Software Architecture

Emina Torlak

emina@cs.washington.edu

Outline

- What is a software architecture?

- What does an architecture look like?

- What is a good architecture?

- Properties of architectures

- Example architectures

© 2007, Robert A. Baron   pix@studiolo.org

software architecture: motivation & definition

Why software architecture?

"There are two ways of constructing a software design: one way is to make it so simple that there are obviously no deficiencies; the other is to make it so complicated that there are no obvious deficiencies."
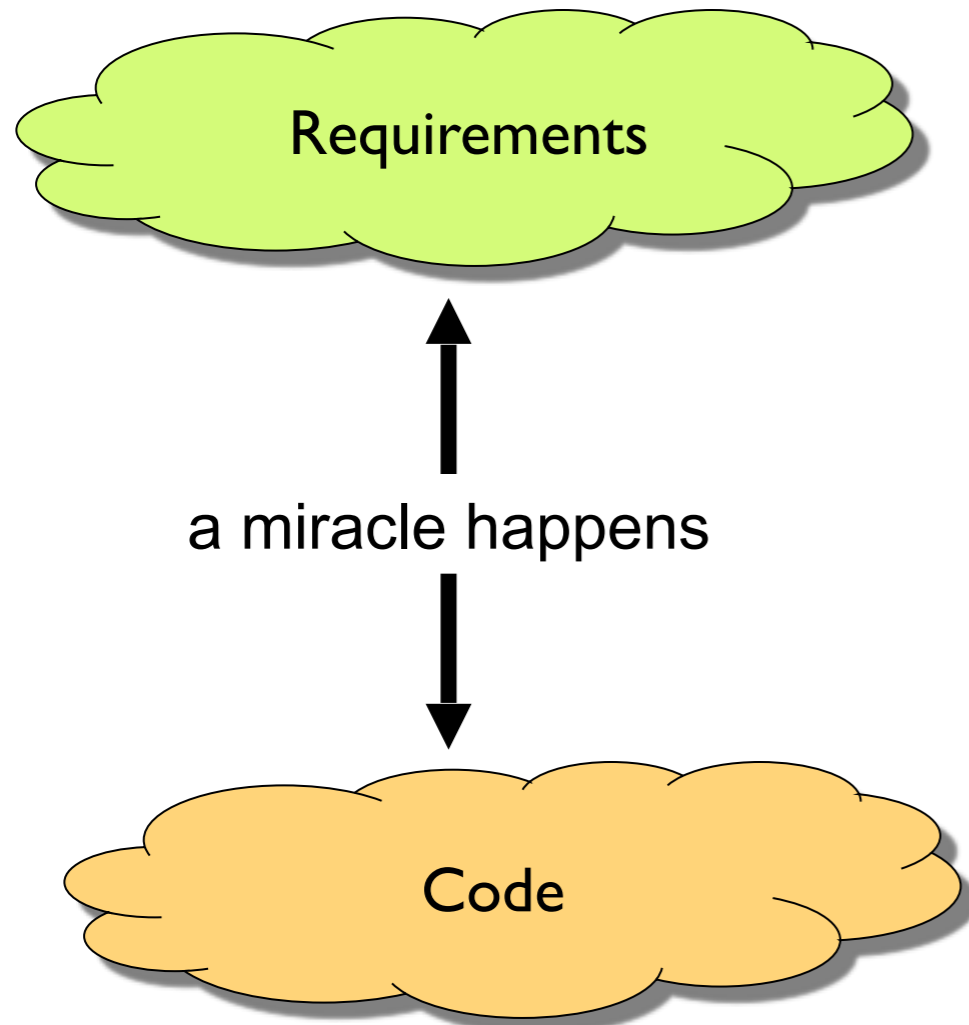
C.A.R. Hoare (1985)
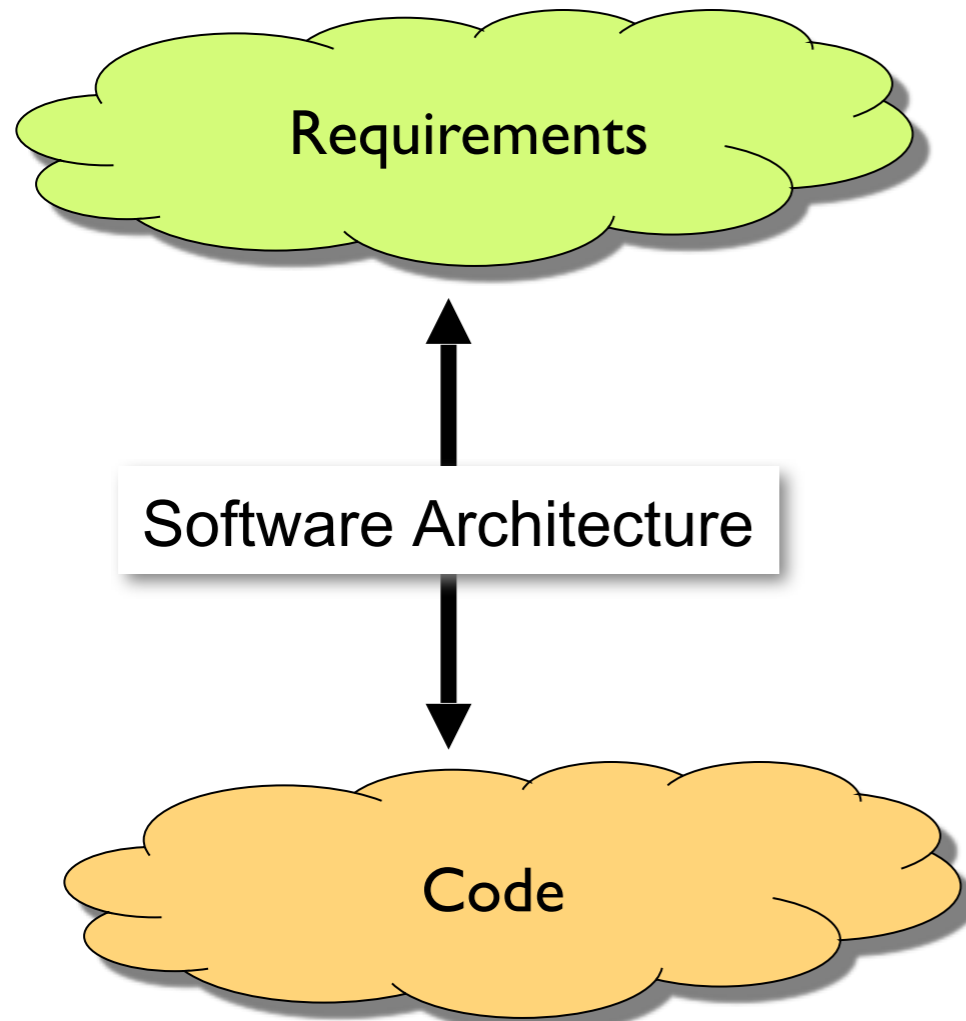
The basic problem: from requirements to code

Requirements

??
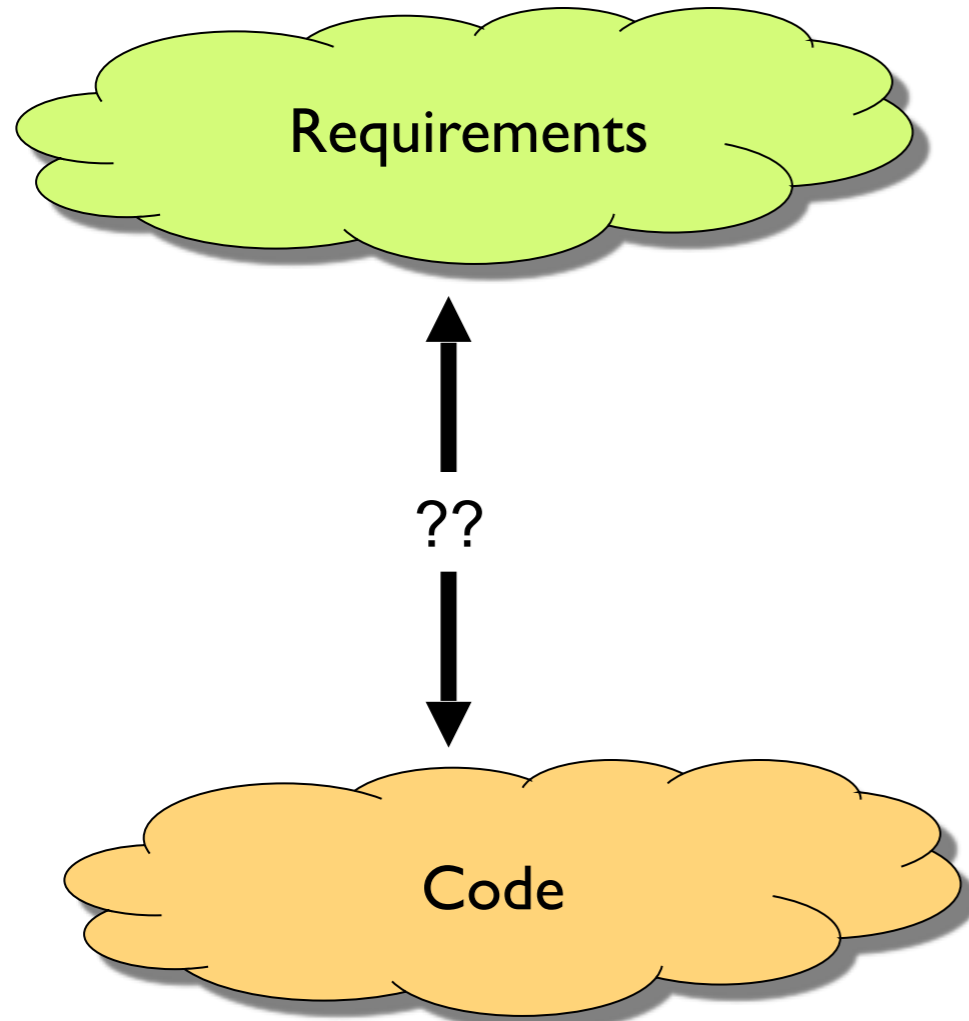
Code

How to bridge the gap between requirements and code?
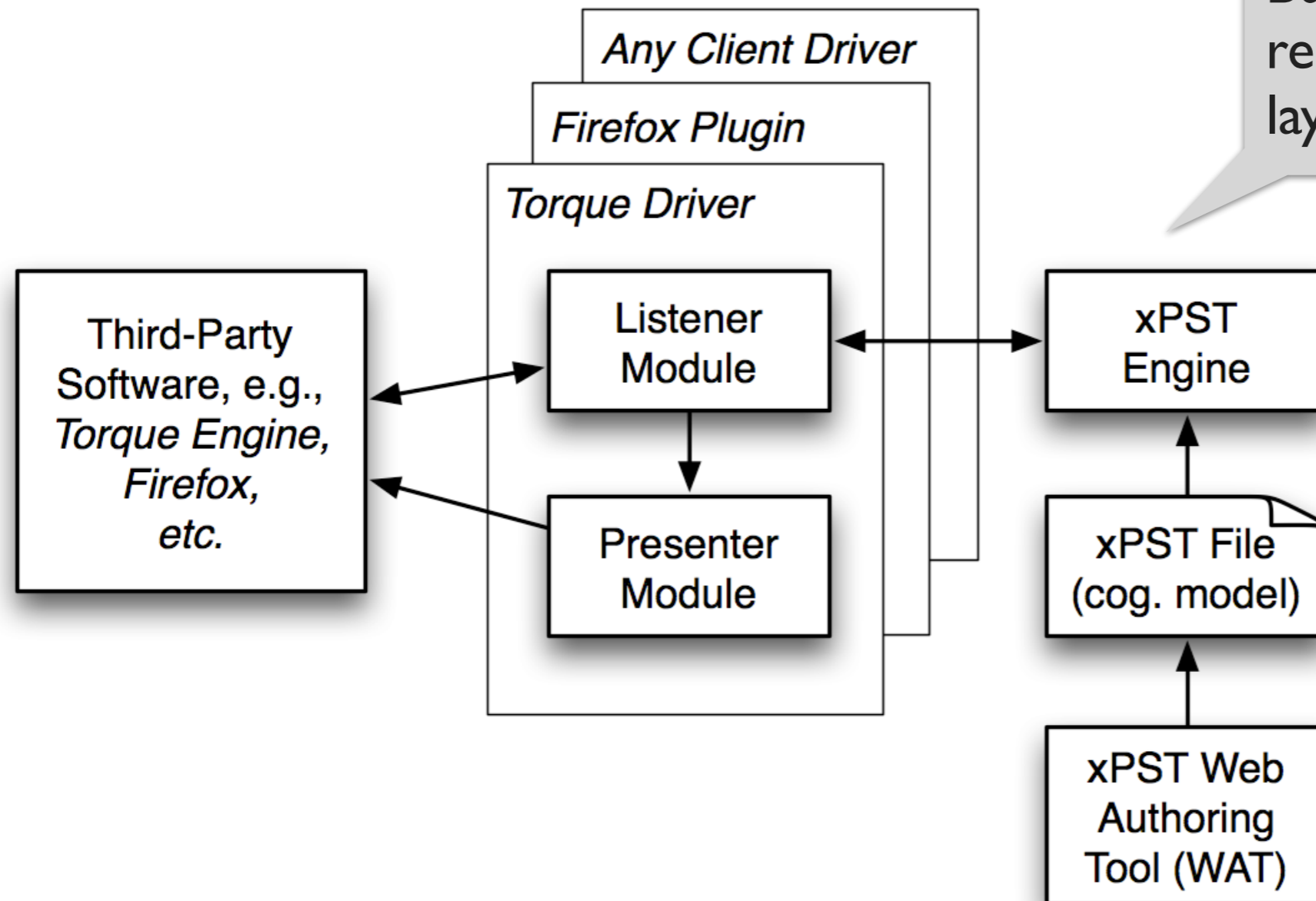
The basic problem: solve with inspiration

Requirements

a miracle happens

Code

The basic problem: solve with engineering

Requirements

Software Architecture

Code

Provides a high-level framework to build and evolve a software system.

what does an architecture look like?

Box and arrow diagrams

Very common and highly valuable.

But what does a box represent? An arrow? A layer? Adjacent boxes?

An architecture: components and connectors

- **Components** define the basic computations comprising the system and their behaviors

    - abstract data types, filters, etc.

- **Connectors** define the interconnections between components

    - procedure call, event announcement, asynchronous message sends, etc.

- The line between them may be fuzzy at times

    - A connector might (de)serialize data, but can it perform other, richer computations?

A standard notation for architecture: UML

- UML = unified modeling language

- A standardized way to describe (draw) architecture

  - Also implementation details such as subclassing, uses (dependences), and much more

- Widely used in industry

- Topic of next lecture

UNIFIED
MODELING
LANGUAGE
UML™

judge

what is a good architecture?

# A good architecture ...

- Satisfies functional and performance requirements

- Manages complexity

- Accommodates future change

- Is concerned with

    - reliability, safety, understandability, compatibility, robustness

A good architecture ...

- Satisfies functional and performance requirements

- Manages complexity

- Accommodates future change

- Is concerned with

  - reliability, safety, understandability, compatibility, robustness

Leads to modularity and separation of concerns.

A modular architecture helps with …

- **System understanding**: interactions between modules

- **Reuse**: high-level view shows opportunity for reuse

- **Construction**: breaks development down into work items

- **Evolution**: high-level view shows evolution path

- **Management**: helps understand work items and track progress

- **Communication**: provides vocabulary; a picture says 1000 words

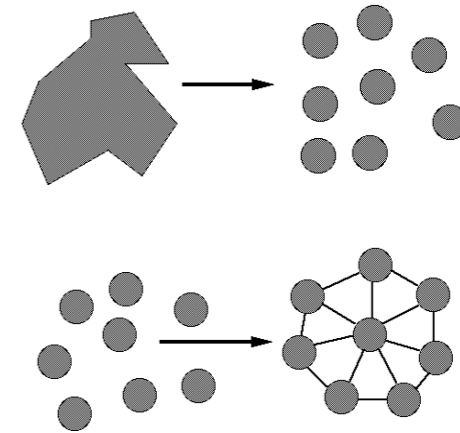# You know your software is modular when it is ...
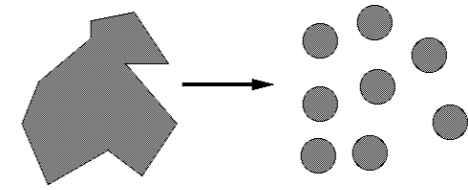
You know your software is modular when it is …
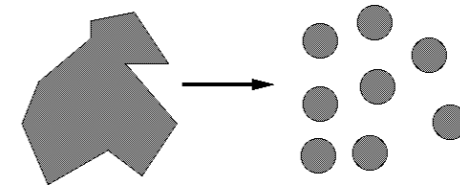
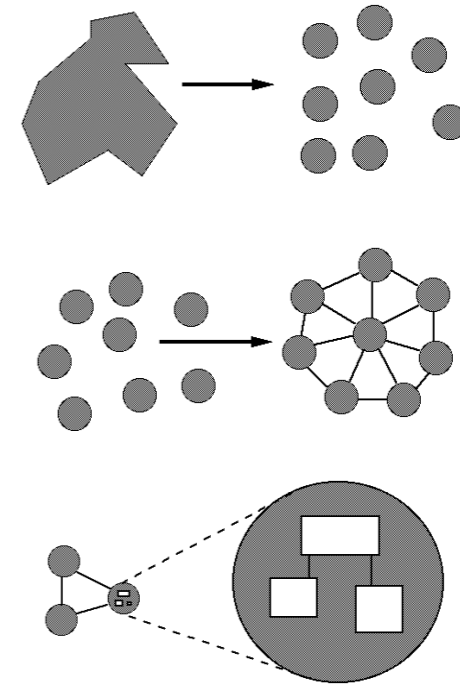- Decomposable
  - can be broken down into pieces

You know your software is modular when it is …

- Decomposable

  - can be broken down into pieces

- Composable
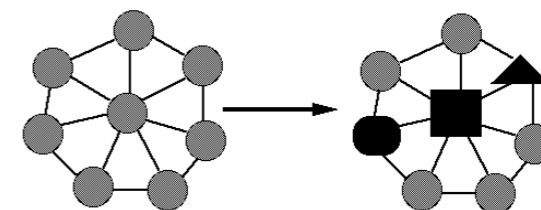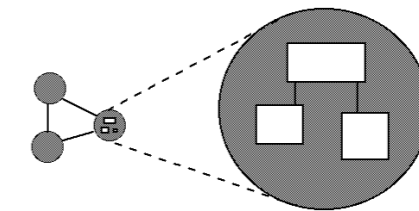
  - pieces are useful and can be combined

You know your software is modular when it is ...

- Decomposable
  - can be broken down into pieces

- Composable
  - pieces are useful and can be combined

- Understandable
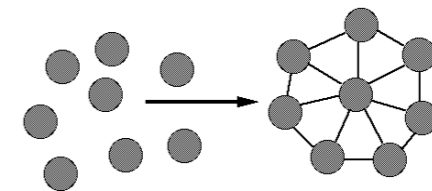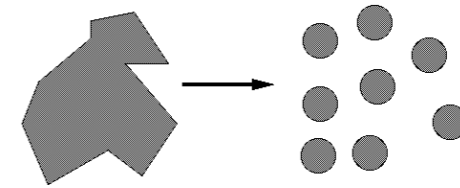 - one piece can be examined in isolation

You know your software is modular when it is ...

- Decomposable
  - can be broken down into pieces

- Composable
  - pieces are useful and can be combined

- Understandable
  - one piece can be examined in isolation

- Adaptable
  - change in requirements affects few modules

You know your software is modular when it is ...

- Decomposable
  - can be broken down into pieces

- Composable
  - pieces are useful and can be combined

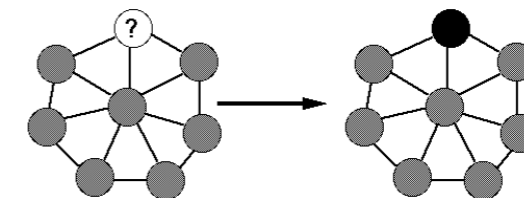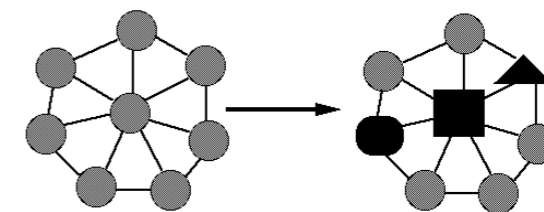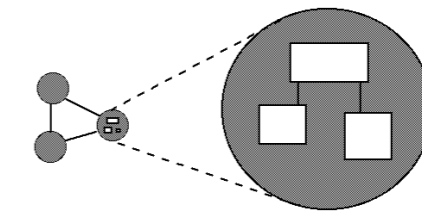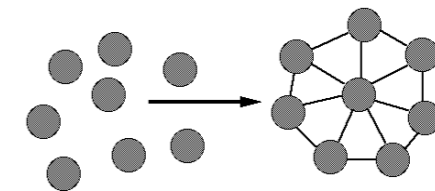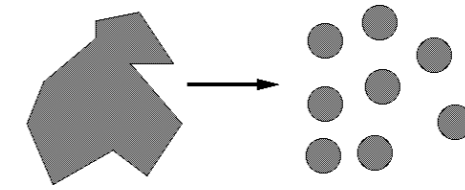- Understandable
  - one piece can be examined in isolation

- Adaptable
  - change in requirements affects few modules

- Safe
  - an error affects few other modules

Achieving modularity: think about interfaces

- **Public interface**: data and behavior of the object that can be seen and executed externally by "client" code.

- **Private implementation**: internal data and methods in the object, used to help implement the public interface, but cannot be directly accessed.

- **Client**: code that uses your module.

Achieving modularity: think about interfaces

- **Public interface**: data and behavior of the object that can be seen and executed externally by "client" code.

- **Private implementation**: internal data and methods in the object, used to help implement the public interface, but cannot be directly accessed.

- **Client**: code that uses your module.

Achieving modularity: think about interfaces

- **Public interface**: data and behavior of the object that can be seen and executed externally by "client" code.

- **Private implementation**: internal data and methods in the object, used to help implement the public interface, but cannot be directly accessed.

- **Client**: code that uses your module.

Public interface is the speaker, volume buttons, station dial.

Private implementation is the guts of the radio (transistors, capacitors, voltage readings, etc.) that user should not see.

know

properties of architectures

Key properties of an architecture

- Coupling

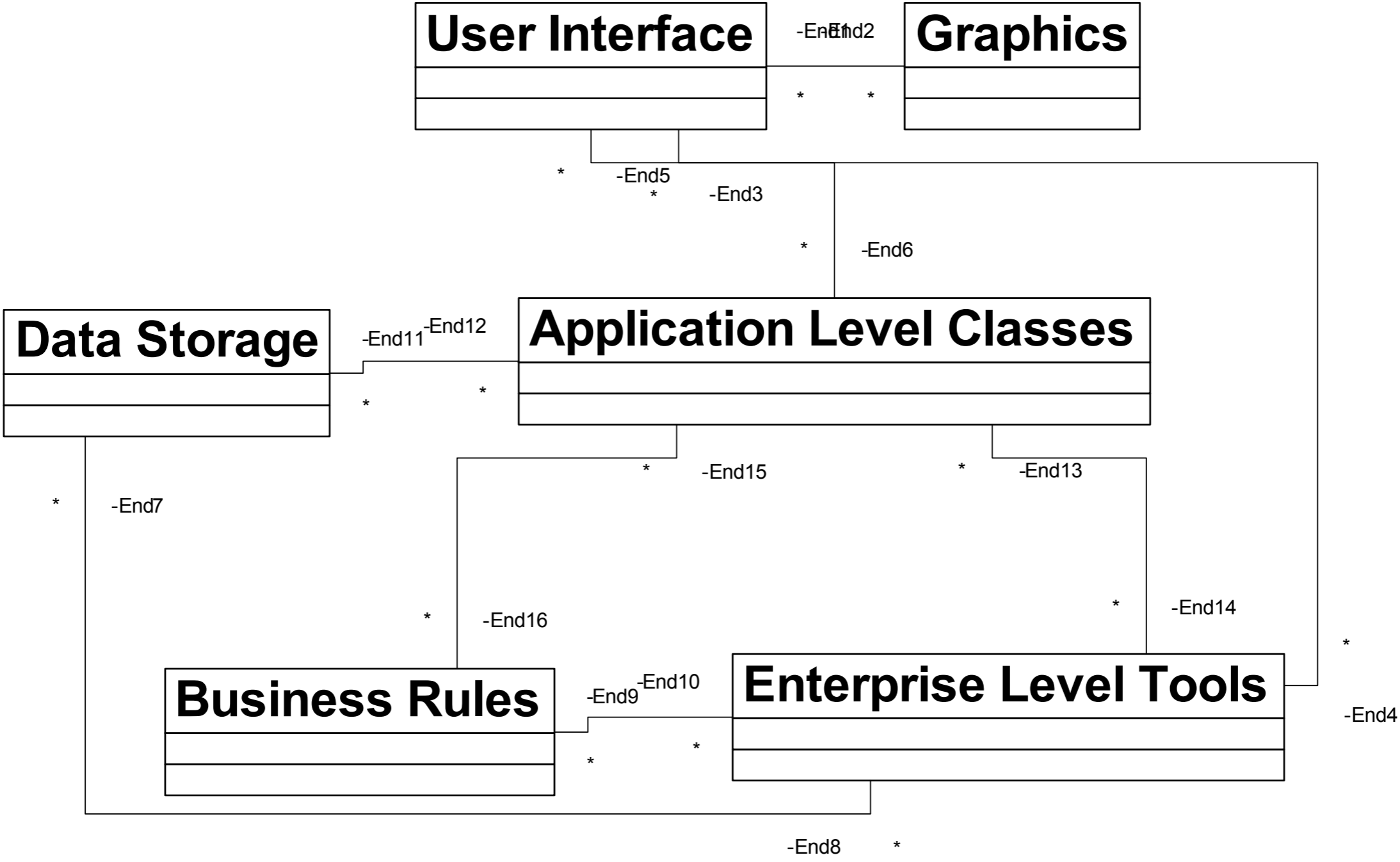- Cohesion

- Style conformity

- Matching

Coupling (loose vs tight)

- **Coupling**: the kind and quantity of interconnections among modules

- 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

Tightly or loosely coupled?
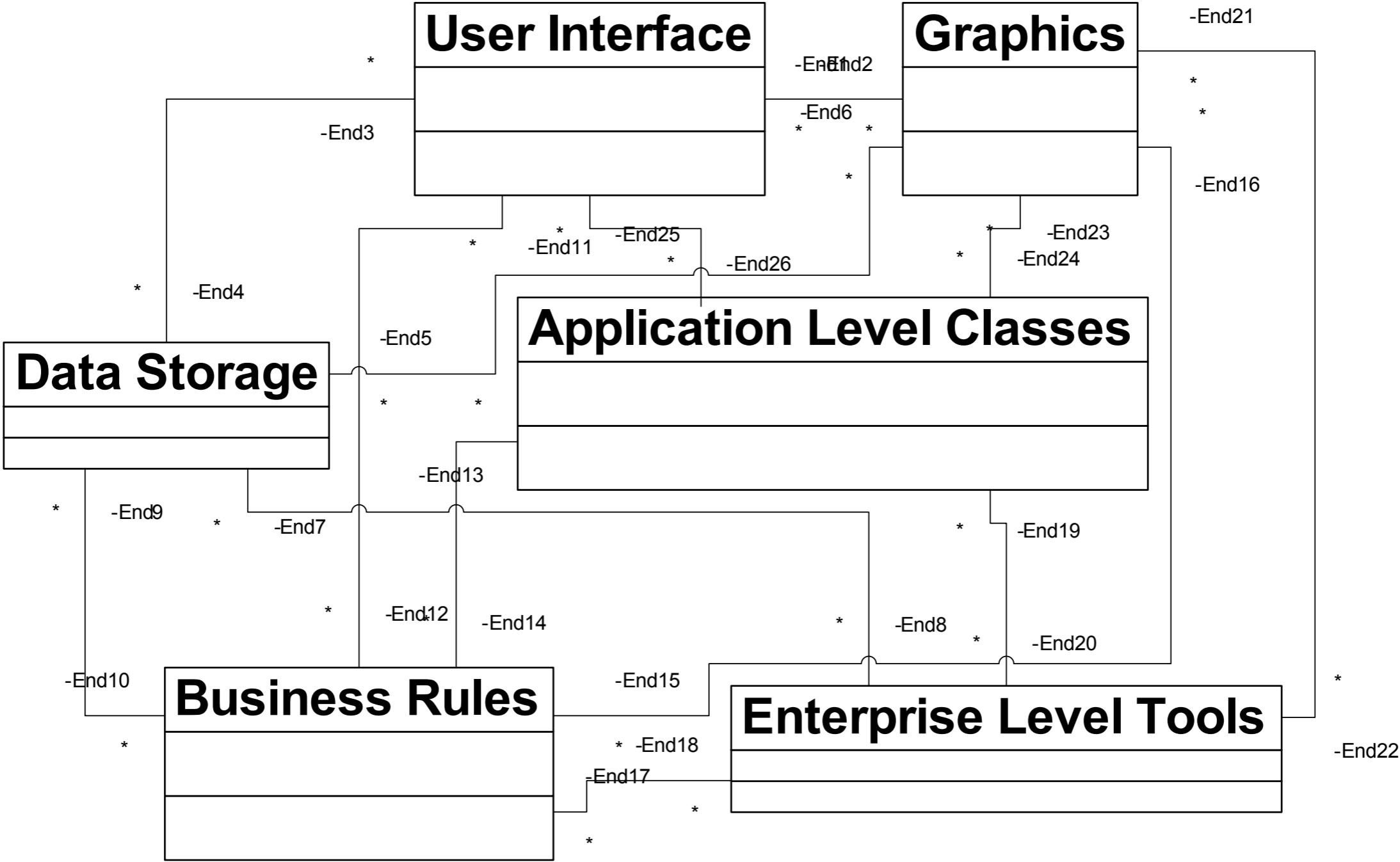
Tightly or loosely coupled?

Cohesion (strong vs weak)

- **Cohesion**: how closely the operations in a module are related

- Tight relationships improve clarity and understanding

- Classes with **good abstraction** usually have **strong cohesion**

- No schizophrenic classes!

Strong or weak cohesion?

```
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;

   …
}
```
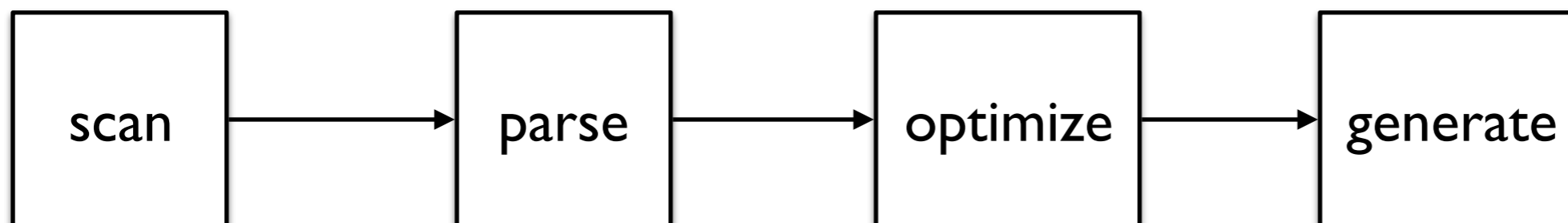
Style conformity: what is a style?

- An **architectural style** defines

    - The vocabulary of components and connectors for a family of architectures

    - Constraints on the elements and their combination

        - Topological constraints (no cycles, etc.)

        - Execution constraints (timing, etc.)

- 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.

Style conformity: more than boxes and arrows

- Consider pipes & filters (Garlan and Shaw)

  - Pipes must compute local transformations

  - Filters must not share state with other filters

  - There must be no cycles

- If these constraints are violated, it's not a pipe & filter system

  - One can't tell generally this from a picture

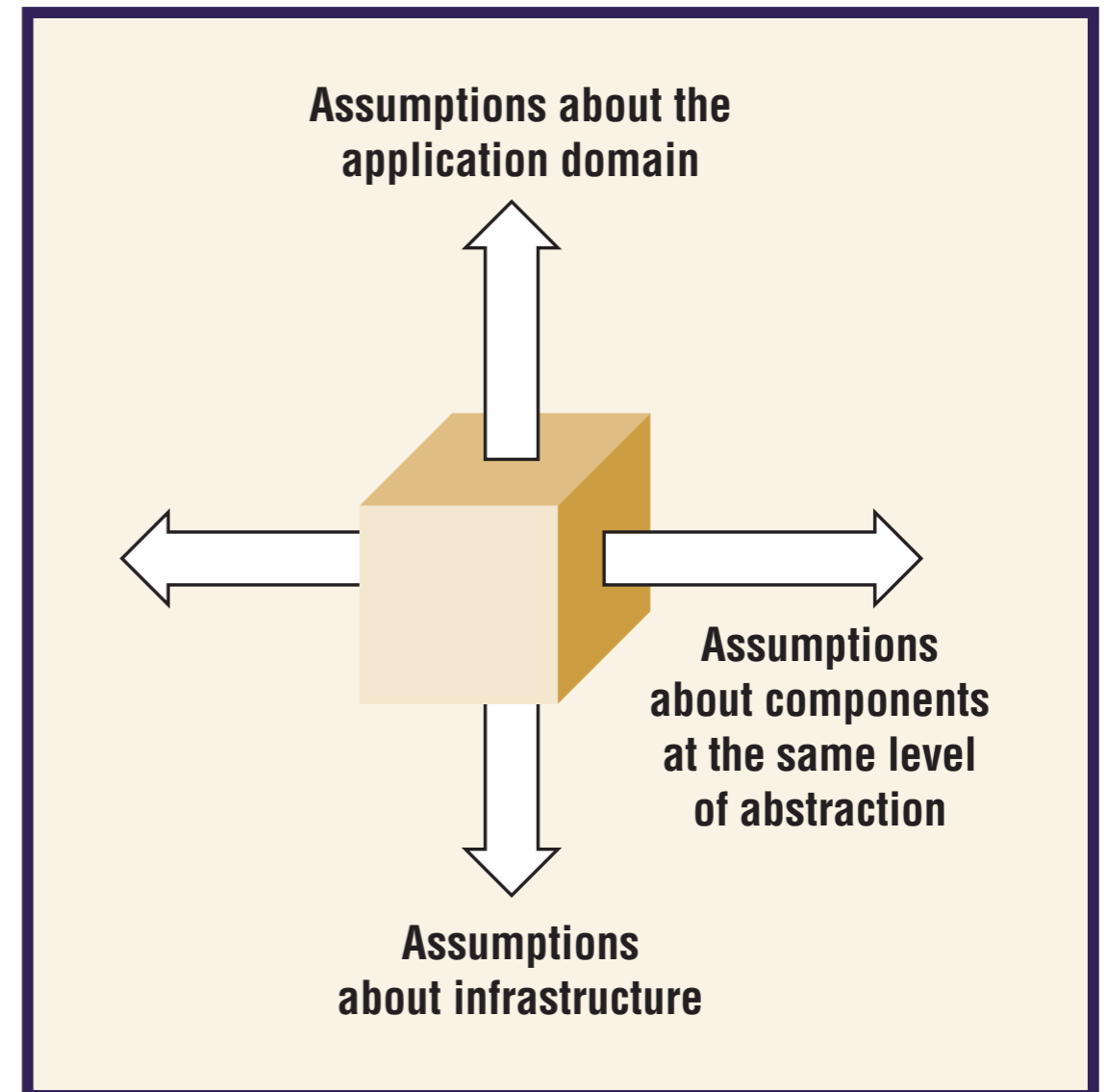 - One can **formalize** these constraints

Style conformity: more than boxes and arrows

- Consider pipes & filters (Garlan and Shaw)

  - Pipes must compute local transformations

  - Filters must not share state with other filters

  - There must be no cycles

- If these constraints are violated, it's not a pipe & filter system

  - One can't tell generally this from a picture

 - One can **formalize** these constraints

```
┌─────────┐      ┌─────────┐      ┌──────────┐      ┌──────────┐
│  scan   │─────▶│  parse  │─────▶│ optimize │─────▶│ generate │
└─────────┘      └─────────┘      └──────────┘      └──────────┘
```

Component matching

- Components in an architecture **match** if they make compatible assumptions about their operating environment (Garlan, Allen, Ockerbloom).

- Mismatches lead to
  - Excessive code size
  - Poor performance
  - Error-prone construction
 - Having to modify off-the-shelf components

Assumptions about the application domain

Assumptions about components at the same level of abstraction

Assumptions about infrastructure

Interface mismatch

NASA lost a $125 million Mars orbiter because one engineering team used metric units while another used English units for a key spacecraft operation.
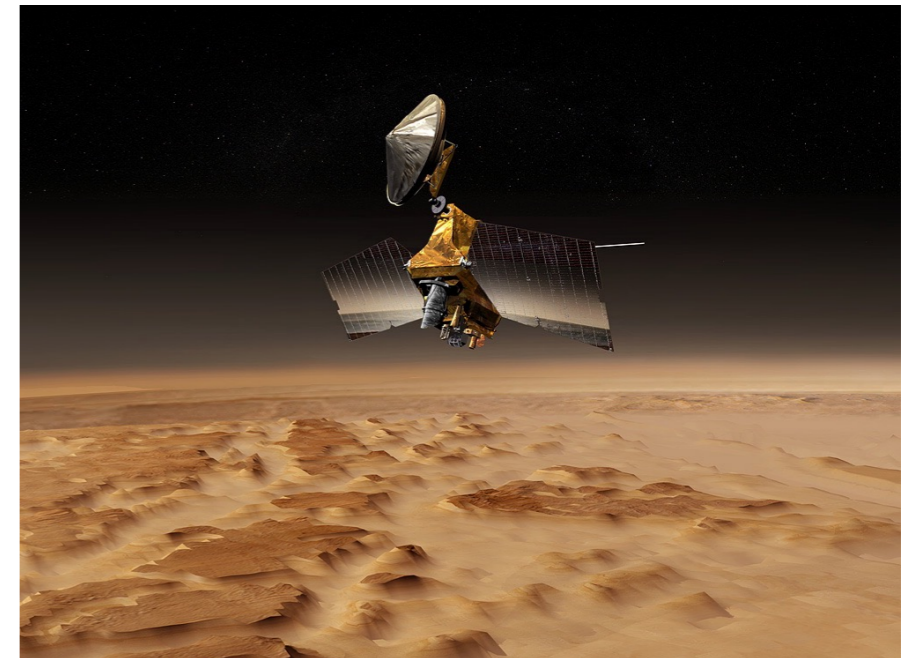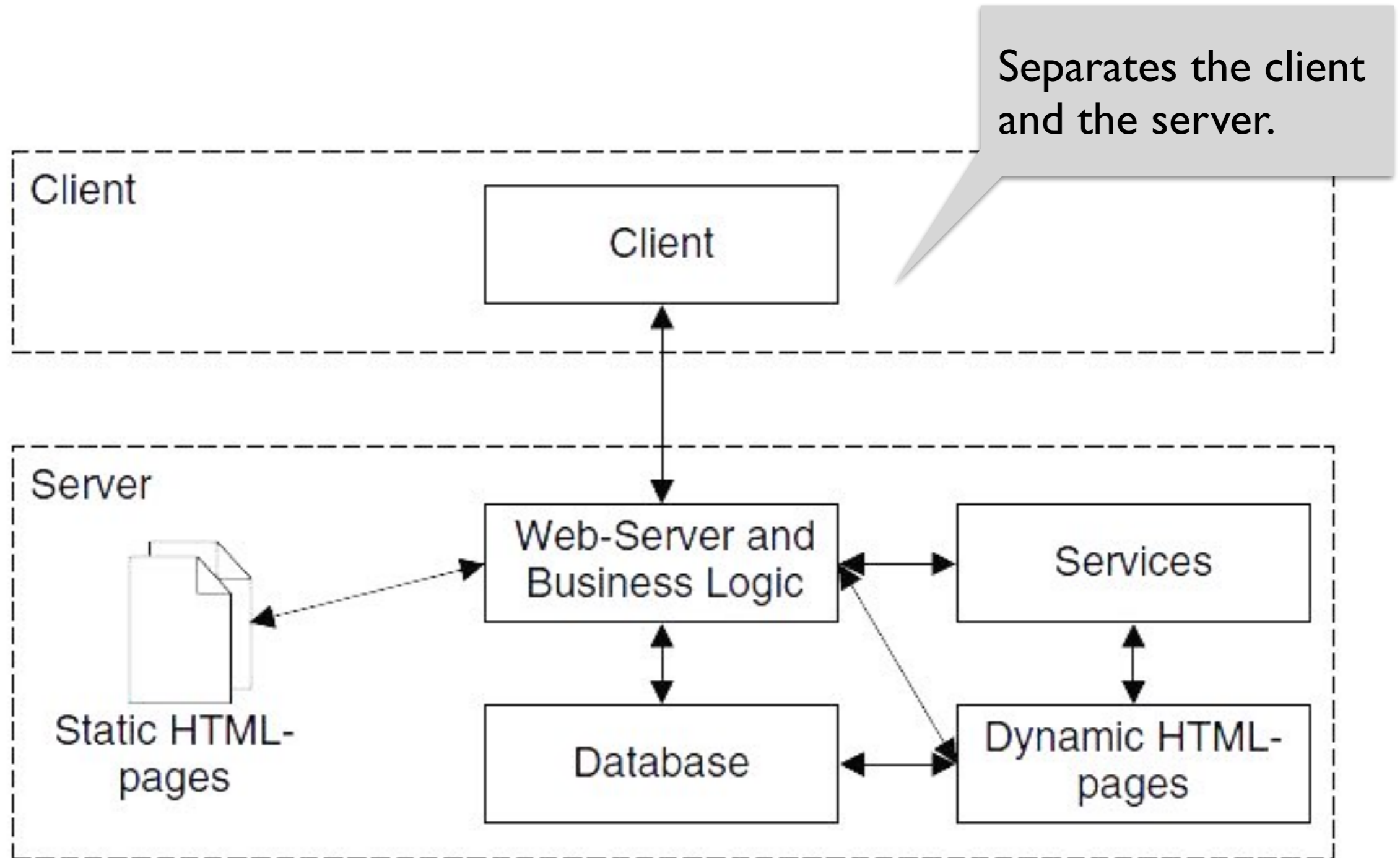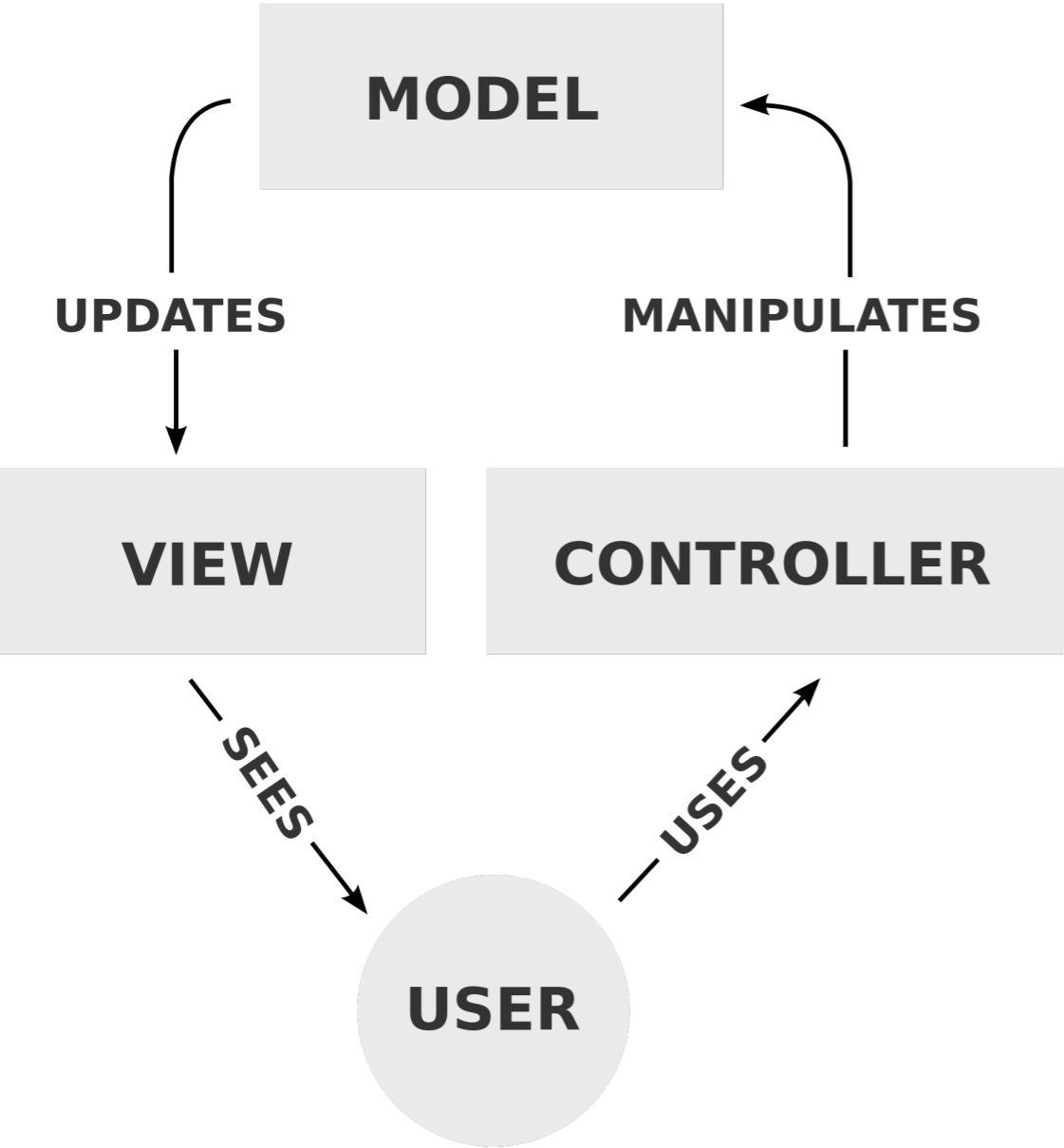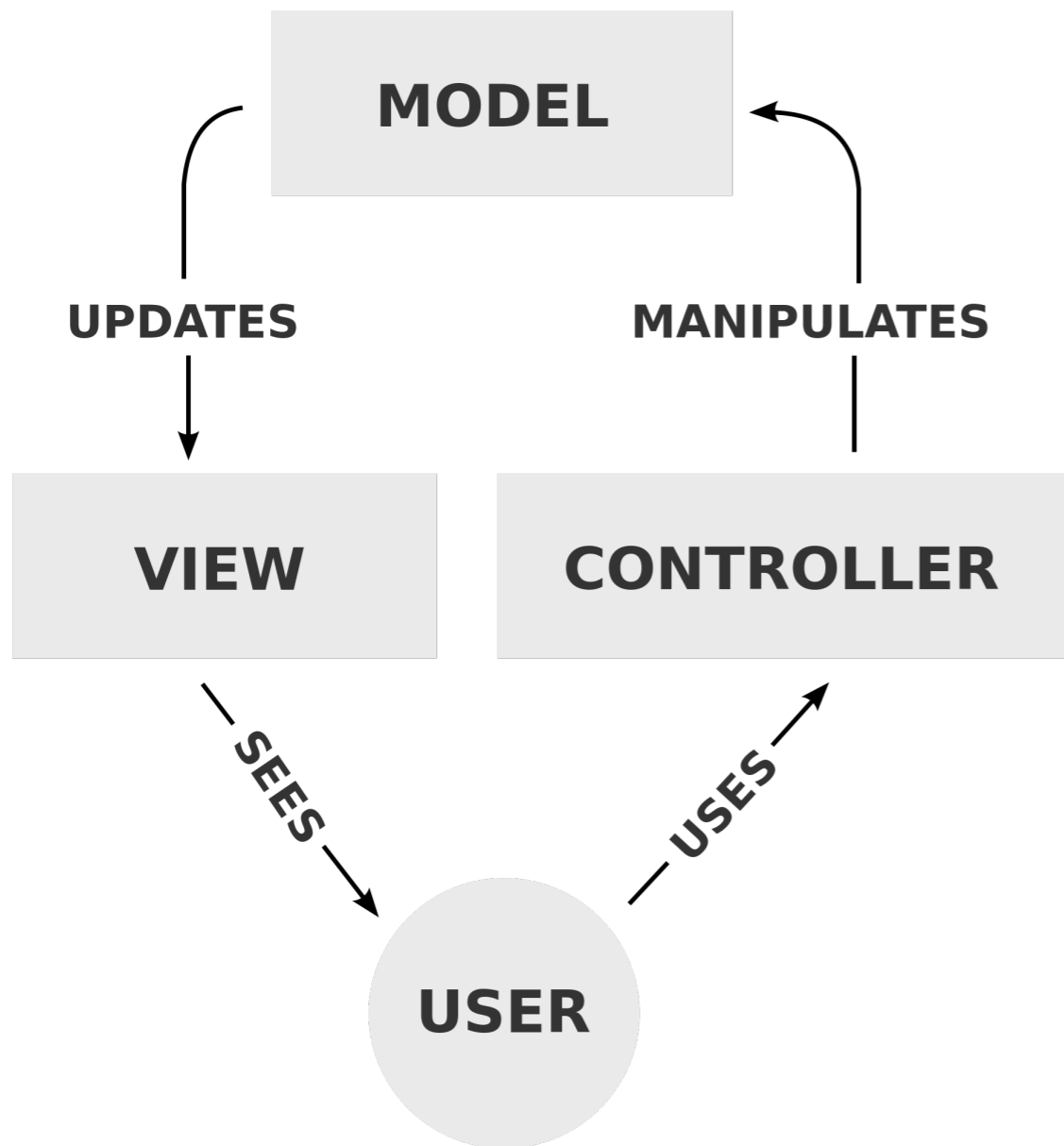
example architectures

Client-server architecture
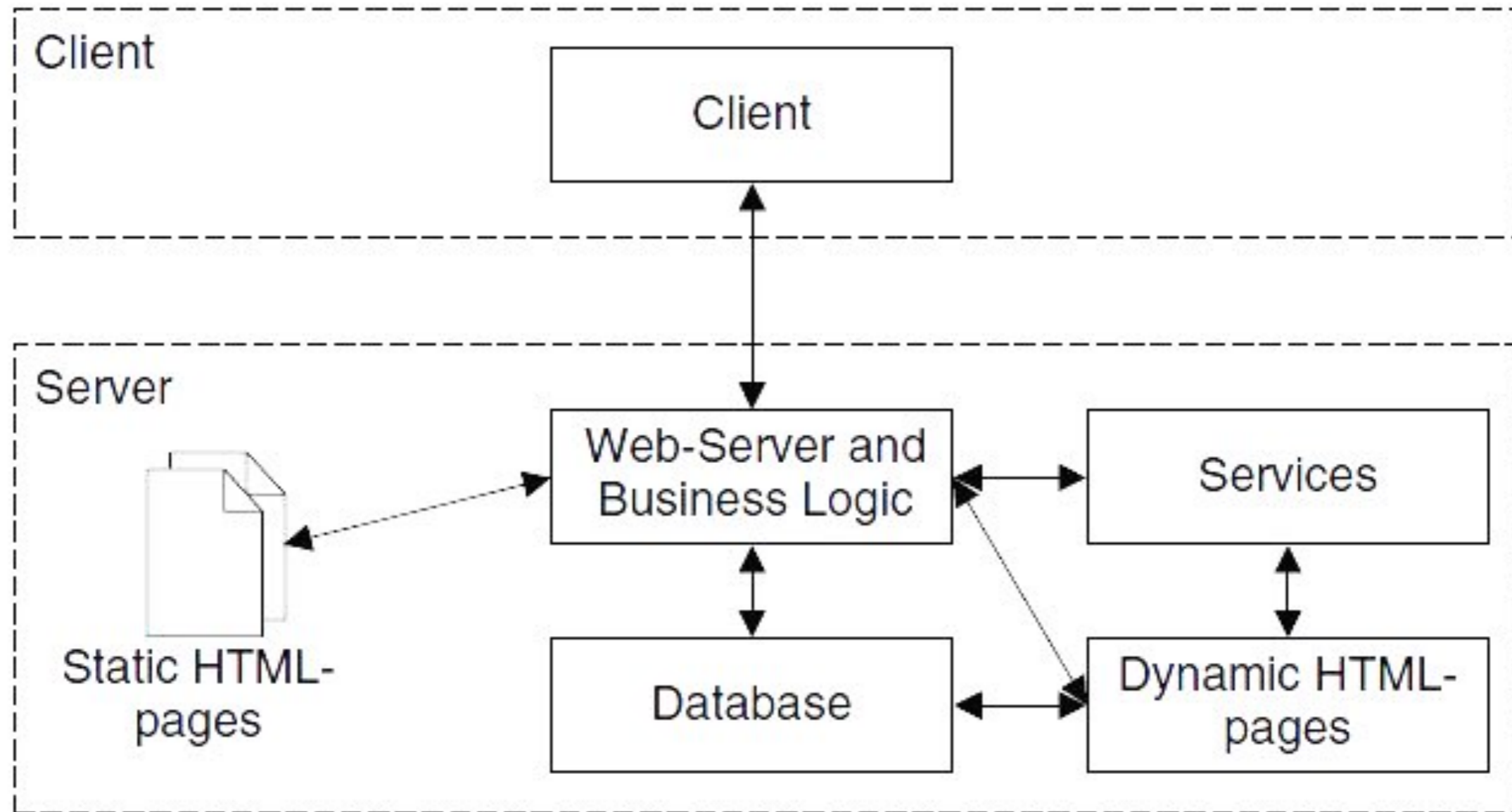
Client-server architecture

Model, view, controller (MVC)

MODEL

UPDATES   MANIPULATES

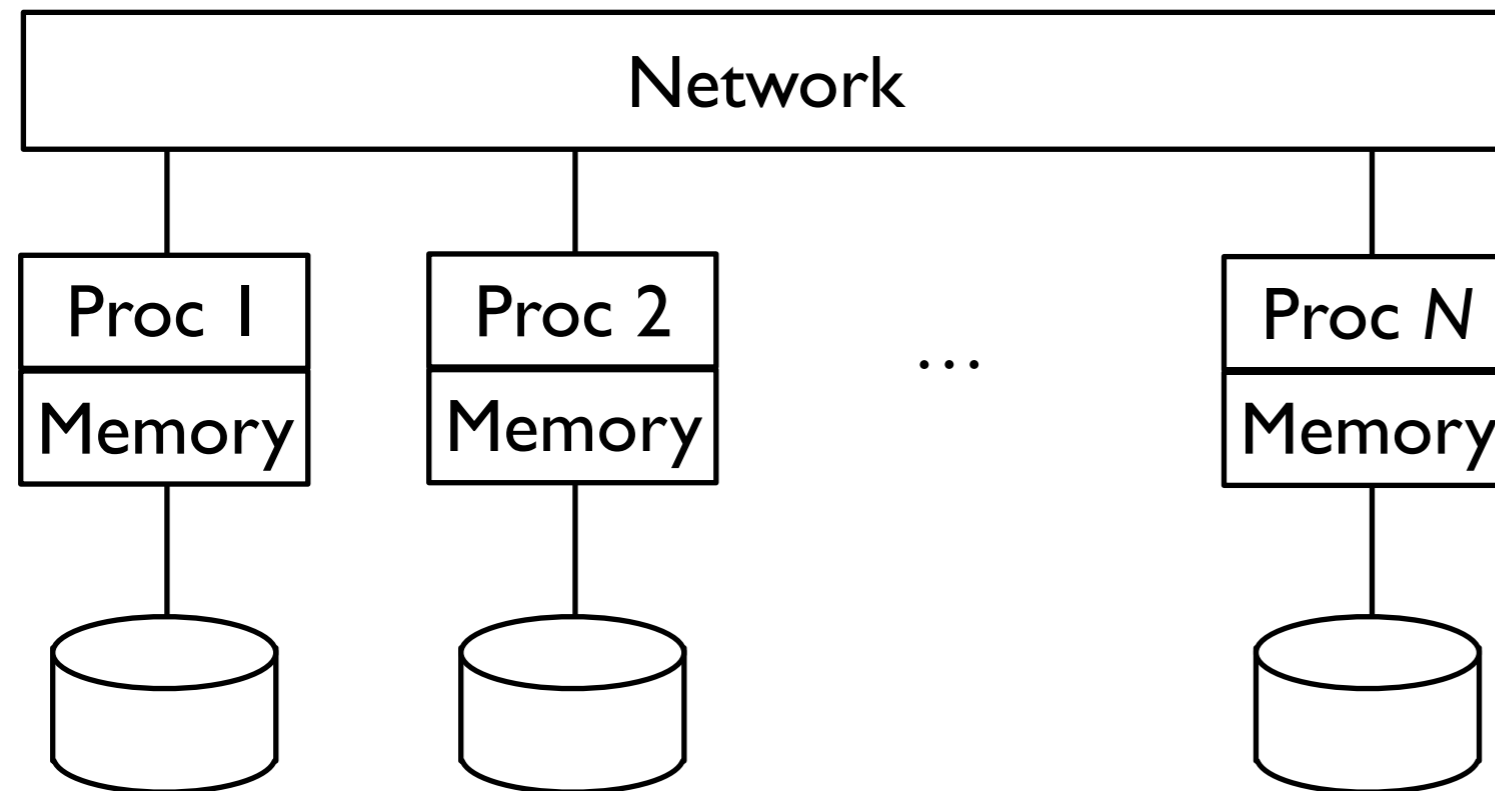VIEW   CONTROLLER

SEES   USES
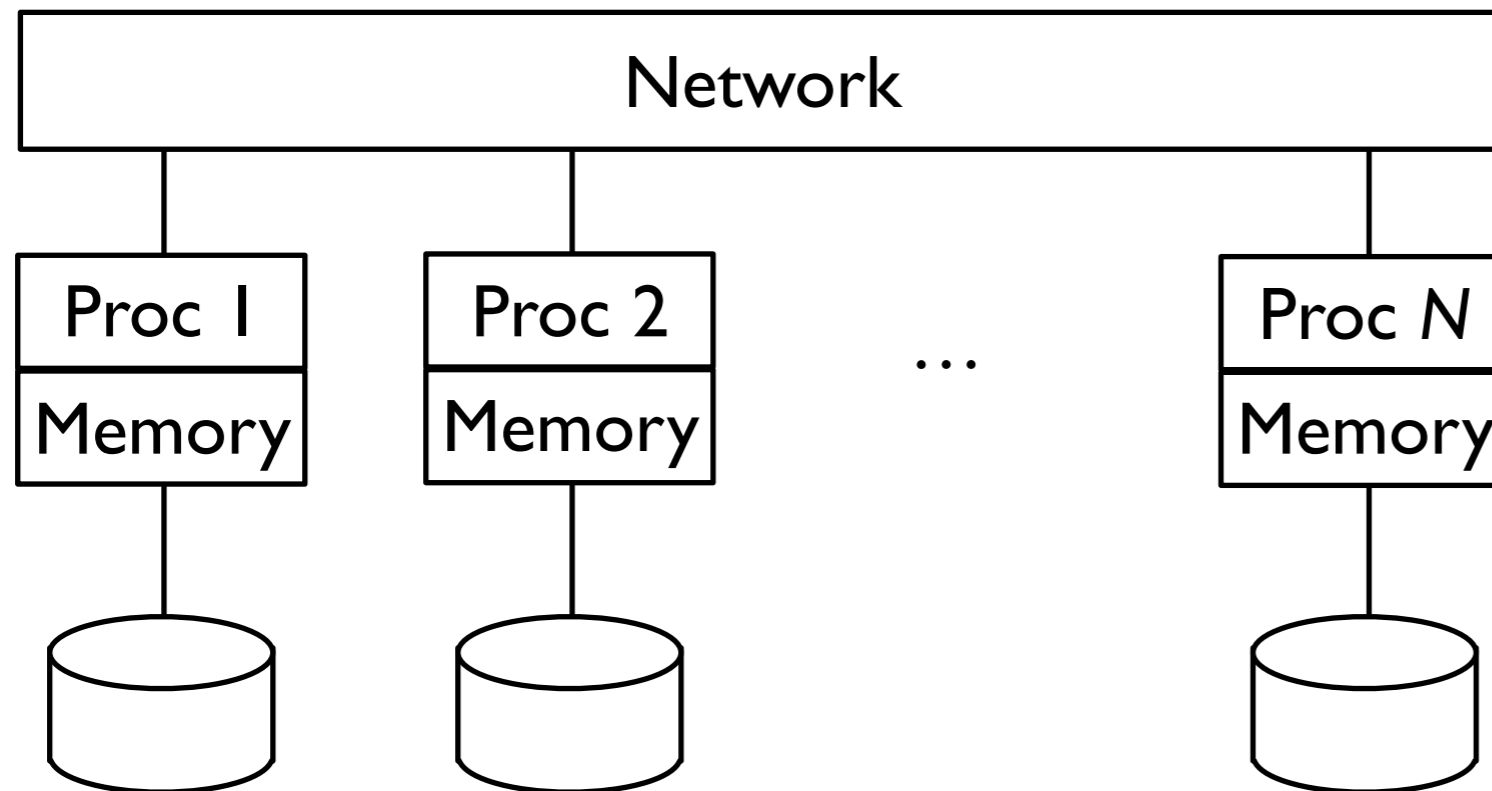
USER

Model, view, controller (MVC)

Separates:

- the application object (model)

- the way it is represented to the user (view)

- the way in which the user controls it (controller)

Shared nothing (SN) architecture

Shared nothing (SN) architecture

Summary

- An architecture provides a high-level framework to build and evolve a software system.

- Strive for modularity: strong cohesion and loose coupling.

- Consider using existing architectural styles or patterns.

© 2007, Robert A. Baron   pix@studiolo.org