# The software design process

Paolo Burgio
paolo.burgio@unimore.it


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

"Weeks of coding can save you hours of planning." - Unknown

# Why do we do this?

For the present

- Enable collaborative development (collaborative tools)
- In > months of dev, the team might change! (documentation, both internal and external)
- Automate testing and releasing

Ultimately, every team member should focus on few tasks, the ones that fit him/her better!

For the future

- Make the mantainance process easier
- Enable future extensions/development

# The Apollo 13

"We need find a way to put this, in the hole for this, using these"

› https://www.youtube.com/watch?v=ry55--J4_VQ

# Software engineering

The discipline of building big, complex systems

- Applies methodologies from the engineering world, to software development process
- The only way of dealing with complex software systems and teams
- A systhematic approach to design, development, testing, deploy and maintenance (IEEE 1990)

...don't worry... ☺

- This won't make of you an engineer
- It will help you engineering software

# Think today, for tomorrow

Engineering:

- Have a strong focus on the process
- Treat everything as "a resource", either physical (a brick for a wall, a chip for a server farm) or non-physical (software artifacts, licenses, etc)
- In years, they (..we… ☺ ) developed an common methodology for multiple application areas

Software, on the contrary, is (correctly) treated as a non-physical entity, "a product of the mind"

- During the development, you care less of physical assets (mostly, computers, desks…)
- *"Sul mio computer funziona"*
- When you design SW, you care more of people and their skills

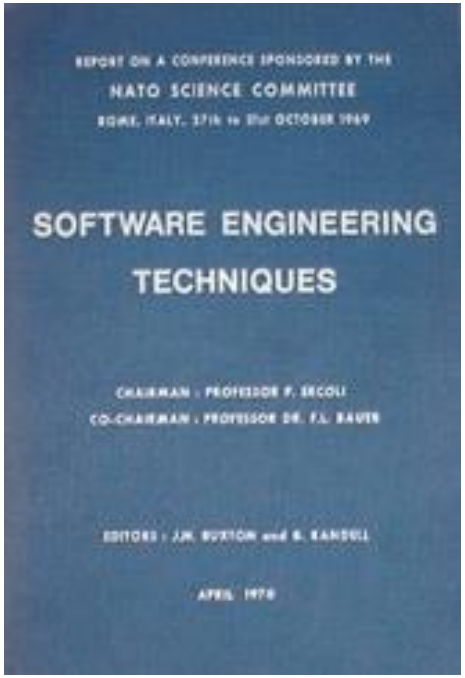
**Adapt this for future complex SW!**

- Future systems will be distributed CPSs, made with different computers (high-performance, energy efficient, ect..) with tight(est) interaction with the world
- Will be large-scale 24/7 distributed systems, updated over-the-air
- Designed today, thought for tomorrow (e.g., Software-Defined Vehicles)

# A bit of history…

SW engineering was born in 1968, at the NATO conference, focusing on

- software crisis
- software reuse
- software engineering




# In the nineties…

- ….the era of object oriented programming
- Design tools (UML), and patterns


# In the last decade(s)

Internet-of-Things

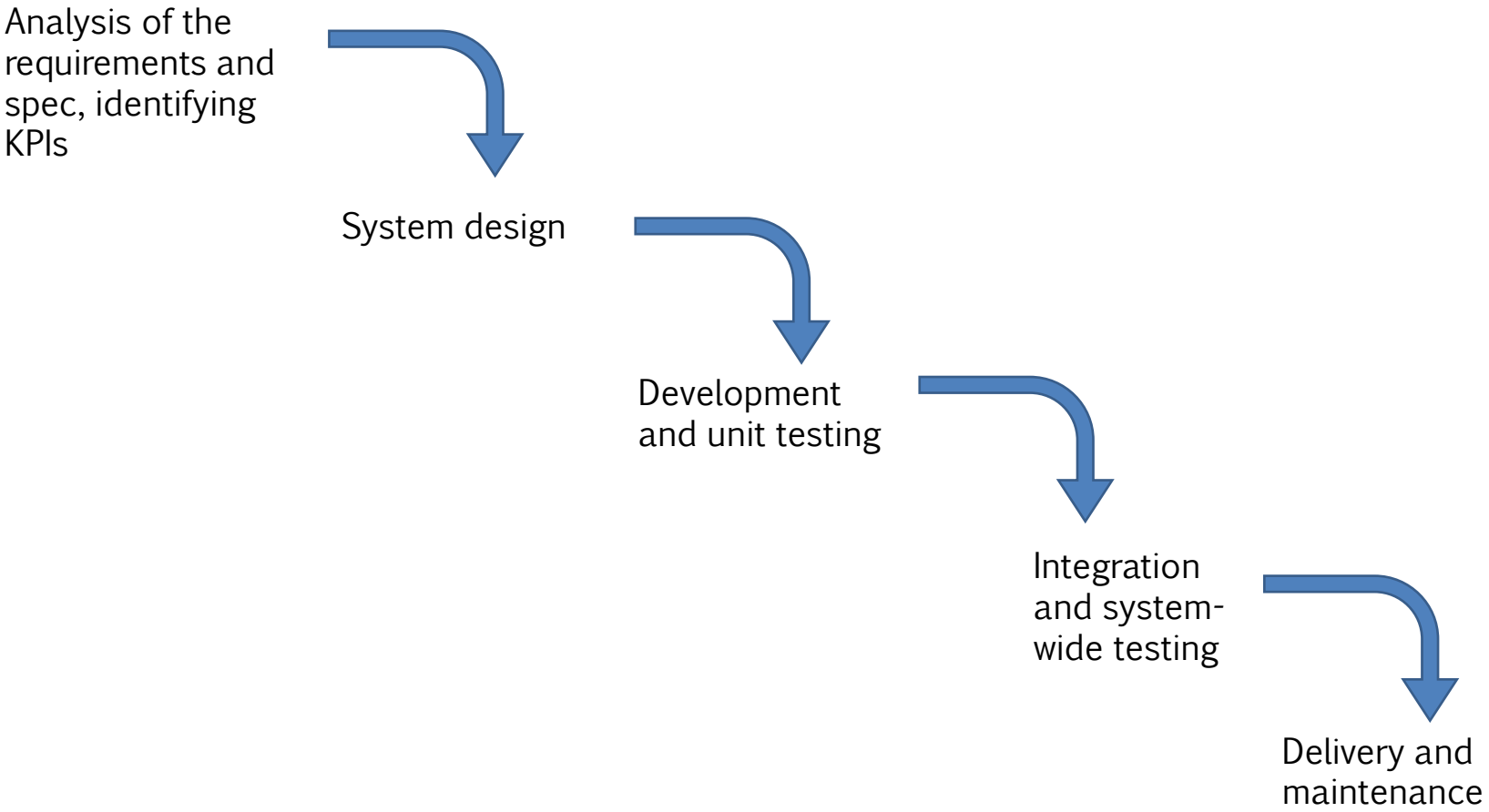
- Large scale cloud projects
- Ubiquity, pervasiveness, CPSs
- Massively parallel computers (GPGPUs)

The era of machine learning

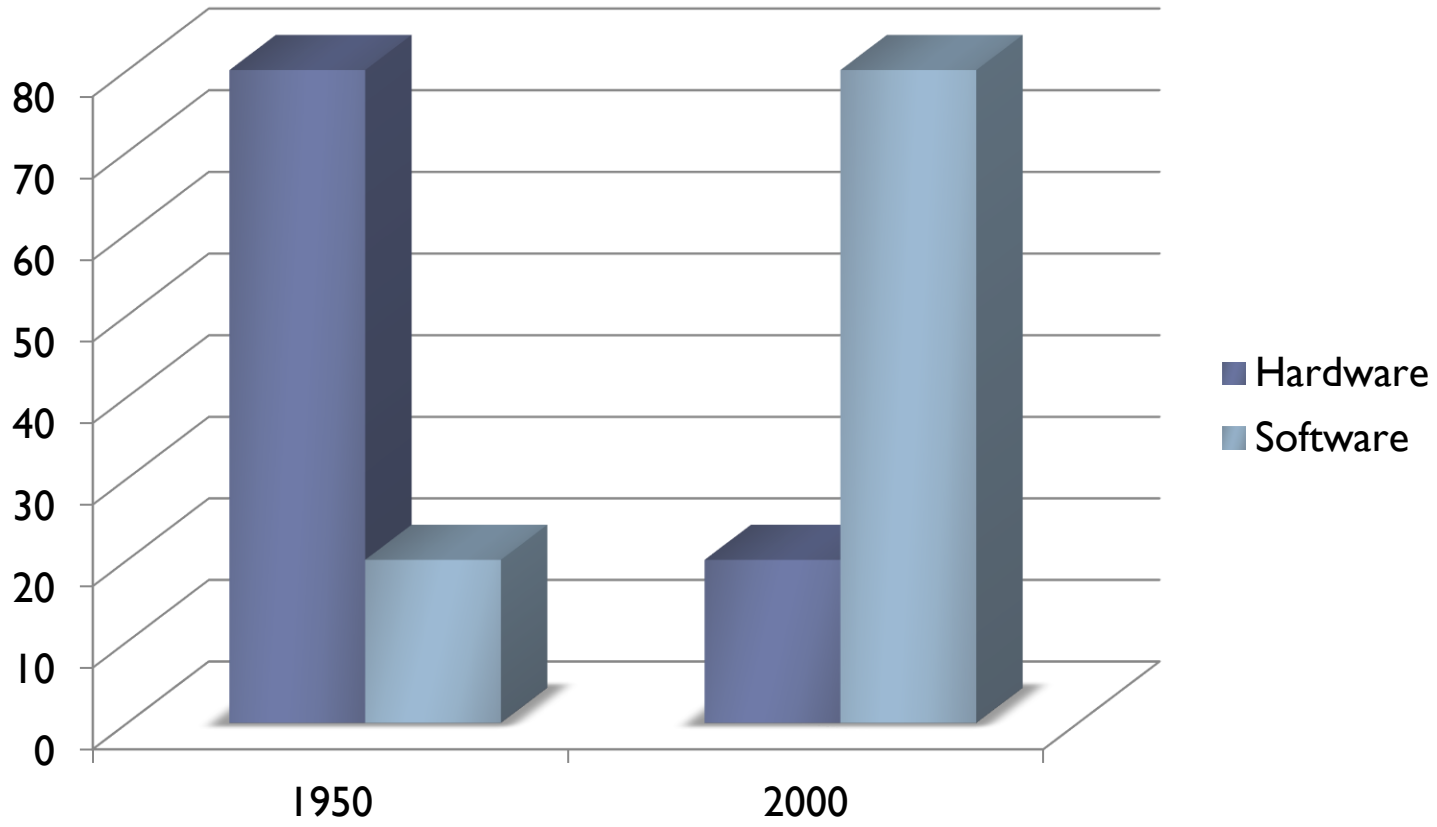
- How can you structure a probabilistic-based SW component?
- Design of the training process
- Data engineering!

# Example - The Waterfall model

(aka: where do we all come from)



# Costs: HW vs SW



# Who is our customer?

For whom it is developed?

- (This includes also open source, and free software)
- We will generically speak of ***customer***, without loss of generality

Custom solutions, tailored for specific customer, or customer segment

- Time-to-market agreed with the customer
- Internal R&D projects (e.g., iotty, Hipert "Fire")
- Market-wide products (E.g., MS Windows)

General-purpose software, released for the masses

- For research  (e.g., our F1tenth stack, tkDNN)
- Business models based on open-source (Home Assistant, GNU/Linux, Erika..)

# Quality of software, and process

## Of product / extrinsics / external

- Refers to the functionality, it's the main quality against which software is assessed!
- By the customer / segment / community / domain
- Has directly reflect on co$t pricing

➢ Assessed by functional requirements

## Of process / intrinsics / internal

- Refer to the process, i.e., how the software is developed
- Relates mainly to the specific domain, or company/team (hence, even more important!)
- Hard to map onto product pricing

➢ Reflects into non-functional requirements

# Assessing the quality / functional properties

### Correctness

- *Does my software do what I want it to do?"*
- The easy part: captured by functional requirements, which are directly negotiated with the customer

### Ease-of-use

- Involves UX, documentation…

### Performance/efficiency

- *"Is it fast?"*
- What do "fast" mean? FPS? E2E latency? On which computer?
- How many resources does it need (e..g, power/Watts? Enery/Joule?, physical space)?

### Dependability

- *"Can I rely on it?"*
- Definition applies to specific fields…

# On dependability

*"a measure of a system's availability, reliability, maintainability, and in some cases, other characteristics such as durability, safety and security. In real-time computing, dependability is the ability to provide services that can be trusted within a time-period. The service guarantees must hold even when the system is subject to attacks or natural failures."*

Specific of application domains (can overlap!!!)

- Real-Time systems
- Embedded systems
- Exascale systems
- ...

The IFIP working group identified three main elements

- **Attributes**, i.e., Key Performance Indicators (KPIs) to assess the dependability
- **Threats** to dependability
- **Means** to increase dependability

# Non-functional properties

A system is

- **Verifyable** if we can assess its characteristics (what about ML?)
- **Mantainable**, if we can easily modify it (docs are in order??)
- **Reusable**, if it's well packed for deployment (docker?)
- **Portable**, if we get the same functionality on different HW/OS/…. (and also performance!!!! – see GPGPUs)
- **Interoperable**, if it's open for interaction with other systems…
- …

# Basic design principles ~~of software engineering~~

# Our friends

- Strictness, formalism
- Separation of concern
- Modularity
- Right level of abstraction
- Resiliency / robustness

SW best practices (we'll see them later)

- Design patterns (architectural, coding)
- SOLID principles
- ~~Tools and methodologies~~ Methodologies and tools

# Strictness, formalism

Still, we are artists! Software is a piece of art!

› GPL licenses apply also to books, paintings…

But…we need to systhematize the process

› Typically, we borrow from mathematics / logics / engineering ☺

› …to create well-known schemes…

› …and leave the artist programmer the freedom to improvise within them

*(Like a painter with a frame)*

# Separation of concern

*Divide-et-impera*

- Split the problem onto subproblems

..but, which problem?

- Lifecycle (Waterfall vs. Agile/Scrum)
- System architecture (e.g., Microservices)
- Internal system architecture MVC – MVVM
- Testing and deployment (CI/CD)

# Modularity

Comes directly from the separation of concern principle, affects system design

Two main approaches

**Top-down**

- Where we have a complete view of the project, and we split it into components
- When we typically start from scratch

**Bottom-up**

- where we first develop the components, and then integrate them
  - A typical scenario is when we need to re-use existing modules

# Abstraction

Example: how shall we model a user?

- In a gym club: name, age, weight, height, gender, email
- In the City Servers: name, age, address, CF, phone nr
- In a smart city roundabout: Lat, Long, velocity, class (car, bike, pedestrian)

# What about costs?

Software costs outperform all other “structural” costs

- Licensing for libraries
- Fees for platforms (who has in-house servers anymore??)
- Electricity/heating/cooling

Maintenance is the main component

- A bad design is costly on the long term (see Apple’s)

Personnel costs

- Developers (80%)
- Support/aftermarket

Other costs

- HR, generic costs (chairs, laptops..)

# Maintenance

The need for modifying the system after it has been deployed

- Bugfixing (typically for free in 12-24 months) – Functional testing with customer is really important to mitigate this – 20%
- Performance improvement – 60%
- Changes in the operational domain (e.g., new version of libraries, OS, hardware) – 20%

But most of all..

- …l'appetito vien mangiando ☺ - customer might ask modifications, even paying them in advance!

Often, more than 50% of the overall costs!

- 75% (Hewlett-Packard)
- 70% (US Defense)

# Main issues with SW, today

Aka: “the generational debt”

- Old, legacy systems, developed with obsolete technologies, which cannot be replaced due to bad engineering practices
- The “Comune di XXX” example
- “Big bang” migrations/updates vs (take longer) step-by-step migrations

Systems are increasingly complex and heterogeneous

- The rise of micro-services architectural pattern

Time-to-Market

- Rush, rush rush!
- Tackled with agile methodologies

# Professionality, and ethics

Sw developers shall always keep an ethic and professional conduct of work

- What does “ethic” mean?
- E.g., Hipert srl doesn’t, and will never do, produce weapons

Confidentiality

- Often, you need to sign an NDA – Non disclosure agreement, before working
- After resigning a contract, some pros might not be hired by other competitor companies for 1-2 years!!!
- Example: Maserati SpA

Intellectual Property and licensing

- How much do you know about licenses/patents?

# Structuring ethics

- Personal ethics
- Company rules (see Hipert)
- Professional
  - see “Ordine degli ingegneri”
  - Association for Computer Machinery (ACM) ed Institute of Electrical and Electronics Engineers (IEEE) - http://www.acm.org/about/se-code

# Structuring the process

# Modeling the process

We need to structure the entire development flow

There are multiple chances, depending on

- Type of technologies - *Might fit or not fit a methodology*
- The time we have for producing it - *Agile vs. more "traditional" methodologies*
- Legacy codebase - M*igrating/updating, or re-implement from scratch?*
- Company processes - *Use the right tool for the right processes*
- Standard processes for specific domains – *The V process in automotive*

# A typical pattern

1. Specs
2. Design
3. Implement (SW and HW)
4. Integration
5. Test
6. Deploy
7. Maintenance/Aftermarket (AM)

Methodologies mainly differ in

- *How much time we dedicate in every phase?*
- *How early do we want to test/integrate?*
- *Shall we iterate on the main process? Or provide sub-processes?*
- *How early/late do we involve the customer? (e.g. graphic interfaces L&F)*
- *Do we need to standardize?*

# Typical choices / mistakes

1. Specs
2. Design

MISTAKE: mixing them

3. Implement (SW and HW)

BEST PRACTICE: tight overlapping

MISTAKE: underestimating documentation

4. Integration
5. Test
6. Deploy

BEST PRACTICE: can automate this!!!

7. Maintenance/Aftermarket (AM)

MISTAKE: undersestimate its cost

# 1) Requirements and specifications

Involve the commitments, and flood them with quesitons

- On what the system should do (functional) / how it interacts with user (non-functional)
- On the environment / ecosystem (hardware vs. software)
- Any legacy codebase? Any legacy process? Any legacy vendor?
- Try to imagine possible issues (for maintenance) and possible future steps (for aftermarket)

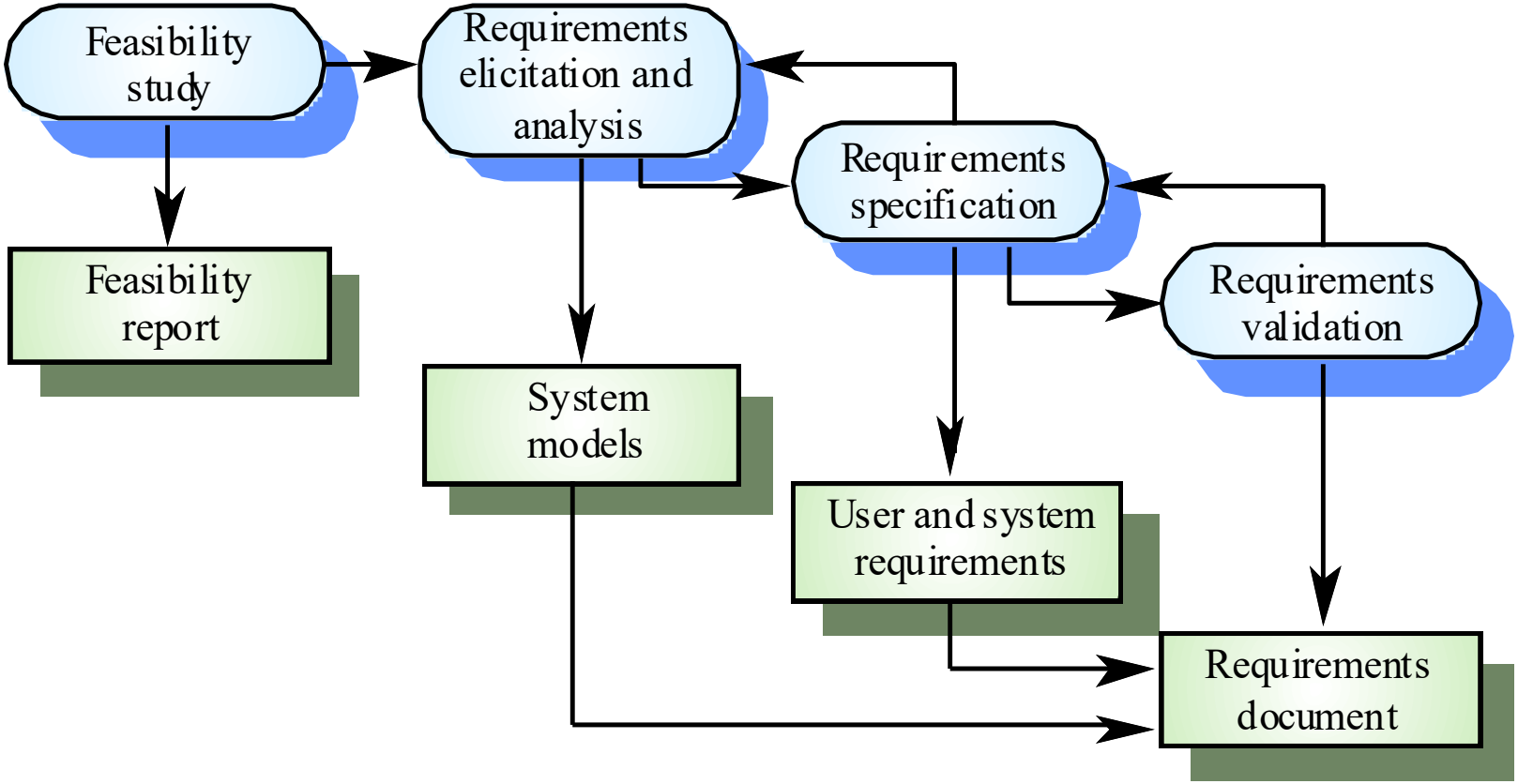
Yearly expertise on this / on specific application domains help

- Often, specific non-dev people: *Business analysts, Performance engineers, Requirements engineers*

The output: a (set of) document(s) that clearly cover all of these topics

- Identifying measurable identifiers (KPIs) to assess whether the system is working properly
- Directly affects testing phase!!!
- This is what defines the **value** for our customer

# Reqs and specs – cont'd



# Wait another minute…

An agreement shall be signed with our customer

- The, we set up / deal the price of our service / sw
- Clearly state what we will do and don't
- …also what the customer shall do
- E.g., who's in charge of maintaining the server infrastructure? Who's paying the possible licenses (yearly)?

At this stage, the customer will still be nice, and lovely…

- …but they will start to get anxious, because they want the product done

**DON'T RUSH!** (yet, try to be as fast as possible)

- Remember, we're in Italy: 95% of companies are PMI/SMEs, and Project Manager have limited expertise/culture of sw design
- They think that *"They have a friend that might also do that"*

This phase is the most important!!! Here, you are making promises!

- Typical scenario: in 6-12 months the customer says: *"Well, the system doesn't' work, unless you also do this, this, and also this. If the system doesn't work, of course I won't pay you"*

# 2) System design

Let's sketch a working system

- How fast do we want a working prototype?
- Are we starting from legacy code, or from scratch?
- Shall we also design functional tests, from KPIs?

At this point you must take some decisions

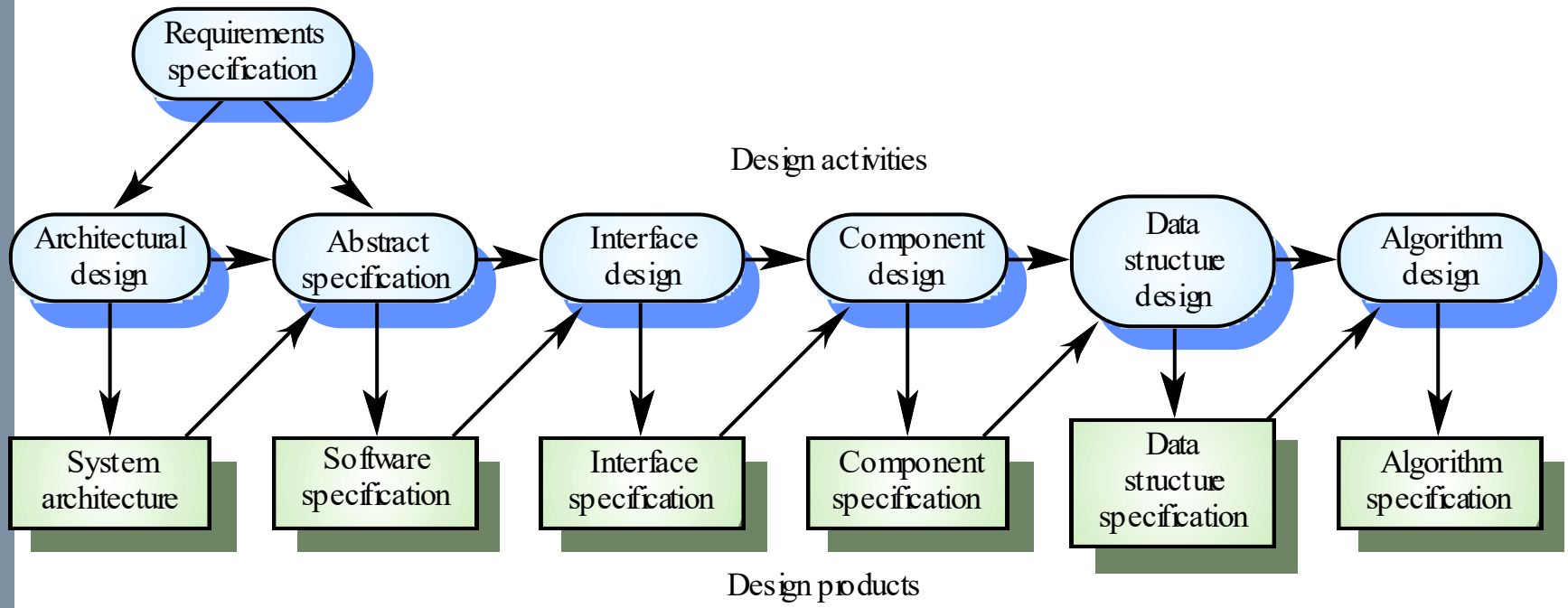
- Architectural design
- Choose the most appropriate language(s), framework(s)
- Choose the hardware
- Plan the integration / define protocols and comm infrastructure

What about the team?

- Which tools shall we use? Which methodology?
- Git (of course..?), Agile, Waterfall?

# 2) System design

› A typical high-level design



# 2) System design

At this point, we can start drawing how our system is actually made, not only what it does

- And the technology it uses

There are a number of tools / graphical models

- Unified Modeling Language / UML (a family of models)
- For depicting the behavior, and the way classes are done in OOP
- Data-Flow Diagrams / DFD
  - If data representation is our main concern
  - Pipeline-like architectures if we cannot store data / have too many data
- Entity-Relation (E-R) diagrams
  - Streamlines the development of DB models, and the main operations
  - E.g., Relational DBs are goot

# References

Course website

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

My contacts

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