Software architecture:
Introduction

Alexander Serebrenik
This week sources

Slides by Johan Lukkien and Rudolf Mak
Software architecture

• Software architecture is the **fundamental organization** of a system embodied in
  • its **elements**,  
  • **relationships**,  
  • and in the principles of its **design** and **evolution**.

[IEEE Std. 42010-2011]
“Fundamental organization”

• Less change-prone:
  • “Architecture of software is a collection of design decisions that are expensive to change.”
    Alexander Ran, Nokia Research
    European Conf on Software Engineering, 2001

• Not all aspects of system organization are fundamental
  • Hence, not all design decisions impact a system’s architecture
  • How one defines “fundamental” depends on the stakeholders’ perspectives on the system goals
Stakeholders?

- **Stakeholder** is a person, group or organization with an interest in a project
  - we focus on the **roles** of stakeholders not their identities.
  - the same person can hold multiple roles.
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<tr>
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<td>Manage the evolution of the system once operational</td>
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<tr>
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Company A, a manufacturer of computer hardware, wants an enterprise resource planning (ERP) system to better manage all aspects of its supply chain from ordering through delivery. Management anticipates the system being constructed from a custom off-the-shelf (COTS) package combined with some in-house development for specialized aspects of functionality. The new system must be deployed within one year, in time for a meeting where shareholders will consider future funding for the company.

- Identify the stakeholders in this story.
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Solution

- **Acquirers**: the business sponsor (senior management), responsible for funding; the purchasing department and representatives of IT, who will evaluate a number of potential ERP packages.

- **Users**: internal staff, including those who work in order entry, purchasing, finance, manufacturing, and distribution.

- **Developers, system administrators, and maintainers**: the internal IT department

- **Assessors**: internal acceptance test team.

- **Communicators**: internal trainers.

- **Support**: an internal help desk (possibly in conjunction with the COTS supplier).
Stakeholders, goals and concerns

- Different **stakeholders** have different **concerns**
- Different **concerns** imply different **viewpoints**
Stakeholders, goals and concerns

- Different **stakeholders** have different **concerns**
- Different **concerns** imply different **viewpoints**
  - **Viewpoint** a way of looking at a system from the position of a certain **stakeholder** with a particular **concern**
    - defines creation, depiction and analysis of a view
    - language, used models, notation, methods, analysis techniques
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    - leaves out details irrelevant to concerns
    - preserves the properties of interest with respect to those concerns
Medical example

- **System**: human heart
- **Stakeholder**: cardiologist [*class*: Tester/Maintainer]
- **Concerns**: identify and treat disorders of the heart
- **Viewpoint**:
  - used models: electrocardiography (ECG), echocardiography, ballistocardiography
  - analysis techniques: ECG interpretation, …

**Model kinds**

**Models**
Viewpoint vs View

• **Viewpoint** should govern the **View**
  • Relation similar to type-instance, grammar/language, ...
  • Viewpoints are generic, and can be stored in libraries for re-use.
  • A view is always specific to the architecture for which it is created.
So far: stakeholders, concerns, views, viewpoints, models and their kinds
Library viewpoints

- “Viewpoints are generic, and can be stored in libraries for re-use”

- What are the popular library viewpoints?
  - IEEE Standards to not indicate specific viewpoints
  - Kruchten’s 4+1 [1995]
  - Rozanski, Woods [2005]
Kruchten’s 4+1

• **1995**: Kruchten, Philippe. *Architectural Blueprints — The “4+1” View Model of Software Architecture*.
• popularized the “multiple views” idea

• **2000**: IEEE Standard 1471
• formal conceptual model for architectural descriptions
• standard terminology
• distinguish between views and viewpoints

• Be careful: Kruchten’s “views” are viewpoints
• The word “view” is used for historical reasons

Kruchten’s “views” (viewpoints)

A number of standard (library) views

end users functionality

Logical View

programmers software management

Development View

Scenarios

Process View

system integrators performance, scalability

Deployment View

system engineers topology, communication

4+1 View Model

[Kruchten 95]
Logical view

- The user’s view on the system, i.e. what a user encounters while using the system
  - classes and objects (class instances) documenting user-visible entities
    - including interfaces, that imply responsibilities
  - interaction diagrams: interactions describing usage scenario’s
  - state diagrams: describing state changes as result of interactions

- Typical relations: is-a, has-a, …
Twitter example: Logical view

A domain model
- class diagram
- captures concepts from the application domain and their relationships

Additional models will typically be used to represent the logical view.
Development view

- **Components**, functions, subsystems organized in modules and **packages**
  - Component/module interface descriptions, access protocols
- Logical organization – **layering** of functionality, **dependencies**
  - Don’t misunderstand the name ‘logical’
- Organization into files and folders

- Typical relations: uses, contains, shares, part-of, depends-on
Twitter example: Development view

With thanks to Rudolf Mak
Process view

- Concurrent **activities** inside the system
- Mapping of applications to distinct memory spaces and units of execution
  - unit of execution: process, thread
  - memory space: associated with a process
- Choice of communication protocols
- Scheduling of activities such as to satisfy **time** and resource constraints
  - Performance
Twitter example: process view

http://www.slideshare.net/raffikrikorian/qcon-nyc-2012-twitters-real-time-architecture

With thanks to Rudolf Mak
Deployment view

- **Machines** (processors, memories), networks, connections
  - including specifications, e.g. speeds, sizes
- **Deployment**: mapping of elements of other views to machines
  - Typical relations: connects-to, contains, maps-to
  - Concerns: performance (throughput, latency), availability, reliability, etc., together with the process view
Twitter example: Deployment view

- Not very convincing
- No physical components

- It is hard to find a twitter deployment model

With thanks to Rudolf Mak
Scenarios

• Set of **use cases**
  • Small set
  • Representative use cases
Twitter scenario example: insertion of a tweet

1. User:
   a) Logon to GUI
   b) Send tweet

2. Process the insertion request

3. Put the request in the queue system

4. Back-end
   a) Get request from front of queue
   b) Insert tweet into memory.
   c) Update the search engine with an index entry

5. Send feedback to queuing system

6. Notify GUI
More examples?

• The original paper by Philippe Kruchten

• Hewlett Packard template for documenting software and firmware architectures
A number of standard (library) views

Class Diagram
Object Diagrams
State machine
Activity Diagram
Sequence Diagram
Timing Diagram

Logical View

Development View

Deployment View

Scenarios
Use Cases

end users
functionality

programmers
software management

system integrators
performance, scalability

system engineers
topology, communication

4+1 View Model

[Kruchten 95]
• **Logical**: capture the logical (often software) entities in a system and how they are interconnected.

• **Physical**: capture the physical (often hardware) entities in a system and how they are interconnected.

• **Deployment**: Capture how logical entities are mapped onto physical entities.

• **Concurrency**: Capture how concurrency and threading will be managed in a system.

• **Behavioral**: Capture the expected behavior of (parts of) a system.
How would we map different classifications?

Kruchten’s “views” (viewpoints)

A number of standard (library) views

- Logical View: end users functionality
- Development View: programmers software management
- Process View: system integrators performance, scalability
- Deployment View: system engineers topology, communication
- Scenarios: end users

4+1 View Model [Kruchten 95]

Link Kruchten’s views and viewpoints of Taylor, Medvidovic Dashofy to each other

Taylor, Medvidovic, Dashofy: Alternative classification of viewpoints

- **Logical**: capture the logical (often software) entities in a system and how they are interconnected.
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A number of standard (library) views

- Logical View: focuses on end users functionality,
- Development View: programmers software management,
- Process View: system integrators, performance, scalability,
- Deployment View: system engineers, topology, communication,
- Scenarios: common theme in views

4+1 View Model [Kruchten 95]

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Rozanski Woods: Alternative classification

- **Viewpoint library**
  - Functional viewpoint
  - Information viewpoint
  - Concurrency viewpoint
  - Development viewpoint
  - Deployment viewpoint
  - Operational viewpoint

Not explicitly addressed by Kruchten’s 4+1
Rozanski Woods: Alternative classification

- **Viewpoint library**
  - Functional viewpoint
  - Information viewpoint
  - Concurrency viewpoint
  - Development viewpoint
  - Deployment viewpoint
  - Operational viewpoint

- **Perspectives** (a.k.a. non-functional requirements)
  - Security
  - Performance and scalability
  - Availability and resilience
  - Evolution
  - and many more ...

Not explicitly addressed by Kruchten’s 4+1

Orthogonal to viewpoints/views
Recall: Kruchten popularized “multiple views” idea

Architectural description aggregates multiple viewpoints and views.
Recall: Kruchten popularized “multiple views” idea

Architectural description aggregates multiple viewpoints and views.

What risks associated with multiplicity of views can you identify?
Risks due to multiplicity of views

Wrong views  
Fragmentation  
Inconsistency
Wrong views

• Which views are suitable?

• Kruchten, Rozanski-Woods provide guidance but **specifics of the system** should be taken into account
  • Is concurrency important? Is security important?

• Matter of experience and skill
Fragmentation

- Kruchten: 4+1, Rozanski-Woods: 6
- What about 50 views?

- Each view has to be created and maintained ⇒ costs!
- Views have to be kept consistent, the more views the more potential inconsistencies ⇒ costs!

- Consider combining less crucial views
  - e.g. deployment & concurrency
  - do not overdo, combined views are more difficult to understand
Inconsistency

• All views are related
  • They describe the same system!
Inconsistency

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- Recall: interaction diagrams should be consistent with the corresponding class diagrams and use case diagrams
Inconsistency

- All views are related
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- Recall: **interaction diagrams** should be consistent with the corresponding **class diagrams and use case diagrams**

  ![Diagram showing class, object, state machine, and activity diagrams with logical view and use cases]

Logical view should be consistent with scenarios
Of course, there are more rules

Quote: “Package A depends on package B if A contains a class which depends on a class in B”

⇒ Development view should be consistent with the logical view
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Quote: “Package A depends on package B if A contains a class which depends on a class in B”

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Quote: “Manifestation maps artifacts to … / components / packages”

⇒ Deployment view should be consistent with the development view
Of course, there are more rules

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⇒ Development view should be consistent with the logical view

Quote: “Manifestation maps artifacts to ... components / packages”

⇒ Deployment view should be consistent with the development view

Quote: “Manifestation maps artifacts to use cases”

⇒ Deployment view should be consistent with scenarios
If something changes at the end of the arrow, a change will probably be required at the start of the arrow.
Still...

- We need a mechanism to record in the architecture description **relations between different views**
  - What views should be consistent with each other?
  - Does one view refine another? (package vs class?)
  - Should one be traced to another?
We need a mechanism to record in the architecture description **relations between different views**

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**Architectural description (AD) elements**
- stakeholders, views, viewpoints, models…

**Correspondences vs. Correspondence rules**
- similarly to views vs. viewpoints
Putting it all together: architecture

**Rationale**: explanation, justification or reasoning about architecture decisions.
Rationale: closer look
Why do we distinguish between architecture and architecture description?
Different flavors of architecture

What other kind of architecture flavor would you expect?

Architecture as intended

Architecture as described
Different flavors of architecture

- Architecture as intended
- Architecture as described
- Architecture as implemented
Different flavors of architecture

Architecture as intended

Architecture as described

Architecture as implemented

- implementation, forward engineering
- architecture reconstruction, reverse engineering
Different flavors of architecture

Prescriptive architecture
Architecture as intended

Descriptive architecture
Architecture as described

Implementation, forward engineering

Architecture as implemented

Architecture reconstruction, reverse engineering
Beware: incompleteness

- **Architecture as described** can/should never be complete with respect to
  - the system
    - architecture = “fundamental organization”
    - not everything is fundamental
  - architecture as intended
    - limitation of the architecture description language(s)
  - architecture as implemented
    - freedom of implementation choices

- Architecture as intended should at least be **complete** wrt the stakeholders’ concerns
Architectural Evolution

• When a system evolves
  • ideally its **prescriptive architecture** is modified first
  • in practice, the system – and thus its **descriptive architecture** – is often directly modified

• This happens because of
  • Developer sloppiness
  • Perception of short deadlines which prevent thinking through and documenting
  • Lack of documented prescriptive architecture
  • Need or desire for code optimizations
  • Inadequate techniques or tool support
Architectural Degradation

- **Architectural drift** is introduction of principal design decisions into a system’s descriptive architecture that
  - are not included in, encompassed by, or implied by the prescriptive architecture
  - but which **do not violate** any of the prescriptive architecture’s design decisions
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- **Architectural erosion** is the introduction of architectural design decisions into a system’s descriptive architecture that violate its prescriptive architecture

- If architectural degradation is allowed to occur,
  - one will be forced to reconstruct the system’s architecture sooner or later
Software architecture

- Software architecture is the **fundamental organization** of a system embodied in
  - its **elements**,
  - relationships,
  - and in the principles of its **design** and **evolution**.

[IEEE Std. 42010-2011]

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UML diagrams and Kruchten’s view(points)?

A number of standard (library) views

- **Class Diagram**
  - end users
  - functionality

- **Interaction Diagrams**
  - Logical View

- **State machine**

- **Activity Diagram**
  - Process View

- **Sequence Diagram**

- **Deployment Diagram**
  - system integrators
  - performance, scalability

- **Deployment View**
  - system engineers
  - topology, communication

- **Development View**

- **Component Diagram**

- **Package Diagram**

- **Scenarios**
  - Use Cases

**4+1 View Model**

[Kruchten 95]

Putting it all together: architecture

Why do we distinguish between architecture and architecture description?
The functional viewpoint
• describes the system’s runtime functional elements and their responsibilities, interfaces and primary inter-actions.
• is relevant to all stakeholders
• addresses concerns like: functional capabilities, external interfaces, internal structure and design philosophy.

The information viewpoint
• describes the way the architecture stores, manipulates and distributes information.
• is primarily relevant for users, acquirers, developers and maintainers
• addresses concerns about information structure, content and flow; data ownership, volume, validness, lifetime, and accessibility; transaction management; recovery; regulations.
The concurrency viewpoint
- describes the concurrency units of the system, their functionality, and the required coordination
- is relevant to developers, testers and some administrators
- addresses concerns like: task structure, inter process communication, state management, synchronization and reentrance, process creation and destruction

The development viewpoint
- describes the architecture that supports the development process
- is relevant to software developers and testers
- addresses their concerns about. Module organization, common processing, standardizations of design and testing, code organization and instrumentation.
The deployment viewpoint
- describes the environment into which the system will be deployed, including dependencies the system has on its run-time environment
- is relevant for system administrators, developers, testers, communicators and assessors and addresses their concerns about hardware (processing elements, storage elements, and network), third-party software, and technology compatibility.

The operational viewpoint
- describes how the system will be operated, administered, and supported when running in its production environment
- is relevant to system administrators, developers, testers, communicator, and assessors, and addresses their concerns about installation and upgrade, operational monitoring and control, configuration management, resource management.