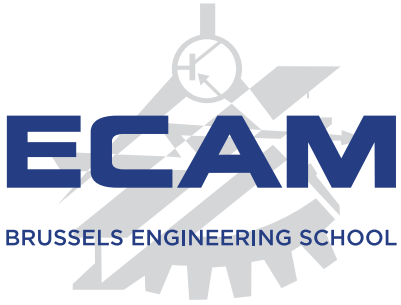

I402A Software Architecture
and Quality Assessment

Session 1

Architecture Models of Software Systems

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Fall 2019

Objectives

- Software solution and its architecture
  - What is a software solution?
  - What is a software architecture?
- Landscape of the main styles of architecture

  Depending on the application type and the level of abstraction
- Why is it useful to define architecture(s)?

  Quality and beauty of code, maintenance, security, etc.

Software and Architecture

Software

- A software is a part of a computer system

  Lies on top of the operating system and the hardware

- Executable/interpretable instructions and datasets

  Compared to the physical hardware on which the system is built

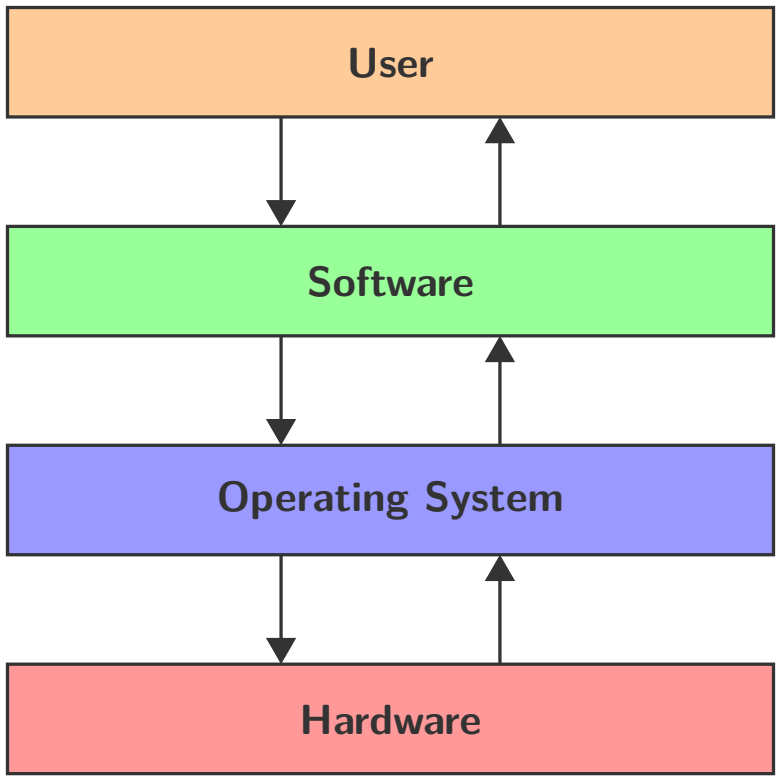
- Several abstraction levels for the code of a software

  From machine language to high-level programming language

Computer System Structure

- A computer system can be seen as a four-layer system

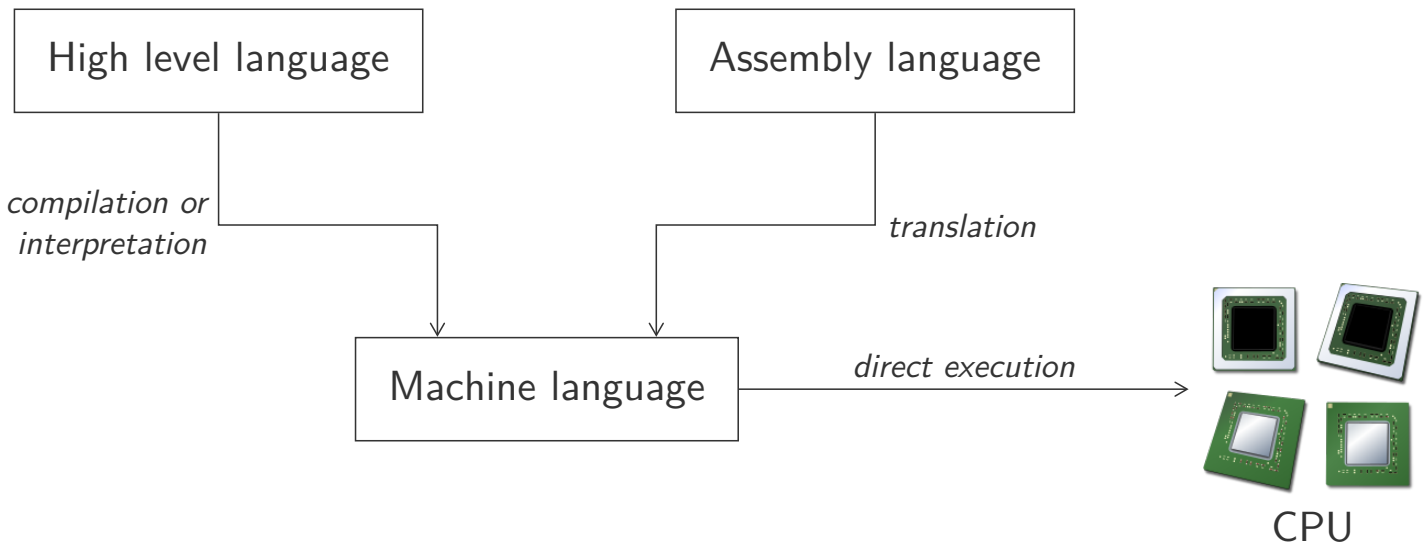
  Use of lower level services to provide services to higher level



Executable Program

- Transformation from programming language to a machine one

  From a language with a more or less high abstraction level



Types of Software

- Depending on the purpose or the area of use of the software

  Application, system program (OS, driver, utility), malware, etc.

- Depending on the nature or the execution domain

  Desktop/server application, script, plugin, embedded application, mobile application, microcode, etc.

- Programming tools

  Compiler/interpreter, linker, editor, debugger, IDE, etc.

Software System

- Software system made of intercommunicating components

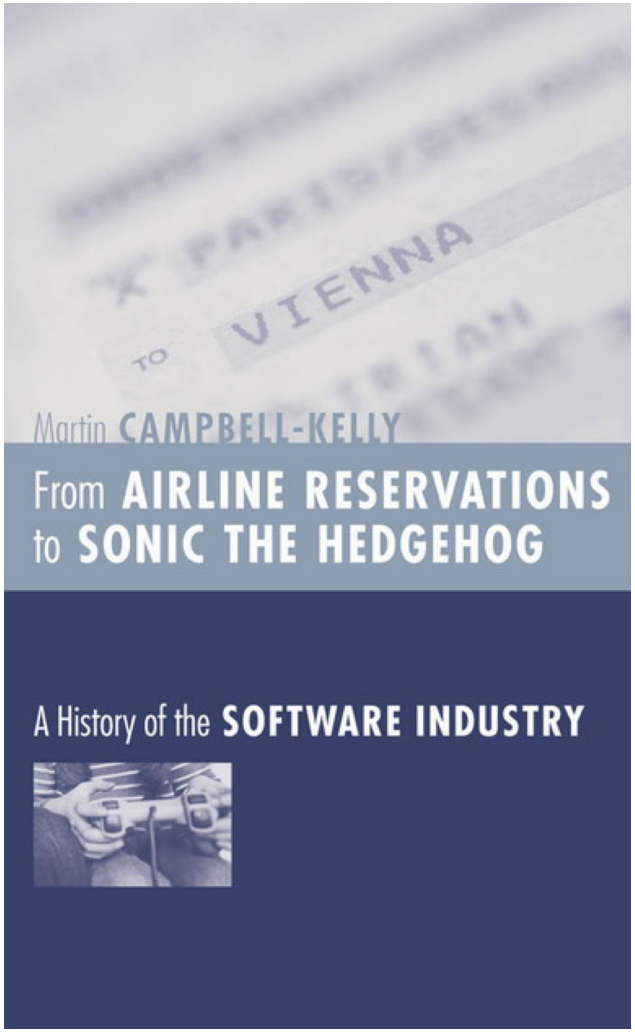
  These components are based on software

- Several types of components, not only software
  - Programs and configuration files
  - System documentation describes system and its architecture
  - User documentation describes how to use the system

- Several categories of software systems

  operating (OS), database management (DBMS), embedded (ES) content management (CMS), central reservation (CRS), etc.

Software Industry History



Architecture (1)

- Architecture of a software (system) describes its structure

  Software elements, relations between these and properties

- Make important choices on the fundamental structure

  Difficult to rewind because very expensive to change

- Analyses to be conducted at several abstraction levels
  - From code to components, libraries, etc. for developers
  - Functional blocks for team leaders
  - Very high level entities for customers

Architecture (2)

- Functional analysis identifies the functions to develop

  WHAT to do in the software system?

- Architecture identifies the structure to give

  HOW to do it in the software system?

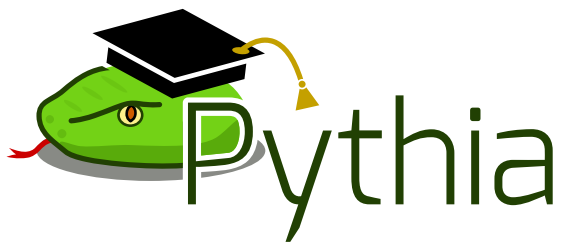
Example: Pythia Platform (1)

- Automatic assessment system for student codes

  Code execution, test suites, feedback generation

- Open source project and code available on GitHub

  https://github.com/pythia-project

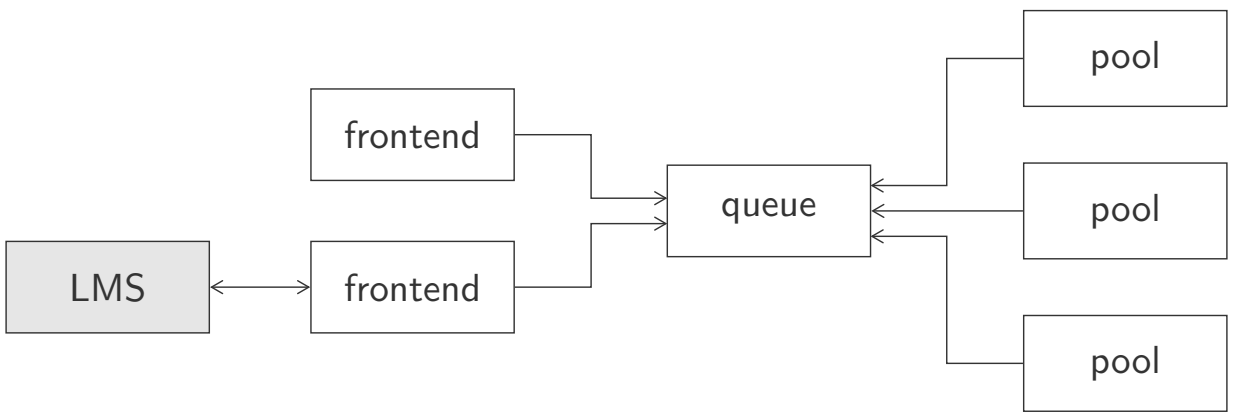


Example: Pythia Platform (2)

- Overview of the architecture of the Pythia platform

  Used to quickly understand the structure of the software system

- Three components and communication links between them
  - the `queue` receives jobs to execute
  - the `pool` executes the job in a virtual machine (VM)
  - the `frontend` interfaces with the user



Definition

- Not a unique definition of what an architecture is

  Symbolic and schematic description of the different components of one or more computer programs, their interrelations and their interactions

- Abstract representation of a software (system)
  - Software component represents a functional unit
  - Connectors provide interaction between components

Code

- The code is not worth a cent, as ideal as it is...
  - The only importance is the implemented business functionality
  - Or rather what people are willing to pay for it
- A software and its code must solve a problem

  ...or provide entertainment for its customers

*"A **stakeholder** is a person or organisation that has rights, share, claims or interests with respect to the system or its properties meeting their needs and expectations."*

Communication Tool

- Several stakeholders around a software system
  - The developer writes the code of the system
  - The business manager integrates the system in the enterprise
  - The final user uses and interacts with the system
  - The infrastructure manager installs and deploys the system
- Each stakeholder has its own concerns

  Several different views of the same software system are needed

Quality

- Strong link between software system architecture and quality

  A given architecture ensures a set of quality criteria

- Numerous quality criteria can be desired

  Fault tolerance, compatibility, maintainability, availability security, extensibility, reliability, scalability, etc.

- Stakeholder concerns translated into requirements

  With strong/soft constraints on several quality attributes

Standard Technique

- Standard techniques to solve recurring problems

  Just base solutions to adapt to each situation

- Depending on the abstraction level of the problem to solve
  - Architecture style (client-server, SOA, etc.)
  - Principle or tactic
  - Reference architecture (Java EE, etc.)
  - Pattern (MVC, *n*-tier, layer, etc.)

Conceptual Integrity (1)

- Overview of what the system needs to do and how

  Vision to completely separate from the system implementation

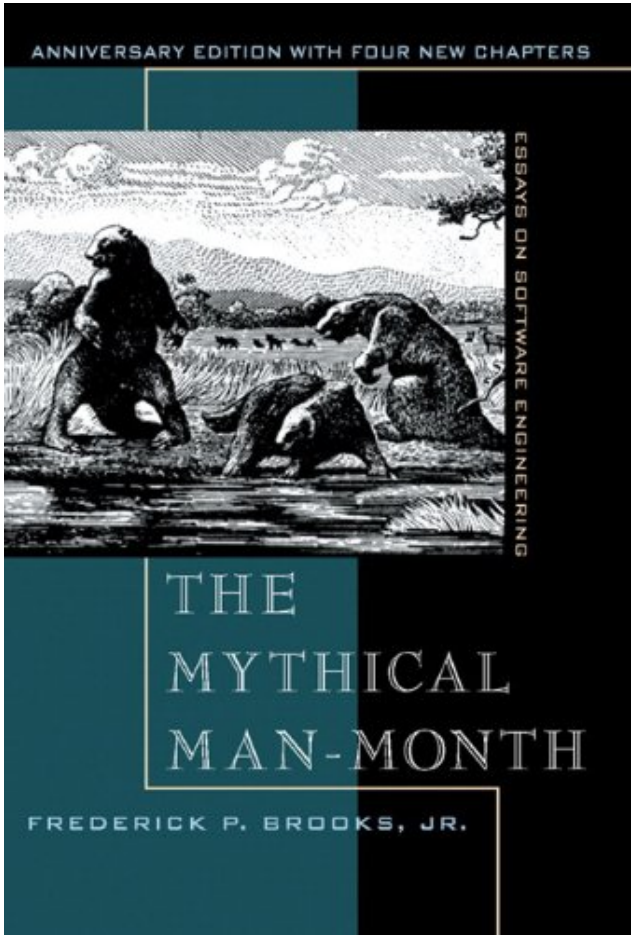
- Software architect ensures we stay in the same global vision

  Changes remain in line with the architecture

- Abstraction of a complex system

  It must be "intellectually understandable"

The Mythical Man-Month



Conceptual Integrity (2)

- Frederick Brooks, The Mythical Man-Month, 1995

  Referred to as "The Bible of Software Engineering"

*"Conceptual integrity is the **most important consideration** in system design. It is better to have a system omit certain anomalous features and improvements, but to reflect **one set of design ideas**, than to have one that contains many good but independent and uncoordinated ideas... **Conceptual integrity** in turn dictates that the design must proceed from one mind, or from a very small number of agreeing resonant minds."*

Motivation

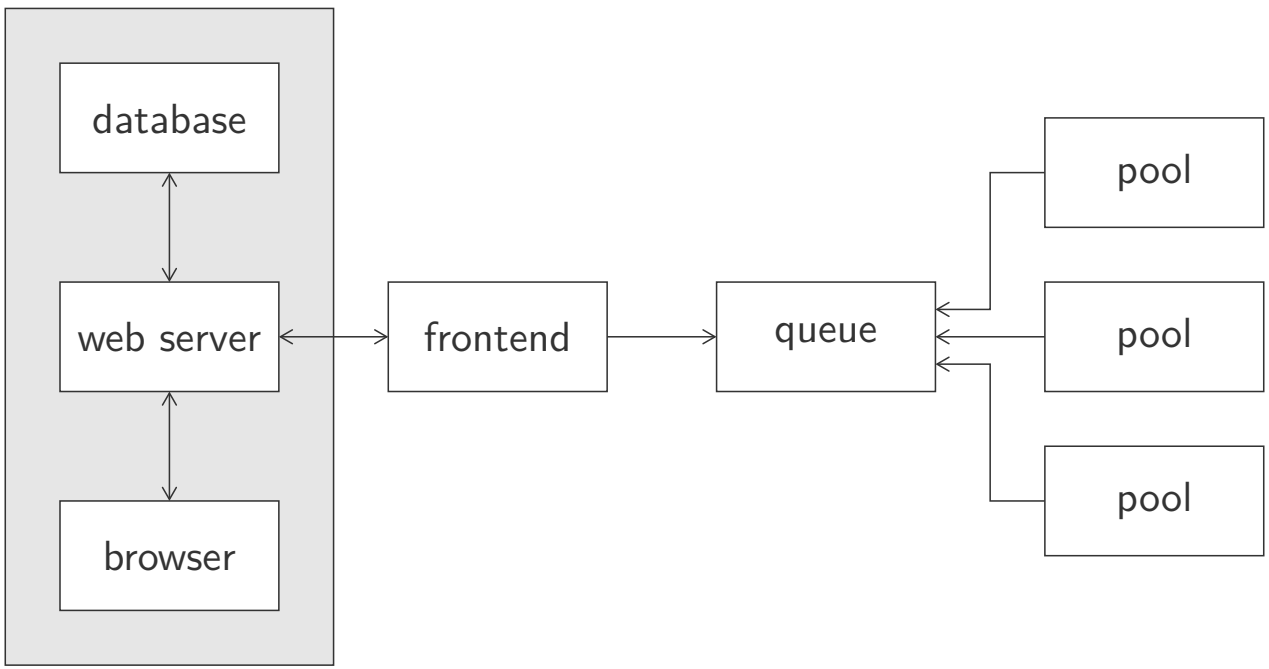
- Several major interests derive from architecture
  - Analysis of the behaviour of a system before implementation
  - Using the same architecture or its elements
  - Force important decision to manage schedule and budget
  - Communication tools between stakeholders
  - Risk and cost analysis and management
- Role of the architect in collaboration with the team leader

  Software system architecture as the main tool

Example: Pythia Platform (3)

- Identification of the structure of the LMS component

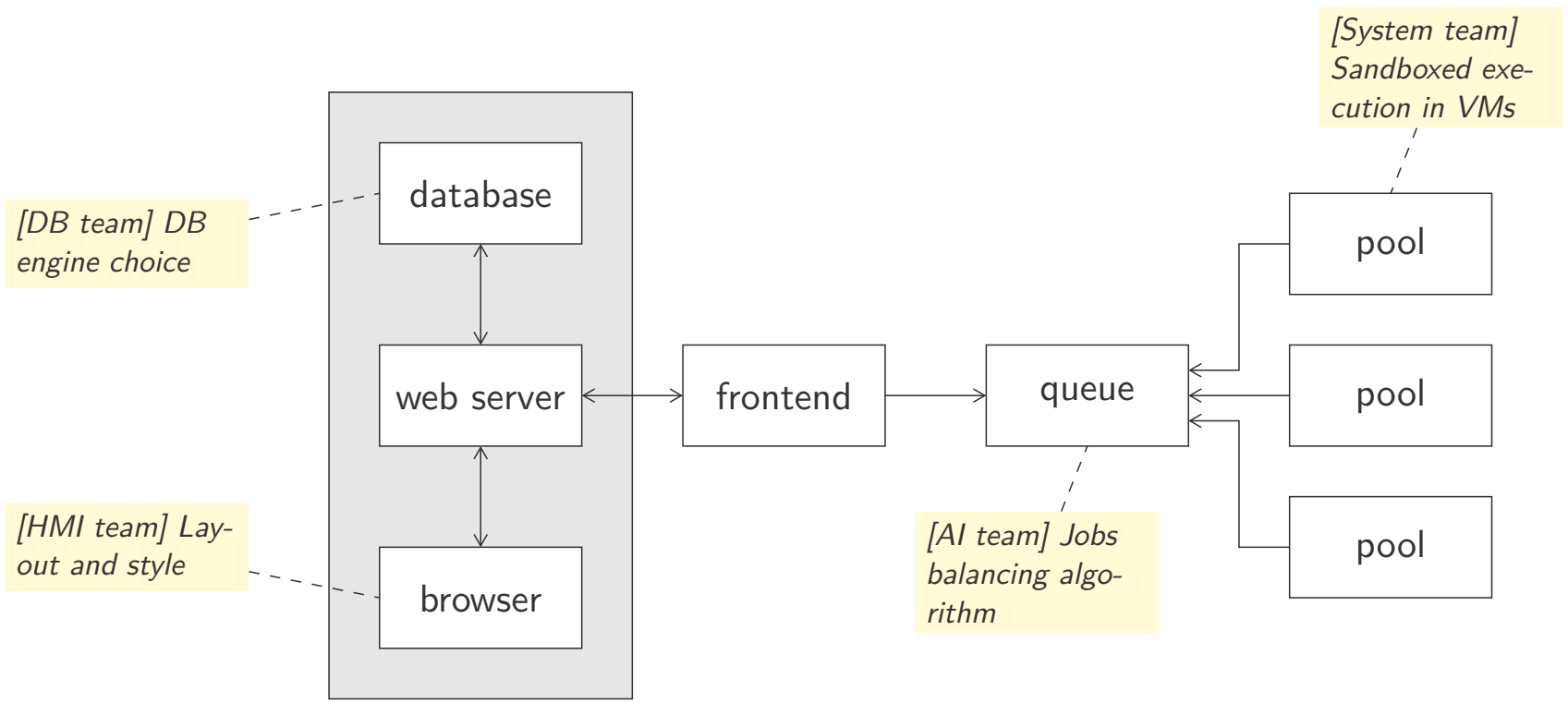
  Lowering the abstraction level of the global architecture



Example: Pythia Platform (4)

- Definition of a work plan for the different teams

  With precise specifications of the different components



Activity

1. **Analysis**

   Establish system requirements and understand the environment

2. **Synthesis**

   Create an architecture for the system

3. **Evaluation**

   Evaluate whether proposed architecture meets the requirements

4. **Evolution**

   Maintain and evolve the architecture in the face of change

ISO/IEC 42010

- Systems and software engineering — Architecture Description

  Architecture description standard for a software (system)

- Define a terminology and basic concepts
  - Architecture, stakeholder, concern, etc.
  - Architectural view, architecture description language, etc.

Viewpoint and View

- Architectural viewpoint
  - Convention to construct, interpret, use and analyse a view
  - Operational, system, technical, logical, deployment, process
- Architectural view
  - Express system architecture from stakeholder's perspective
  - Addressing specific concerns following viewpoints convention
  - Consisting of one or more architecture models

Architecture Style

Architecture Presentation

- Definition of a software system architecture

  Identification of the components and their relationships

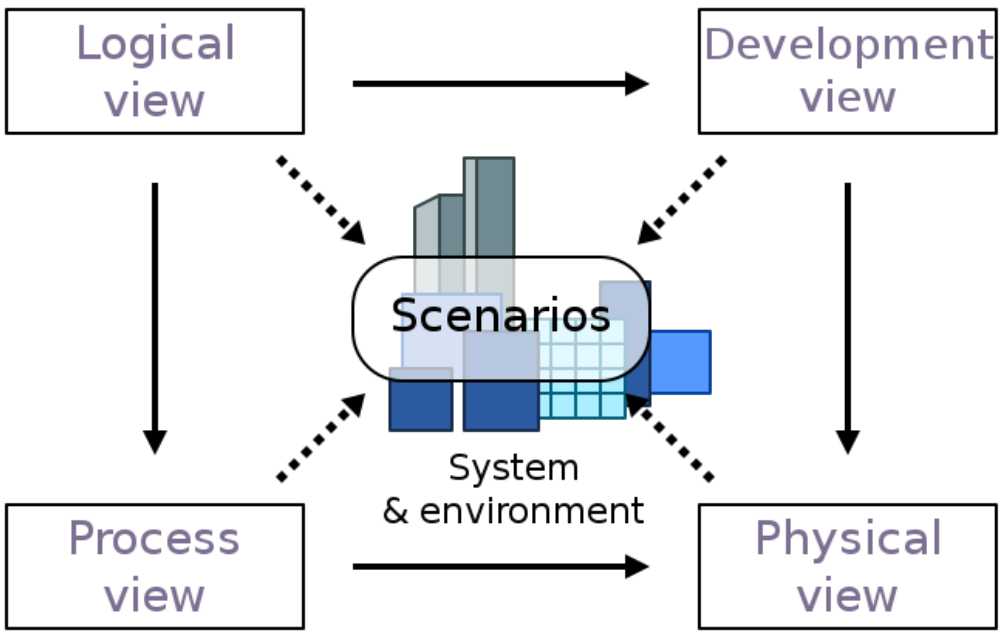
- Representations of an architecture

  Set of views presenting specific perspectives

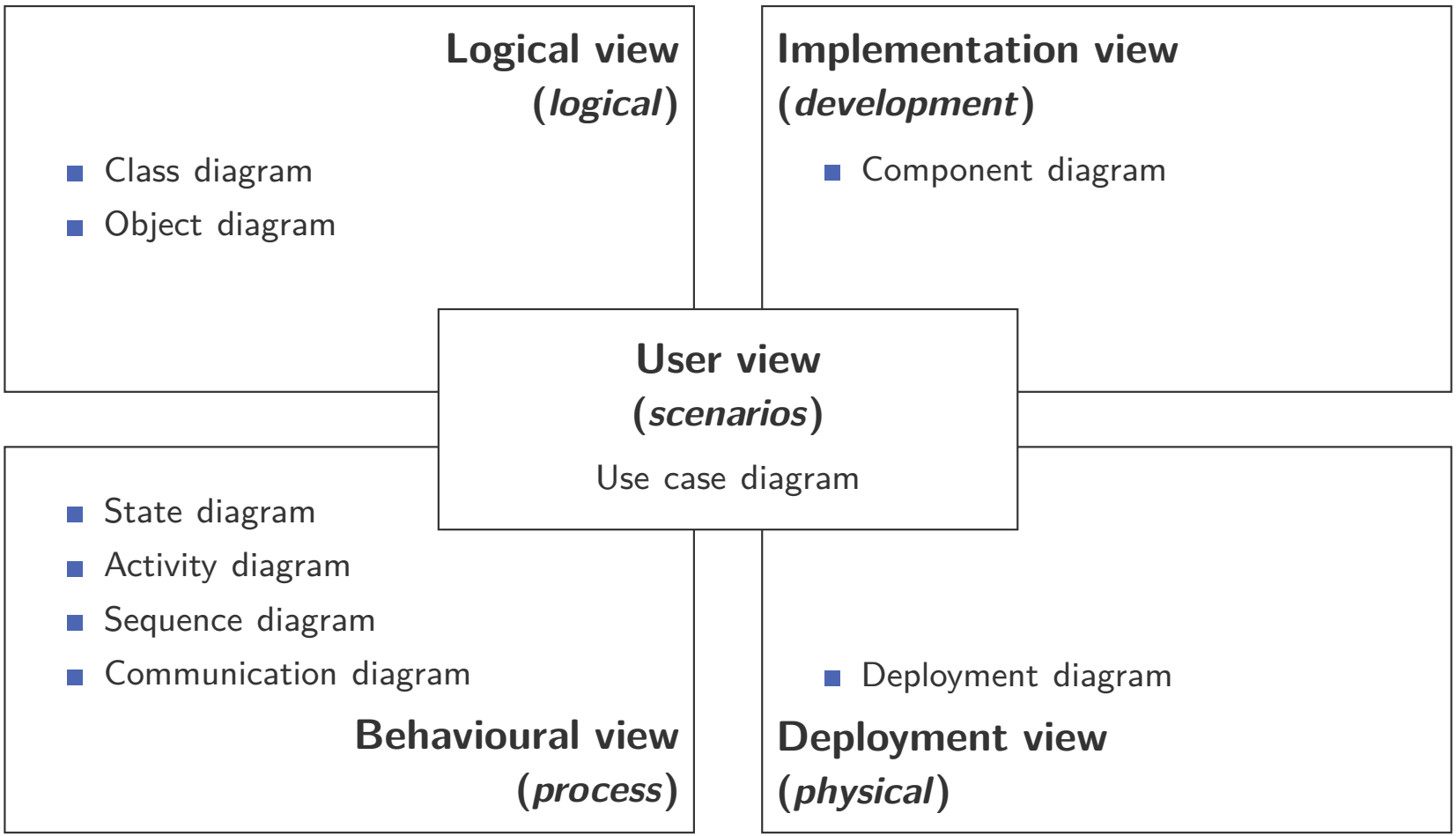
4+1 architectural view model (1)

- View model designed by Philippe Kruchten

  Architecture description based on multiple concurrent views



4+1 architectural view model (2)



4+1 architectural view model (3)

- Conceptual view of the system
  - Logical: describes the features
  - Behavioural: describes performance, extensibility, throughput
- Physical view of the system
  - Implementation: describes configuration management
  - Deployment: describes topology, communication
- User view links the different views between them

  Serves as a starting point to test architecture prototype

Style

- Architecture style related to data
  - Data centric: database, blackboard
  - Data flow: batch, pipe and filter
- Hierarchical organisation of the system

  Construction with successive layers of abstraction
- Description by implicit invocation between components

  Event-oriented, Model-View-Controller (MVC)

Data Centric Architecture

- Central repository for data communicating with customers

  Read/write requests on the data

- **Goal**

  Maintain and guarantee data integrity

- **Use case**

  Shared and frequently used data between components

Data Flow Architecture

- Successions of data transformations
  - Process broken down into successive processing steps
  - Sequential style (each one is turn) or pipeline (simultaneous)
- **Goal**

  Reuse and evolutivity
- **Use case**

  Scientific computations workflow, stages processing

Layer Architecture

- Hierarchical organisation into a set of layers
  - Important to properly define interfaces between layers
  - A layer servers the higher ones and is client of lower ones
- **Goal**

  Complexity $\downarrow$ *and modularity, reusability and maintainability* $\uparrow$
- **Use case**

  Division in successive abstraction levels

Tier Architecture

- Distribution of tiers at the physical level

  Level change through a communication middleware

- Several possibilities to define tiers

  2-tiers: client-server, 3-tiers: client-server-database, etc.

- **Goal**

  Decoupling, distribution, maintainability

- **Use case**

  Distribution of a software on several machines

Implicit Invocation

- Reaction to events rather than explicit calls

  Listeners listen to events produced by sources

- **Goal**

  Flexibility of reaction

- **Use case**

  Model with observers that are notified with events

Model-View-Controller

- Separating the interface from other parts of the system

  The interface is more likely to change than the rest

- Made up of three components
  - **Model**: gathers domain data
  - **View**: presents/displays data
  - **Controller**: controls user-view/model interactions

Why an Architecture?

Software Quality (1)

- Architecture strongly influences the properties of the system

  Nearly definitive choice at the architectural level

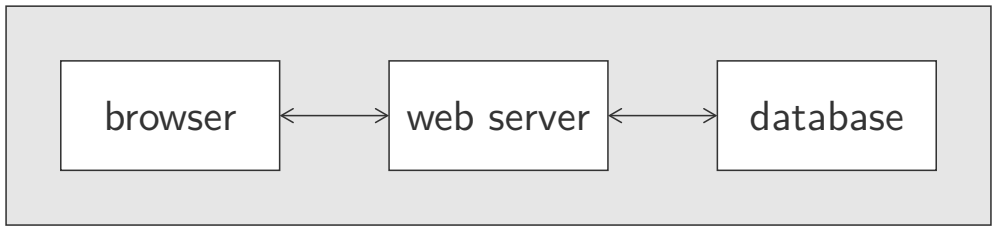
- Favours or penalises non-functional properties

  Performance, security, availability, maintainability, etc.

- No single choice that optimises all criteria

  Criteria relevant to the system must be chosen

Example: Pythia Platform (5)



Analysis of two choices for the web server and database

- On the same machine
  - More security
  - More performance (faster communication)
- On two different machines
  - More maintainability
  - More reliability (replication)

Compromise

- An architecture is a compromise of choice

  Influence the quality of the system, but not a guarantee

- Number of components in the system
  - **Few components**: communication $\downarrow$, performance $\uparrow$
  - **Many components**: performance $\downarrow$, maintainability $\uparrow$
- Redundancy increases reliability/availability

  But will have a negative impact on compactness and security

Software Quality (2)

- Two solutions to improve software quality
  - Create more unit tests to fully cover the code
  - Ask to developers to make more *"manual tests"*
- Positive dynamics of software improvement
  1. Choose quality criteria
  2. Establish how to measure these criteria
  3. Define what is a good quality software

Quality Criterion and Measure (1)

- Common language to model the qualities of a software

  Vocabulary and properties in "-ity"

- Five main criteria from the ISO/CEI 9126 standard
  - **Functionality**
    - Respect of specifications, solving the problem of the user
    - Measured with feature coverage
  - **Reliability**
    - Resistance to user or external services errors/faults
    - Measured with number of passed tests (unit, integration, etc.)
    - Measured with code coverage

Quality Criterion and Measure (2)

- Five main criteria from the ISO/CEI 9126 standard
  - **Usability**
    - Should be easy/intuitive for the user to use the UI
    - Measured with user feedback
    - Measured with tests on groups of people
  - **Efficiency** response time, memory, processor, etc.
    - Measured with response time, CPU/memory consumption
    - Measured with execution time of long operations
  - **Maintainability** standards, documentation, etc.
    - Standard, documentation and maintenance at a lower cost
    - Measured with code complexity, code compliance

Software Quality Criteria

- Autonomy
- Compatibility
- Composability
- Efficiency
- Extensibility
- Reliability
- Integrity
- Interoperability
- Maintainability
- Portability
- Reusability
- Simplicity
- Transparency
- Validity
- Verifiability
- ...

Maintenance and Evolution

- An architecture ease the maintenance and evolution
  - Easy identification of components to be modified/fixed
  - Easy extension through interfaces
  - Make it possible to reuse components
- Work on individual parts in isolation

  Teamwork, updates of parts of the system
- Development with good intentions under difficult conditions

  Deadlines, different qualifications in teams, old code, etc.

Technical Debt (1)

- Need for high-quality architecture with little technical debt

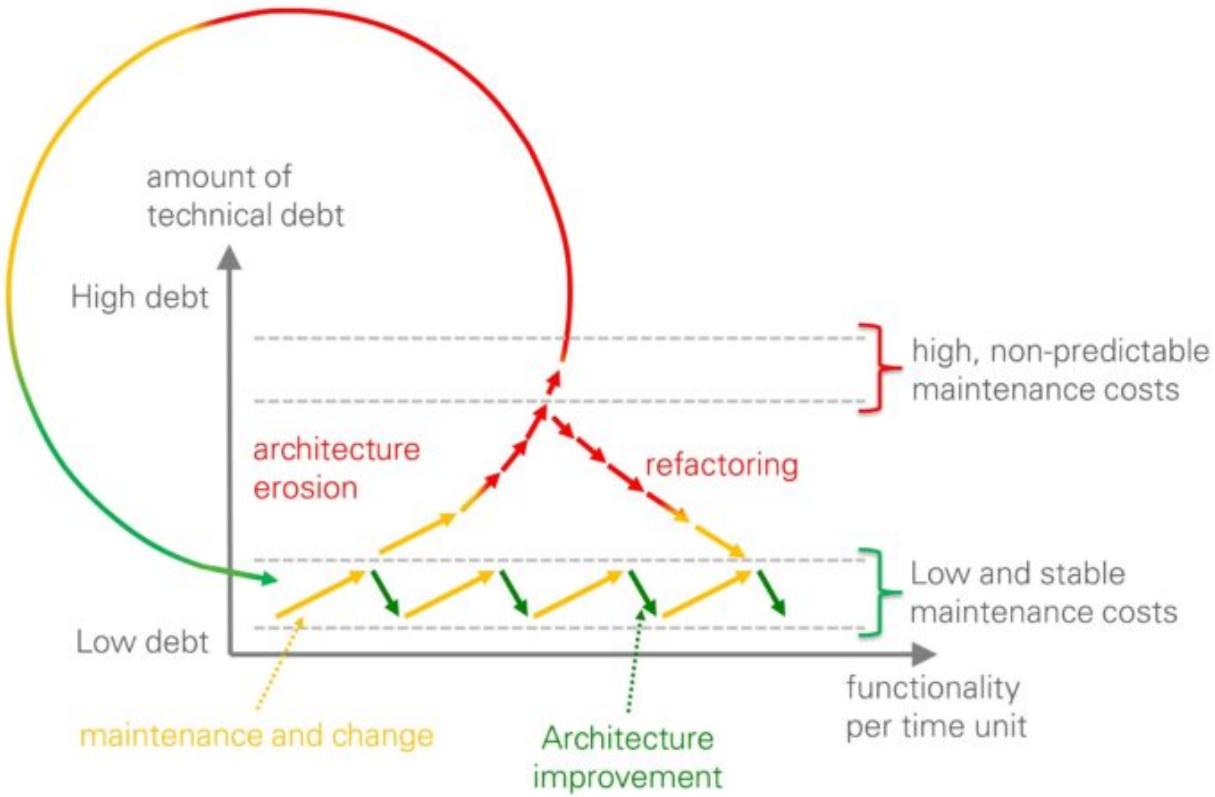
  Maintenance should be structured programming, not defensive

- Due to wrong or sub-optimal technical decisions
  - Always lead to additional costs and very expensive maintenance
  - Implementation debt and design/architecture debt
- Sustainable software architecture follows cognitive mechanisms
  - Chunking, formation of hierarchies and structure of schemata
  - Modularity, hierarchical layering and pattern consistency

Technical Debt (2)

- Maintenance is an opportunity for architecture improvement

  In addition to quick bug fixes since only few errors



Architect Dilemma (1)

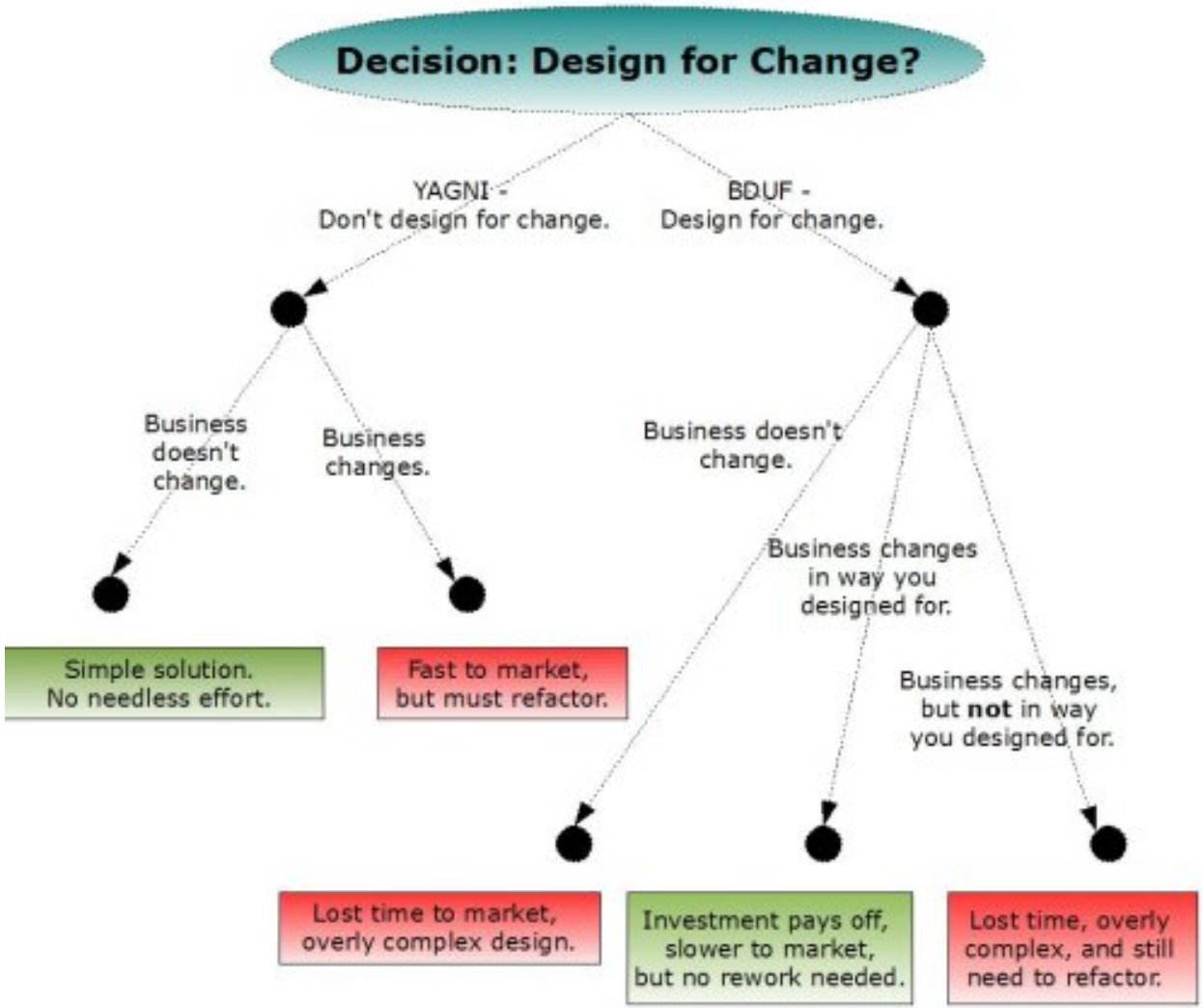
"Your system needs to do X now, but in the future it may need to do Y as well. Knowing that X and Y are closely related, do you spend a little extra time now and design X in such a way that adding Y in the future would be easy? Or do you keep things simple, focus on the more pressing X now, and ignore Y until the day when you really need it?"

- Two opposing sides to tackle this problem
  - Big Design Up Front (BDUF)

    Invest for dividends in maintainability, extensibility, quality...
  - You Arent Gonna Need It (YAGNI)

    Agile approach, Y maybe not necessary anymore, changed to Z...

Architect Dilemma (2)



Good Architecture

- An architecture may be inherently good
  - Contribute to a better extensibility, scalability, reliability, etc.
  - If we ignore the eternal debate BDUF versus YAGNI
- *"A good architecture is one which meets the needs of the entity that funds its existence."*
  - The "good" is not an intrinsic property of a system
  - Sacrifices can be made at the request of business

Software Architect

- Role of the software architect is to define an architecture
  - which satisfies the **requirements** of the customer
  - given the **constraints** imposed on the system
- Communication and promotion of the system architecture

  Bridge between the different stakeholders of the system
- Defending the conceptual integrity of the architecture

  While regularly criticising and refining it

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