Software Architecture (1/2)

Martin Kellogg

Software Architecture (Part 1 of ~~3~~ 2)

Today's agenda:

- Finish delta debugging slides
- Reading Quiz
- Architecture vs Design
- Architecture diagrams
- What makes an architecture good
- Architectural styles (with examples)

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Announcements:

- all optional readings graded; I will accept more late for ½ credit until next Wednesday
- mid-semester grade projection emails out this morning (sorry for the delay)
- schedule sprint 2 retro for tomorrow, Monday, or Tuesday

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Assumptions restated on this slide for convenience

Delta debugging: questioning assumptions

- **All three** assumptions are **questionable**
- Interesting is **Monotonic**
  - Interesting(X)→ Interesting(X ∪ {c})
- Interesting is **Unambiguous**
  - Interesting(X) & Interesting(Y) → Interesting(X ∩ Y)
- Interesting is **Consistent**
  - Interesting(X) = True xor Interesting(X) = False
  - (Some formulations also allow: Interesting(X) = Unknown)

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Monotonicity is rare in the real world. But DD still finds *an* interesting subset if Interesting is not monotonic (migh tnot be minimal)

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Ambiguity will cause DD to fail. Hint: try tracing DD on Interesting ({2, 8}) = True, but Interesting({2, 8} intersect {3, 6}) = False

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The world is **often inconsistent**. Example: we are minimizing changes to a program to find patches that makes it crash. Some subsets may not build or run!

Delta debugging: in the real world

- `git bisect` implements a DD-like algorithm (look it up!)
- for thread schedules: DejaVu tool by IBM, CHESS by Microsoft, etc.
- Eclipse plugins for code changes (“DDinput”, “DDchange”)
- you can also do delta debugging **by hand** (I do this often for programs that cause compiler bugs!)

Debugging: takeaways

- Debugging is a lot easier when you treat it as a science, rather than an art
- printf debugging and logging are good for determining what causes failures after the fact
- debuggers are fantastic when you want to understand a program's internal state
- delta debugging is a semi-automated approach to formalizing the abstract debugging problem
  - useful way of thinking about how to debug anything
  - try `git bisect`

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A. the existing implementation
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Our goals: **separation of concerns** and **modularity**

“Architecture” vs “Design”

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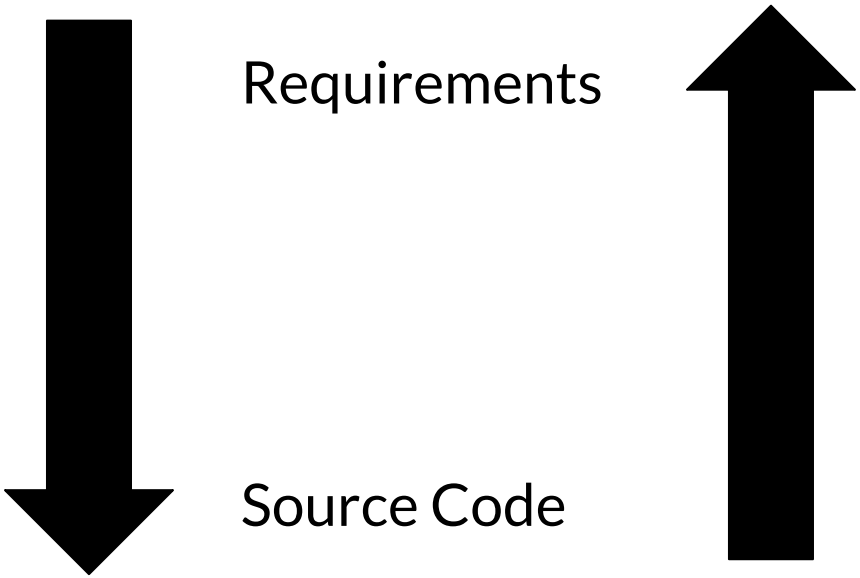

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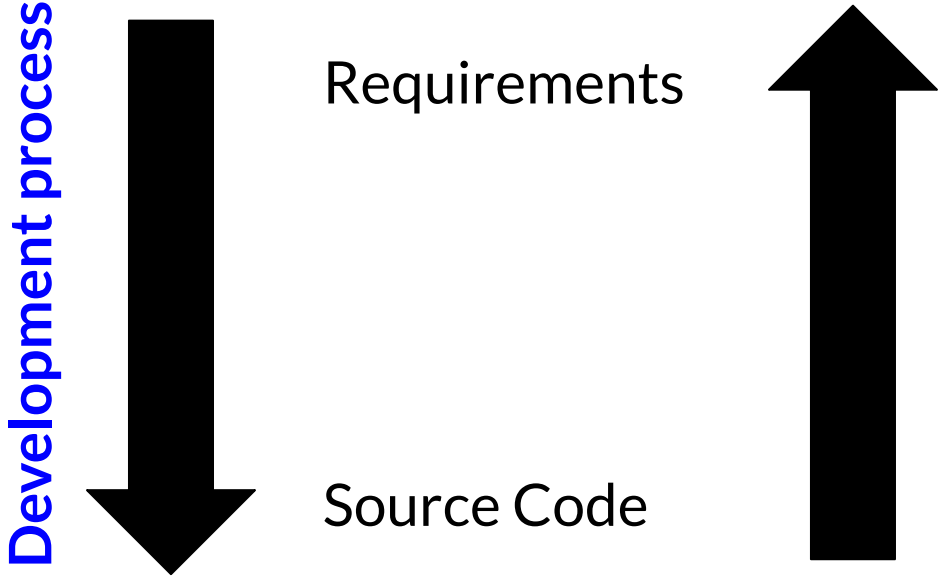

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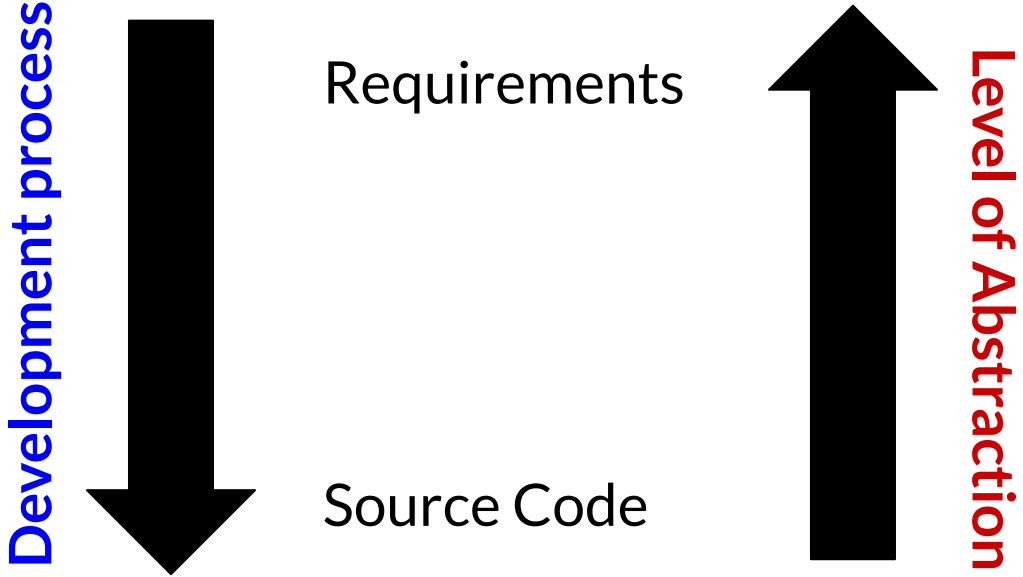

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- Different ***levels of abstraction*** are characterized by the amount of details ignored
  - more abstract = ignore more details
  - which details to ignore depends on your **purpose** (analogy: what abstract values to choose in dataflow analysis?)
- **Implication**: requirements have fewer details than code. Architecture and design are somewhere in the middle. But **where**?

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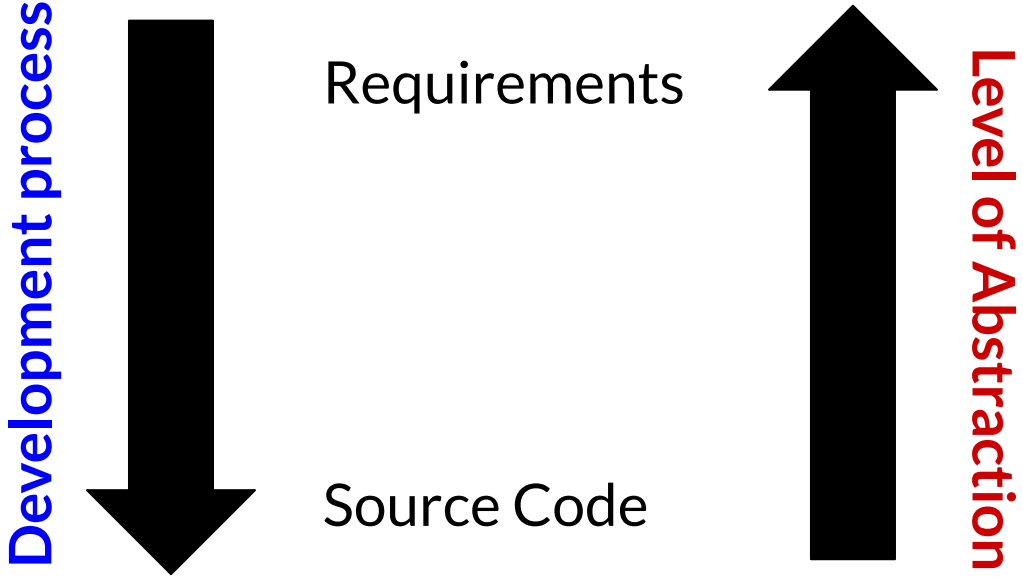

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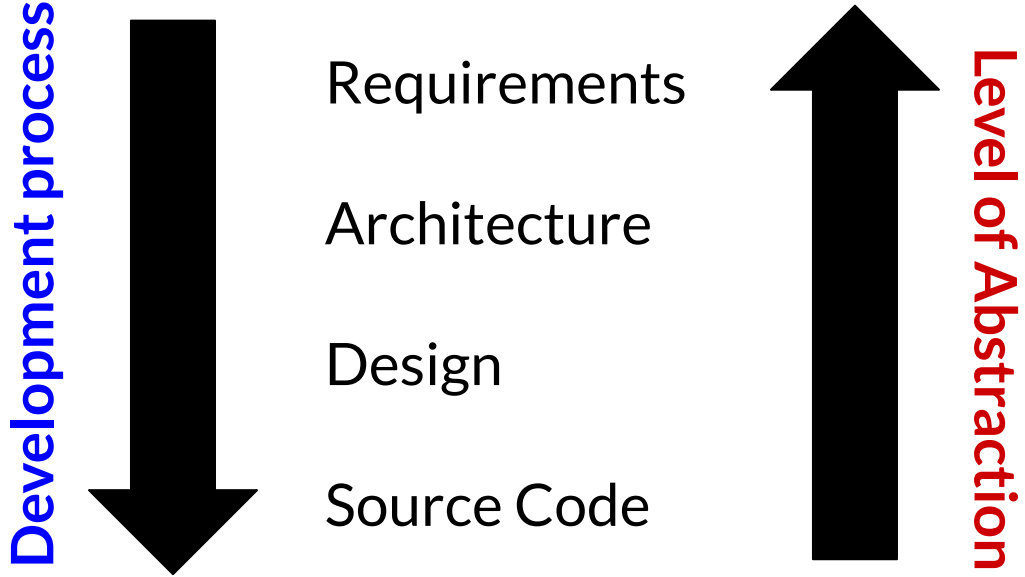

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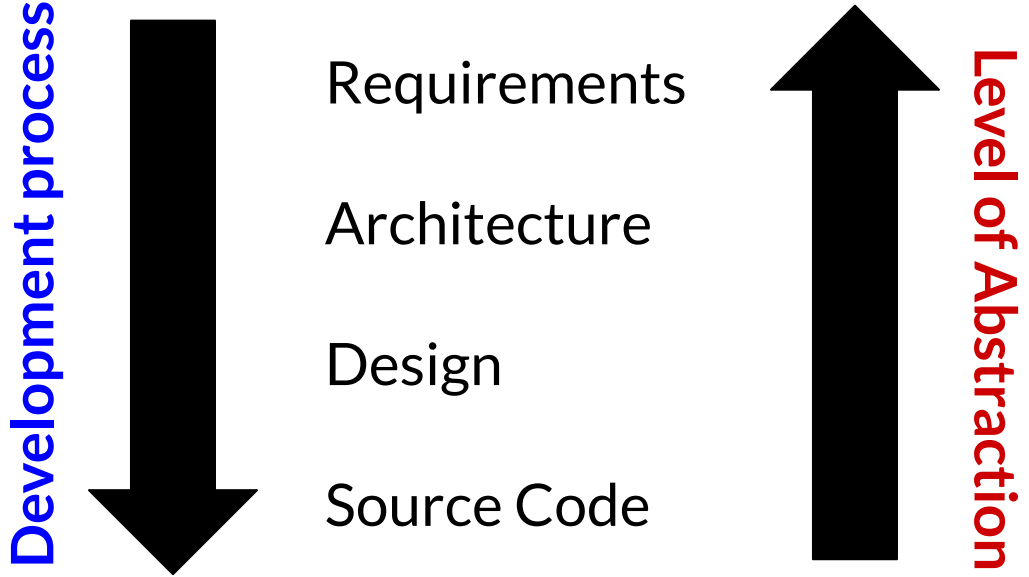

Architecture and design are the “**glue**” between the **code** you actually write and what your software is **supposed to do**

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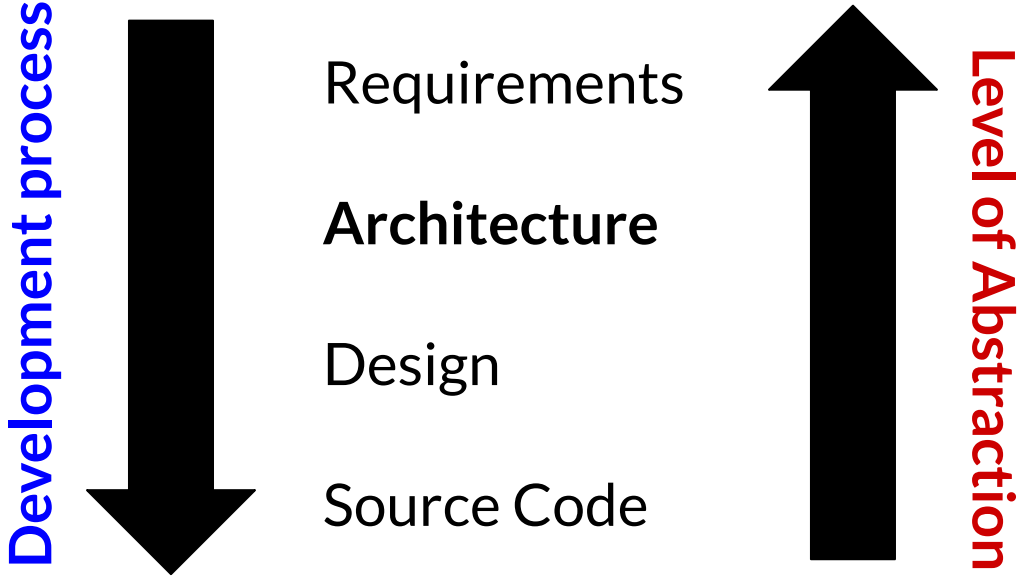

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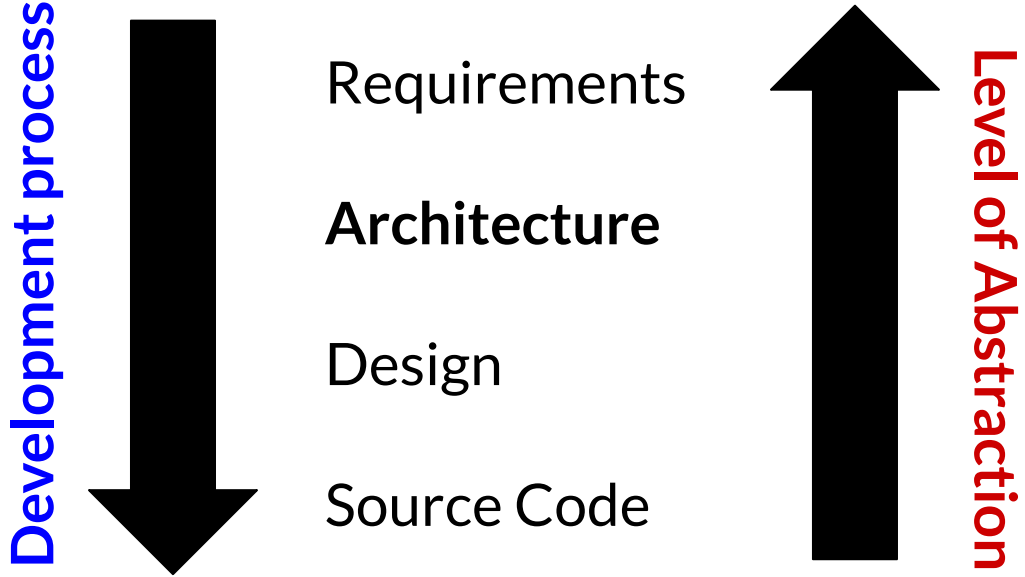
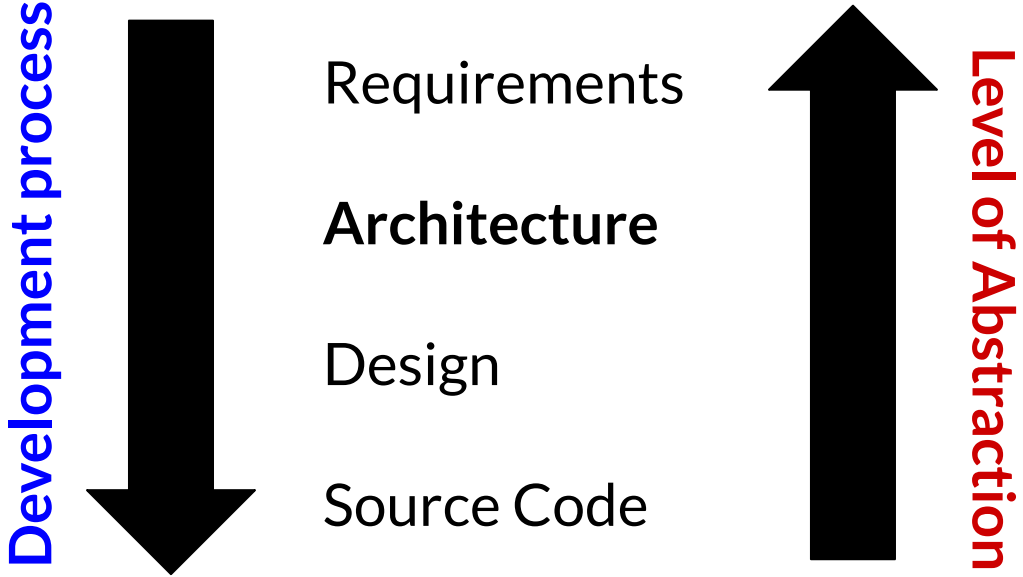


Definition: “the ***software architecture*** of a program or computing system is the structure or structures of the system, which comprise software components, the externally visible properties of those components, and the relationships among them”

[L. Bass, P. Clements and R. Kazman. Software Architecture in Practice. Addison Wesley, 1999, ISBN 0- 201-19930-0.]

“Architecture” vs “Design”

Architecture = **high-level view** of the system



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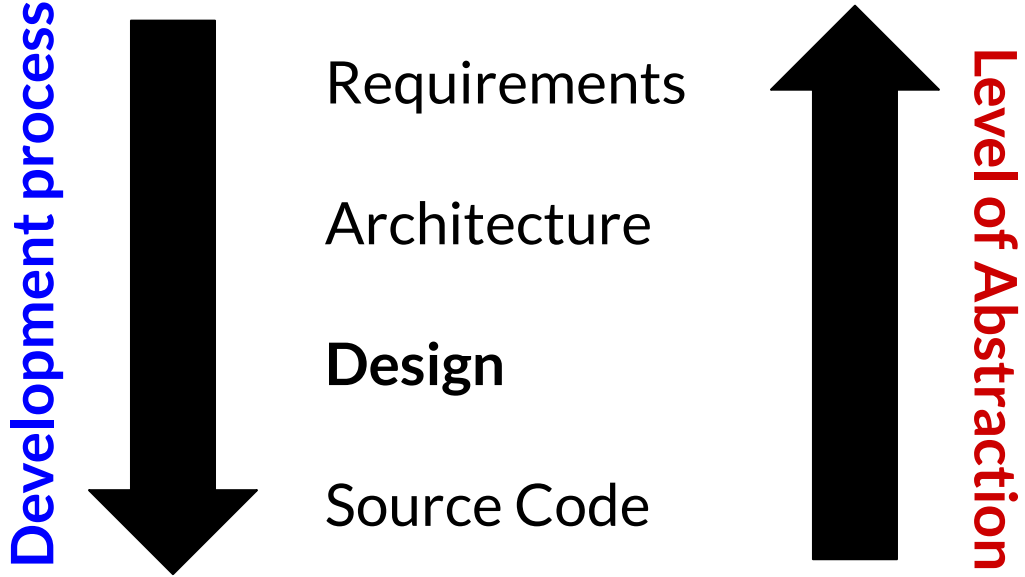

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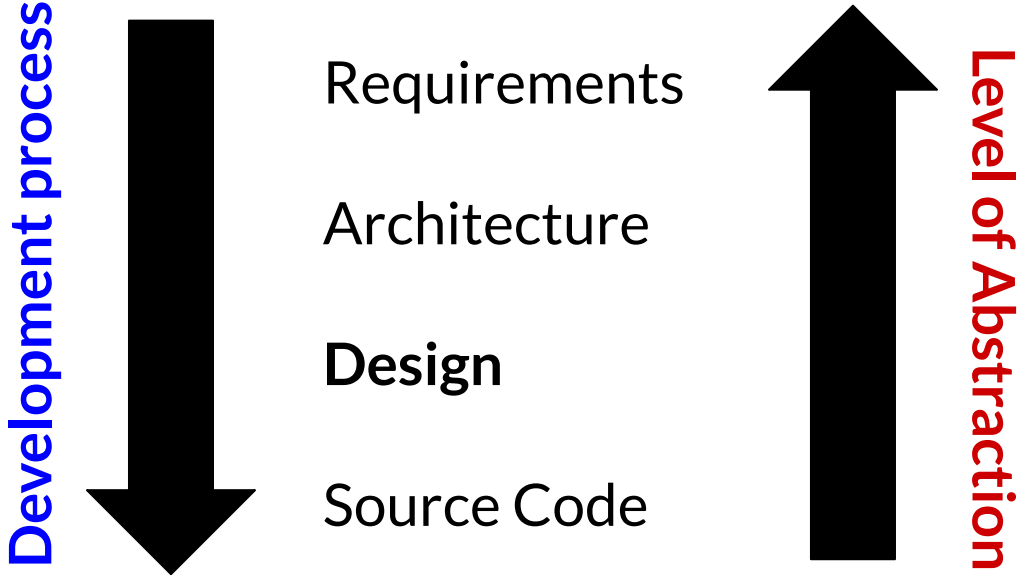

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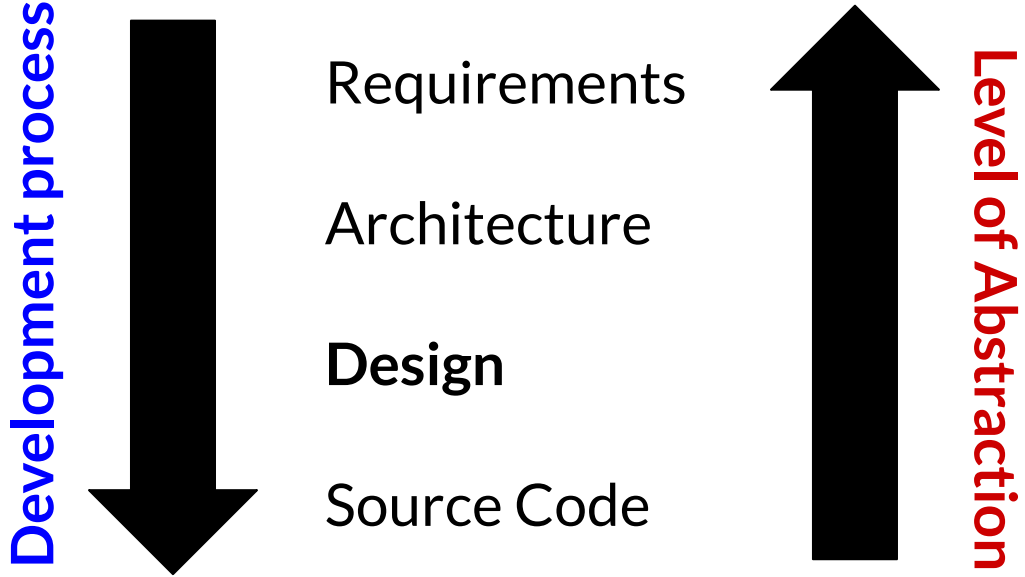

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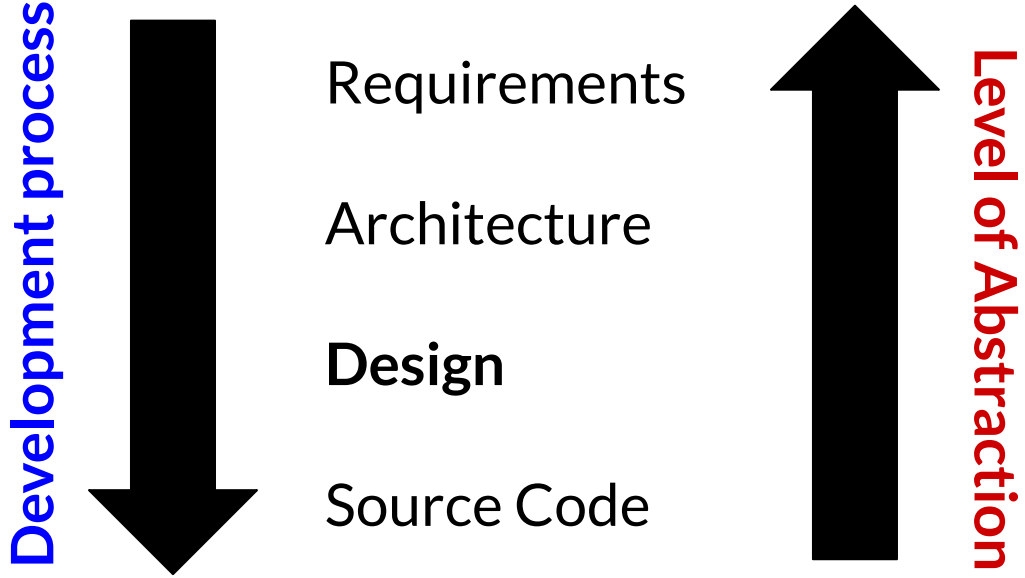

Definition: ***software design*** is the structure or organization of a particular component of your system

- the phrase “software design” often refers to the **process** of producing a software design
- both “design” and “architecture” are **flexible** terms, used differently by different people

“Architecture” vs “Design”: summary

- Architecture (what is developed?)
  - High-level view of the overall system:
    - What components do exist?
    - What are the protocols between components?
    - What type of storage etc.?
- Design (how are the components developed?)
  - Considers individual components:
    - Data representation
    - Interfaces, Class hierarchy
    - …

“Architecture” vs “Design”: analogy: offices

“Architecture”

[UW Gates Center, LMN]

“Design”

[Office design, New York Times]

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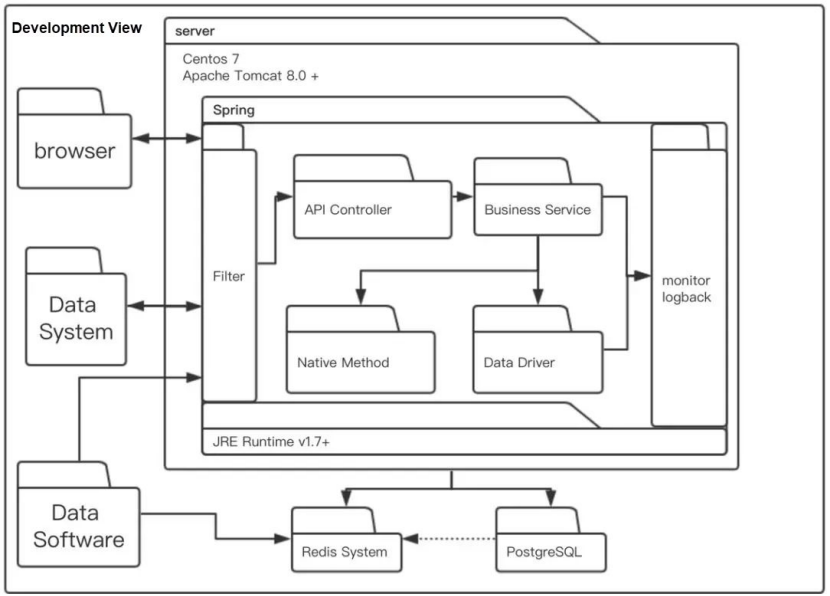

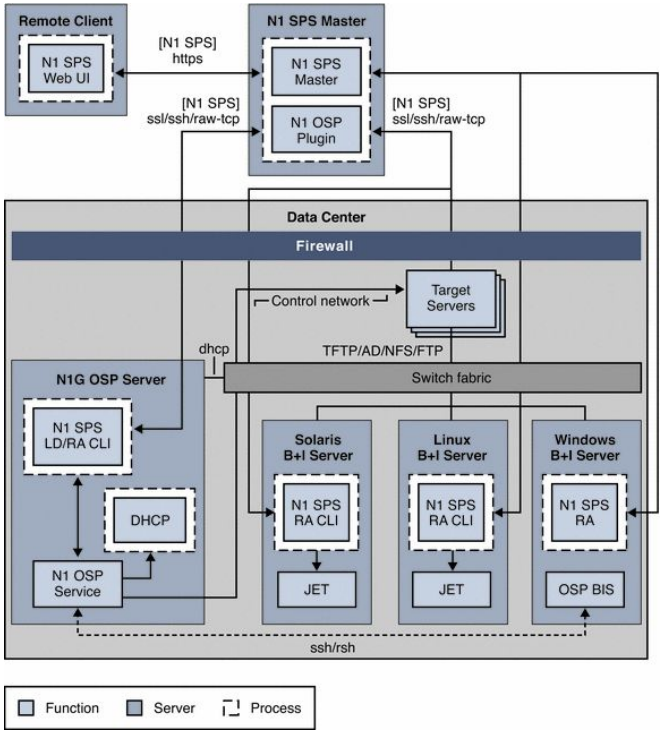

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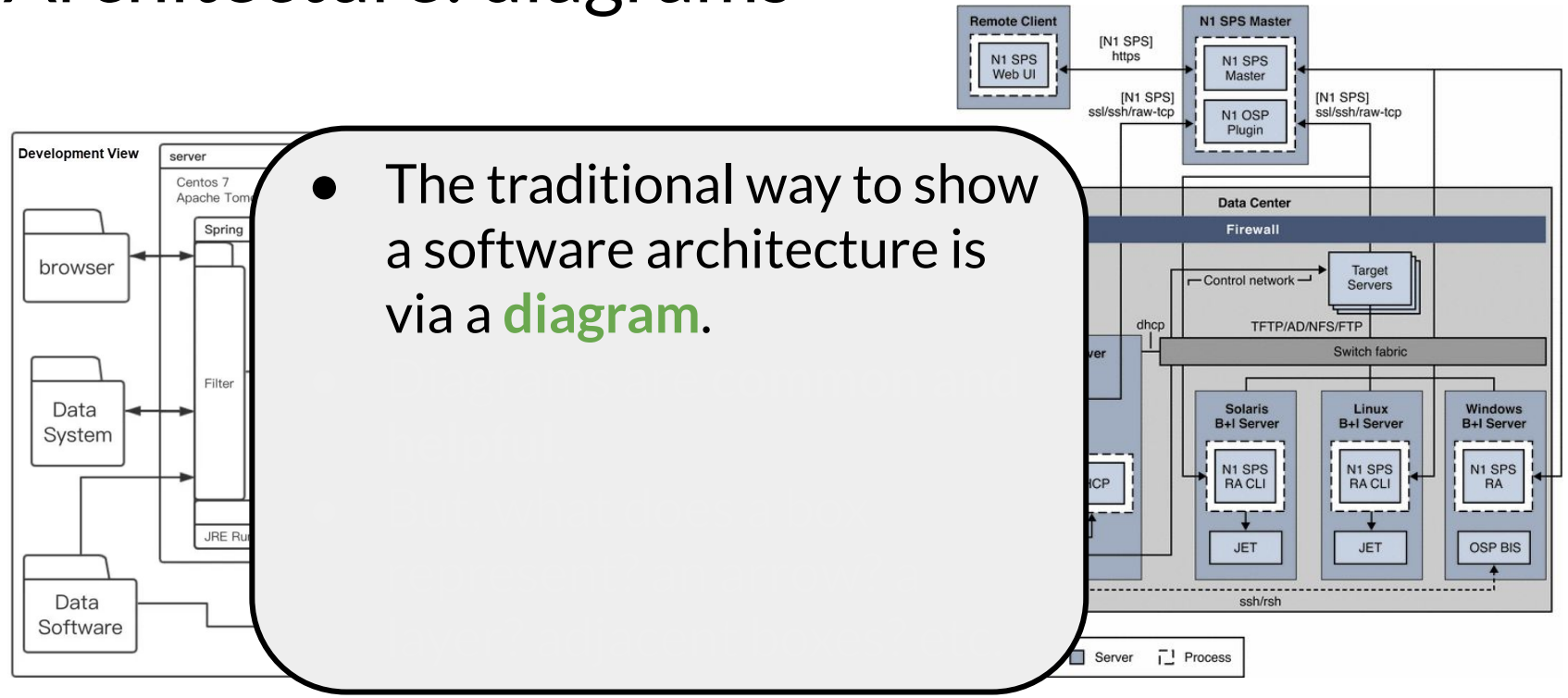

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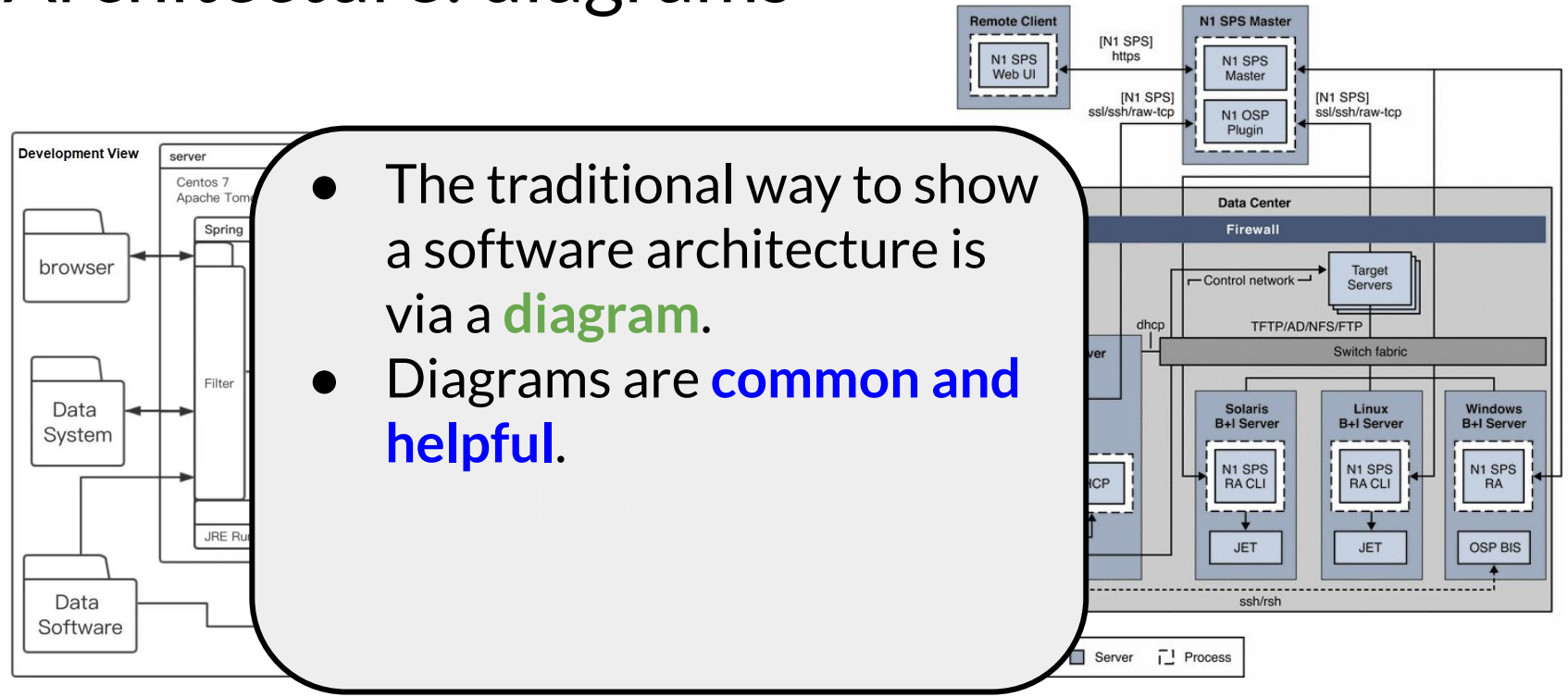

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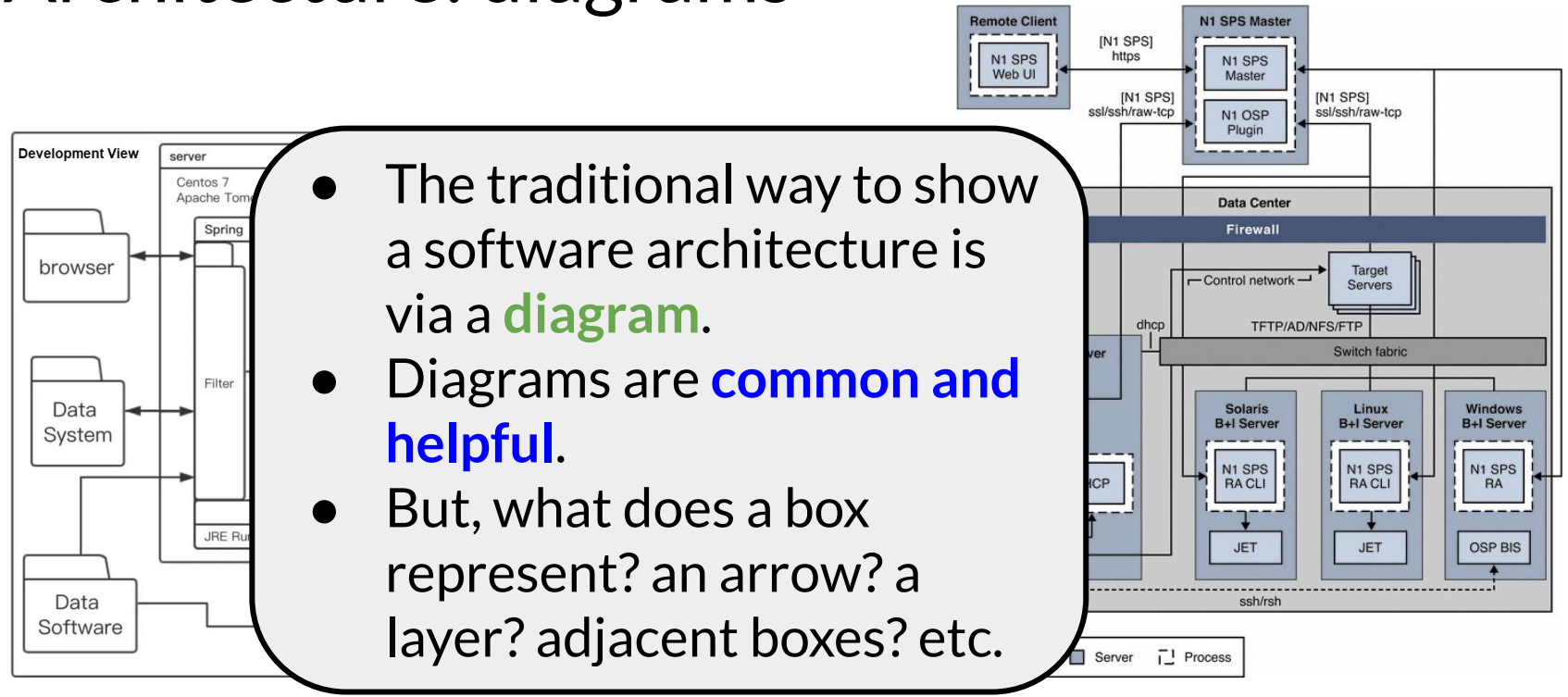

- The traditional way to show a software architecture is via a **diagram**.
- Diagrams are **common and helpful**.
- But, what does a box represent? an arrow? a layer? adjacent boxes? etc.

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Note: the line between them may be **fuzzy**. For example, a connector might (de)serialize data, but can it perform other, richer computations?

Aside: UML diagrams

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  - so, it’s not going to be the topic of this lecture
  - if and when you do encounter UML, look up the symbols and map them back to the **concepts** we’re discussing today

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Properties of a good architecture

Properties of a good architecture

- Satisfies functional and performance requirements
- Manages complexity
- Accommodates future change
- Is concerned with reliability, safety, understandability, compatibility, robustness, etc.
    - but, the emphasis on these may more larger or smaller depending on the domain

Properties of a good architecture

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- **Management**: helps understand work items and track progress
- **Communication**: provides vocabulary; a picture says 1000 words

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Modularity also enables **decomposition**, which:

- decreases size of tasks
- supports independent testing and analysis
- enables separate work assignments
- eases understanding

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- Tight relationships **improve clarity and understanding**
- A class with good abstraction usually has strong internal cohesion
- **Avoid** classes that have multiple, independent jobs
  - and especially avoid "**god**" classes that control the entire application!
  - such classes almost always have weak cohesion

Modularity: cohesion: strong or weak?

```
class Employee {
    public:
    …
    FullName GetName() const;
    Address GetAddress() const;
    PhoneNumber GetWorkPhone() const;
    …
    bool IsJobClassificationValid(JobClassification jobClass);
    bool IsZipCodeValid (Address address);
    bool IsPhoneNumberValid (PhoneNumber phoneNumber);
    …
    SqlQuery GetQueryToCreateNewEmployee() const;
    SqlQuery GetQueryToModifyEmployee() const;
    SqlQuery GetQueryToRetrieveEmployee() const;
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No problem for cohesion here

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    PhoneNumber GetWorkPhone() const;
    …
    bool IsJobClassificationValid(JobClassification jobClass);
    bool IsZipCodeValid (Address address);
    bool IsPhoneNumberValid (PhoneNumber phoneNumber);
    …
    SqlQuery GetQueryToCreateNewEmployee() const;
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    SqlQuery GetQueryToRetrieveEmployee() const;
    …
}
```

Probably a cohesion problem here (what does “valid” mean? is it a property of being an Employee?)

Modularity: cohesion: strong or weak?

```
class Employee {
     public:
     …
     FullName GetName() const;
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     bool IsJobClassificationValid(JobClassification jobClass);
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     SqlQuery GetQueryToCreateNewEmployee() const;
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```

Definitely a cohesion problem here! (SQL query generation != model of employee)

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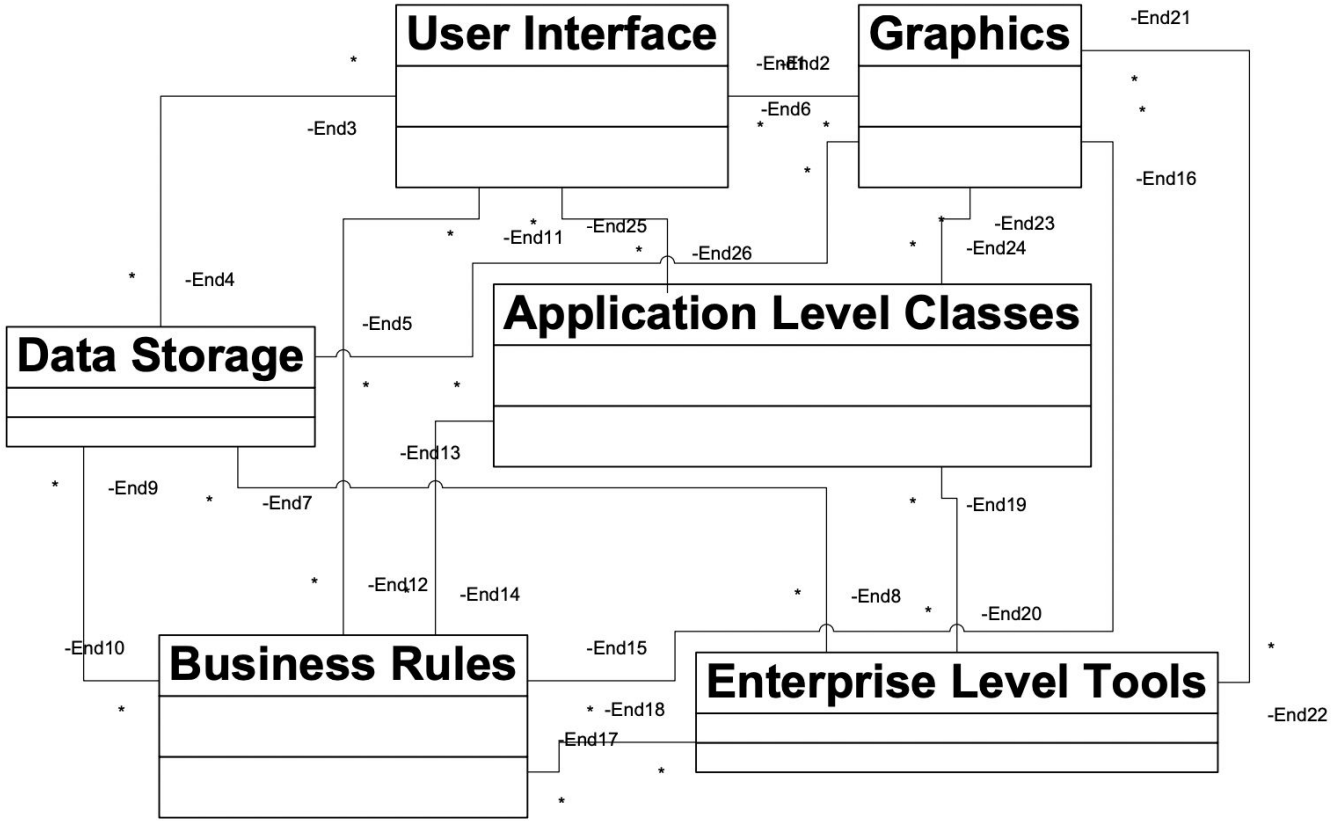
Definition: the ***coupling*** of a software project is the kind and quantity of interconnections among its modules

- scale: “loose” vs “tight”
- modules that are **loosely coupled** (or uncoupled) are **better** than those that are tightly coupled
  - the more tightly coupled two modules are, the harder it is to work with them separately

Modularity: coupling: loose or tight?



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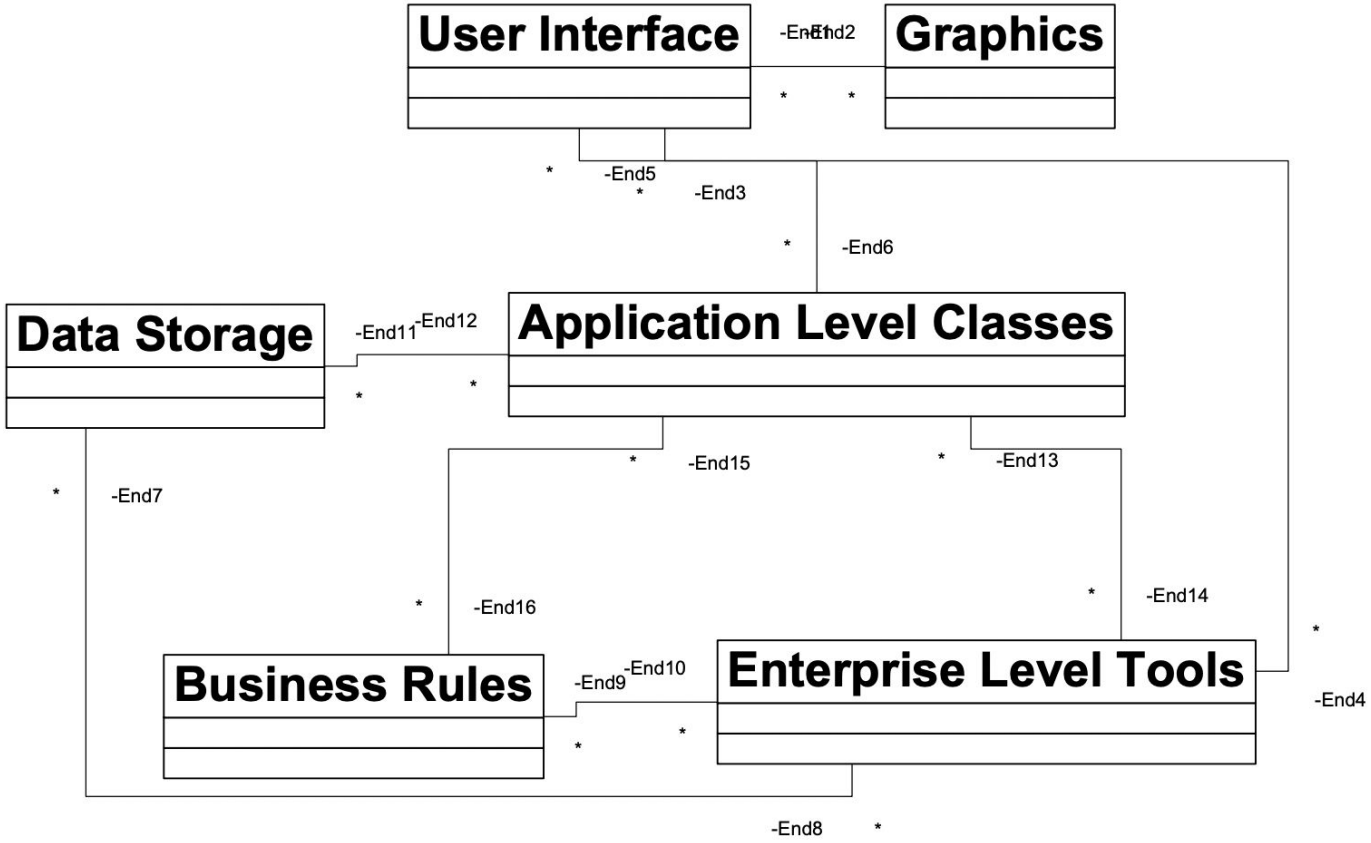

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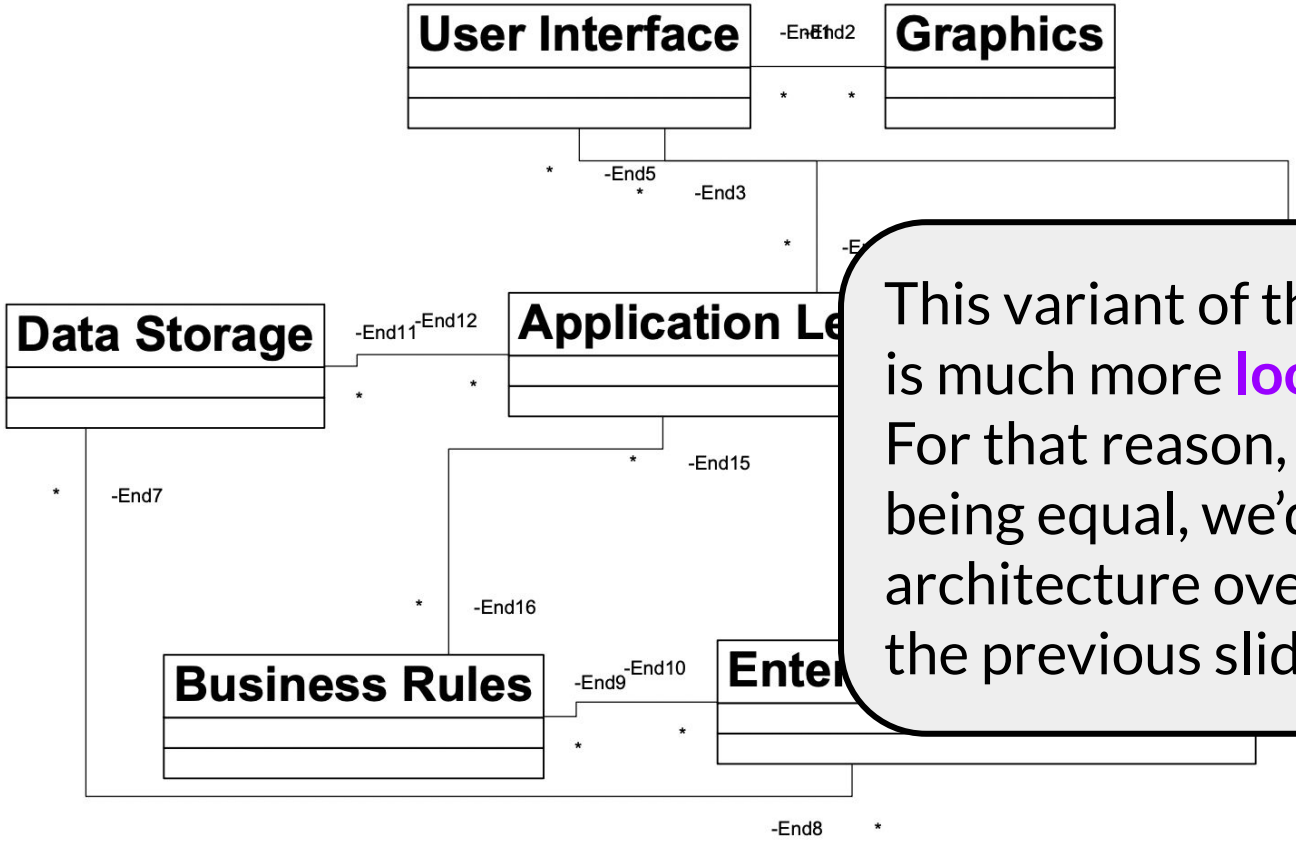

This variant of the architecture is much more **loosely coupled**. For that reason, all other things being equal, we'd prefer this architecture over the one on the previous slide.

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- How do you actually achieve modularity?

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Example: a radio

- public interface is the speaker, volume buttons, station dial
- private implementation is the guts of the radio; the transistors, capacitors, voltage readings, frequencies, etc. that user should not see

Software Architecture (Part 1 of ~~3~~ 2)

Today's agenda:

- Finish delta debugging slides
- Reading Quiz
- Architecture vs Design
- Architecture diagrams
- What makes an architecture good
- **Architectural styles (with examples)**

Architecture: styles

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  - topological constraints (no cycles, etc.)
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By choosing a style, one gets all the **known properties** of that style (for any architecture in that style)

- for example: performance, lack of deadlock, ease of making particular classes of changes, etc.

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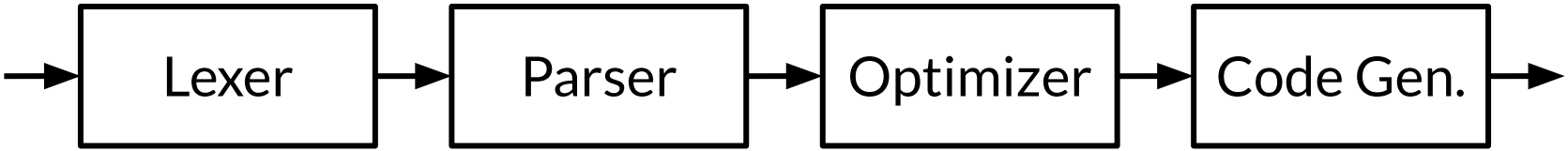

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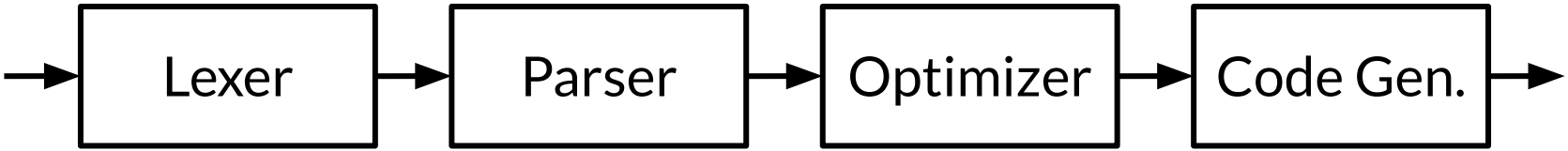

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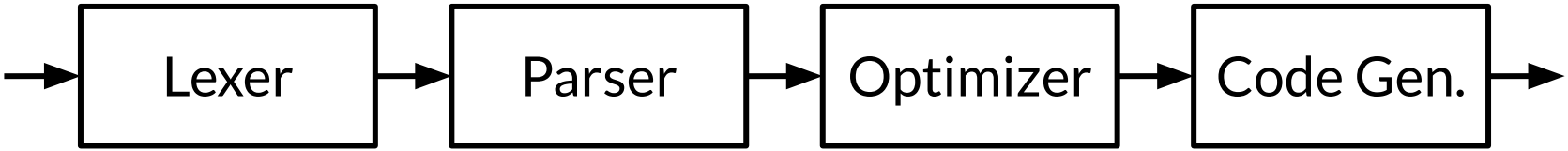

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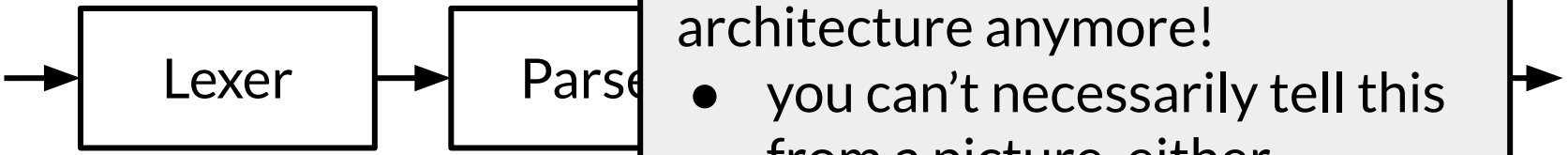

If these constraints are violated, it's not a pipe-and-filter architecture anymore!

- you can't necessarily tell this from a picture, either

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  - selected **deviations** can be explained more concisely and with clearer reasoning

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- When looking at an architecture, small details do matter a lot at the **interface** between components
  - e.g., NASA lost a $125 million Mars orbiter because one engineering team used metric units while another used Imperial units
- Architecture should warn about **incompatibility between components**, which can be caused by (among other things):
  - mismatched interfaces
  - mismatched operating assumptions (e.g., one component assumes Windows, the other assumes Linux)

Architecture: styles: other examples

Examples of architectural styles:

- pipe-and-filter
- client-server
- model-view-controller
- microservices

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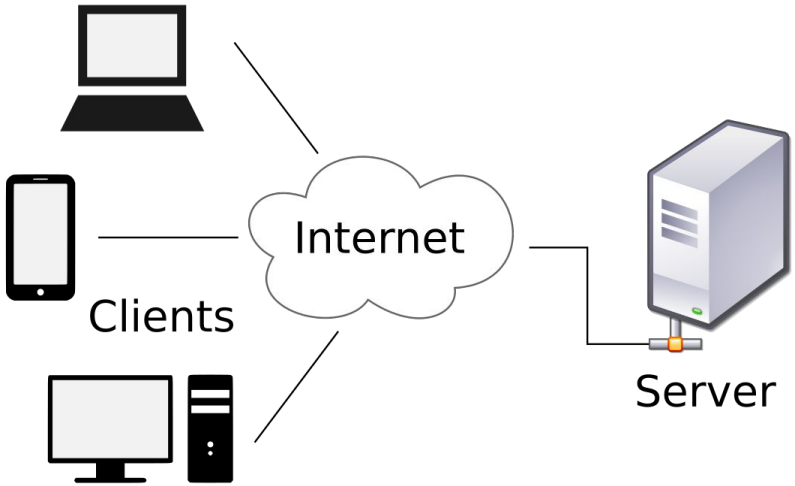

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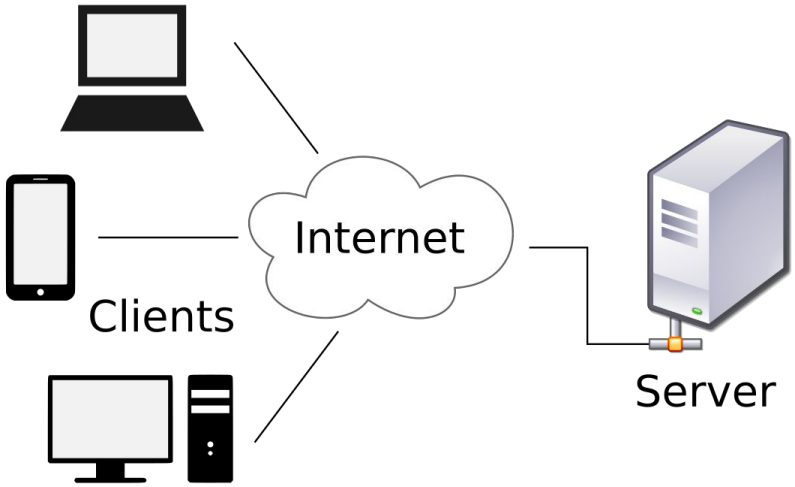

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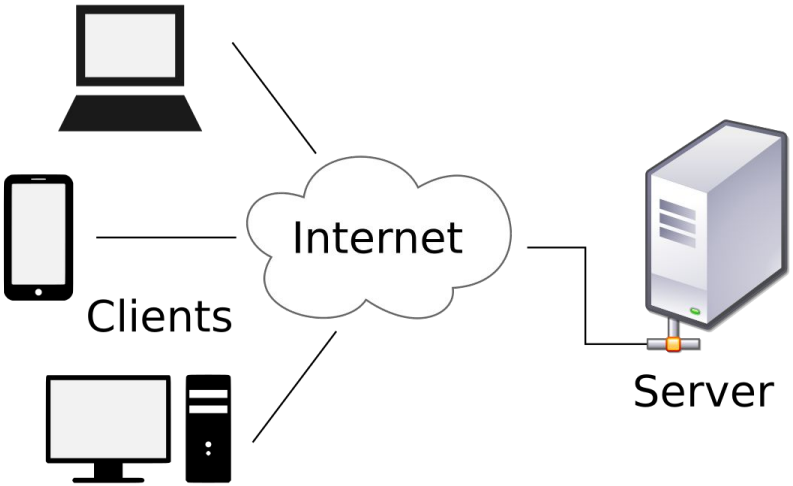
- network doesn't have to be the internet (client and server can even be on the same machine!)
- example of decomposition: server has its **own architecture** internally, but we don't see it



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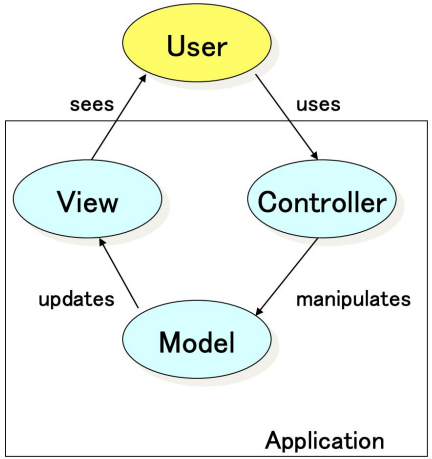

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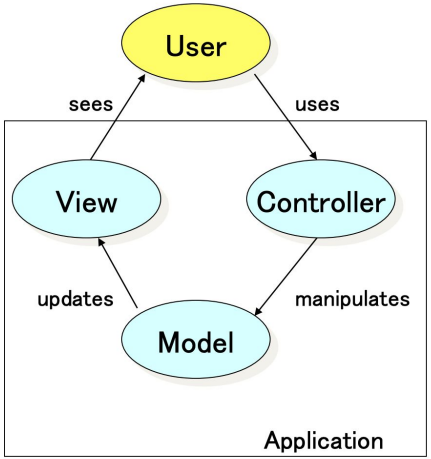

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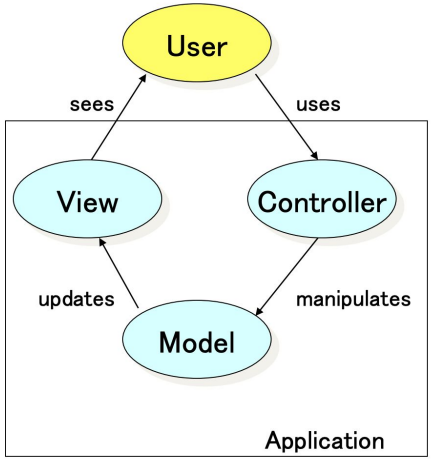

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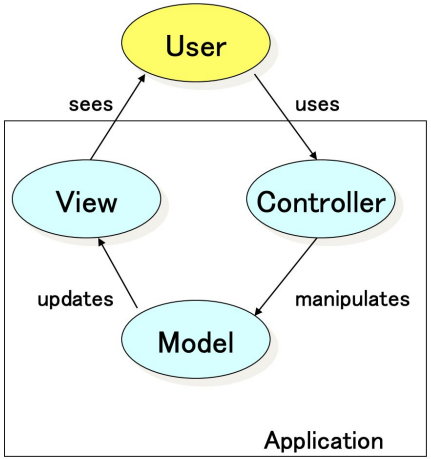

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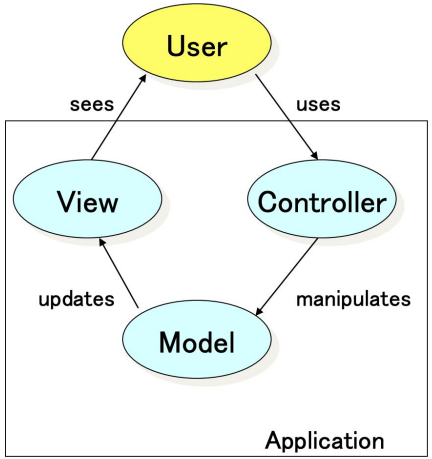

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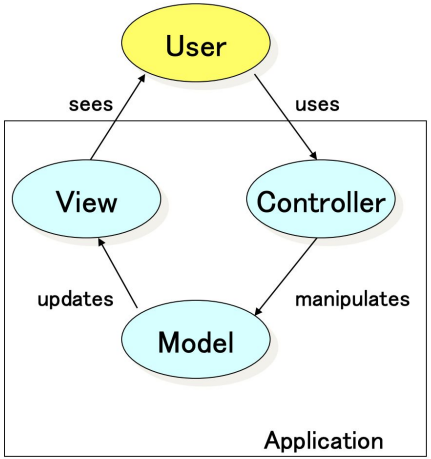
Key advantage of MVC: **separates** data representation (Model), visualization/user interface (View), and client interaction (Controller)



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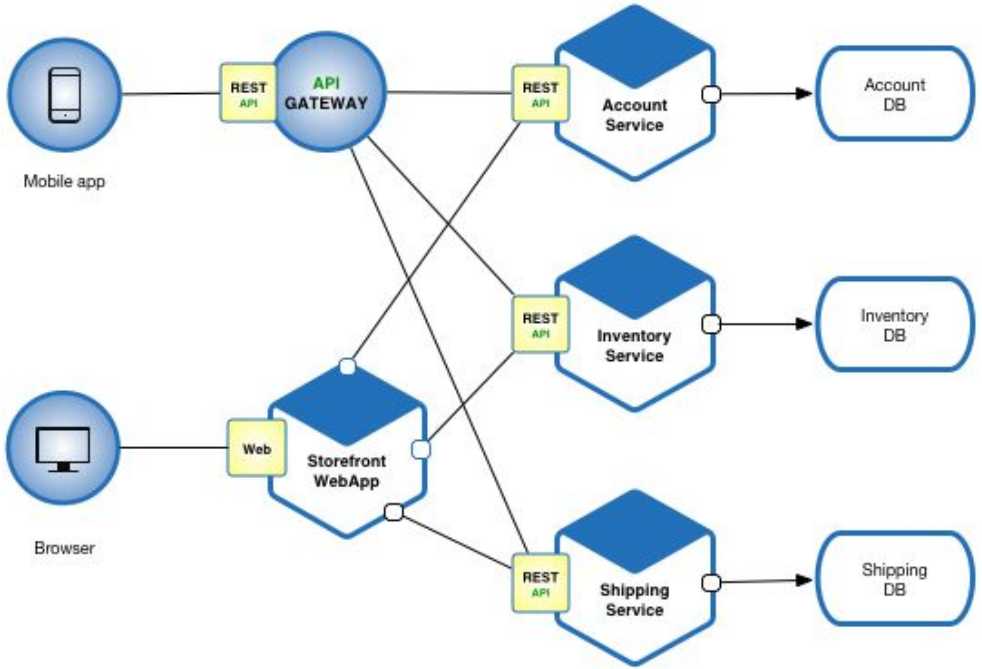

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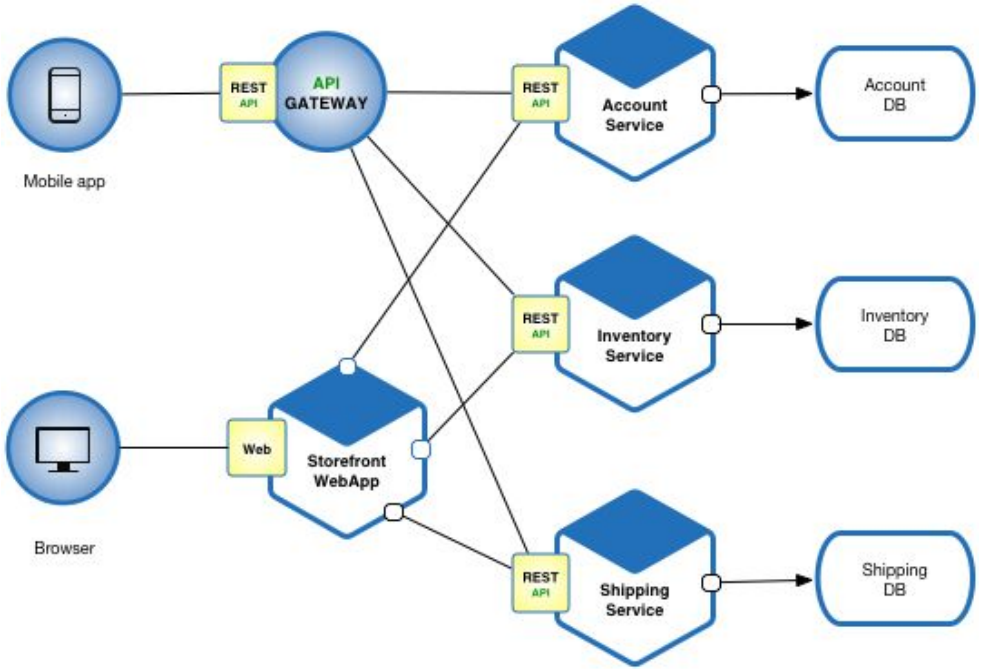

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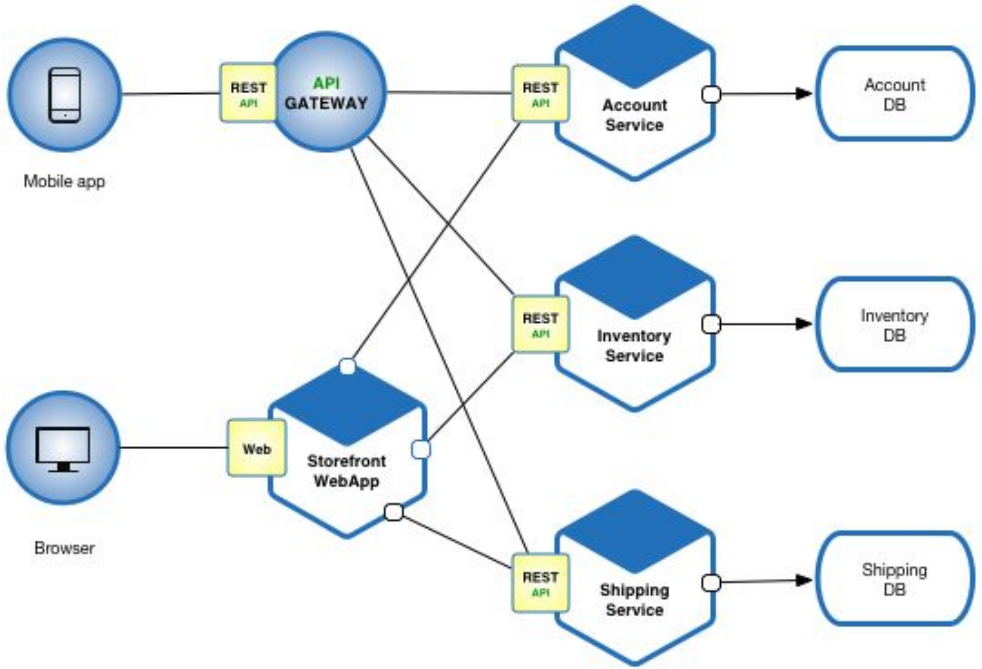

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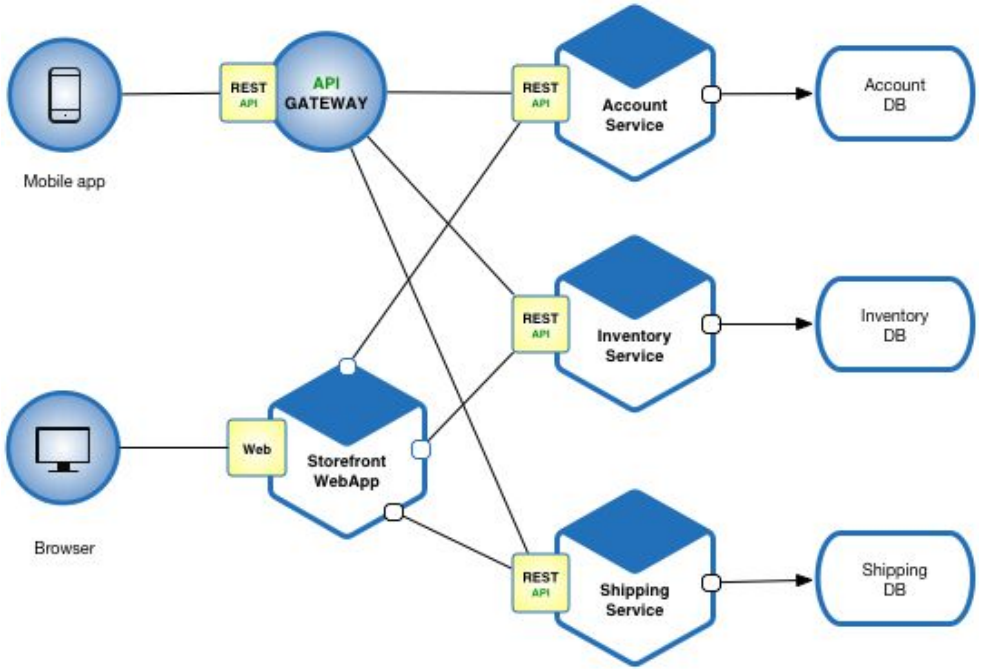

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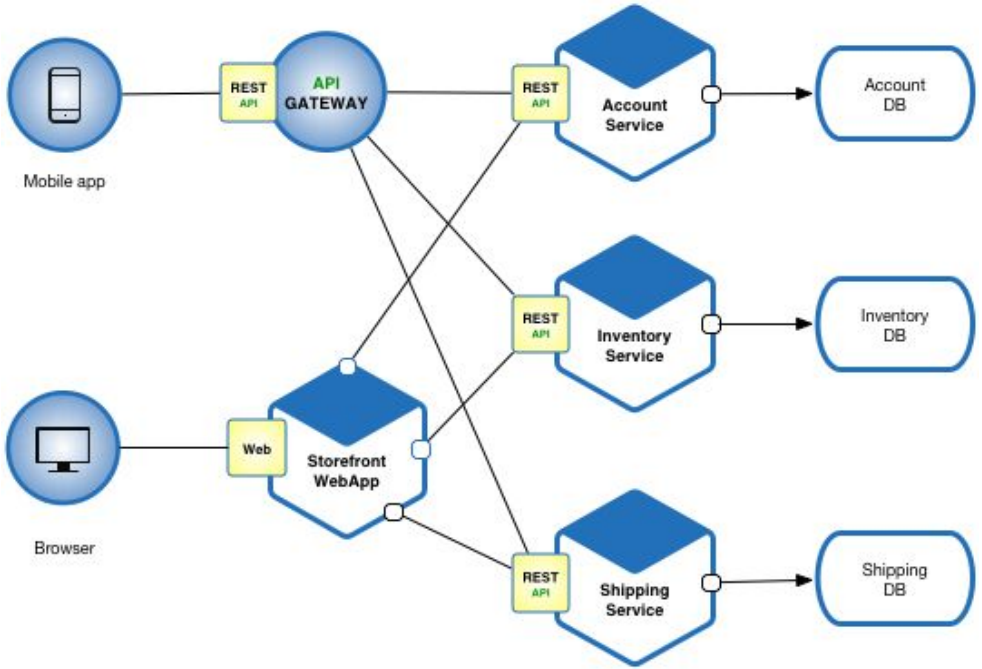

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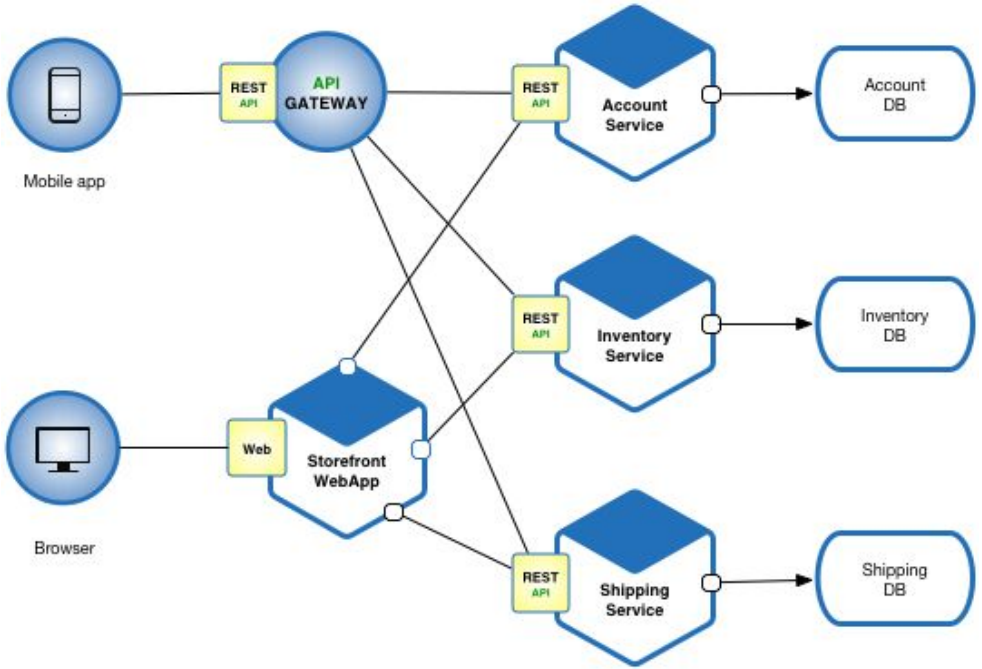

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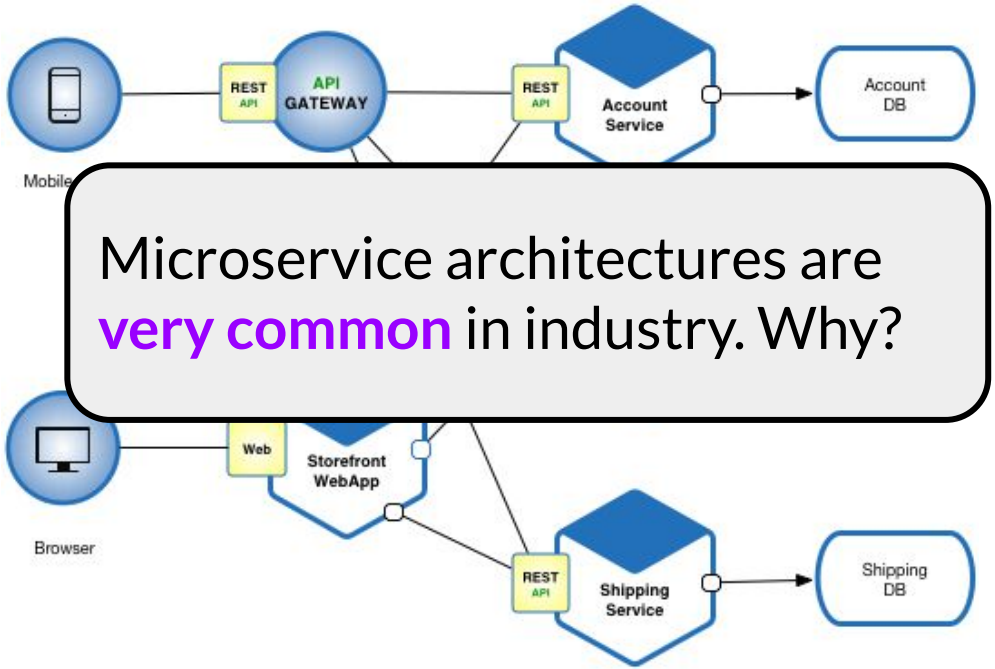

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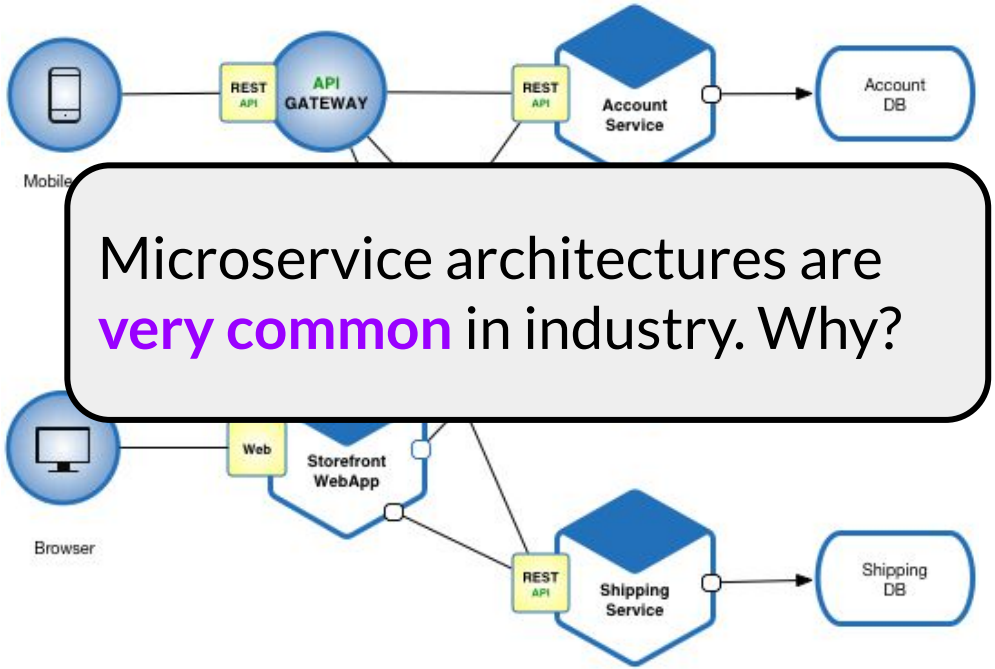

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- **Key skill**: understand what an architecture diagram is and is not communicating
  - does communicate overall structure of the system
  - does communicate how components are related
  - does not communicate internal structure of components
    - definitely does not tell you how to implement them!

Takeaways: architecture

- An architecture is a high-level view of a software system
- Good architectures communicate how the pieces of the system (the components) fit together
- Many architectural styles exist, and you should have a passing familiarity with several
    - common interview question: “on the whiteboard, design a [insert architectural style here] system to do X”
- Architectural styles are a guide, but are not prescriptive
    - real systems usually deviate from their “whiteboard architecture”, but deviations can be explained