System architecture and design

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UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA
High Performance Real Time Lab

Pizza as a Service 2.0

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Tradition On-Premises (legacy)	Infrastructure as a Service (IaaS)	Containers as a Service (CaaS)	Platform as a Service (PaaS)	Function as a Service (FaaS)	Software as a Service (SaaS)
Conversation	Conversation	Conversation	Conversation	Conversation	Conversation
Friends	Friends	Friends	Friends	Friends	Friends
Beer	Beer	Beer	Beer	Beer	Beer
Pizza	Pizza	Pizza	Pizza	Pizza	Pizza
Fire	Fire	Fire	Fire	Fire	Fire
Oven	Oven	Oven	Oven	Oven	Oven
Electric / Gas	Electric / Gas	Electric / Gas	Electric / Gas	Electric / Gas	Electric / Gas
Homemade	Communal Kitchen	Bring Your Own	Takeaway	Restaurant	Party

- Configuration
- Functions
- Scaling...
- Runtime
- OS
- Virtualisation
- Hardware

You Manage

Vendor Manages

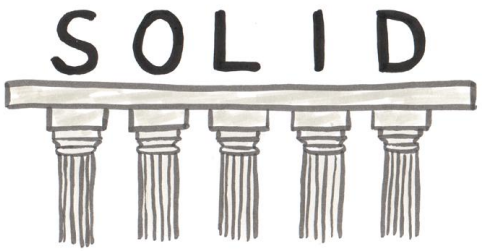
System design

We (finally!!) are going to translate customer specifications

into a set of technological specifications that developers can understand

Output of this step: the system architecture

- Identify a set of modules
- Each module has a single specific functionality (or sub-functionality)
- And we need to describe their interaction with other modules (i.e., their contracts*)



** aka: prototypes, OOP-like interfaces, Web endpoints, C/C++ headers…*

Ingredients

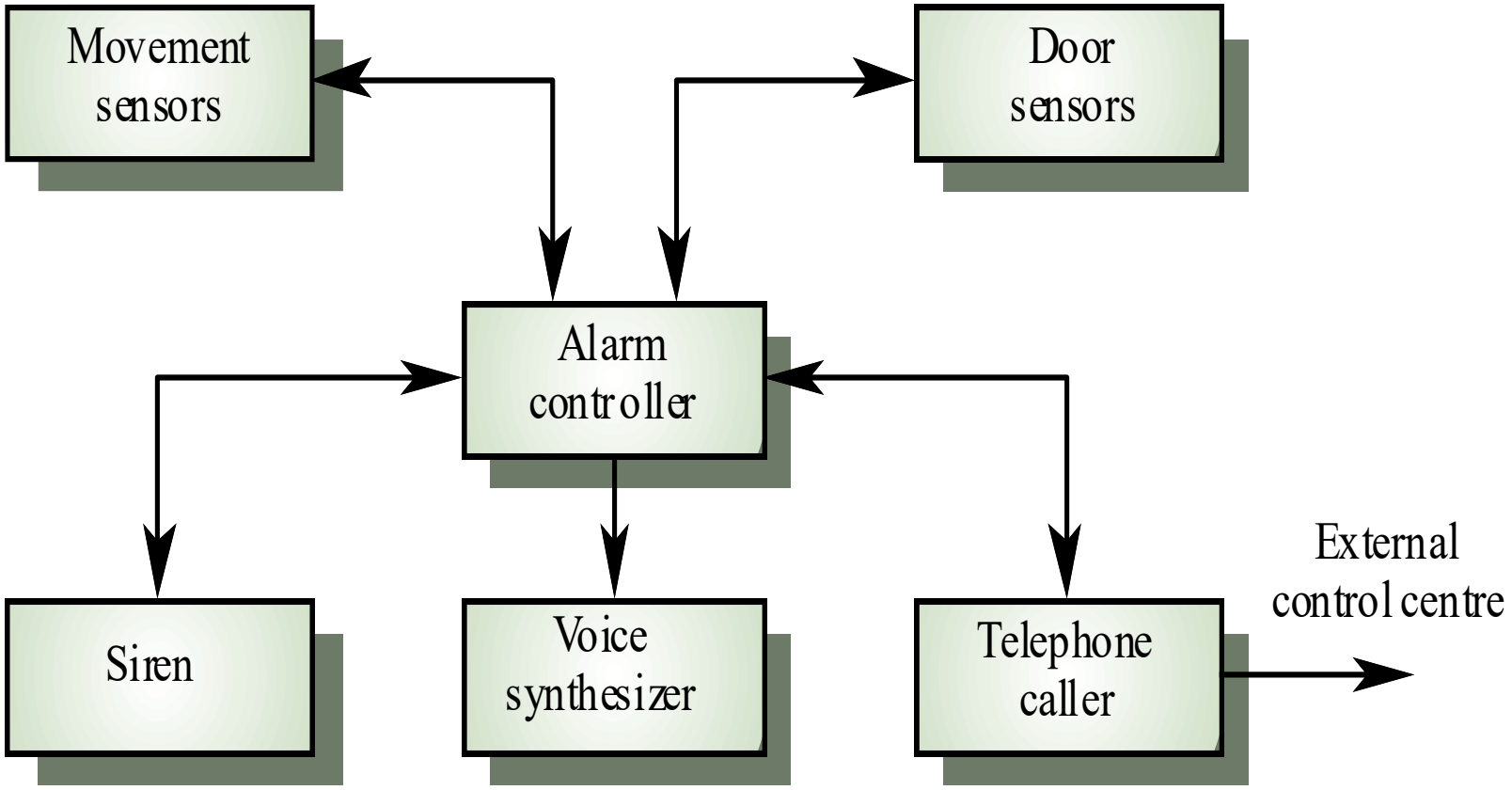
Decomposition

- First into subsystems, that interact among themselves, but that **do not depend among themselves**
- Then into modules and sub-modules, each **providing a specific service** to other (sub)modules
- Then into components, the basic unit of implementation (e.g., Java libraries)

Identification and assignment of Control

- Who does what?
- Identifying active components and passive components
- Where are the threads/processes? ITA: *"Chi ha il pallino"?*

Example: smart home alarm



Exercise

Let's do this for our amazing project!

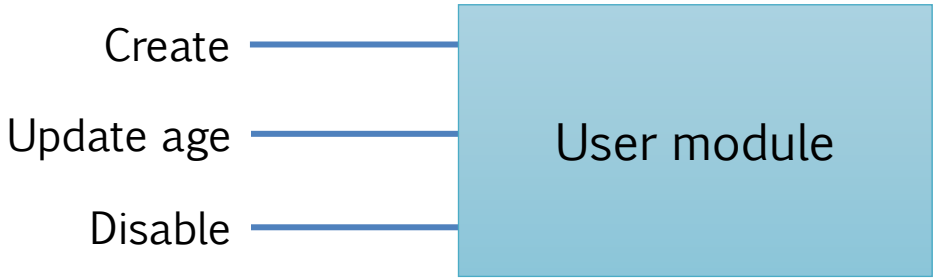
Modules

- …
- ….

Modules

Group functionalities that are in tight relation

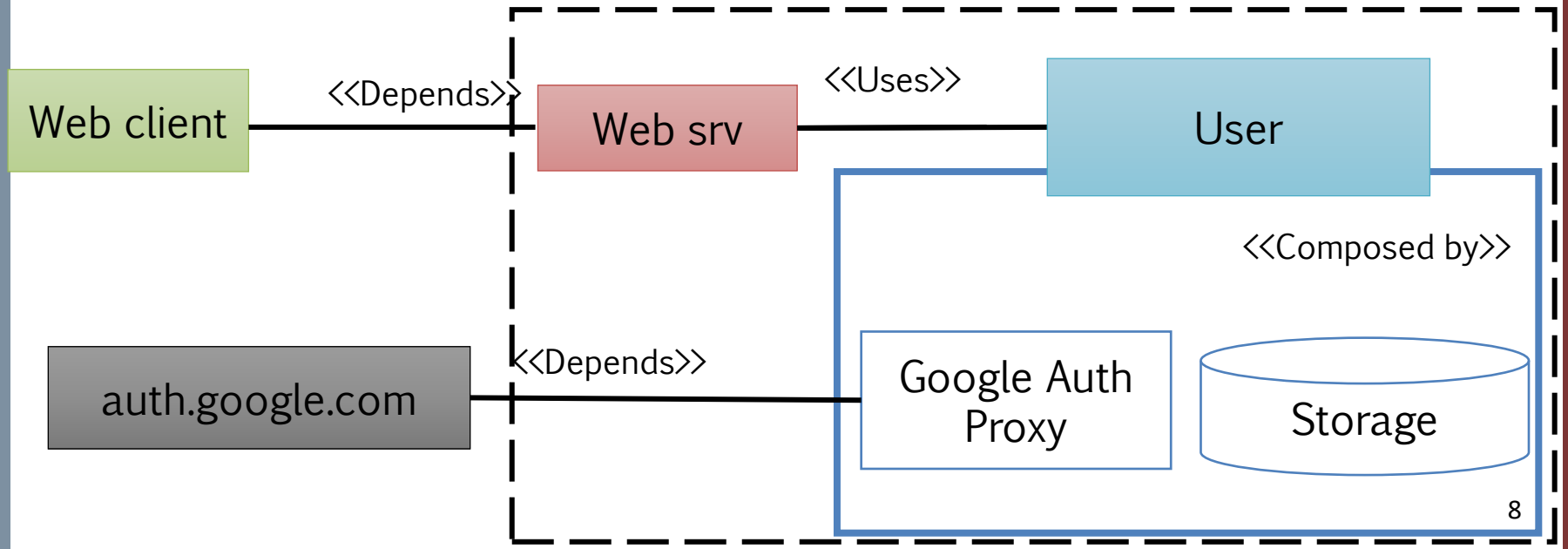
- Ex: everything that relates to user accounts (CRUD), or that reside on the same HW device
- At system design level, we need to clearly identify interfaces toward other modules/the external world
- The, identify the sub-functionalities that each module shall produce



Inter-module relations

Typically

- Modules expose services that are **used** by other modules to complete theirs
- Modules are **composed** by sub-modules (so, we can work at different level of details)
  - *Divide et impera!*
- Modules **depend** on other modules (typically, to adhere/follow a sequence diagram for a specific use-case)



Partitioning strategy

Top-down

- From specs, to services, to modules, to components, etc…
- Streamlined from documentation!

Bottom up

- Data-structure/functionality centric
- Typical if we already have a framework/codebase

Going on with the project, you realize that we mix the two…

Architectural patterns

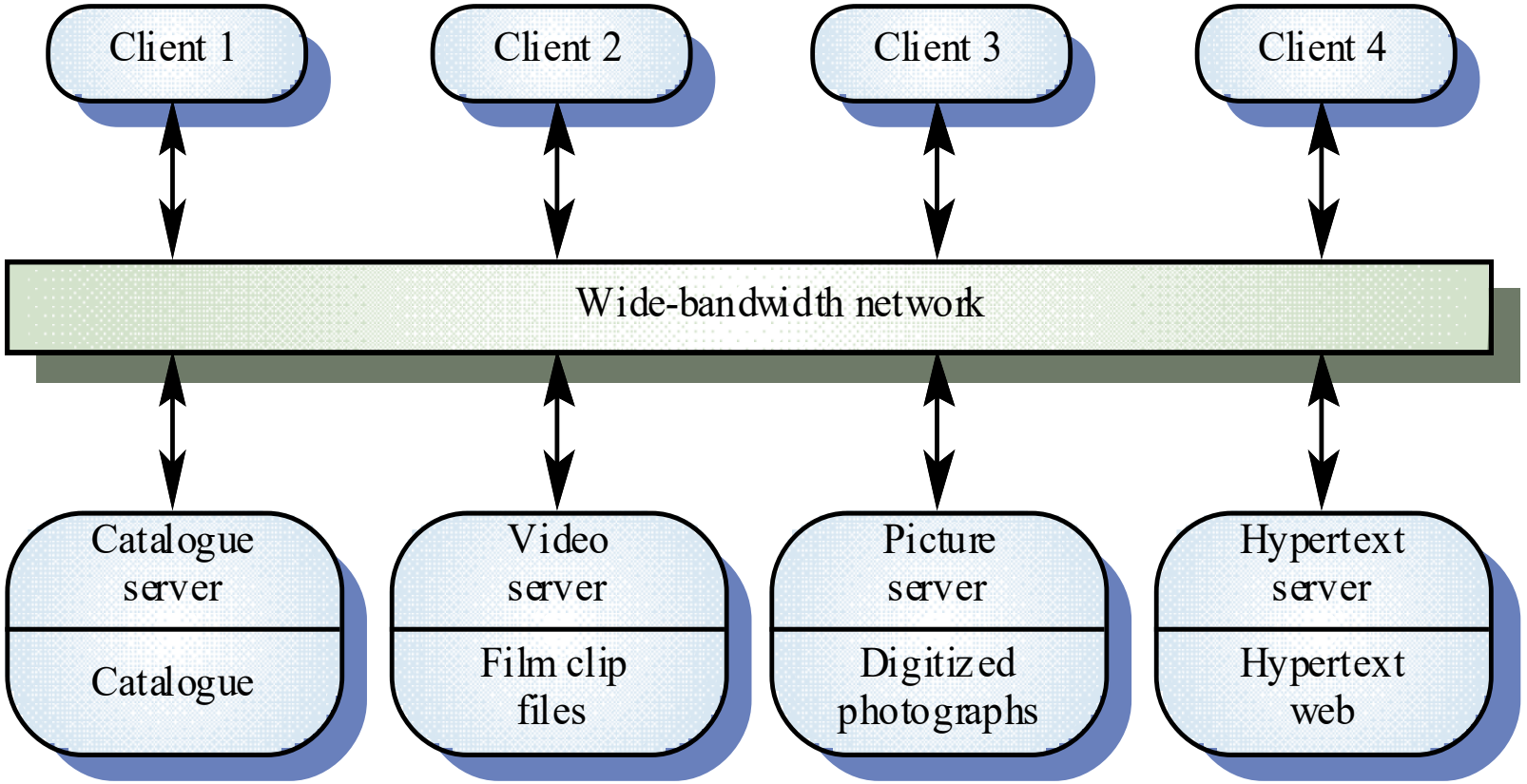
Client-server architecture

Typical of distributed systems, it is composed by

- One or more servers, offering generic services
  - Accounting, storage, customer-specific logics..
- Clients that use those services
  - Web apps, mobile apps…
- A communication network, here assumed as “first class citizen”
  - On 24/7, e.g., such as power provisioning

- Communication is asymmetric, hence based on requests and responses
- Quality-of-Service (QoS) / Service-Level Agreement (SLA) shall be agreed

Example: web services



Why client-server? (and why not?)

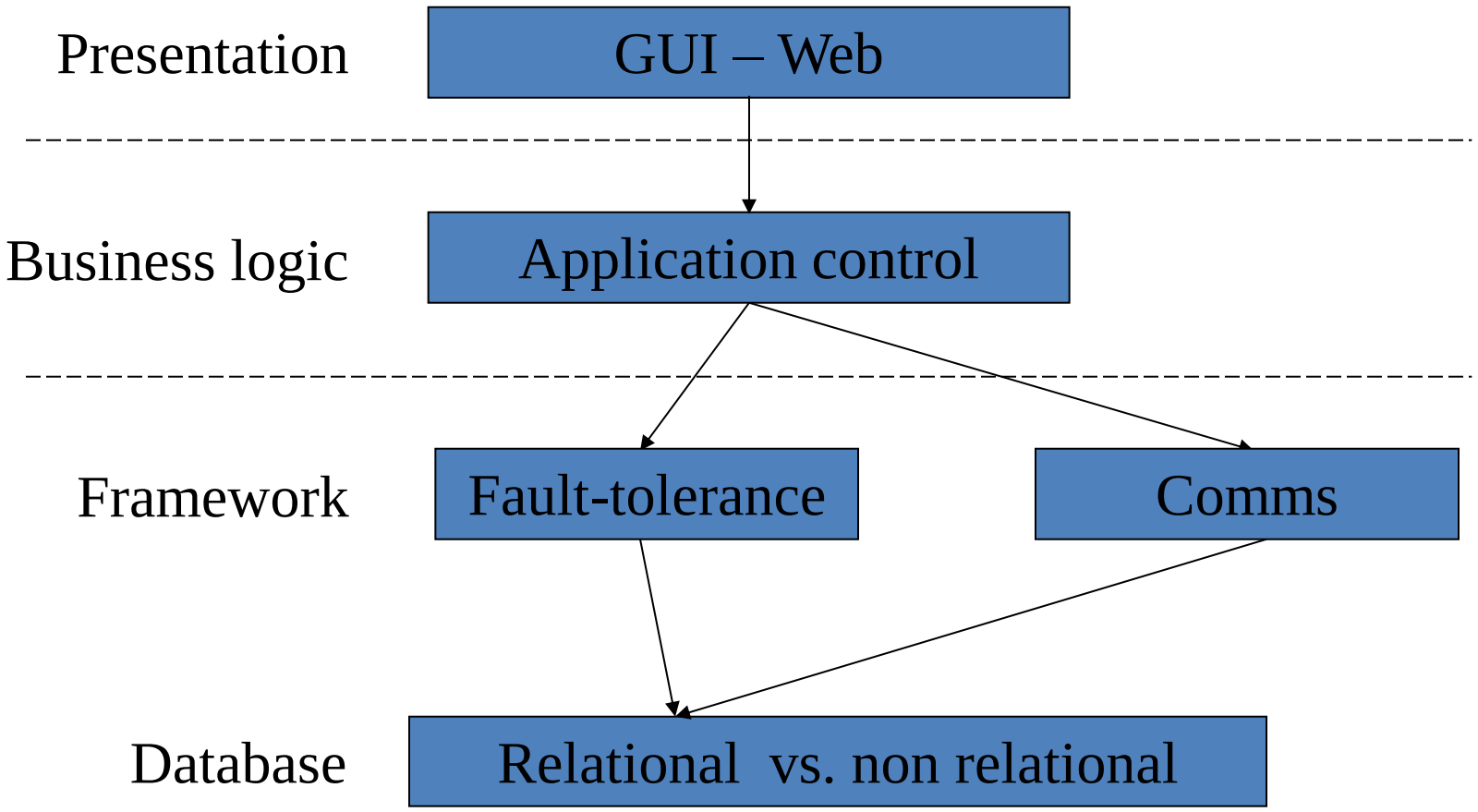
Pros

- It is easy to perform data distribution and responsibilities
- Can scale the number of clients
  - "It is easy to add new clients"
- Can scale the number of servers
  - "It is easy to add new servers"
  - Both horizontally (increasing the nr of machines for a single services) and vertically (increasing their resources)
  - Aka: scale-up and scale-out (speed-up)

Cons

- Typically requires high resources, and can be redundant
- Servers must be known by clients
  - We need a naming service
- We create a dependency!
  - What if we change URLs?

Multi-tier architecture



› Most of scalable systems implement this: Java Enterprise Edition, dotNet, etc...

Design of control

What do we mean by “control”?

Design of control

What do we mean by “control”?

- “Who does what?”
- “Who *runs* the use cases?” vs “Who has the *logic* that implements use-cases”?
- Follow the vertical bar of sequence diagrams

Can be centralized, or de-centralized

- Has strong implications on the system architecture

1. Centralized control (synchronous)

A single system serves all requests (e.g., a web server)

- It depends on other sub-systems
- Typical, when we design the frontend of a web-app (also call *service*)
- Based on synchronous communication (e.g., function calls)

Pros and cons

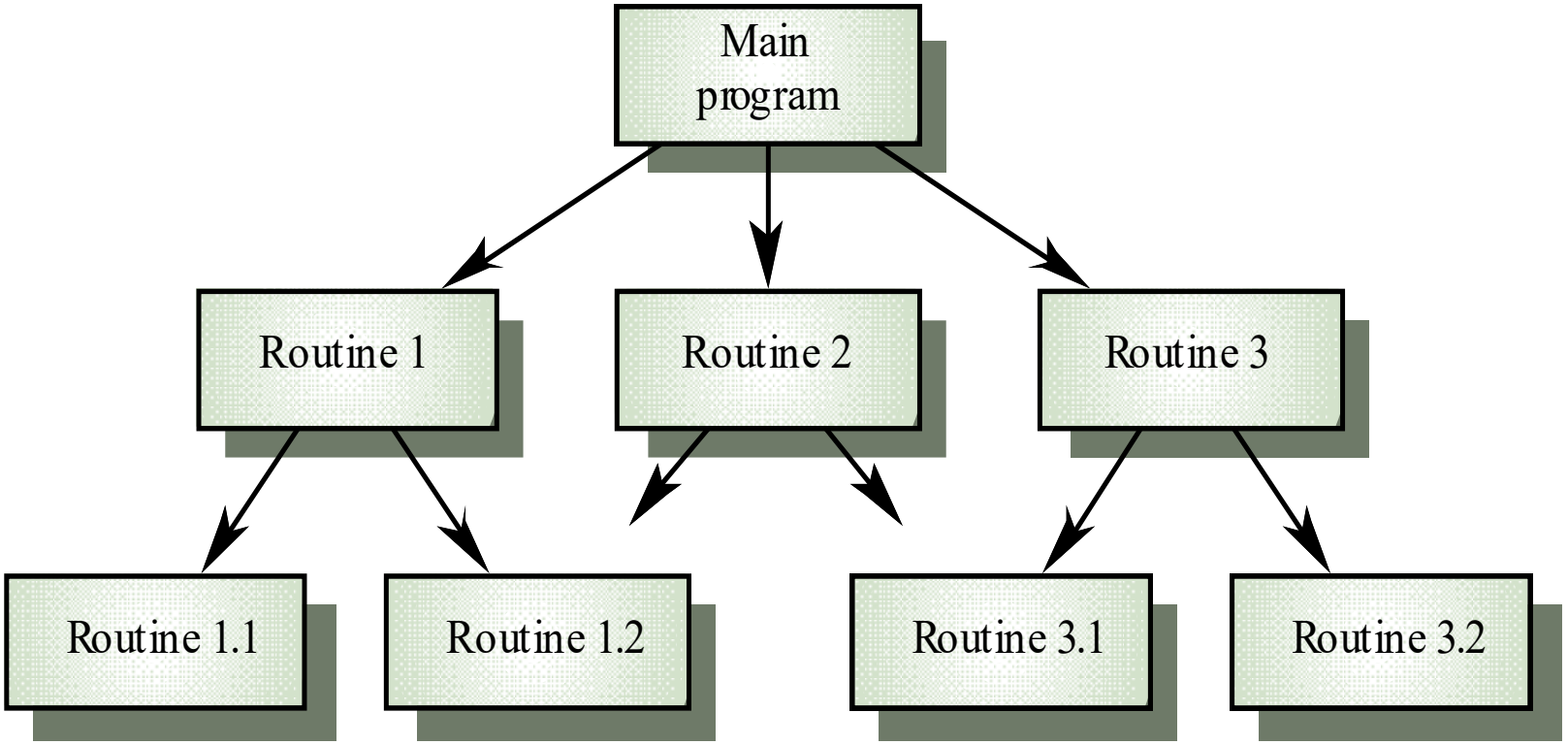
- Single point of access (easy to implement)
- Single point of failure (require thorough design of SLAs)

Noticeable examples

- Request-response in sequential systems
- Master-slave in parallel systems

Synchronous request-response

- Based on function calls
- Do I need to say more? ☺



Parallel execution models

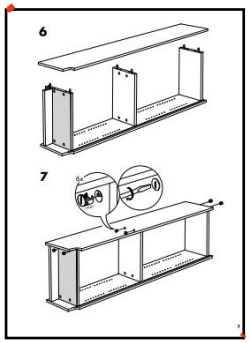
So far, synchronous programming

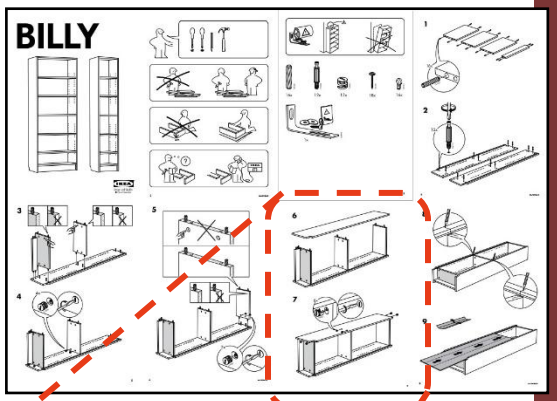
- Based on function calls
- High cohesion/coupling
- Blocking

..but what if we go parallel?

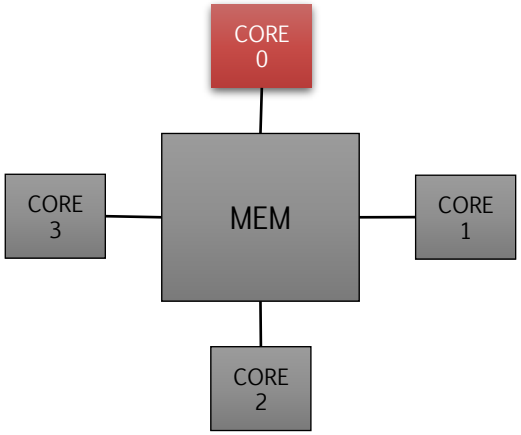
What is...

- ..a core?
  - An electronic circuit to execute instruction (=> programs)
- ...a program?
  - The implementation of an algorithm
- ...a process?
  - A program that is executing
- ...a thread?
  - A unit of execution (of a process)
- ..a task?
  - A unit of work (of a program)

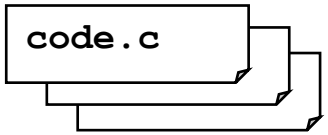




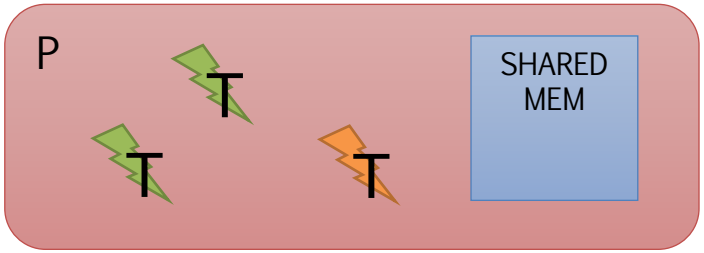
What is...



- ..a core?
  - An electronic circuit to execute instruction (=> programs)
- ...a program?
  - The implementation of an algorithm

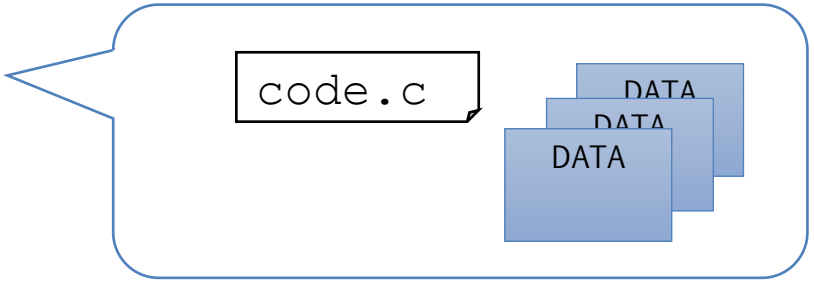


- ...a process?
  - A program that is executing



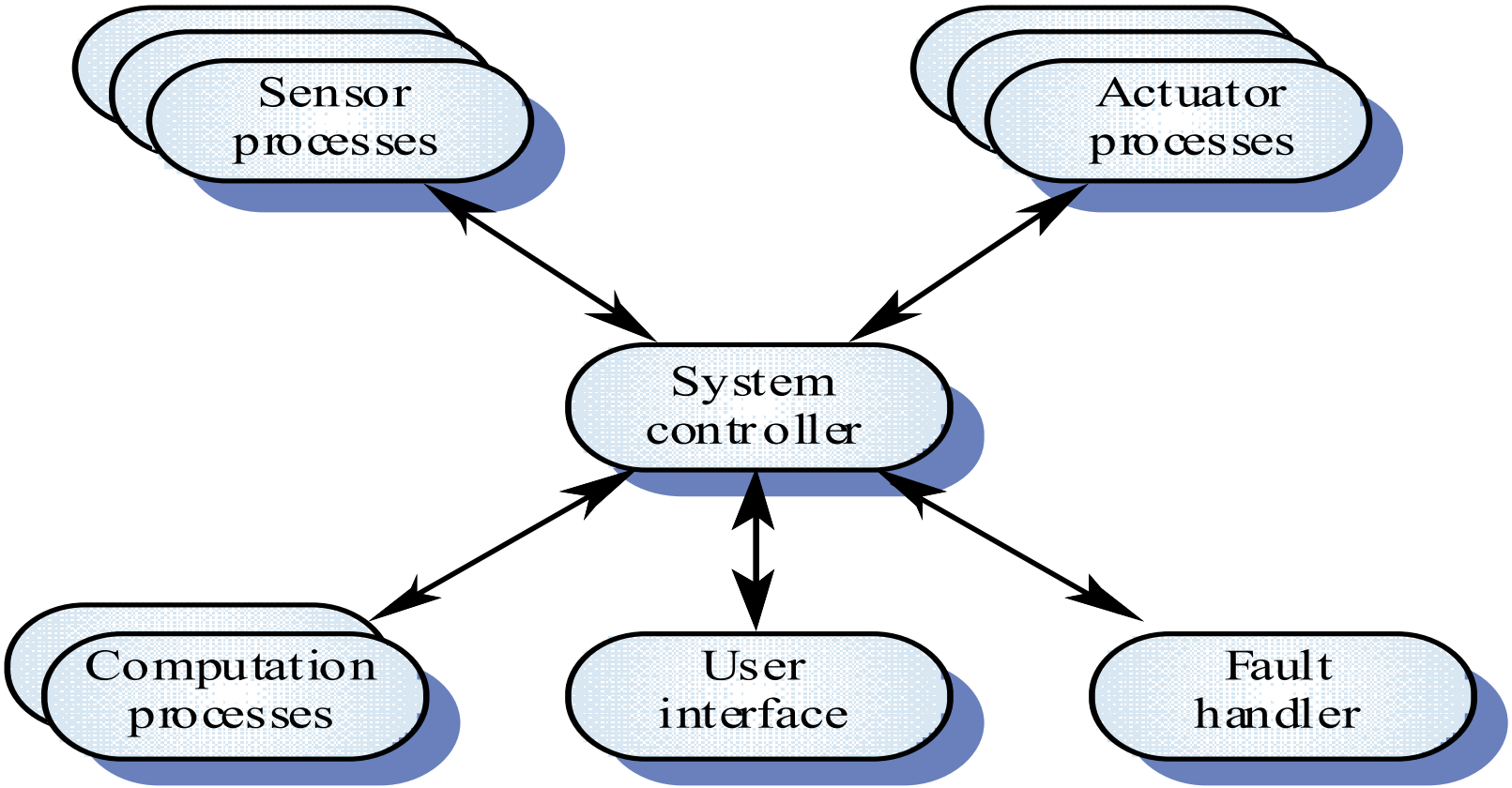
- ...a thread?
  - A unit of execution (of a process)

- ..a task?
  - A unit of work (of a program)



Asynchronous master-slave: multi-process

› Requires inter-process communication: Sockets, MQTT, ROS, etc



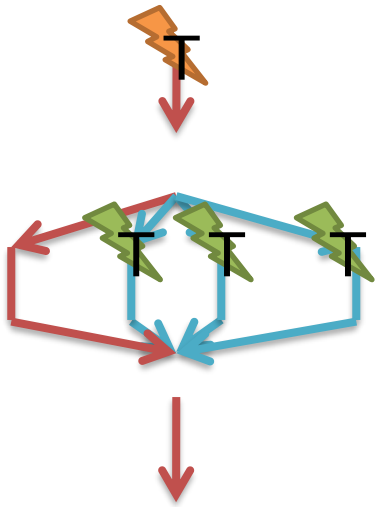
Asynchronous master-slave: multi-thread

- Inter-process model, based on shared memory
- AKA: fork-join
- Es: PThreads,GPUs, etc...

```
int main()
{
  int err;
  pthread_t mythreads[NTHREADS];
  for (int i=0; i<NTHREADS; i++)
    err = pthread_create (&mythreads[i], // ==> FORK
                          &myattr,
                          my_pthread_fn,
                          NULL);
  // Here, the main thread can do other stuff!
  other_fn();

  for (int i=0; i<NTHREADS; i++)
    pthread_join (mythreads[i], &returnvalue); // <== JOIN

}
```



2. Event-based (asynchronous)

Every sub-system module works independently, without knowing the others

› Based on asynchronous communication

Pros and cons

› Distributed system (more complex to implement)

› Loosely-coupled interaction between modules (more robust, removes dependencies)

› *(You might start realizing in informatics, dependencies **are a big problem**)*

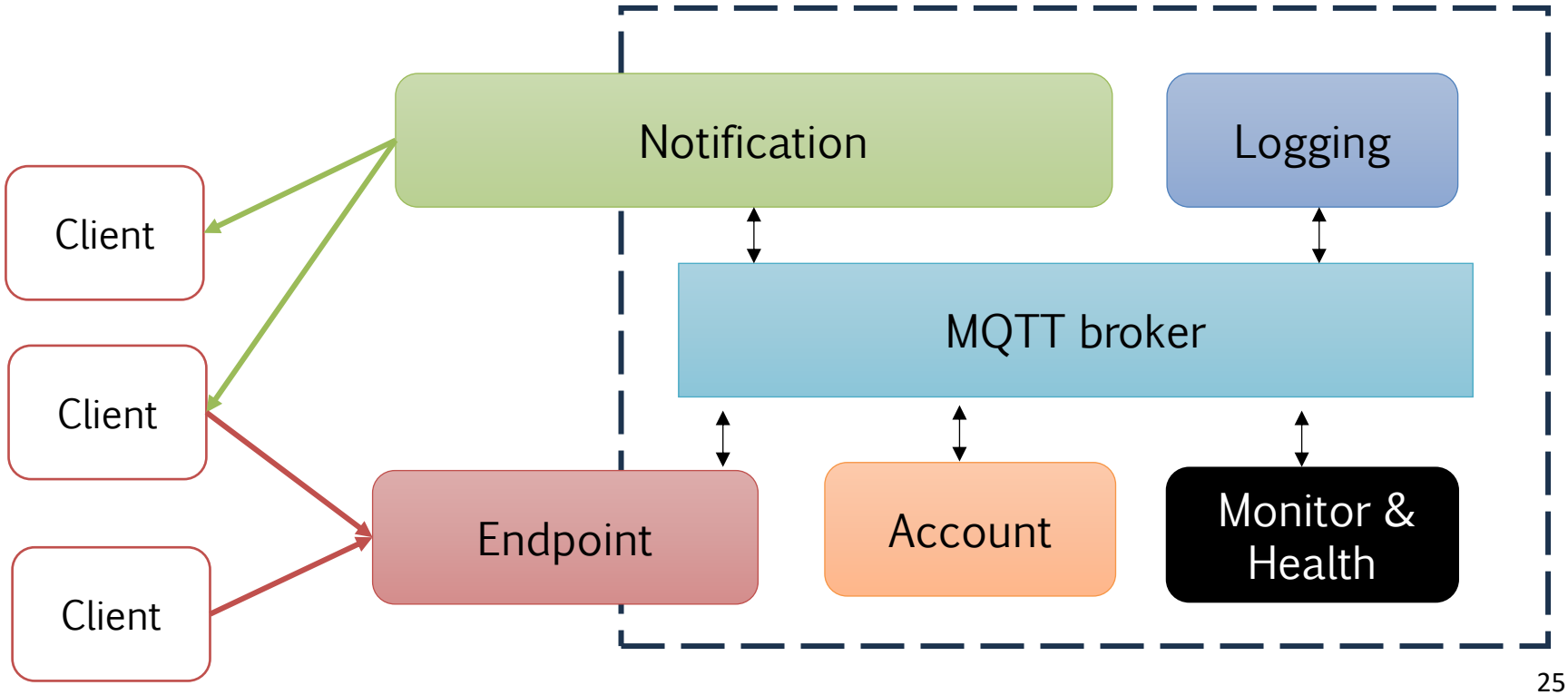
Noticeable examples

› Broadcast models, in highly parallel systems

› Interrupt-based model, inside computers

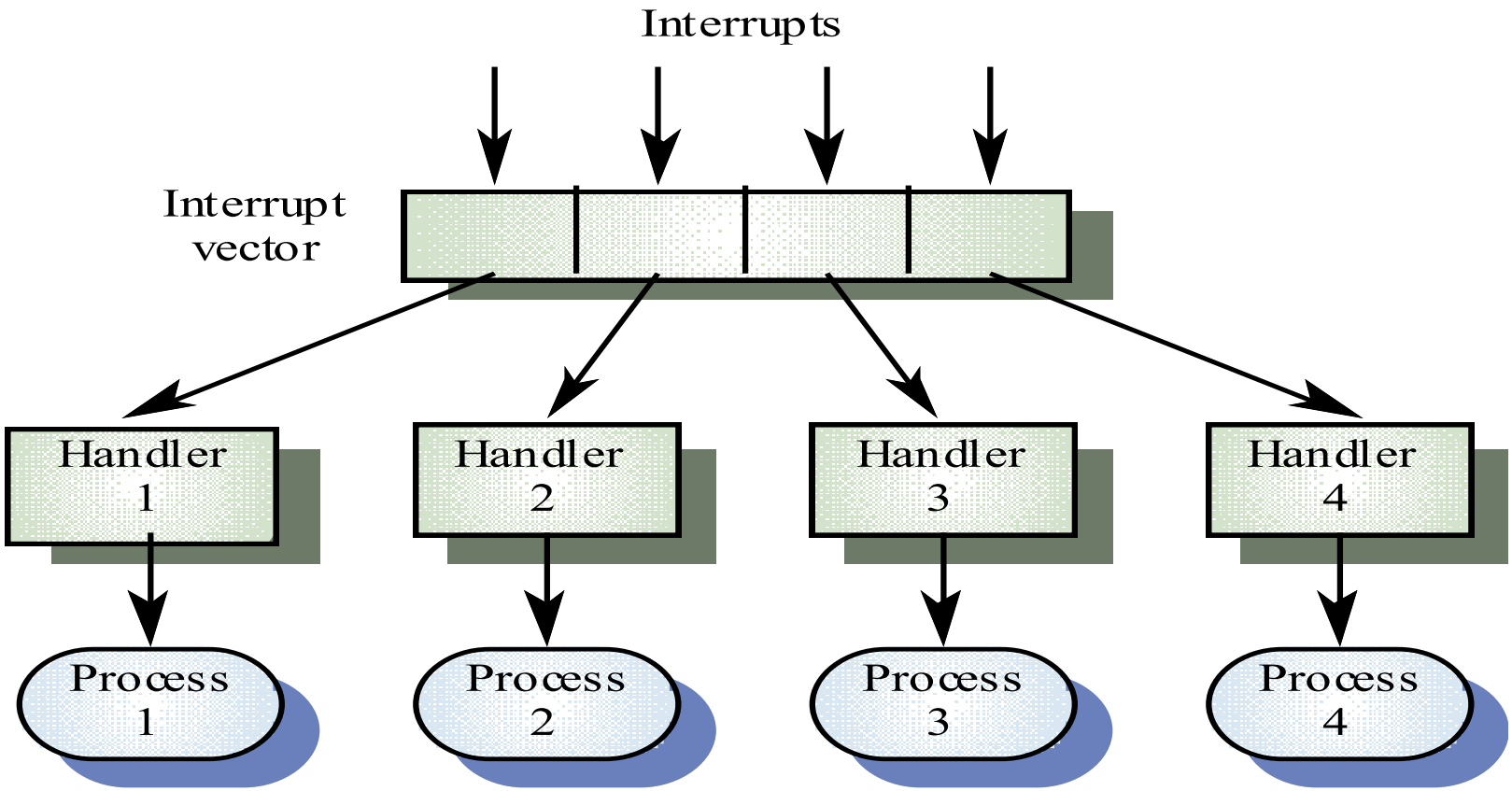
Event-based

- Message broker as first-class citizen (MQTT; COAp)
- Typical for modern micro-service infrastructures
- DMZ with no (major) security issues



(Asynchronous) interrupts

› What happens inside our computers



Bonus pills of computers

- Interrupts: want to know more?

Specifications for the single module

Once we defined the architectural model, let's write specifications for the single module

Basic principles

- Every module shall be as much as possible independent on other modules (*low coupling, loosely-coupled*)
- Minimal inter-module knowledge between developers
- Services that are highly dependant shall belong to the same module (*high cohesion*)
  - E.g., "update age" functionality, and storage of user data

First of all, defining the contract/interface towards other modules!

Module contract

- I don't use the word "interface" because it might be misleading..but it's actually an interface!

We must clearly define (possibly in UML)

- Which functionalities are we exposing?
  - "Update age", "Delete user"
- How do we expose them?
  - Functions to invoke? Services to call?
- Input-output parameters
  - Number of parameters, their types..

UML provides the same notations both for the analysis phase and for the design & implementation phase (remember the "different level of abstraction" thing?)

...so...

Let's talk about coding!

Model
View
Control

Aka: il papà di tutti…

MVC – Model View Control

Partitioning strategy for software components/modules

- Model – represents the status of the application
  - How we represent the world, how we store it, how we communicate it (Data Transfer Objects)
- View – how we show the Model
  - Basically, the user interfaces
- Control – application logics, how we modify the model
  - Directly inherited by behavioral diagrams

As a general rule, Model, View and Control **must** be (at least) in separate files!

- Often, in separate packages/components/libraries

Example: MVC in Java EE

Model

- We store the status of our model in components implemented in **JavaBeans**
- Eases deployment/mapping of these data into Databases, files, session objects, DTOs, …

Three simple rules. JavaBeans classes:

- Must implement `java.io.Serializable`
- Should have a public constructor with no-args
- Properties/fields must be private, and have public getters and setters methods

Example: MVC in Java EE

```
public class Person implements java.io.Serializable {
  private int id;
  private String name;

  // Ctor
  public Person() {}

  // Setter for Id
  public void setId(int id) { this.id = id; }

  // Getter for Id
  public int getId() { return id; }

  // Setter for Name
  public void setName(String name) { this.name = name; }

  // Getter for Name
  public String getName() { return name; }

}
```

Example: MVC in Java EE

View

- In JEE, we use Java Server Pages (JSPs), which directly access our model
- Here, we use the `oracle.jsp.dbutil.ConnBean` to access to a DB

```
<%@ page import="java.sql.*, oracle.jsp.dbutil.*" %>

<jsp:useBean id="cbean" class="oracle.jsp.dbutil.ConnBean"
scope="session">
  <jsp:setProperty name="cbean" property="dataSource"
     value="<%=request.getParameter("myRecord")%>"/>
</jsp:useBean>

<% try {
  cbean.connect();
  String sql="SELECT ename, sal FROM scott.emp ORDER BY ename"
  CursorBean cb = cbean.getCursorBean (CursorBean.PREP_STMT, sql);
  System.out.println(cb.getResultAsHTMLTable());
  cb.close(); cbean.close();
} catch (SQLException e) {
  //...
}
%>
```

Example: MVC in Java EE

Controller

› JSPs or Servlets as JSP backends (aka: Code Behind)

```
@WebServlet(name = "MyServlet", urlPatterns = "/my-record")
public class MyServlet extends HttpServlet {
  // MyWervice holds the model
  private MyService myService = new MyService();

  @Override
  protected void doPost(HttpServletRequest request,
            HttpServletResponse response) throws ServletException {

    String myID = request.getParameter("id");
    // Get the object by underlying logics...
    MyService.get(Integer.parseInt(myID))
      .ifPresent(s -> request.setAttribute("myRecord", s));

    // .. and forward it to the JSP
    RequestDispatcher dispatcher =
      request.getRequestDispatcher("/WEB-INF/jsp/my-record.jsp");
    dispatcher.forward(request, response);
  }
}
```

Integrating MVC parts

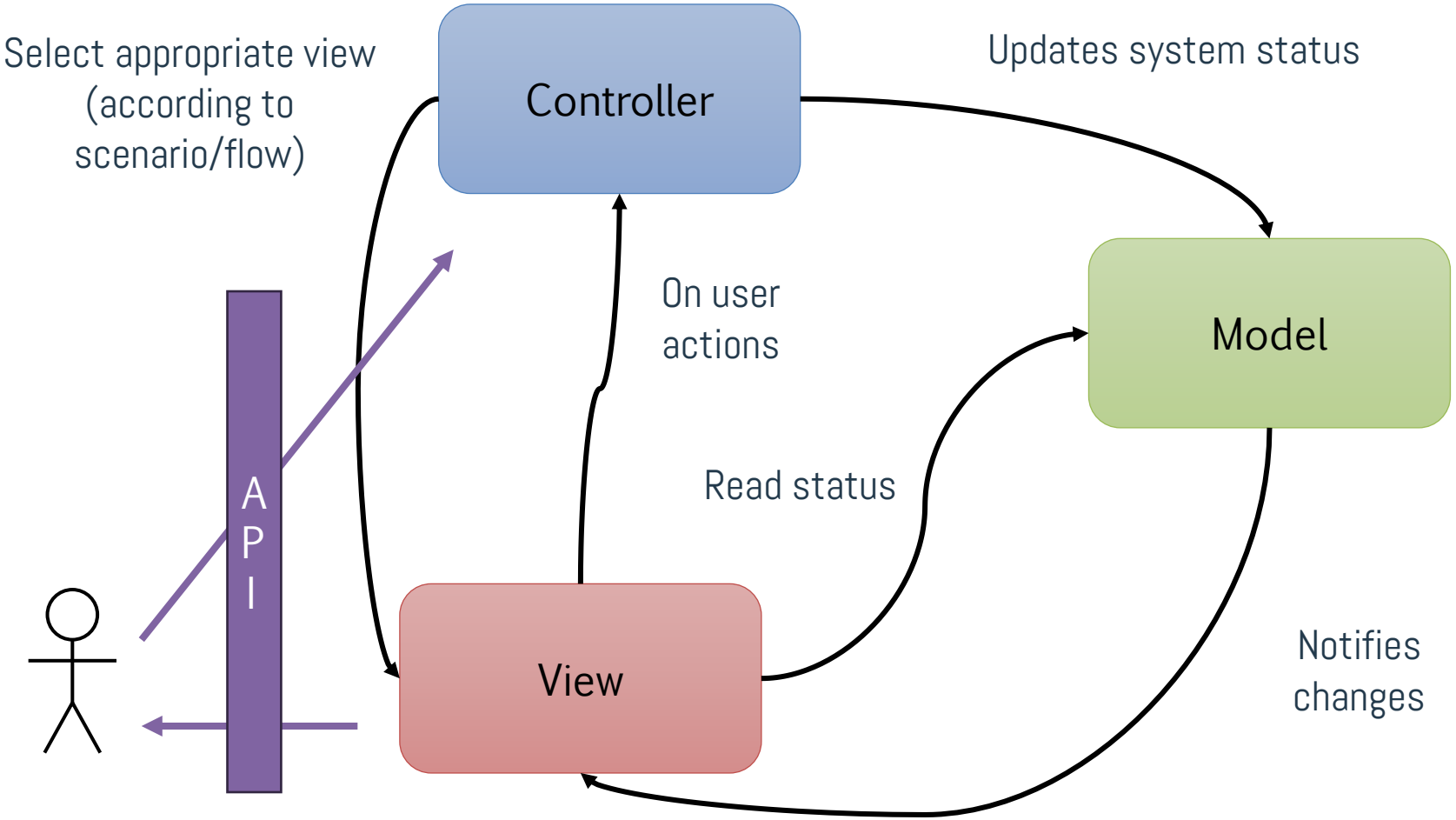
View accesses to Model with getters

Control modifies Model with setters, and accesses it with getters

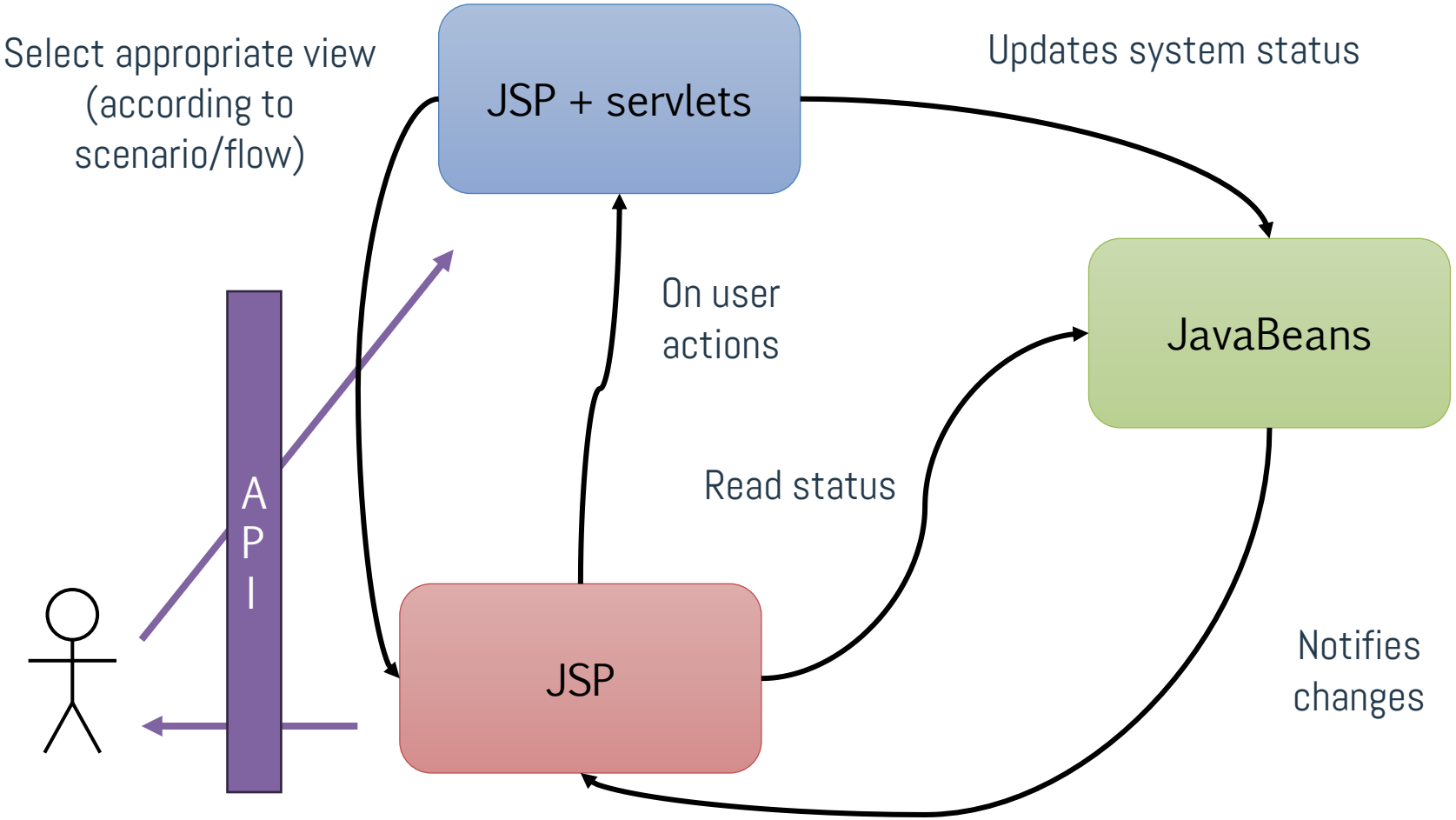
View and Control are decoupled

- Control stands as code-behind of a View
- It injects (processed) data into it
- And triggers modification to Model, as response to user interaction

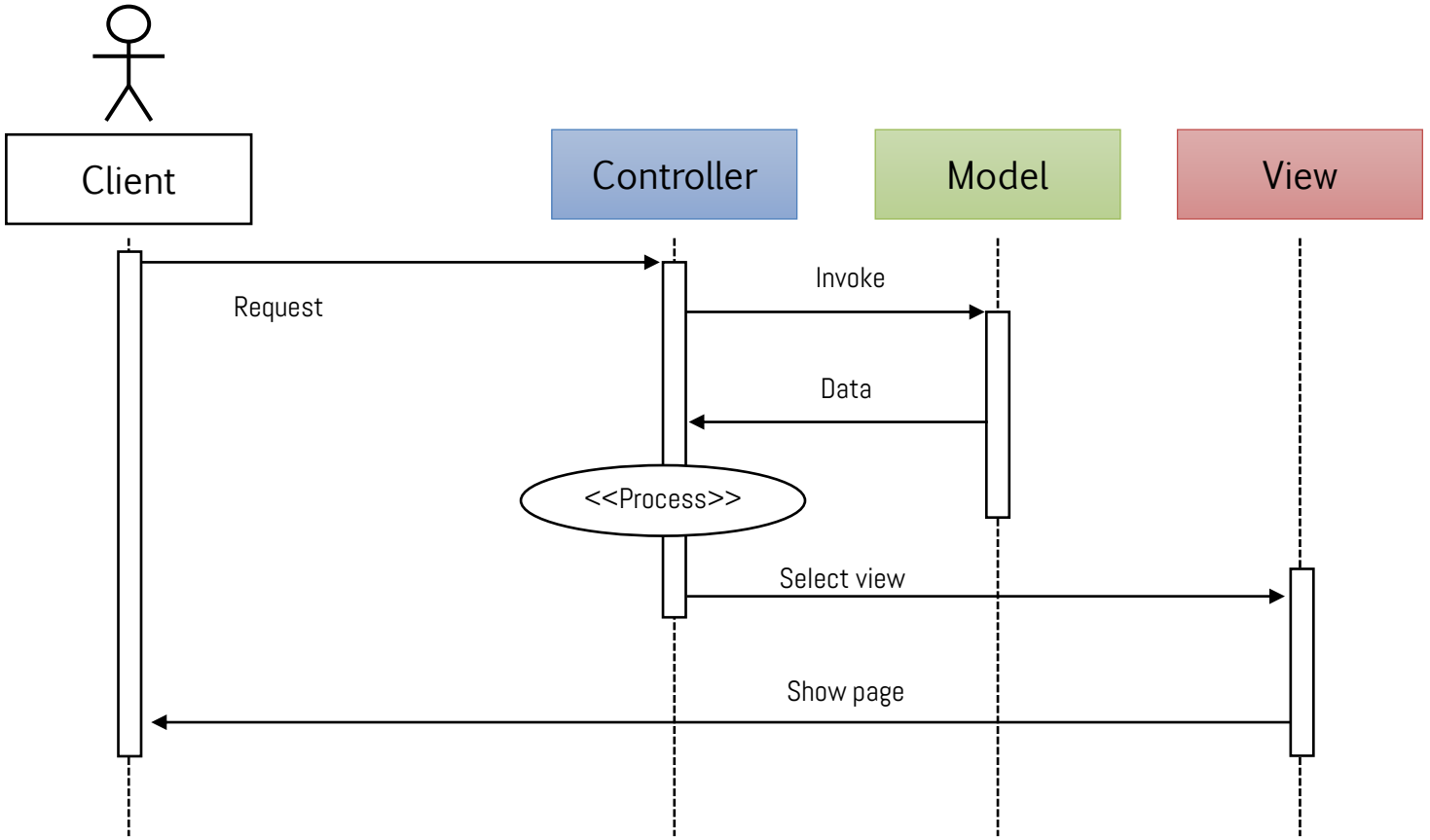
Integrating MVC parts



Integrating MVC parts - JEE



MVC sequence diagram



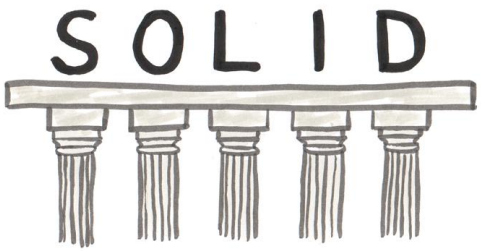
Why MVC?

Pros

- Isolation between component improves modularity and reusability
- E.g., we can switch from JSP/Web view to a mobile app, written using another technology

Cons

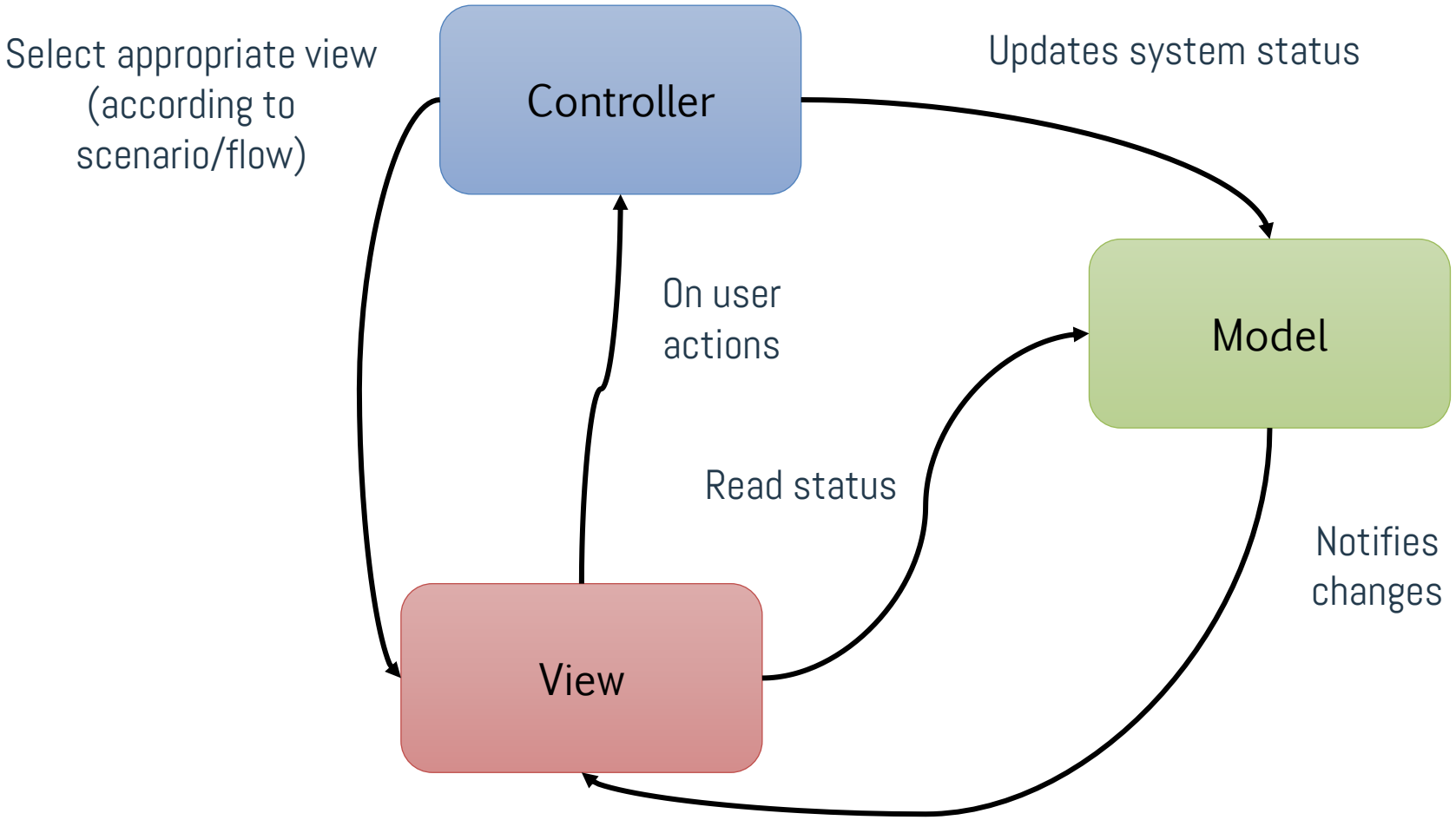
- Architecture is more complex, with more files and components
- But this is not too much of a problem, as we will see..



Model
View
ViewModel

Aka: il figliol prodigo

..but we can do better!



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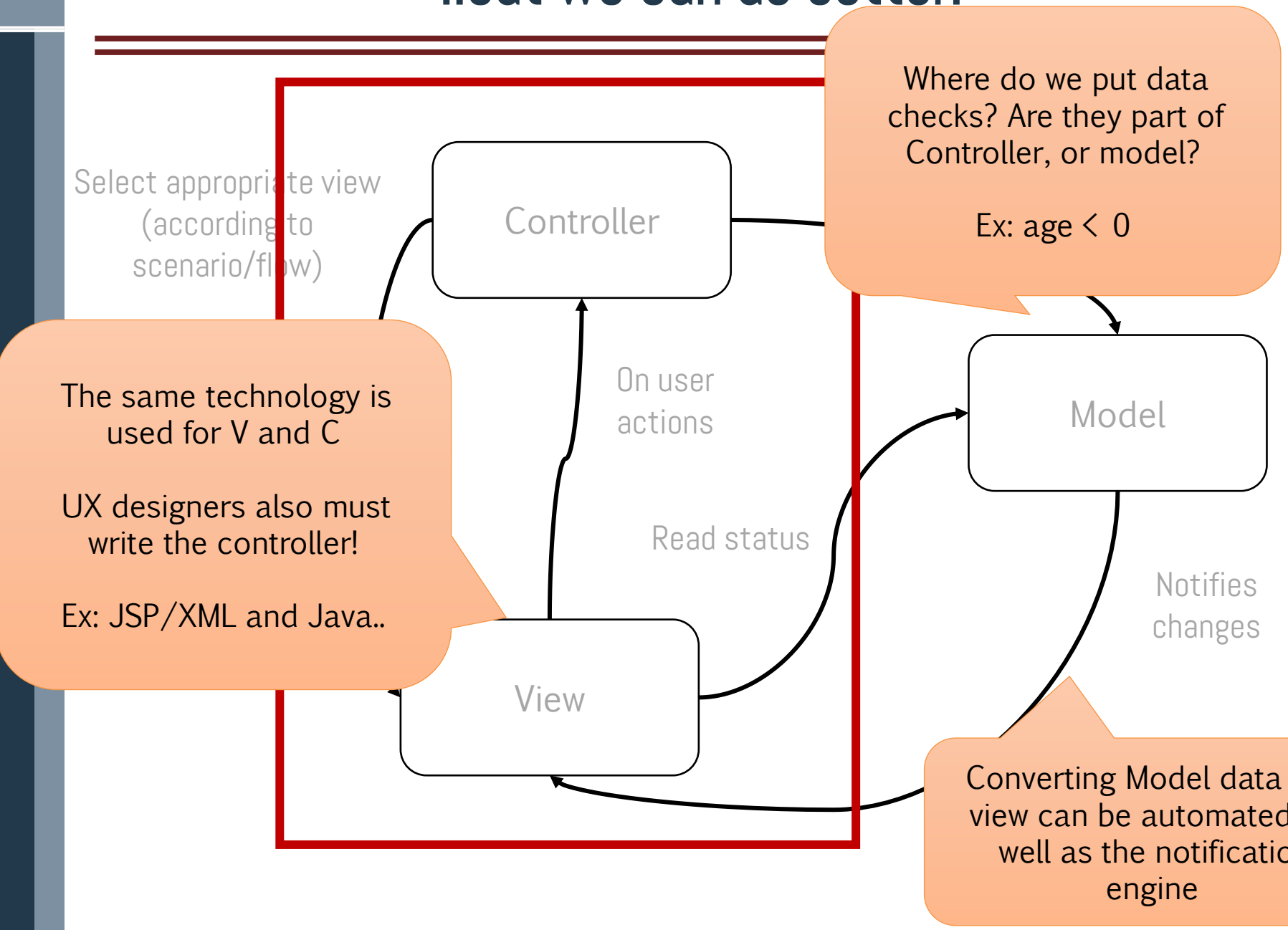
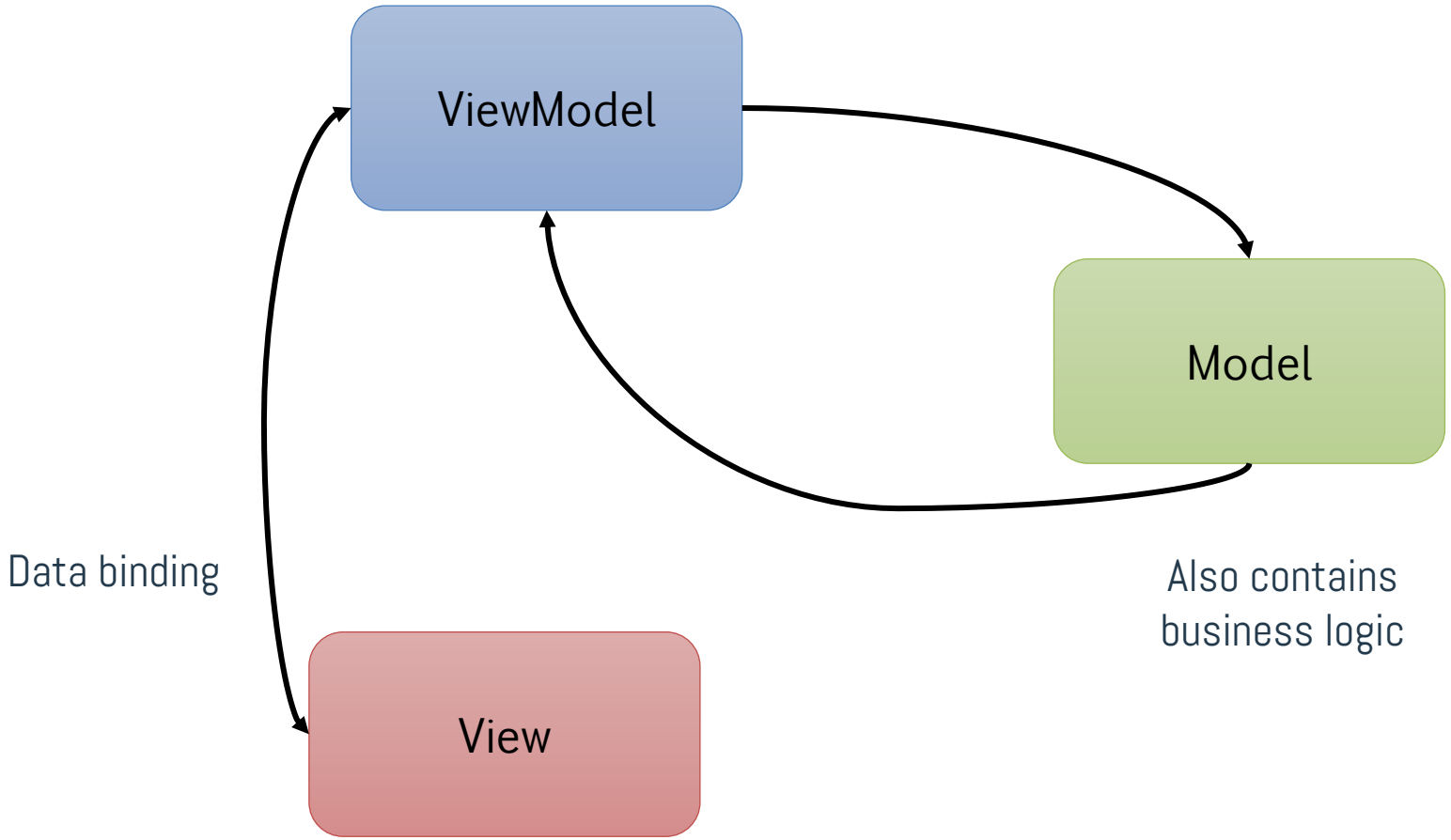
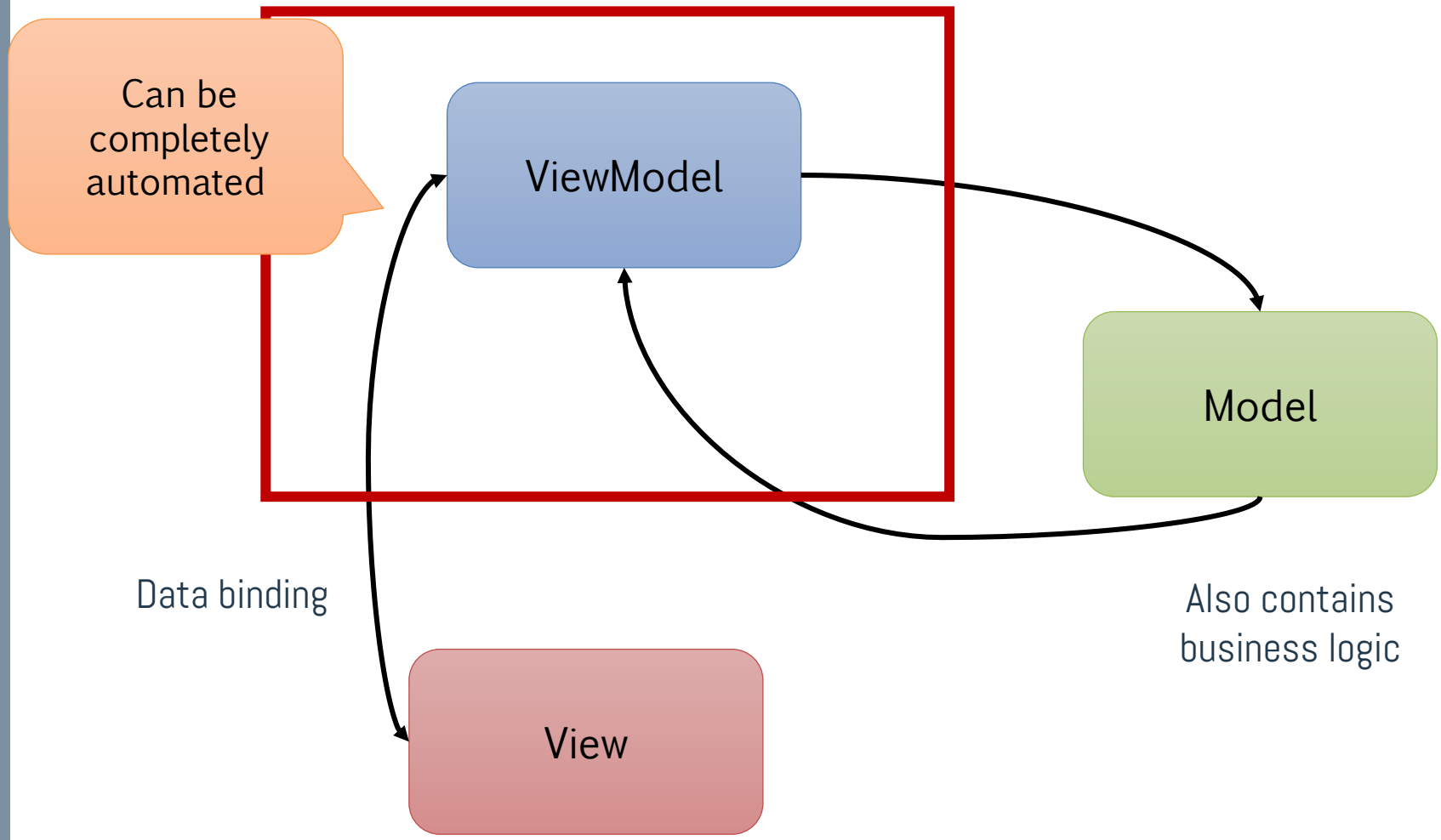


MVVM structure

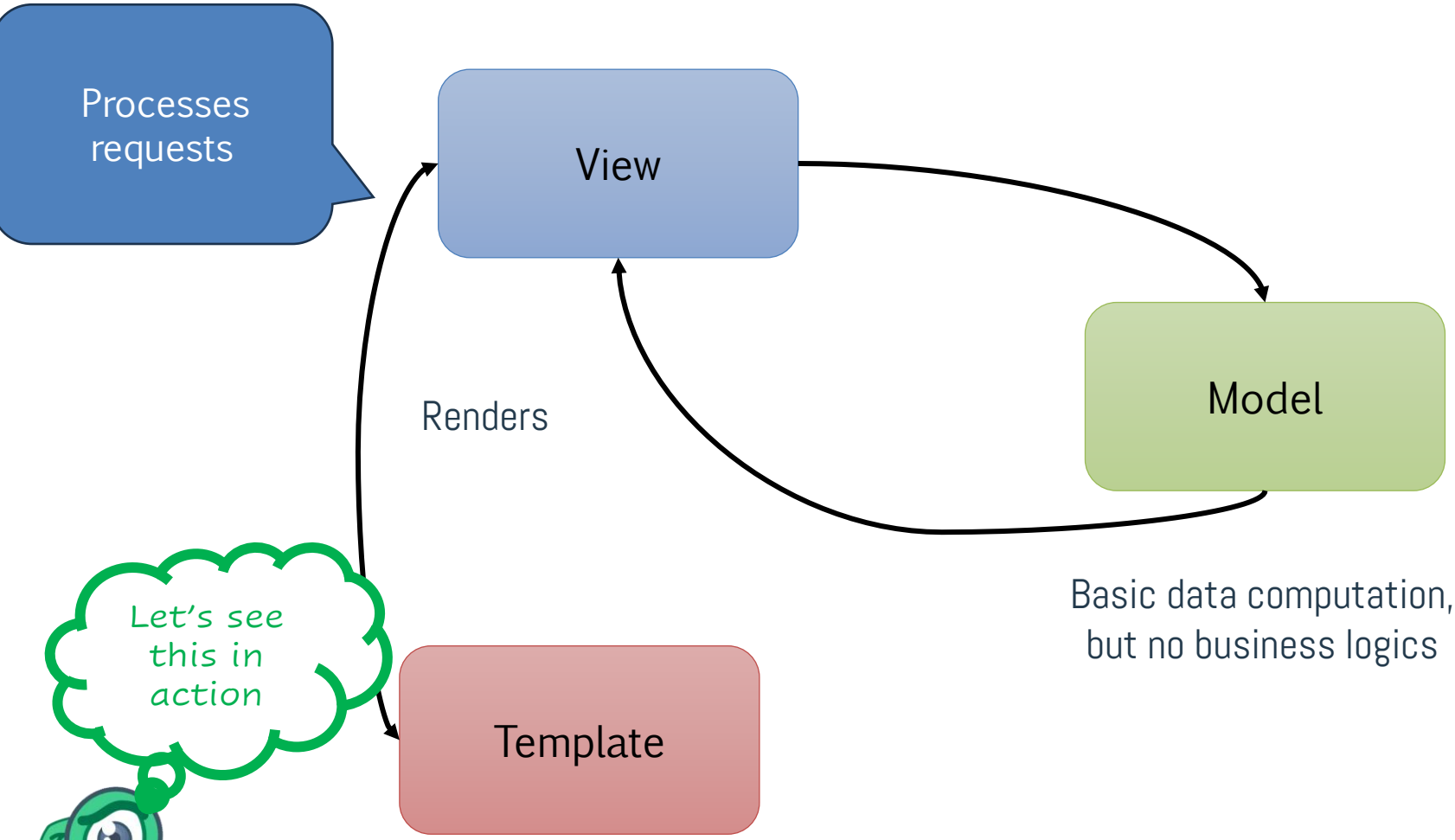


MVVM structure



BY MICROSOFT

MVT structure - Djanbo



References

Course website

- http://hipert.unimore.it/people/paolob/pub/ProgSW/index.html

Book

- I. Sommerville, "Introduzione all ingegneria del software moderna", Pearson
  - Chapter 3
- For MVVM - https://learn.microsoft.com/en-gb/archive/blogs/johngossman/advantages-and-disadvantages-of-m-v-vm
- Any book that teaches SOLID principles

My contacts

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