

System architecture and design

Paolo Burgio
paolo.burgio@unimore.it



UNIMORE
UNIVERSITÀ DEGLI STUDI DI
MODENA E REGGIO EMILIA

High Performance
Real Time **Lab**



Pizza as a Service 2.0

<http://www.paulkerrison.co.uk>

Tradition
On-Premises
(legacy)

Conversation

Friends

Beer

Pizza

Fire

Oven

Electric / Gas

Homemade

Infrastructure as a
Service
(IaaS)

Conversation

Friends

Beer

Pizza

Fire

Oven

Electric / Gas

Communal
Kitchen

Containers as a
Service
(CaaS)

Conversation

Friends

Beer

Pizza

Fire

Oven

Electric / Gas

Bring Your Own

Platform as a
Service
(PaaS)

Conversation

Friends

Beer

Pizza

Fire

Oven

Electric / Gas

Takeaway

Function as a
Service
(FaaS)

Conversation

Friends

Beer

Pizza

Fire

Oven

Electric / Gas

Restaurant

Software as a
Service
(SaaS)

Conversation

Friends

Beer

Pizza

Fire

Oven

Electric / Gas

Party



You Manage



Vendor Manages

Configuration

Functions

Scaling...

Runtime

OS

Virtualisation

Hardware

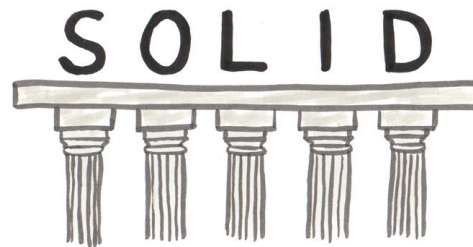


System design

We (finally!!) are going to translate customer specifications into a set of technological specifications that developers can understand

Output of this step: the a 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 modules
- › Then into components, the basic unit of implementation (e.g., Java libraries)

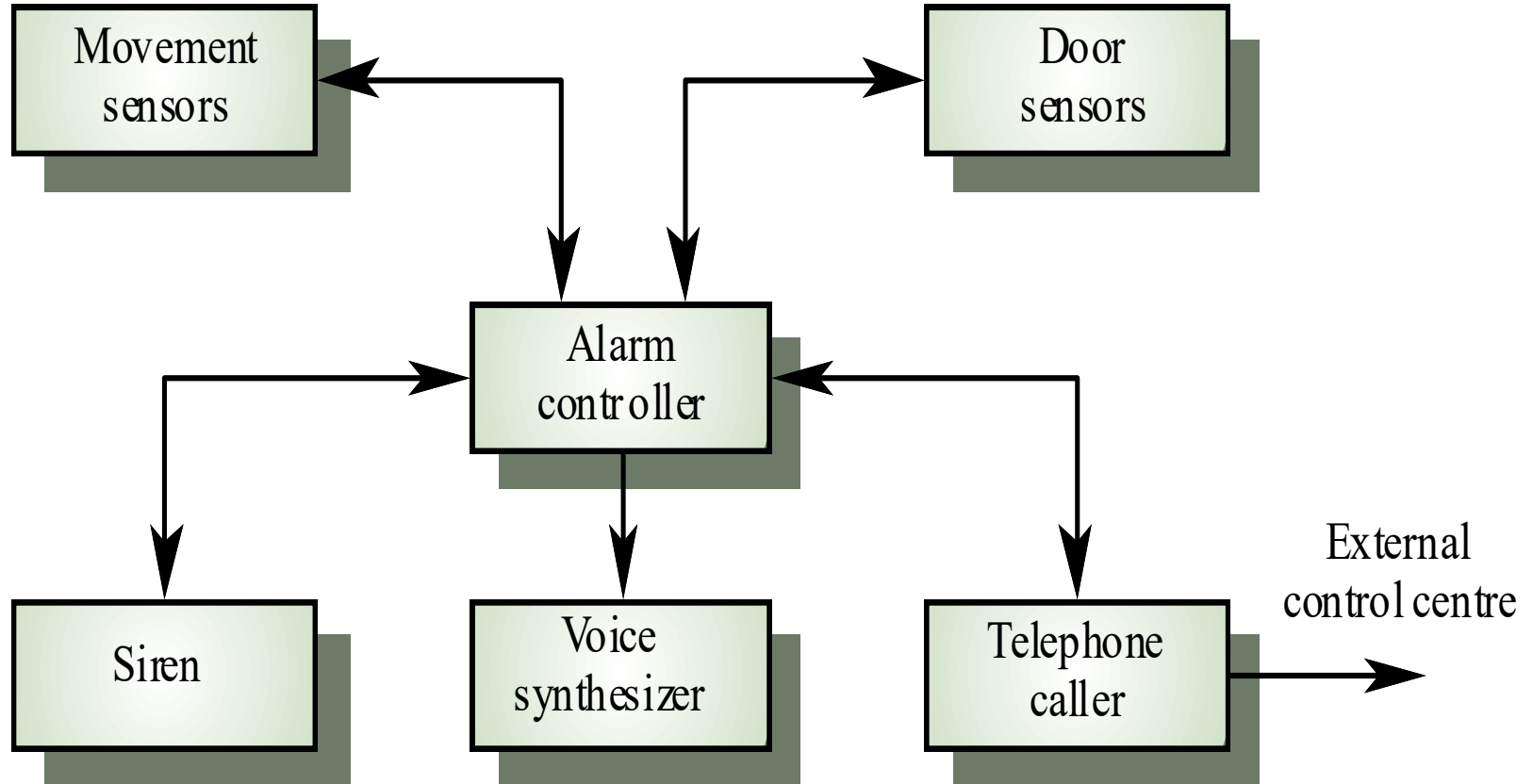
Identification and assignment of **Control**

- › 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

- › Es: everything that relates to user accounts (CRUD)
- › 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

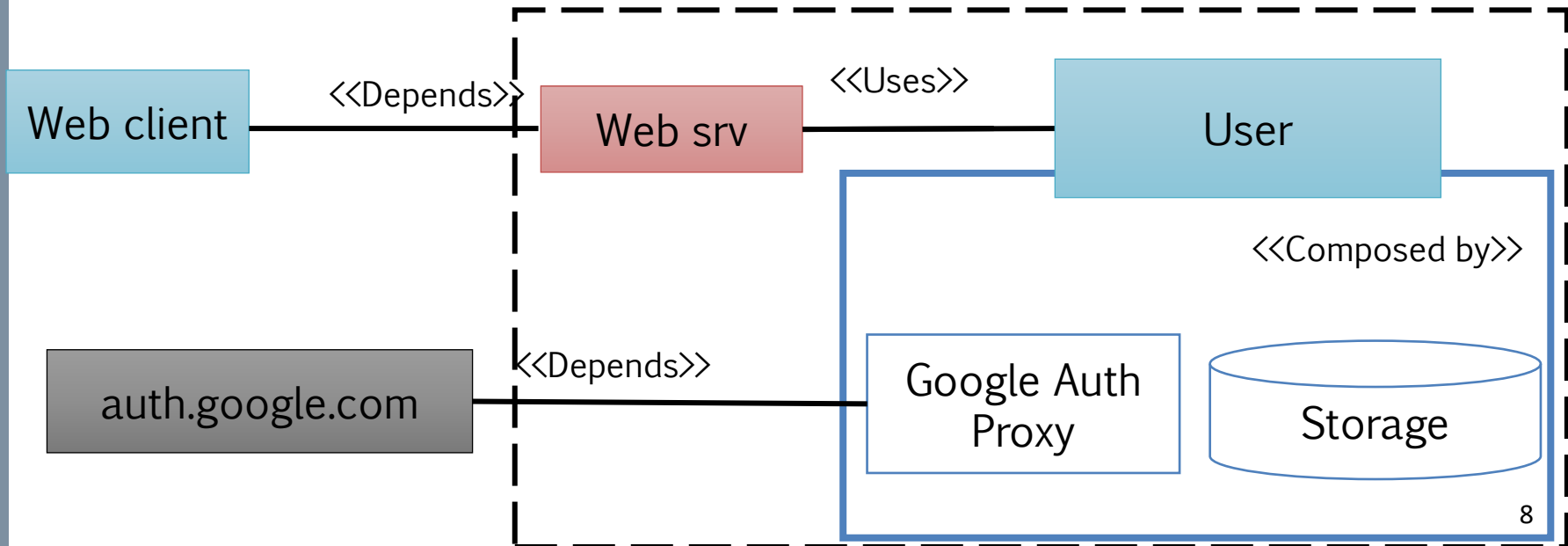




Inter-module relations

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

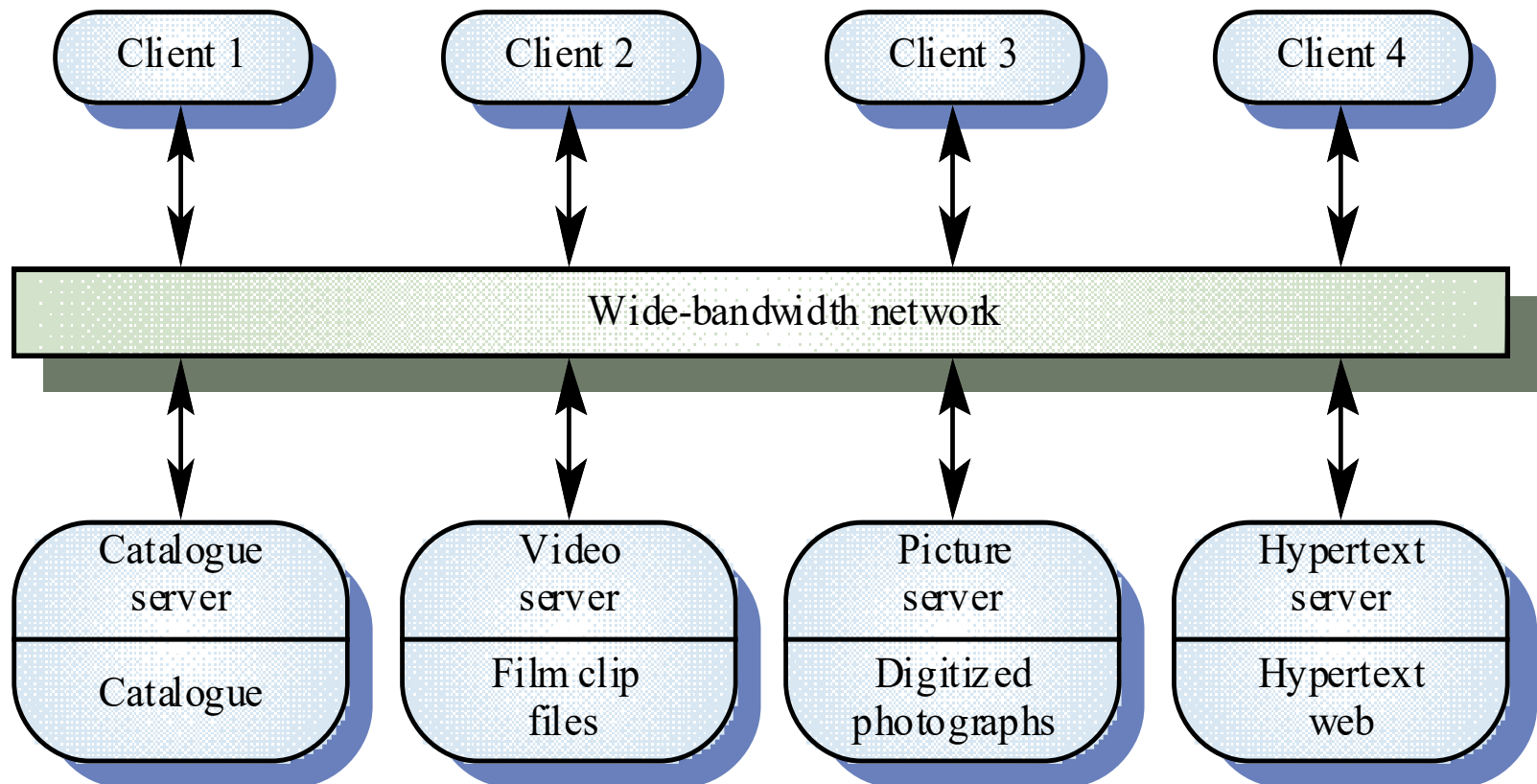
Typical of distributed systems, it is composed by

- › 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

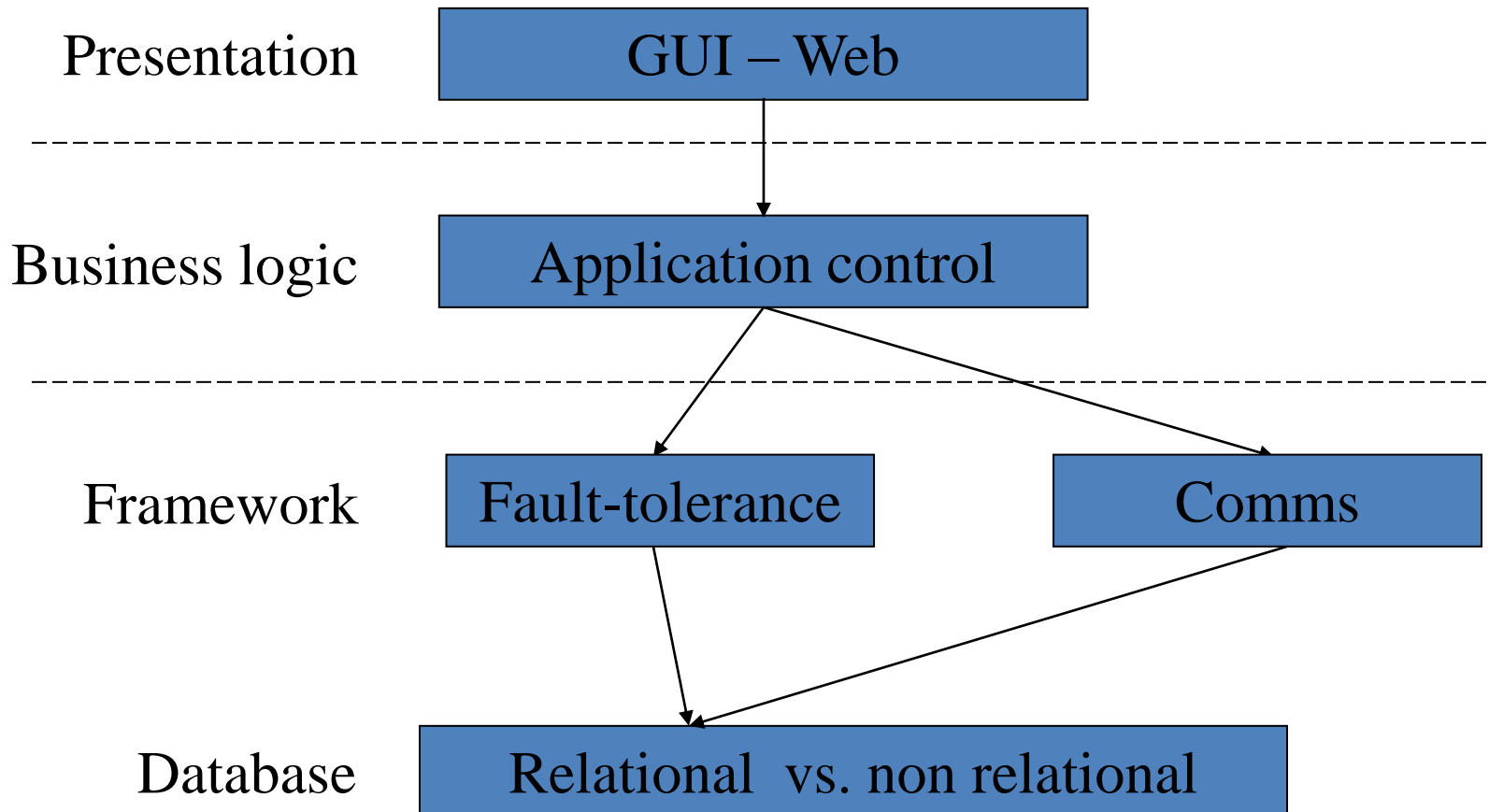
- › It is easy to perform data distribution and responsibilities
- › Can scale the number of clients
 - “It is easy to add new clients”
- › Can scale the number of servers
 - “It is easy to add new servers”
 - Both horizontally (increasing the nr of machines for a single services) and vertically (increasing their resources)

Cons

- › Typically requires a number of 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





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)

- › He 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)

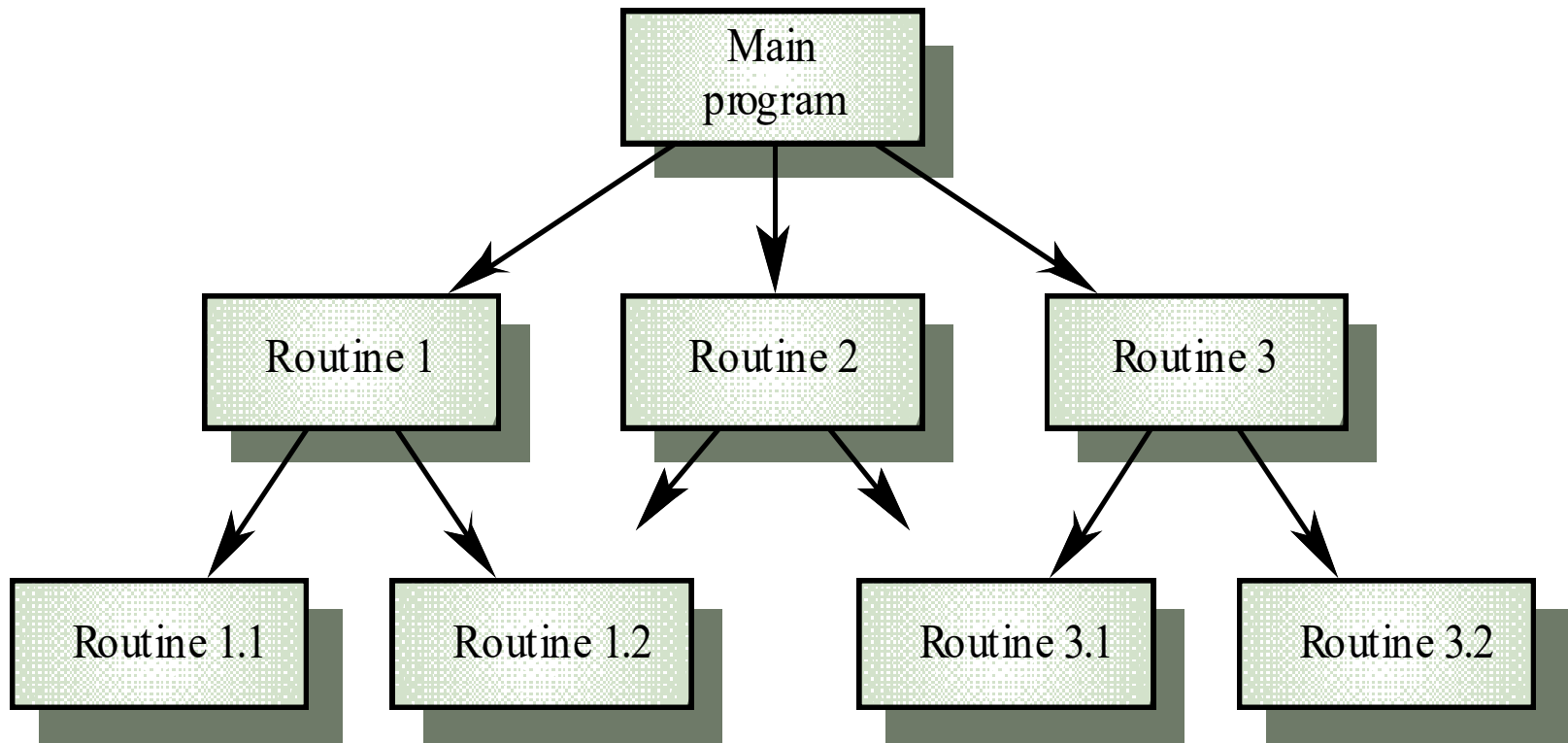
Noticeable examples

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



Request-response

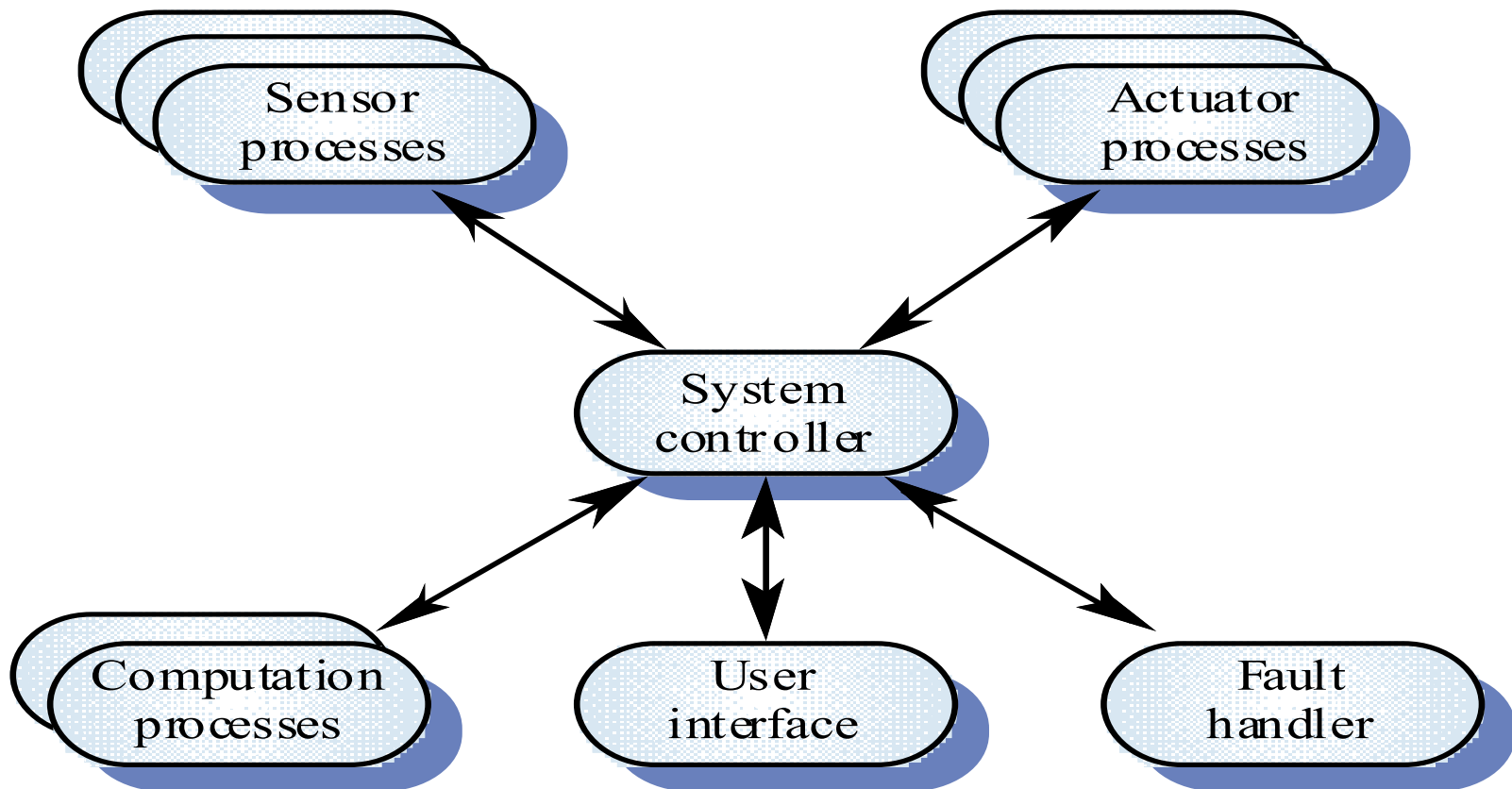
- › Based on function calls
- › Do I need to say more? ☺





Master-slave: multi-process

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





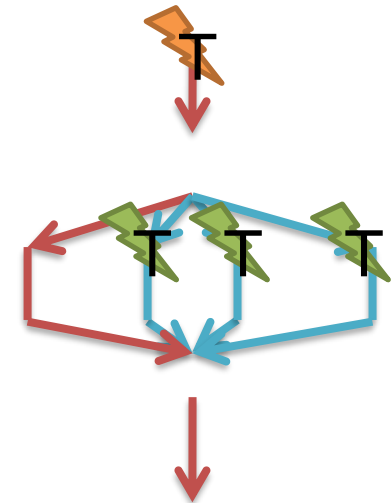
Master-slave: multi-thread

- › Inter-process model, based on shared memory
- › 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**)*

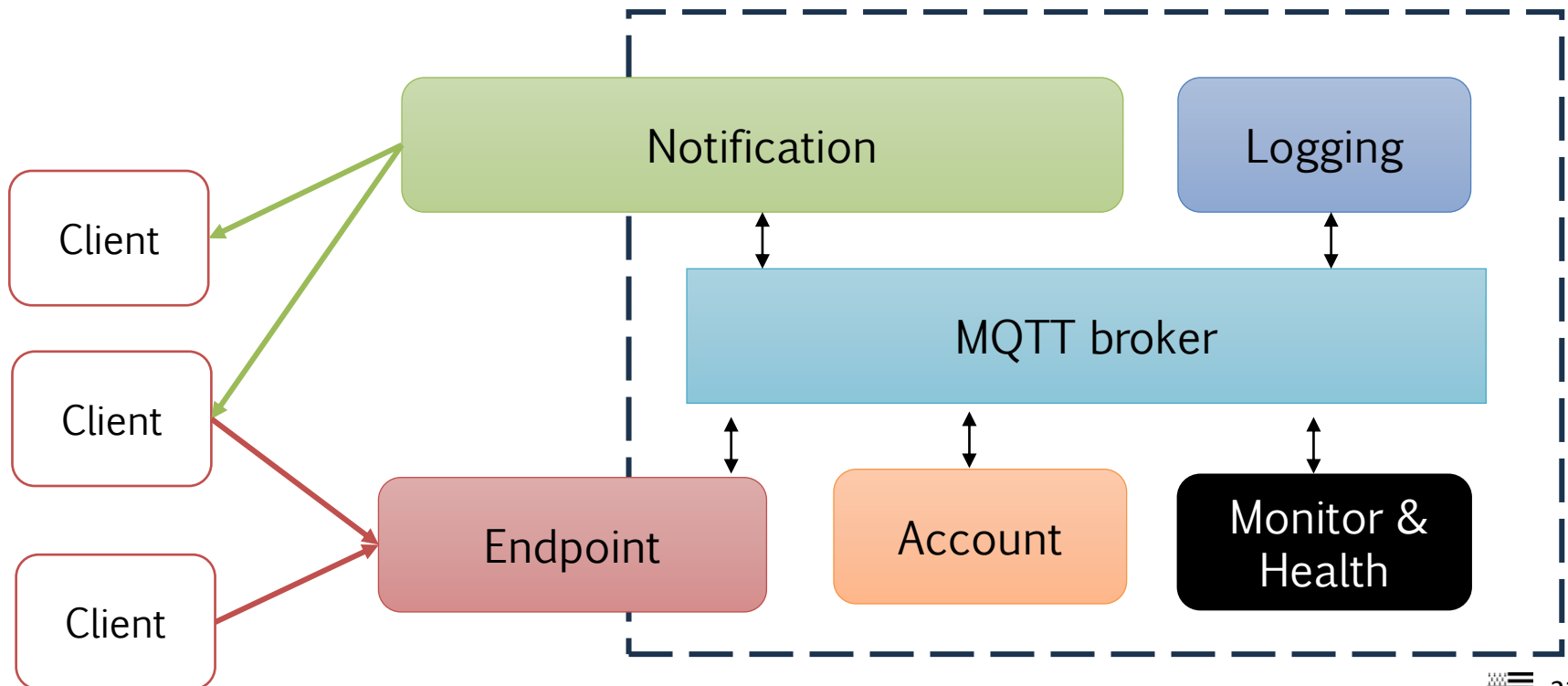
Noticeable examples

- › Broadcast models, in highly parallel systems
- › Interrupt-based model, inside computers



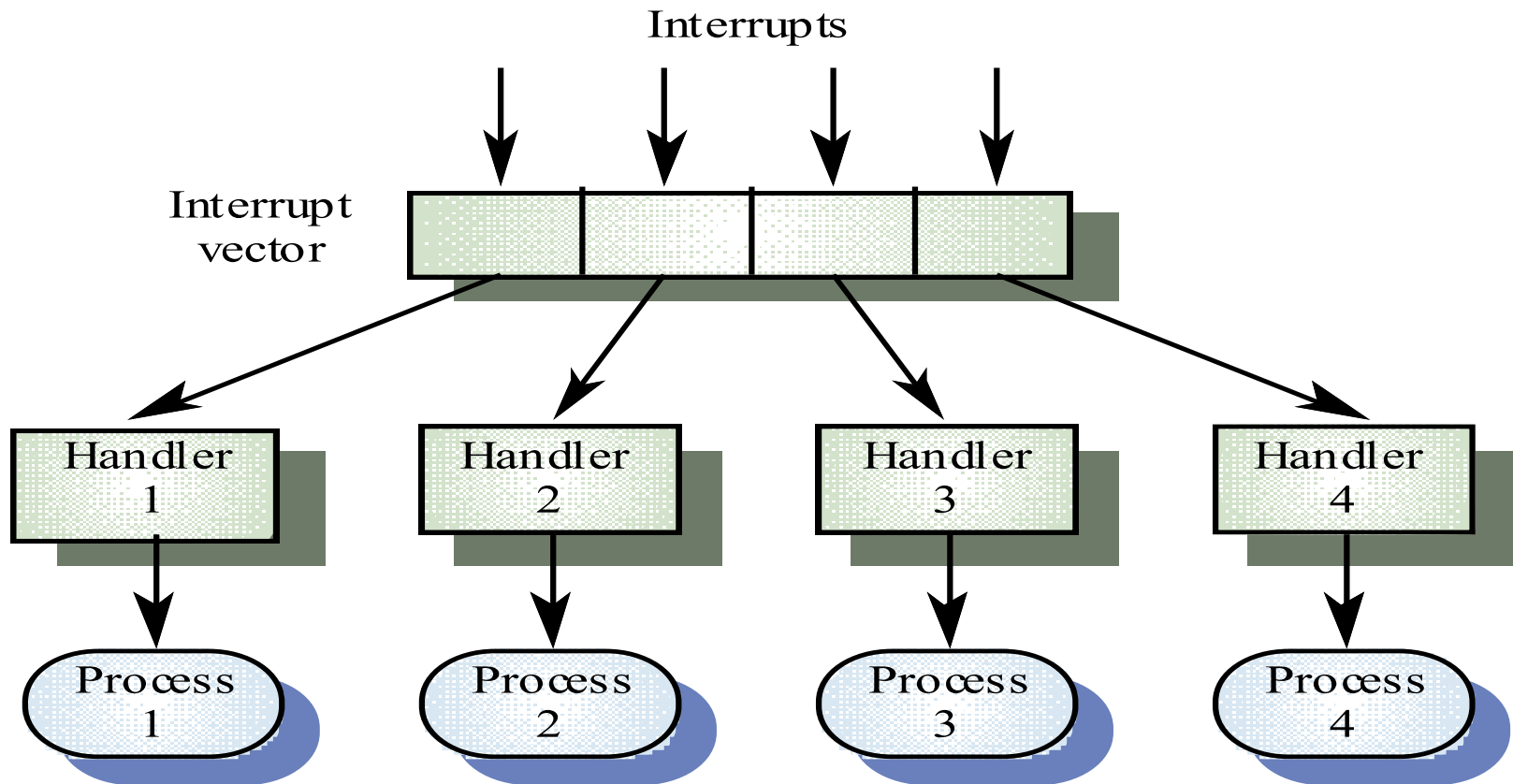
Event-based

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



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 Student() {}  
  
    // 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

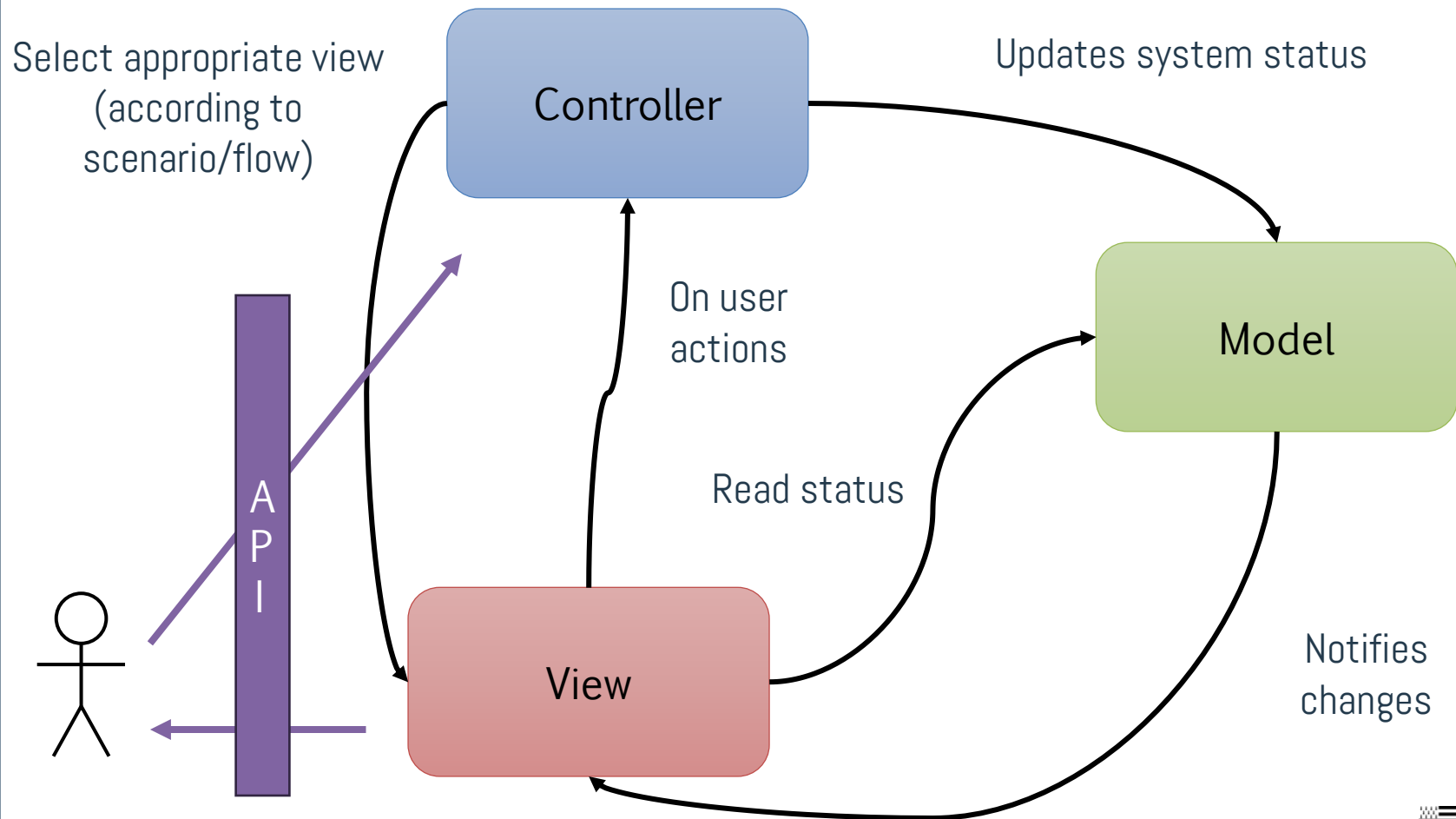
Control modifies Model with setters, and accesses it with getters

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

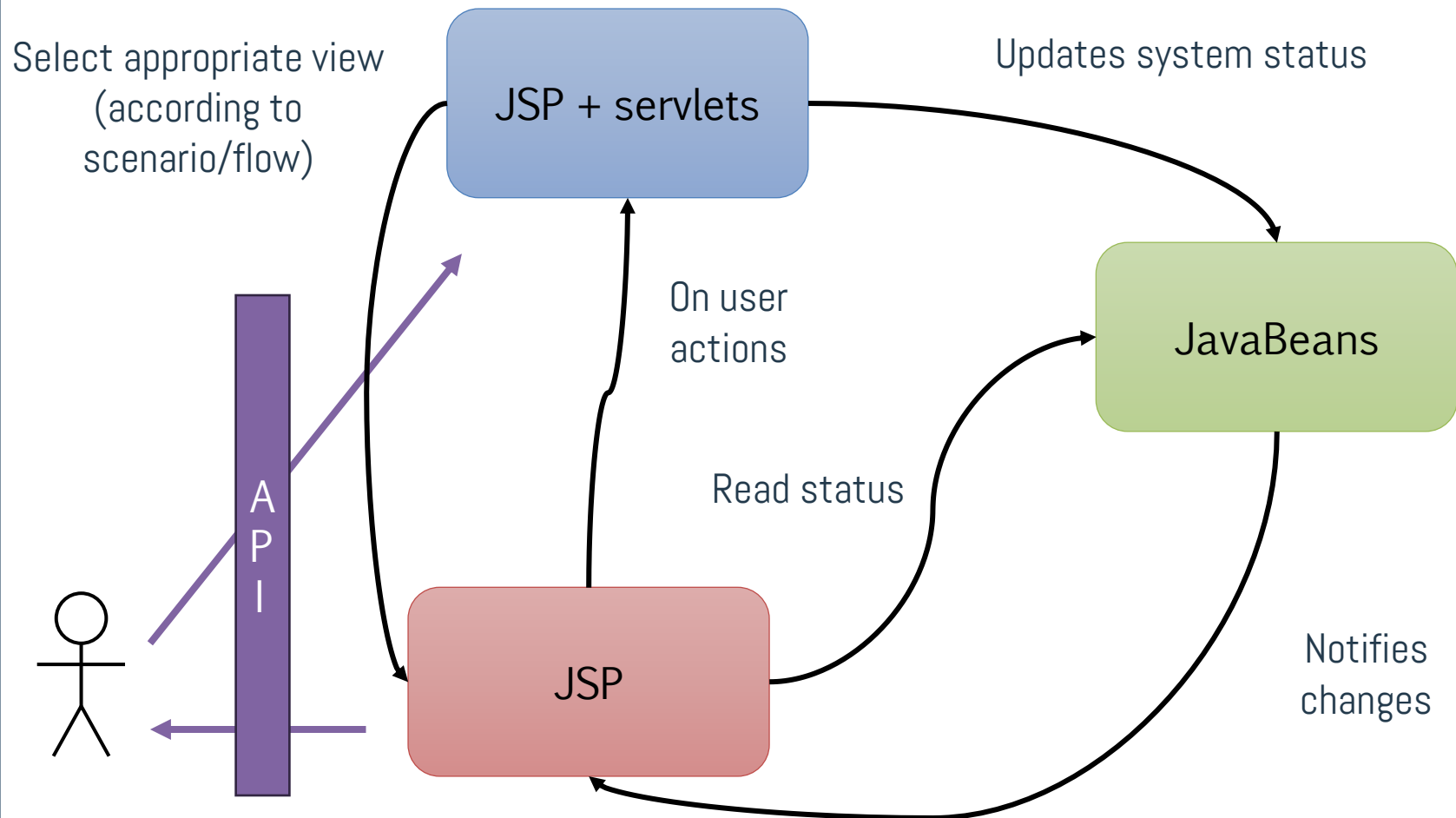


Integrating MVC parts



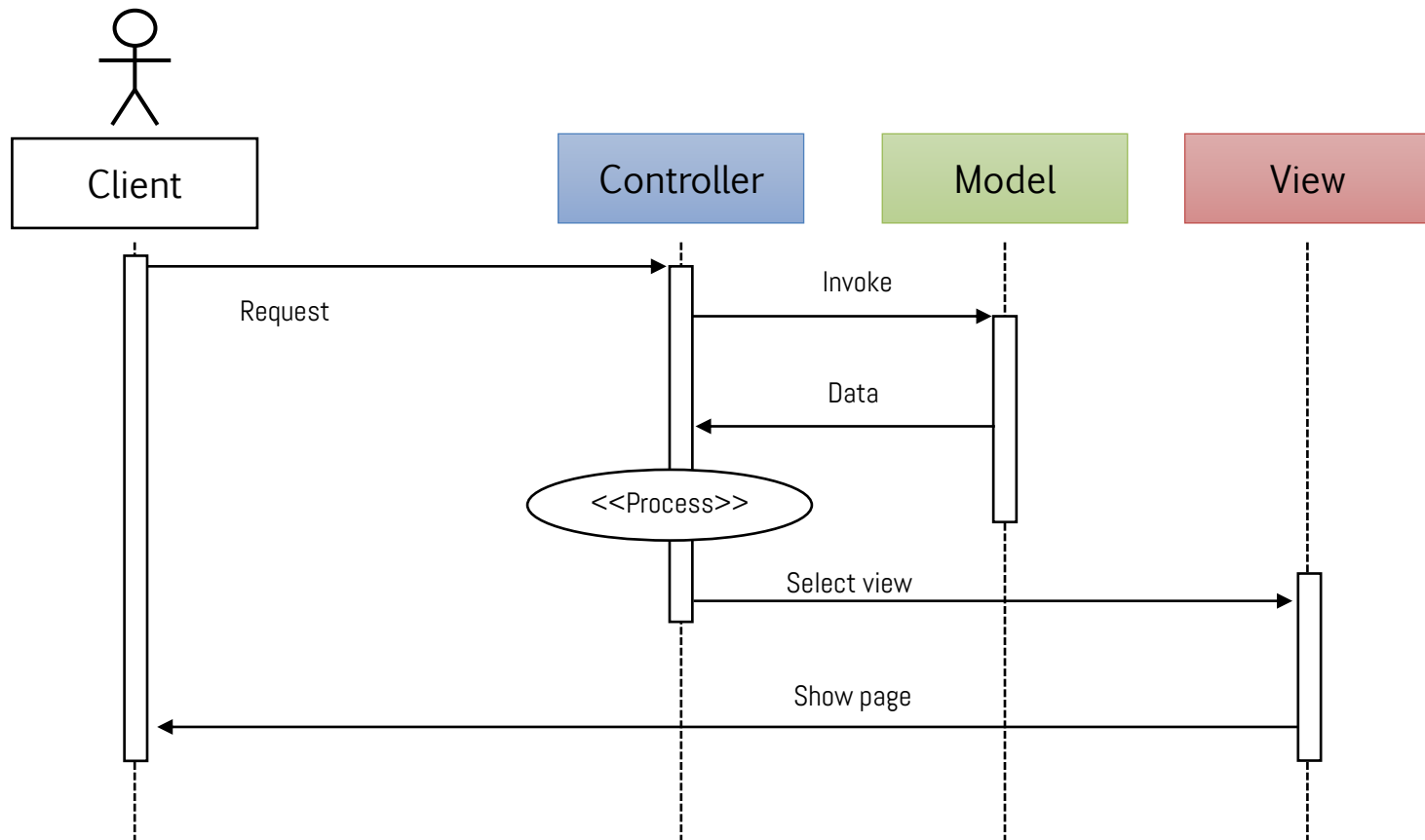


Integrating MVC parts - JEE





MVC sequence diagram





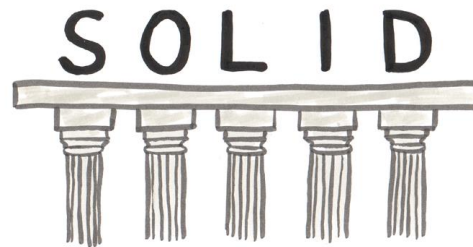
Why MVC?

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..



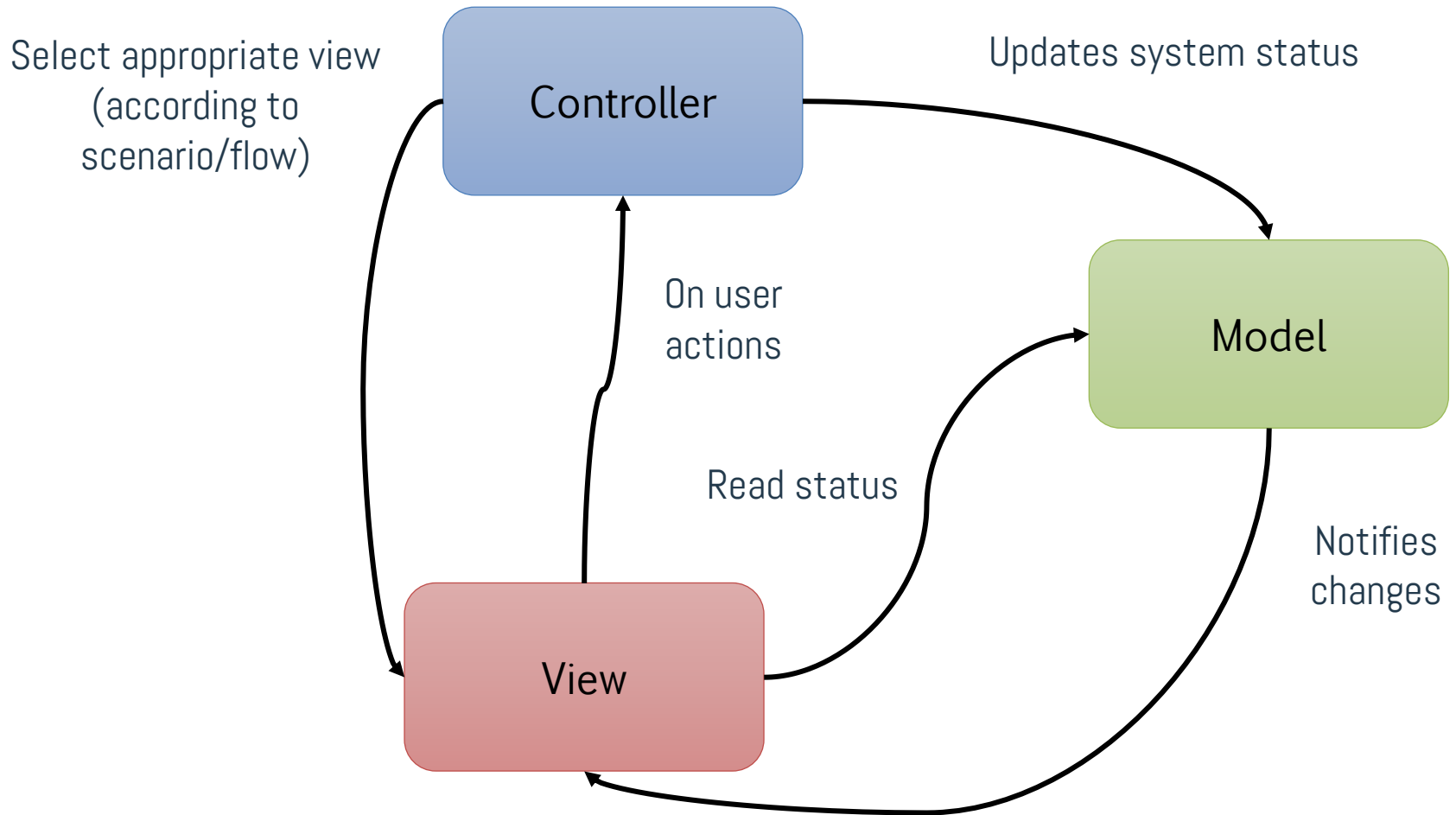


Model View ViewModel

Aka: il figliol prodigo



..but we can do better!





..but we can do better!

Select appropriate view
(according to
scenario/flow)

Controller

Where do we put data
checks? Are they part of
Controller, or model?

Ex: $\text{age} < 0$

The same technology is
used for V and C

UX designers also must
write the controller!

Ex: JSP/XML and Java..

On user
actions

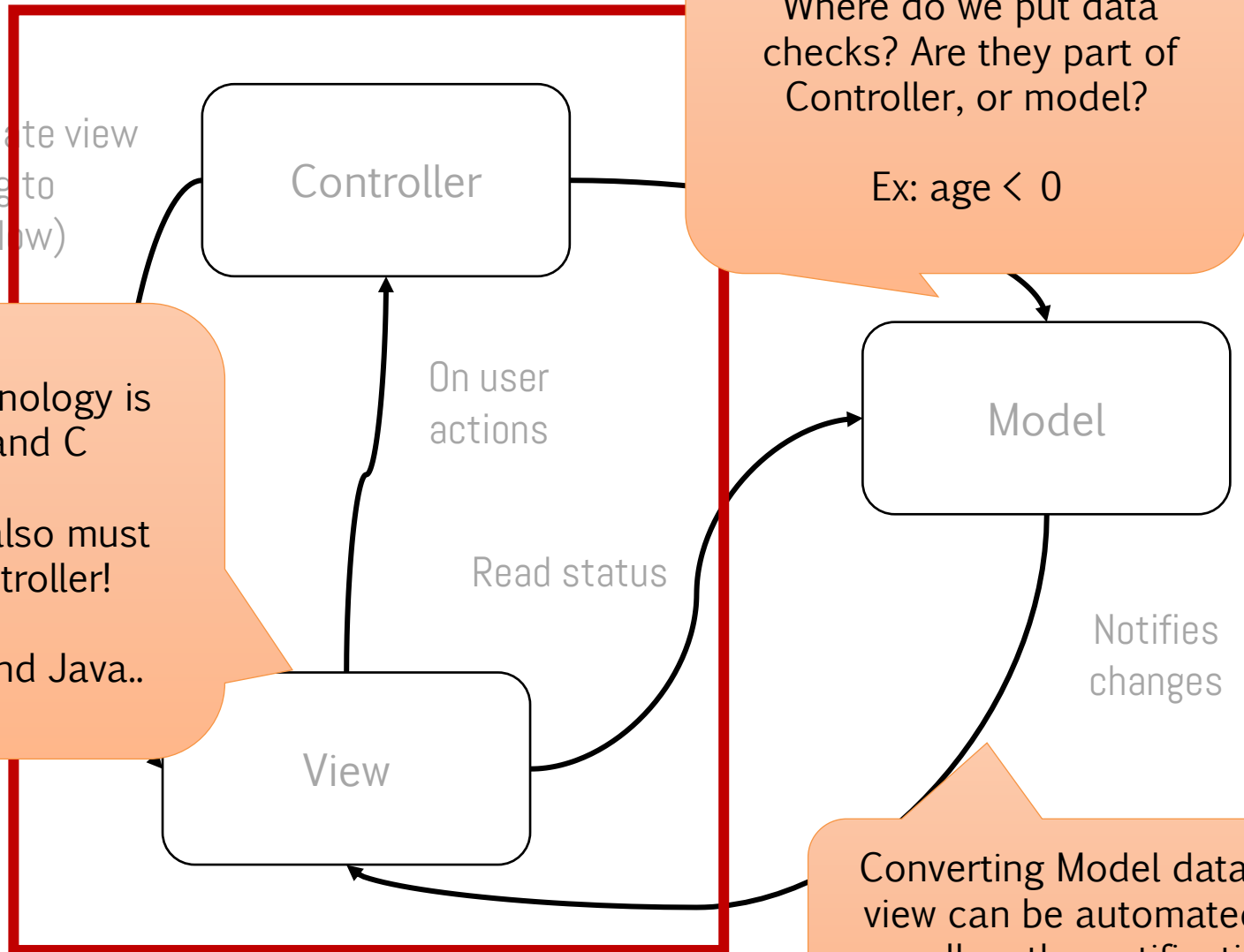
Read status

Model

Notifies
changes

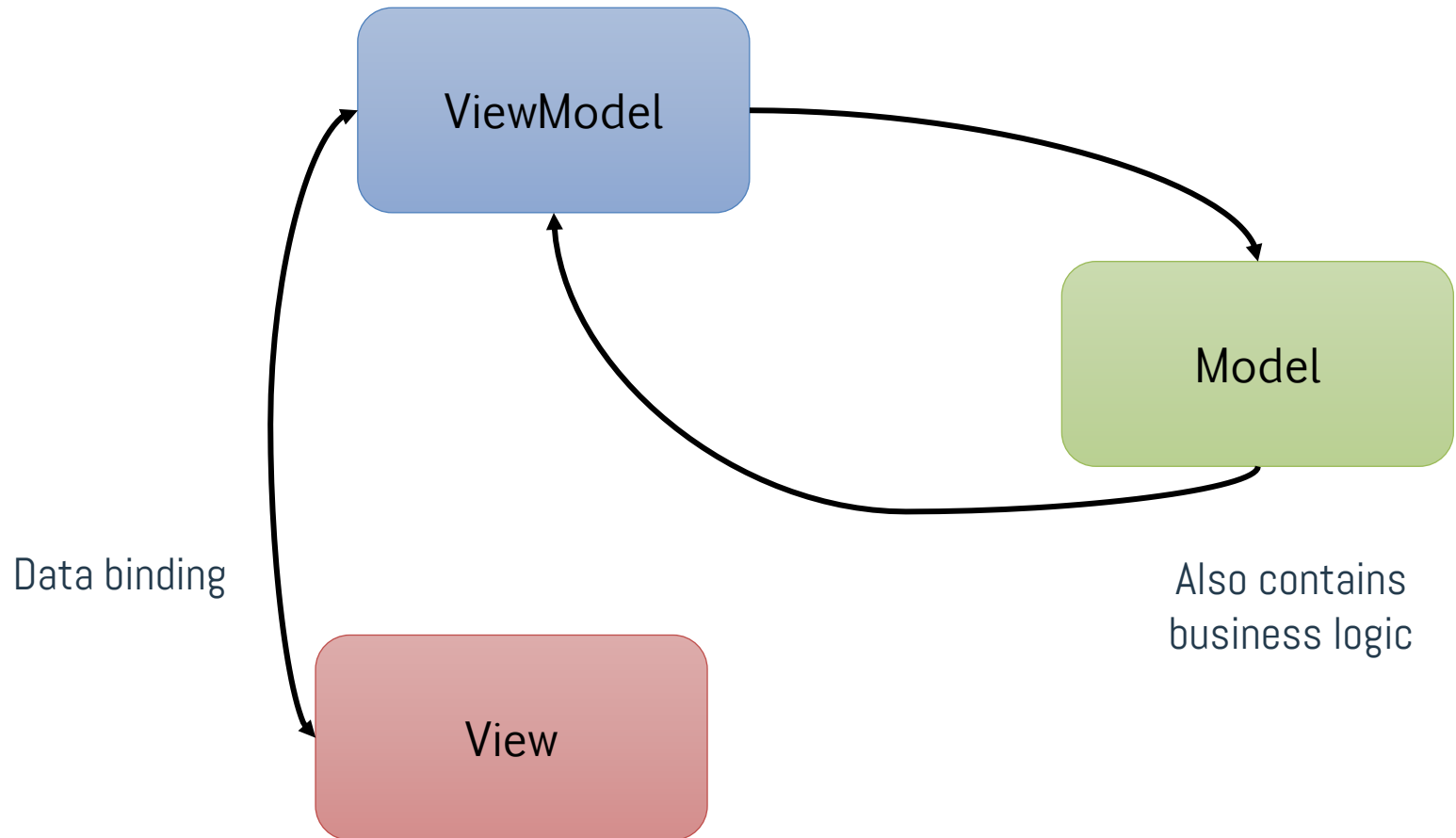
View

Converting Model data into
view can be automated, as
well as the notification
engine



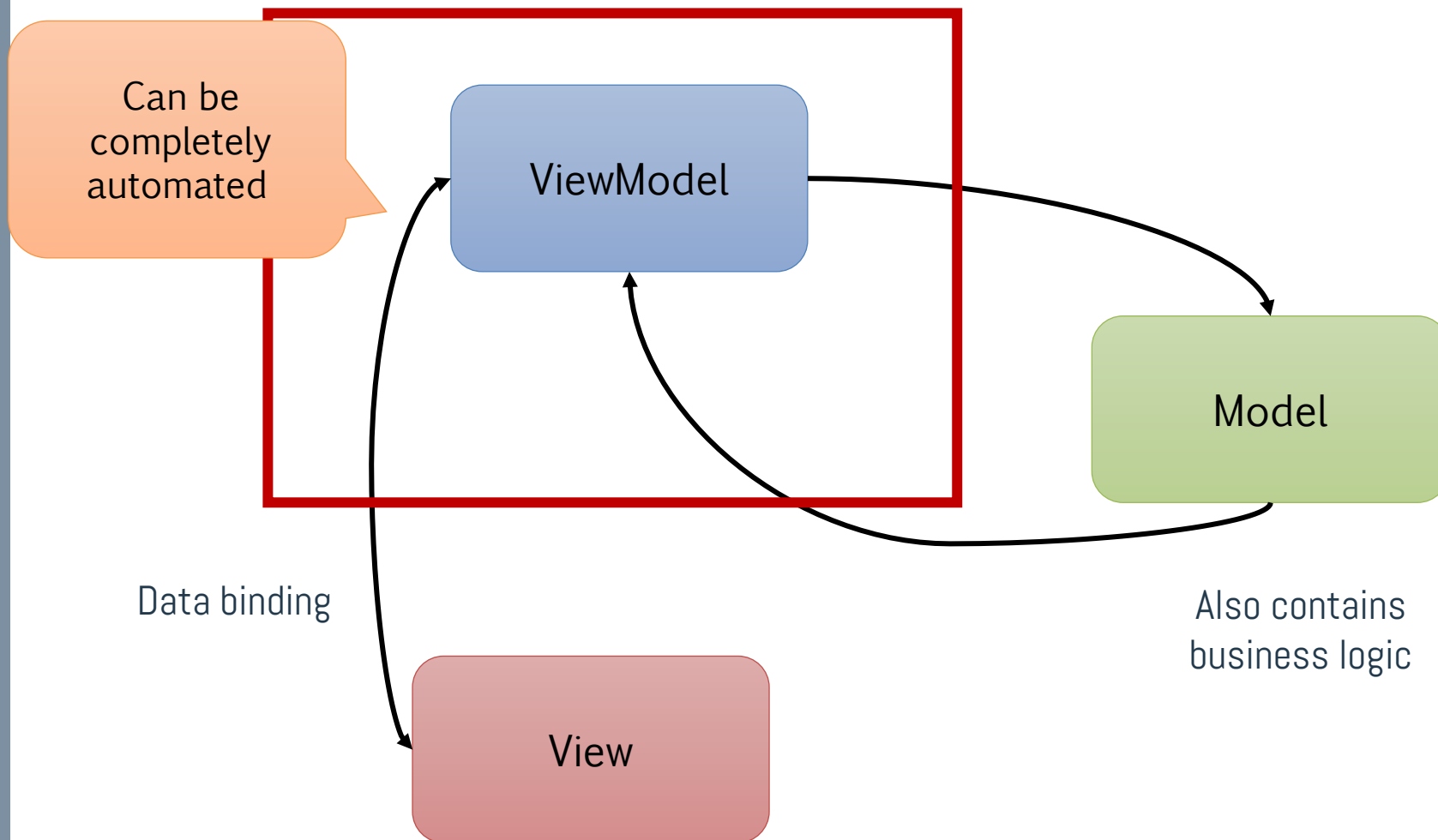


MVVM structure





MVVM structure



BY MICROSOFT

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

- › paolo.burgio@unimore.it
- › <http://hipert.mat.unimore.it/people/paolob/>
- › <https://github.com/pburgio>