- Descendant of IBM's Generalized Markup Language (1960's) via SGML (Standard Generalized Markup Language, 1986)
- Document = Hierarchical collection of *elements*
  - inline (headings, tables, lists...)
  - embedded (images, JavaScript code...)
  - forms—allow user to submit simple input (text, radio/check buttons, dropdown menus...)
- Each element can have *attributes* (many optional) and some elements also have *content*
  - of particular interest: *id* and *class* attributes, for *styling*

Cascading Style Sheets

- Idea: *visual appearance of page described* in a separate document (*stylesheet*)
  - accessibility
  - branding/targeting
  - separate designers' & developers' concerns
- *Current best practice: HTML markup should contain* ***no*** *visual styling information*

How does it work?

- `<link rel="stylesheet" href="http://..."/>` (inside `<head>` element) says what stylesheet goes with this HTML page
- HTML `id` & `class` attributes important in CSS
  - *id* must be ***unique within this page***
  - same *class* can be attached to many elements

```
<div id="right" class="content">
  <p>
   I'm Vitaly.  I work at the University
    of Aizu and do research in the
    Software Engineering  Lab.
  </p>
</div>
```

Selectors identify specific tag(s)

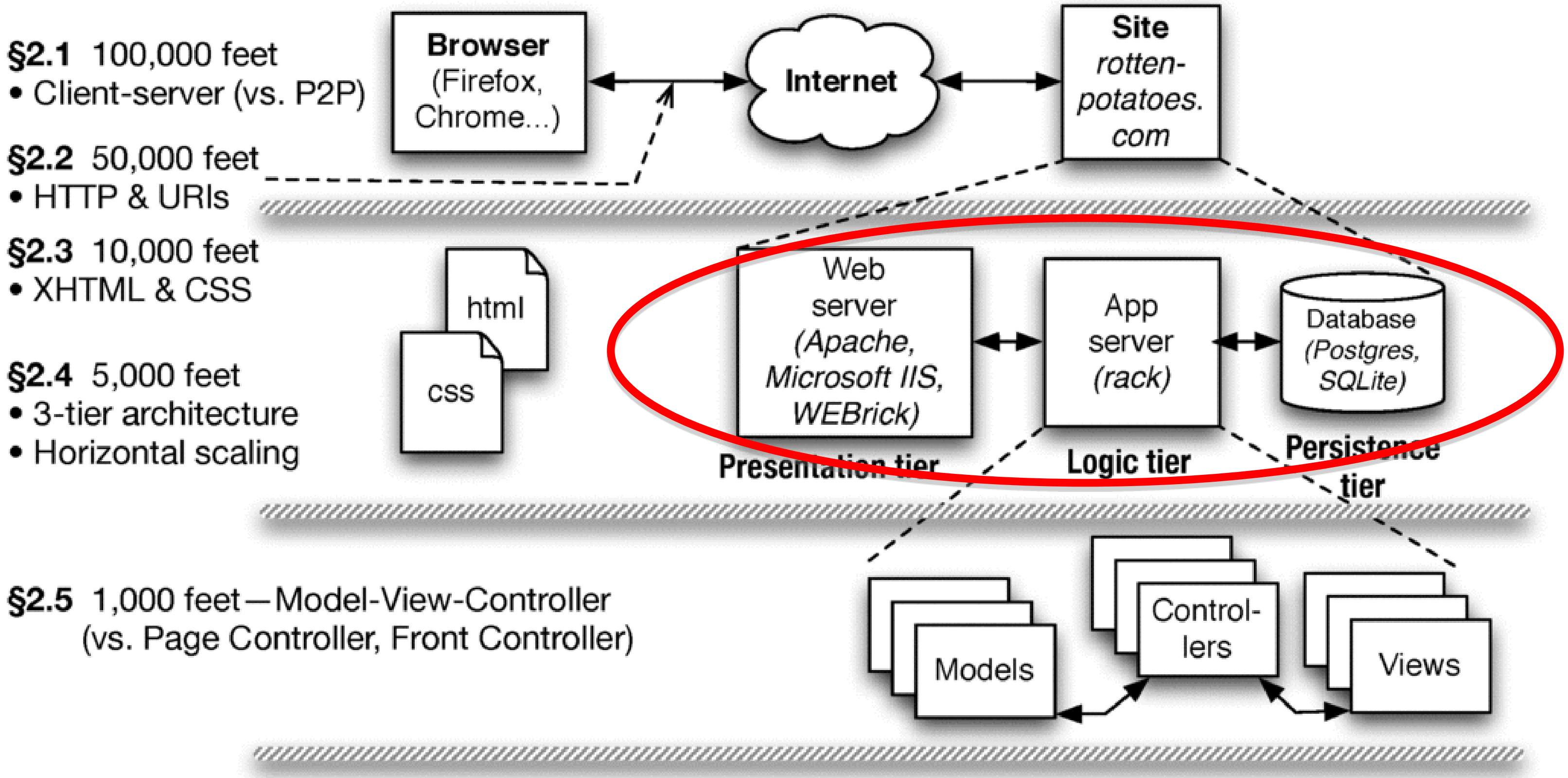
```
<div class="pageFrame" id="pageHead">
  <h1>
    Welcome,
    <span id="custName">Vitaly</span>
    <img src="welcome.jpg" id="welcome"/>
  </h1>
</div>
```

- tag name: `h1`
- class name: `.pageFrame`
- element ID: `#pageHead`

both of these match the outer *div* above. Don’t do this!

- tag name & class: `div.pageFrame`
- tag name & id: `img#welcome` (usually redundant)
- descendant relationship: `div .custName`
- Attributes *inherit* browser defaults unless overridden

3-tier shared-nothing architecture & scaling



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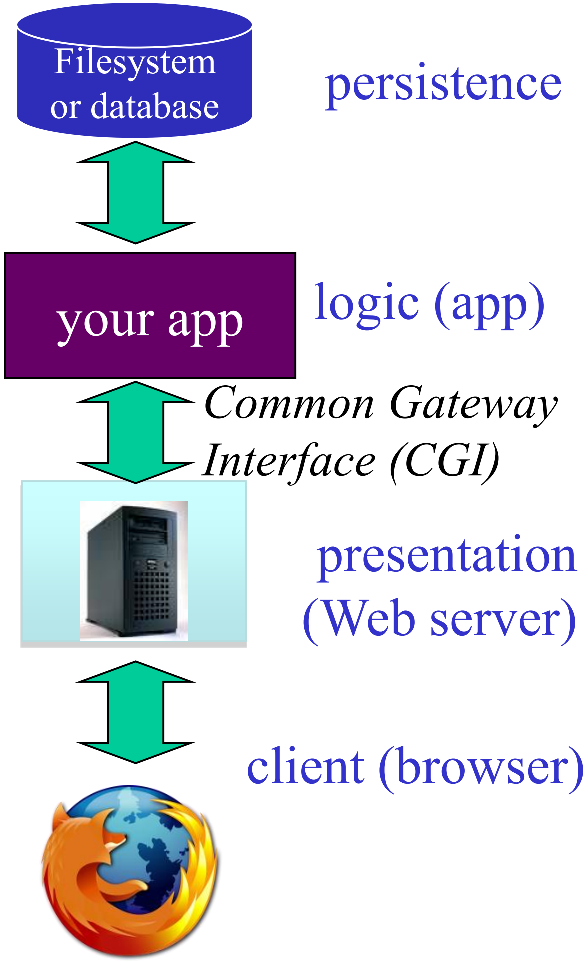
Dynamic content generation

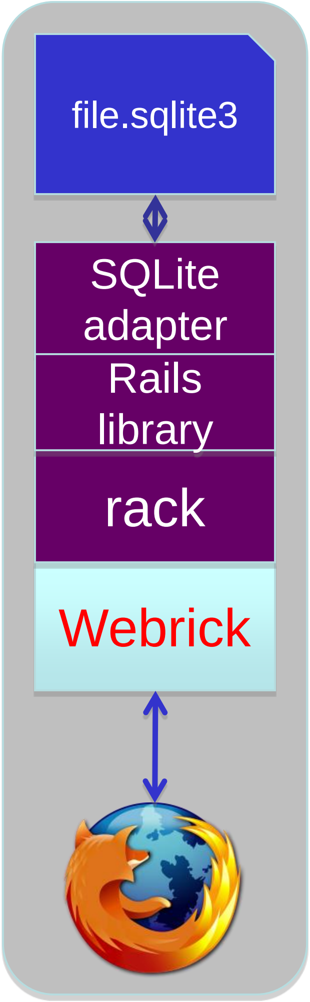
- In the elder days, most web pages were (collections of) plain old files
- But most interesting Web 1.0/e-commerce sites actually *run a program* to generate the "page"
- Originally: templates with embedded code "snippets"
- Eventually, code became "tail that wagged the dog" and moved out of the Web server

Sites that are really programs

- How do you:
  - "map" URI to correct program & function?
  - pass arguments?
  - invoke program on server?
  - handle persistent storage?
  - handle cookies?
  - handle errors?
  - package output back to user?
- *Frameworks* support these common tasks



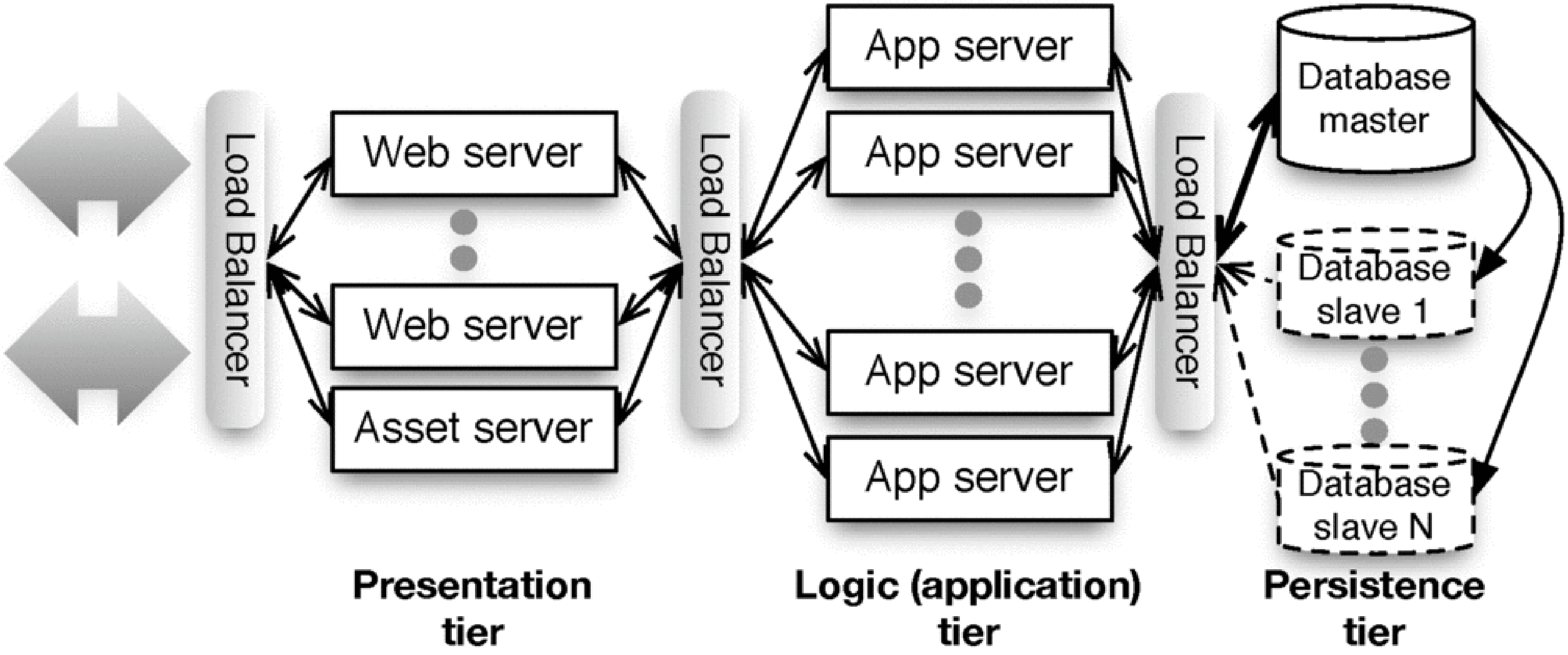
Developer environment



- ❒ SQlite 3 - database
- ❒ Rack - - the application server
- ❒ Webrick – the Web server

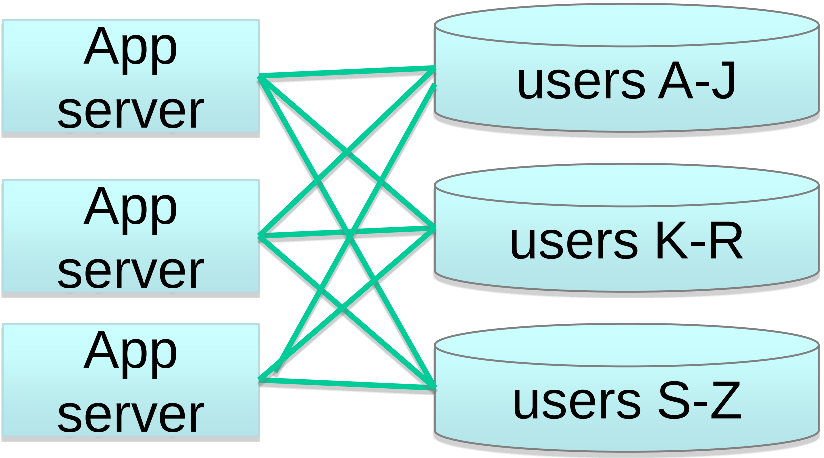
Developer

“Shared nothing”

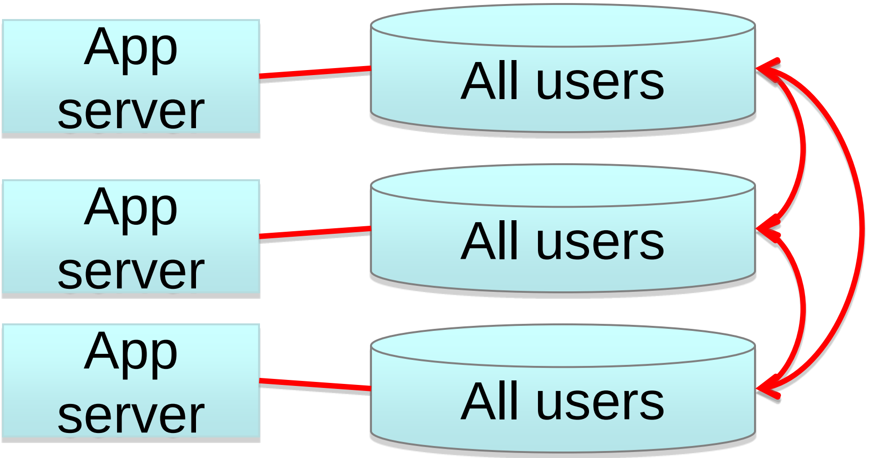


Sharding vs. Replication

- Partition data across independent "shards"?
  - + Scales great
  - Bad when operations touch >1 table
  - Example use: user profile



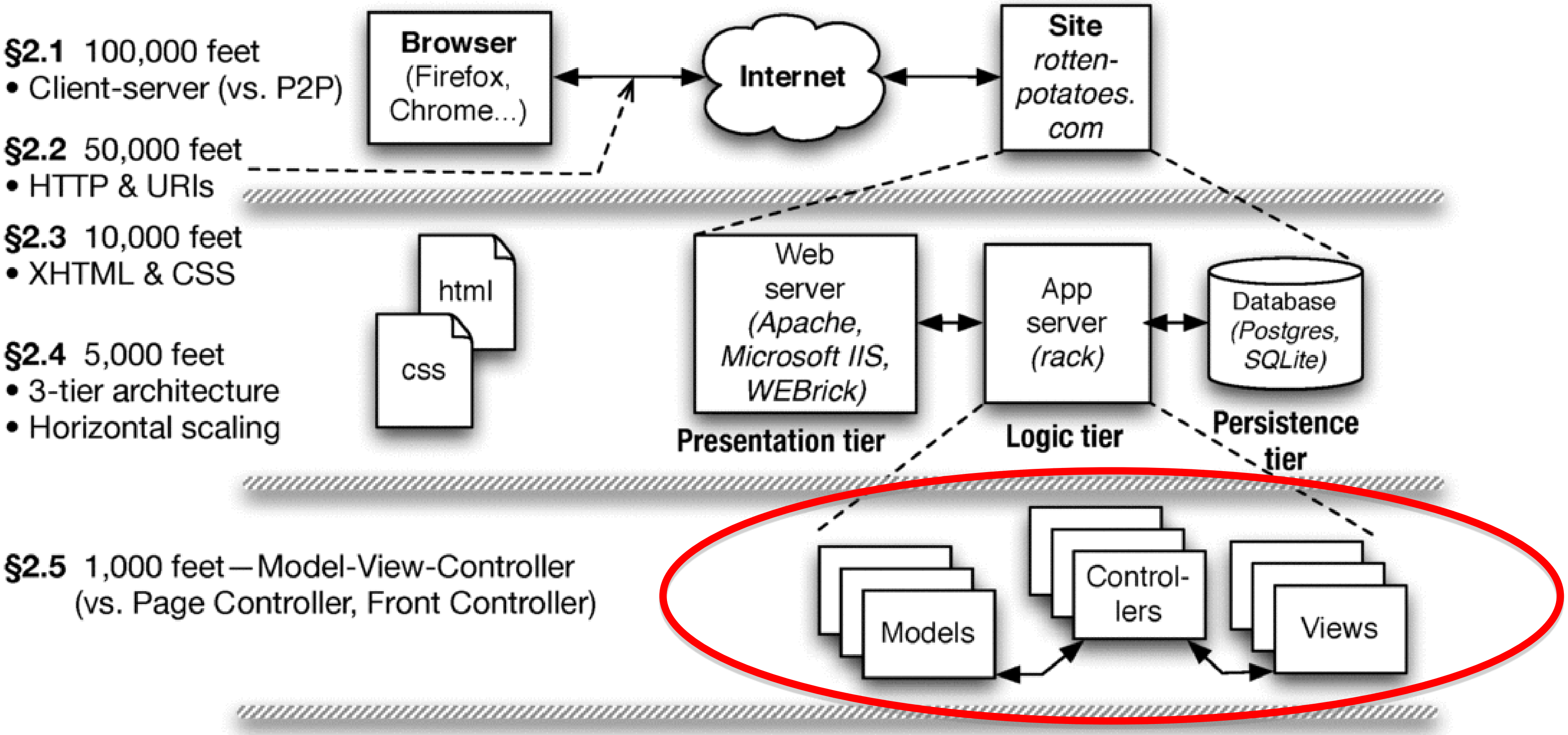
- Replicate all data everywhere?
  - + Multi-table queries fast
  - Hard to scale: writes must propagate to all copies => temporary *inconsistency* in data values
  - Example: Facebook wall posts/"likes"



Summary: Web 1.0

- Browser *requests* web resource (URI) using HTTP
  - HTTP is a simple request-reply protocol that relies on TCP/IP
  - In WebApps, most URI's cause a program to be run, rather than a static file to be fetched
- *HTML* is used to encode content, *CSS* to style it visually
- *Cookies* allow the server to track client
  - Browser automatically passes cookie to the server on each request
  - Server may change cookie on each response
  - Typical usage: cookie includes a *handle* to server-side information
  - That's why some sites don't work if cookies are completely disabled
- *Frameworks* make all these abstractions convenient for programmers to use, without going into the details
- ...and help map the application structure to 3-tier, shared-nothing architecture

MVC: Model-View-Controller



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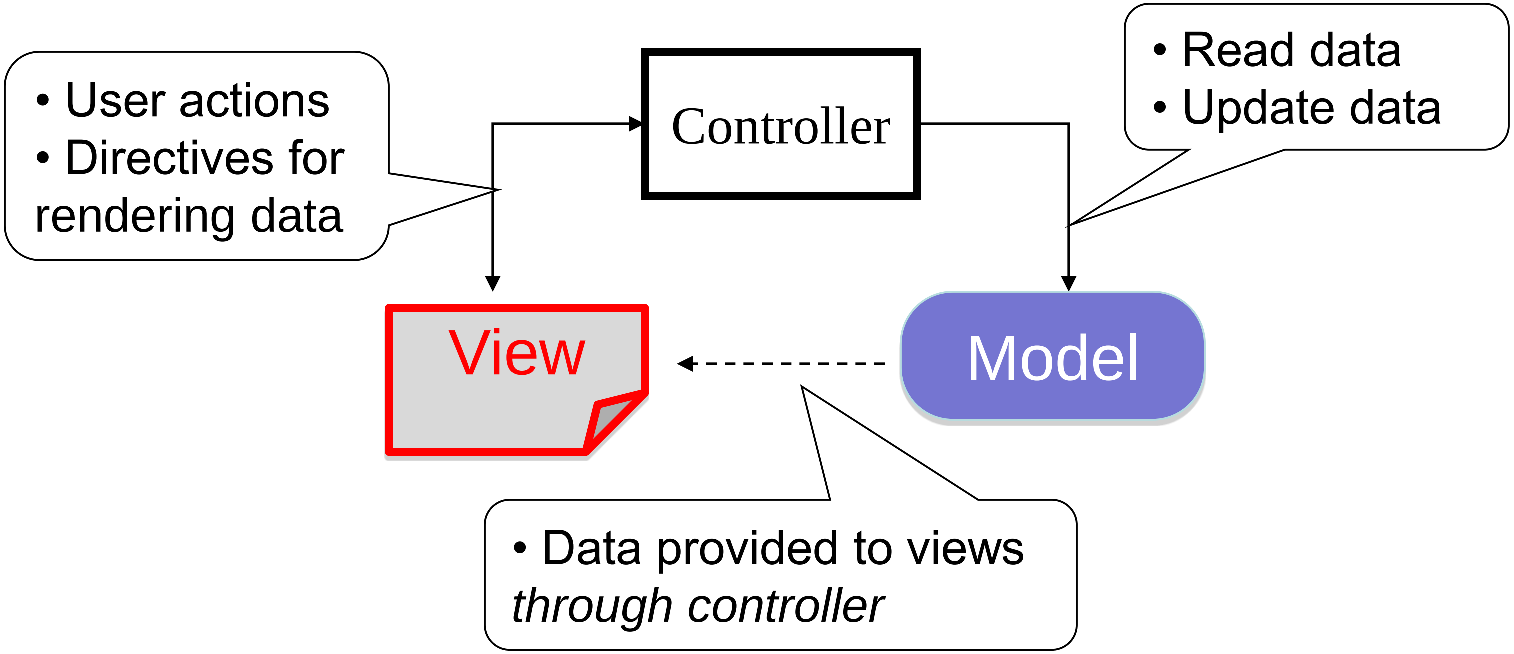
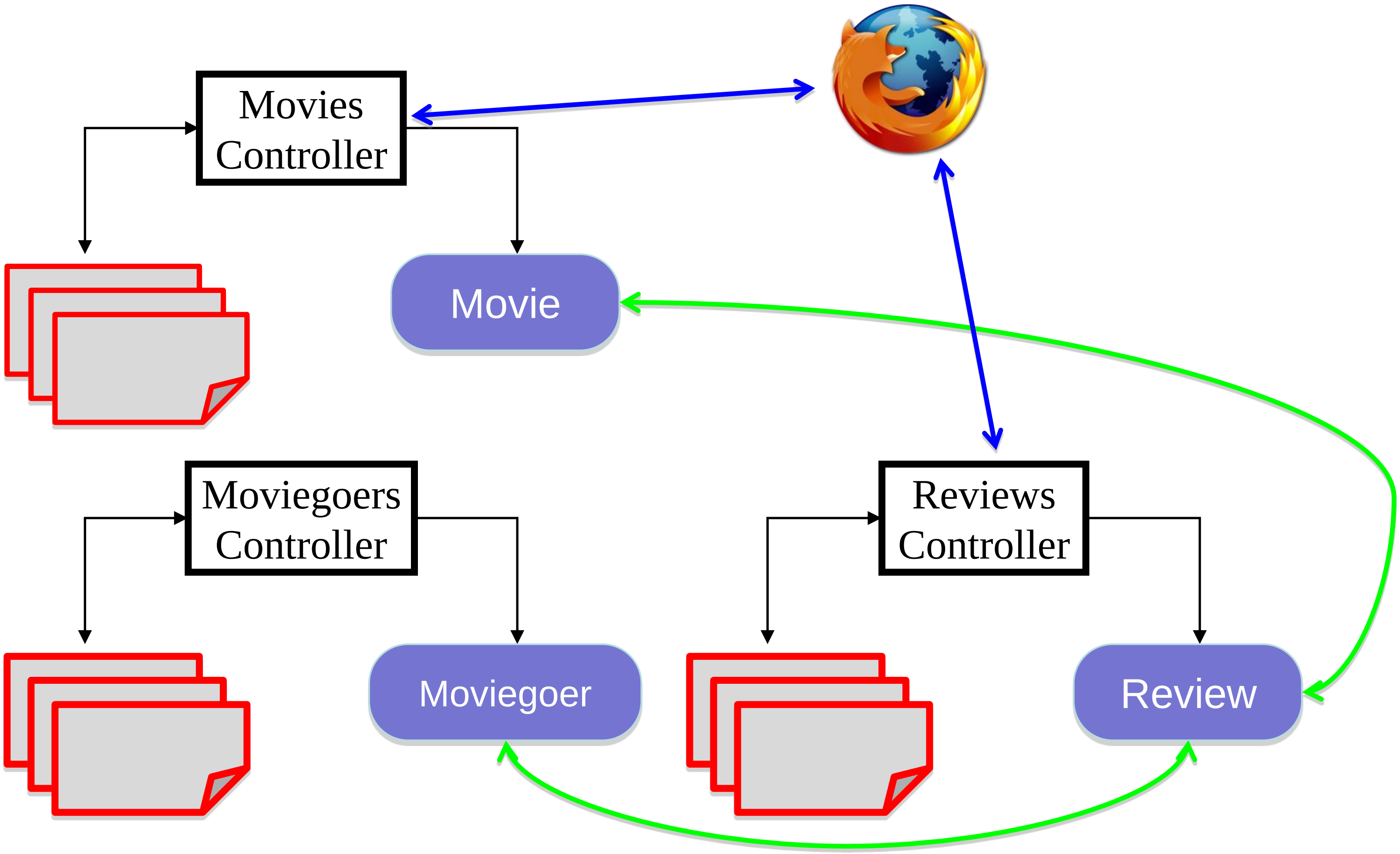
The MVC Design Pattern

- Goal: separate organization of data (model) from UI & presentation (view) by introducing a *controller*
    - mediates user actions requesting access to data
    - presents data for *rendering* by the view
- Web apps may seem "obviously" MVC by design, but other alternatives are possible...



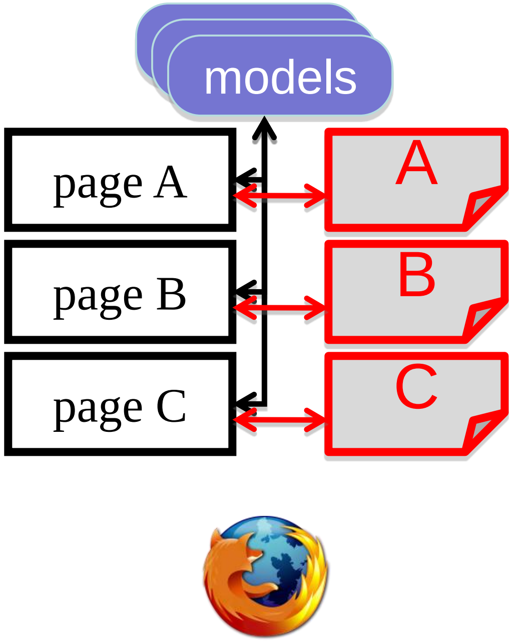
• User actions
• Directives for rendering data
Controller
• Read data
• Update data
View
Model
• Data provided to views *through controller*

Each entity has a model, controller, & set of views

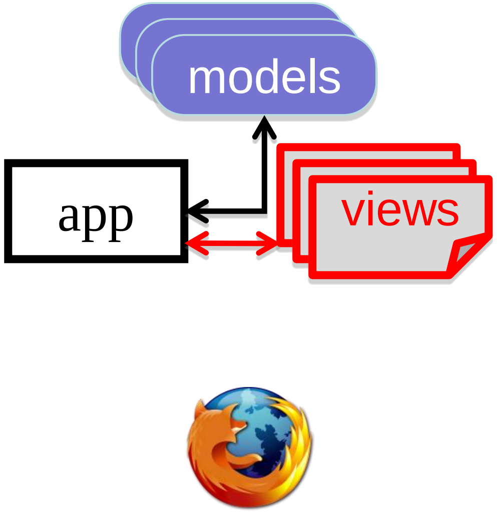


Alternatives to MVC

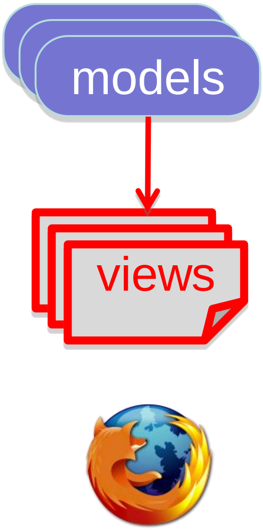
Page Controller
(Ruby Sinatra)



Front Controller
(J2EE servlet)



Template View
(PHP)



Rails supports Web apps structured as MVC, but other architectures may be better fit for some apps.

Models, Databases, and Active Record

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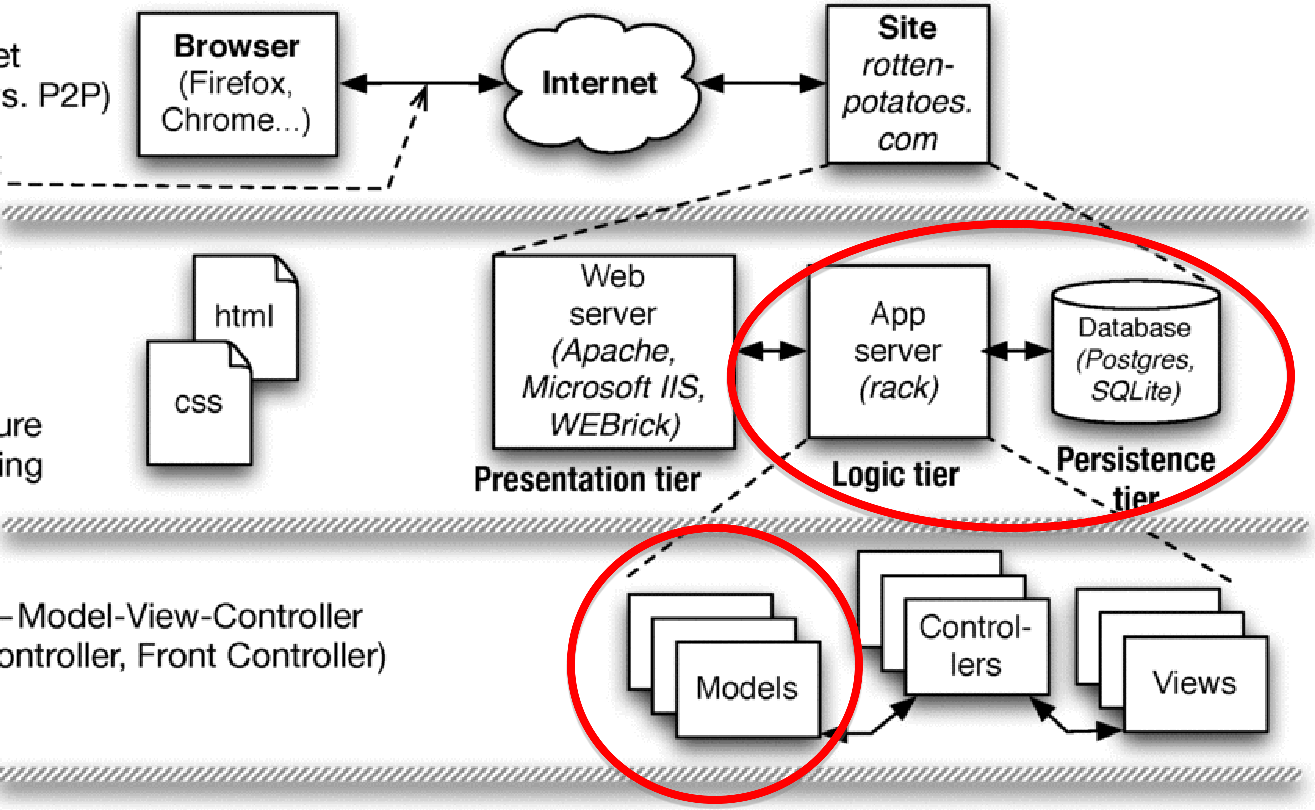

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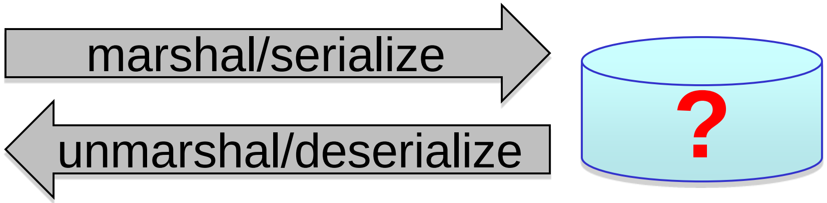
In-Memory vs. In-Storage objects

```
#<Movie:0x1295580>
m.name, m.rating, ...
#<Movie:0x32ffe416>
m.name, m.rating, ...
```



marshal/serialize

unmarshal/deserialize

?

- Marshall/serialize is converting an in-memory object to the storage representation
  - Unmarshall/deserialize is the opposite conversion
- How to represent persisted object in storage
  - Example: Movie and Reviews
- Basic operations on object: CRUD (Create, Read, Update, Delete)
- ActiveRecord: every model knows how to CRUD itself, using common mechanisms

Rails Models and Relational Database Management Systems (RDBMS)

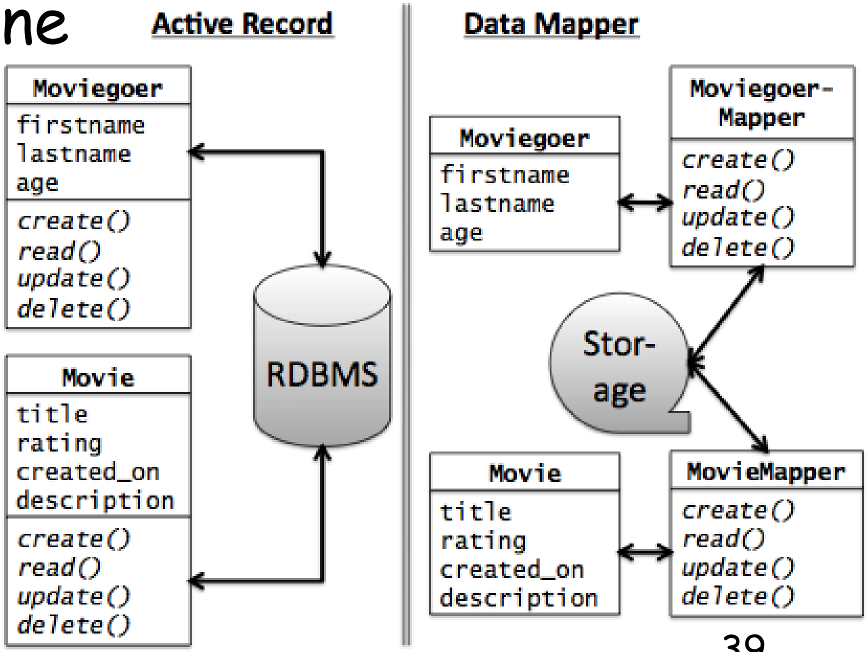
- Each type of model gets its own database *table*
  - All rows in a table have identical structure
  - 1 row in the table == one model instance
  - Each column stores value of an *attribute* of the model
  - Each row has unique value for *primary key* (by convention, in Rails this is an integer and is called *id*)

id	rating	title	release_date
2	G	Gone With the Wind	1939-12-15
11	PG	Casablanca	1942-11-26
...	...	...	...
35	PG	Star Wars	1977-05-25

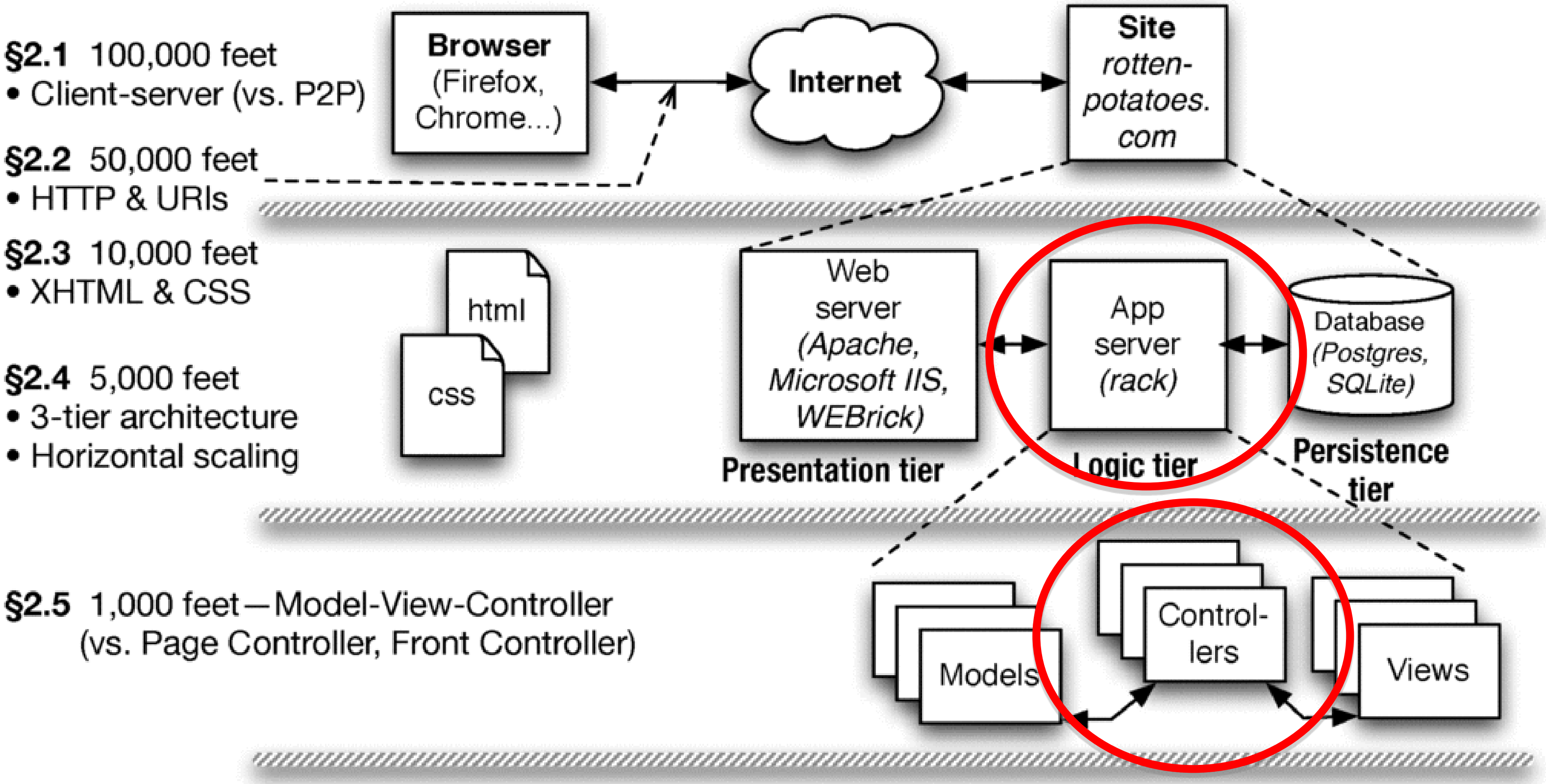
- *Schema:* Collection of all tables and their structure

Alternative: DataMapper

- Data Mapper associates separate *mapper* with each model
  - Idea: keep mapping *independent* of particular data store used => works with more types of databases
  - Used by Google AppEngine
  - Con: can't exploit RDBMS features to simplify complex queries & relationships



Controllers, Routes, and RESTfulness



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Routes

- In MVC, each interaction the user can do is handled by a *controller action*
  - Ruby method that handles that interaction
- A *route* maps `<HTTP method, URI>` to controller action

Route	Action
`GET /movies/3`	Show info about movie whose ID=3
`POST /movies`	Create new movie from attached form data
`PUT /movies/5`	Update movie ID 5 from attached form data
`DELETE /movies/5`	Delete movie whose ID=5

Intro to Rails' Routing Subsystem

- dispatch <method,URI> to correct controller action
- provides *helper methods* that generate a <method,URI> pair given a controller action
- parses query *parameters* from both URI and form submission into a convenient hash
- Built-in shortcuts to generate all CRUD routes (though most apps will also have other routes)

rake routes

```
I    GET /movies          {:action=>"index", :controller=>"movies"}
C   POST /movies          {:action=>"create", :controller=>"movies"}
     GET /movies/new      {:action=>"new", :controller=>"movies"}
     GET /movies/:id/edit {:action=>"edit", :controller=>"movies"}
R    GET /movies/:id      {:action=>"show", :controller=>"movies"}
U    PUT /movies/:id      {:action=>"update", :controller=>"movies"}
D DELETE /movies/:id      {:action=>"destroy", :controller=>"movies"}
```

GET /movies/3/edit HTTP/1.0

- Matches route:

```
GET /movies/:id/edit {:action=>"edit", :controller=>"movies"}
```

- Parse wildcard parameters: `params[:id] = "3"`
- Dispatch to `edit` method in `movies_controller.rb`
- To include a URI in generated view that will submit the form to the update controller action with `params[:id]==3`, call helper:

```
 update_movie_path(3) # => PUT /movies/3
```

rake routes

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```

REST (Representational State Transfer)

- Idea: *Self-contained* requests specify what *resource* to operate on and what to do to it
  - Roy Fielding's PhD thesis, 2000
  - Wikipedia: "a *post hoc description of the features that made the Web successful*"
- A service (in the SOA sense) whose operations are like this is a RESTful service
- Ideally, RESTful URIs name the operations
- Let's see an *anti-example:*

http://pastebin.com/edF2NzCF

Template Views and Haml

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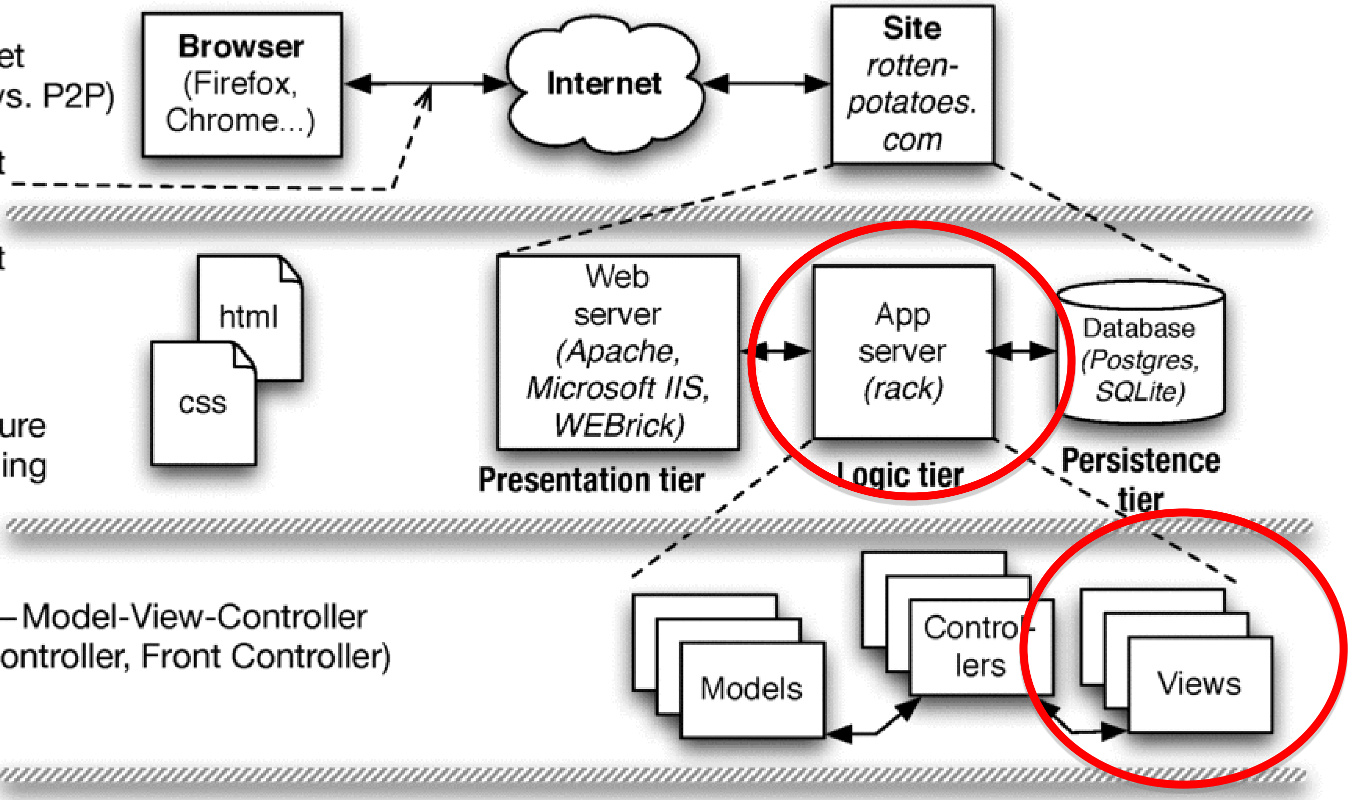
- Horizontal scaling

§2.5 1,000 feet—Model-View-Controller
(vs. Page Controller, Front Controller)



§2.6 500 feet: Active Record models (vs. Data Mapper)
§2.7 500 feet: RESTful controllers (Representational State Transfer for self-contained actions)
§2.8 500 feet: Template View (vs. Transform View)

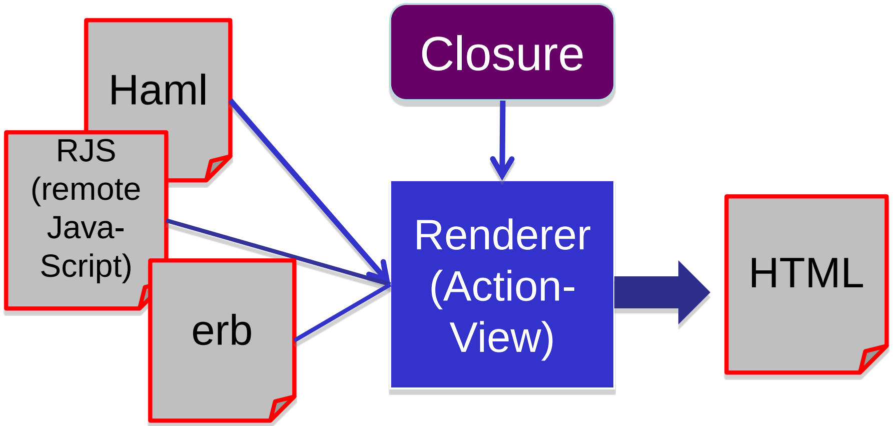
- **Active Record**
- Data Mapper

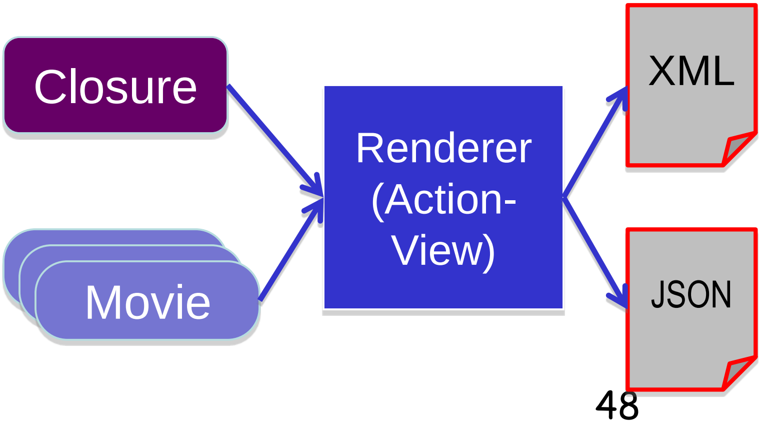
- **REST**

- **Template View**
- Transform View

Template View pattern

- View consists of markup with selected *interpolation* to happen at runtime
  - Usually, values of variables or result of evaluating short bits of code
- In elder days, this *was* the app (e.g. PHP)
- *Alternative:* Transform View





Haml is HTML on a diet

- Templating system called Halm (HTML Abstraction Markup Language) is to streamline the creation of HTML template views.

```
%h1.pagename All Movies
%table#movies
  %thead
    %tr
      %th Movie Title
      %th Release Date
      %th More Info
  %tbody
    - @movies.each do |movie|
      %tr
        %td= movie.title
        %td= movie.release_date
        %td= link_to "More on #{movie.title}",  |
          movie_path(movie) |
= link_to 'Add new movie', new_movie_path
```

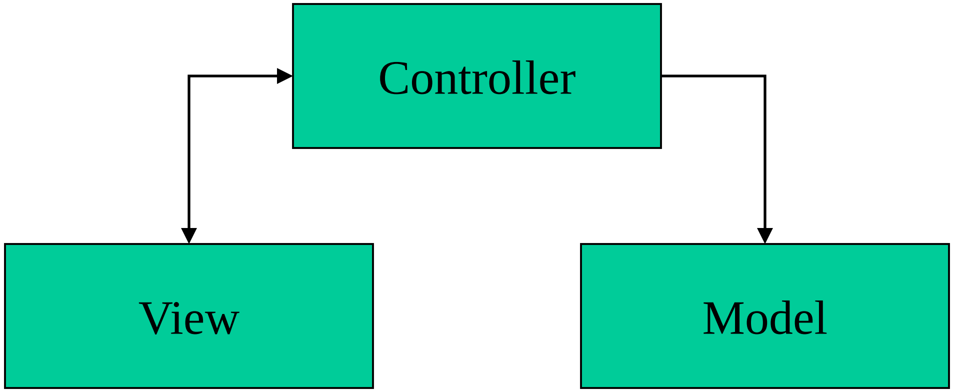
Don't put code in your views

- Syntactically, you can put any code in view
- But MVC advocates thin views & controllers
  - Haml makes deliberately awkward to put in lots of code
- *Helpers* (methods that "prettify" objects for including in views) have their own place in Rails app
- Alternative to Haml: html.erb (Embedded Ruby) templates, look more like PHP

Summary & Reflections: Web Application Architecture

The big picture (technologies)

- URI’s, HTTP, TCP/IP stack
- REST & RESTful routes



- HTML & CSS
- XML & XPath

- Databases & migrations
- CRUD

In 2008: “Rails doesn’t scale” and Now

- Scalability is an *architectural* concern—not confined to language or framework
- The stateless tiers of 3-tier arch *do scale*
  - With cloud computing, just worry about constants
- Traditional <u>relational</u> databases *do not scale*
- Various solutions combining relational and non-relational storage (“NoSQL”) *scale much better*
  - DataMapper works well with some of them
- Intelligent use of *caching* (later in course) can greatly improve the constant factors

Frameworks, Apps, Design patterns

- Many design patterns so far, more to come
- *In 1995, it was the wild west:* biggest Web sites were minicomputers, *not* 3-tier/cloud
- Best practices (patterns) “extracted” from experience and captured in frameworks
- But *API*’s transcended it: 1969 protocols + 1960s markup language + 1990 browser + 1992 Web server works in 2011

Architecture is about Alternatives

Pattern we’ re using	Alternatives
Client-Server	Peer-to-Peer
Shared-nothing (cloud computing)	Symmetric multiprocessor, shared global address space
Model-View-Controller	Page controller, Front controller, Template view
Active Record	Data Mapper
RESTful URIs (all state affecting request is explicit)	Same URI does different things depending on internal state

As you work on other Web apps beyond this course, you should find yourself considering different architectural choices and questioning the choices being made.

Summary: Architecture & Rails

- Model-view-controller is a well known *architectural pattern* for structuring apps
- Rails codifies Web app structure as MVC
- *Views* are Haml with embedded Ruby code, transformed to HTML when sent to browser
- *Models* are stored in tables of a relational database, accessed using ActiveRecord
- *Controllers* tie views and models together via *routes* and code in controller methods