Softwarekomponentensysteme

Software Architecture and Components

Bernhard Löwenstein

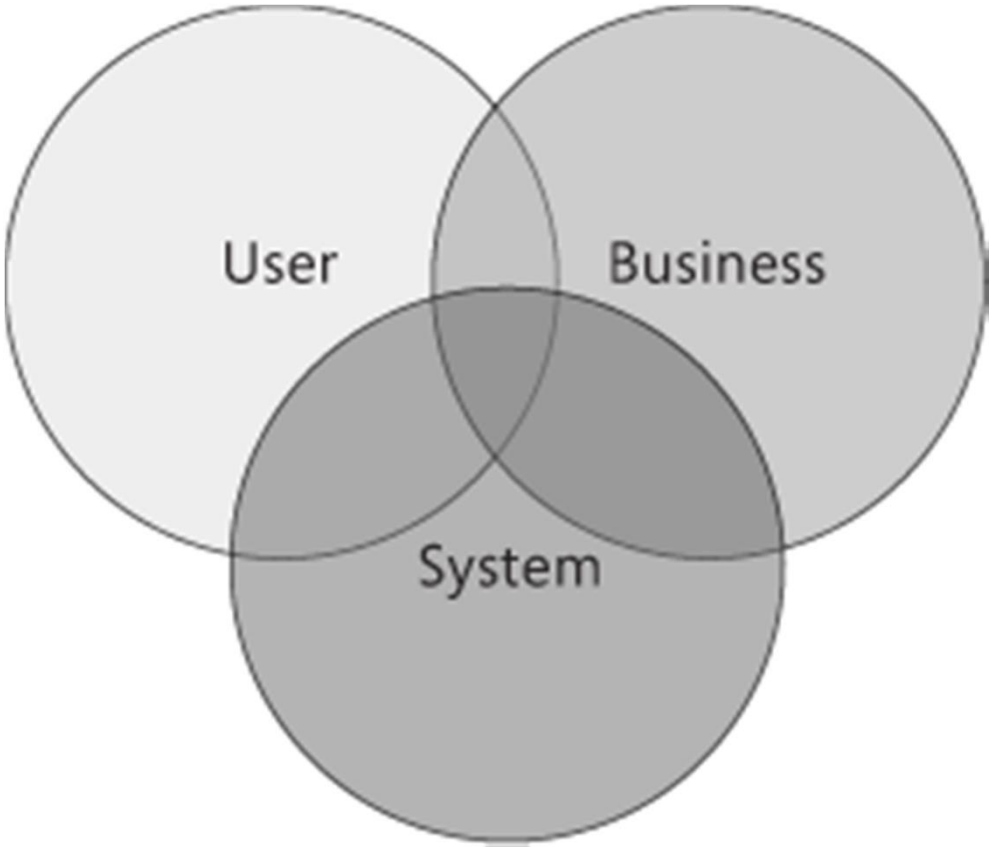
Software Architecture

What is Software Architecture?

"Software architecture encompasses the set of significant decisions about the organization of a software system including the selection of the structural elements and their interfaces by which the system is composed; behavior as specified in collaboration among those elements; composition of these structural and behavioral elements into larger subsystems; and an architectural style that guides this organization. Software architecture also involves functionality, usability, resilience, performance, reuse, comprehensibility, economic and technology constraints, tradeoffs and aesthetic concerns."

(Mary Shaw & David Garlan)

Why is Architecture Important?



Key Principles

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Key Architecture Principles

- Build to change instead of building to last
- Model to analyze and reduce risk
- Use models and visualizations as a communication and collaboration tool
- Identify key engineering decisions

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Key Design Principles

- Separation of concerns
- Single responsibility principle
- Don’t repeat yourself (DRY)
- Minimize upfront design

Separation of Concerns

- *"Separating a computer program into distinct features that overlap in functionality as little as possible"*
- Examples:
  - OSI Layer Stack
  - HTML, CSS, JavaScript
  - MVC
  - Aspected-Oriented Programming

Single Responsibility Principle

- *"Every class should have a single responsibility, and that responsibility should be entirely encapsulated by the class"*
- Example:
  - Format & Print Document
  - 2 Classes: Formatter, Printer

Don’t Repeat Yourself (DRY)

- *"Every piece of knowledge must have a single, unambiguous, authoritative representation within a system"*
- Tools:
  - Methods, Classes, Libraries, …
  - Code Generators
  - Build Systems

Minimize Upfront Design

- *"Only design what is necessary"*
- You Ain't Gonna Need It (YAGNI)
- The time spent is taken from adding, testing or improving necessary functionality.
- The new features must be debugged, documented, and supported.
- Any new feature imposes constraints on what can be done in the future, so an unnecessary feature now opens the possibility of conflicting with a necessary feature later.
- Until the feature is actually needed, it is difficult to fully define what it should do and to test it.

Key Design Considerations

- Determine the Application Type
- Determine the Deployment Strategy
- Determine the Appropriate Technologies
- Determine the Quality Attributes
- Determine the Crosscutting Concerns

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SOLID OOP Principle

S **Single responsibility principle**
an object should have only a single responsibility

O **Open/closed principle**
software entities should be open for extension, but closed for modification

L **Liskov substitution principle**
objects in a program should be replaceable with instances of their subtypes without altering the correctness of that program

I **Interface segregation principle**
many client specific interfaces are better than one general purpose interface

D **Dependency inversion principle**
do not depend upon concretions, one should depend upon abstractions

Architectural Styles

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Architectural Style

A set of principles that provide an abstract framework for a family of systems

Architectural Styles

Category	Architecture Styles
Communication	Service-Oriented Architecture (SOA) Message Bus
Deployment	Client/Server N-Tier (common: 3-Tier)
Structure	Component-Based Object-Oriented Layered Architecture

Service-Oriented Architectural Style

- Functionality as a set of services
- Standards based interfaces
- Services:
  - are autonomous
  - are distributable
  - are loosely coupled
  - share schema and contract, not classes
  - Compatibility is based on policy

Service-Oriented Architectural Style

- Principles:
  - Abstraction
  - Discoverability
  - Interoperability

Message Bus Architectural Style

- Ability to receive & send messages over channels
- Applications don't need to know each other
- Pluggable architecture: Systems attach and detach
- Asynchronously by design
- Common Bus = Router, Producer/Consumer, Publish/Subscribe patterns

Message Bus Architectural Style

- Variations:
  - Intra-System Message Bus (e.g. CAN)
  - Enterprise Service Bus (ESB)
  - Internet Service Bus (ISB)
- Pros:
  - Extensibility
  - Low complexity
  - Flexibility
  - Loose coupling
  - Scalability
  - Application simplicity

Architectural Styles

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Client/Server Architectural Style

- Classically referred to as "2-Tier Architecture"
- UI Client to access a database with logic (triggers, stored procedures)
- Examples:
  - Websites: Browser ⇔ Web Server
  - FTP Clients

Client/Server Architectural Style

- Pros:
  - High security: central data store
  - Centralized data access
  - Ease of maintenance
  - …
- Cons:
  - Data & Business logic closely coupled
  - Does not scale
  - Hard to extend
  - …

N-Tier / 3-Tier Architectural Style

- Independent tiers
  - Only the direct neighbours know each other
- Partitions the concerns of the application into stacked groups (layers)
- Tiers communicate with each other via defined interfaces / communication channels
- Can be deployed on different machines

N-Tier / 3-Tier Architectural Style

- Pros:
  - Maintainability: Each tier is independent
  - Scalability: Tiers on different machines
- Cons:
  - More complex development efforts
  - Clear separation between tiers can be hard

Architectural Styles

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Component-Based Architectural Style

- Decomposition of design into functional or logical components
- Components expose well-defined interfaces with methods, events and properties
- Examples: UI components, business components, data access components
- Execution environment: CORBA, Jakarta EE, Spring, …

Object-Oriented Architectural Style

- System consists of cooperating objects instead of routines or procedural instructions
- Principles:
  - Abstraction
  - Composition
  - Inheritance
  - Encapsulation
  - Polymorphism

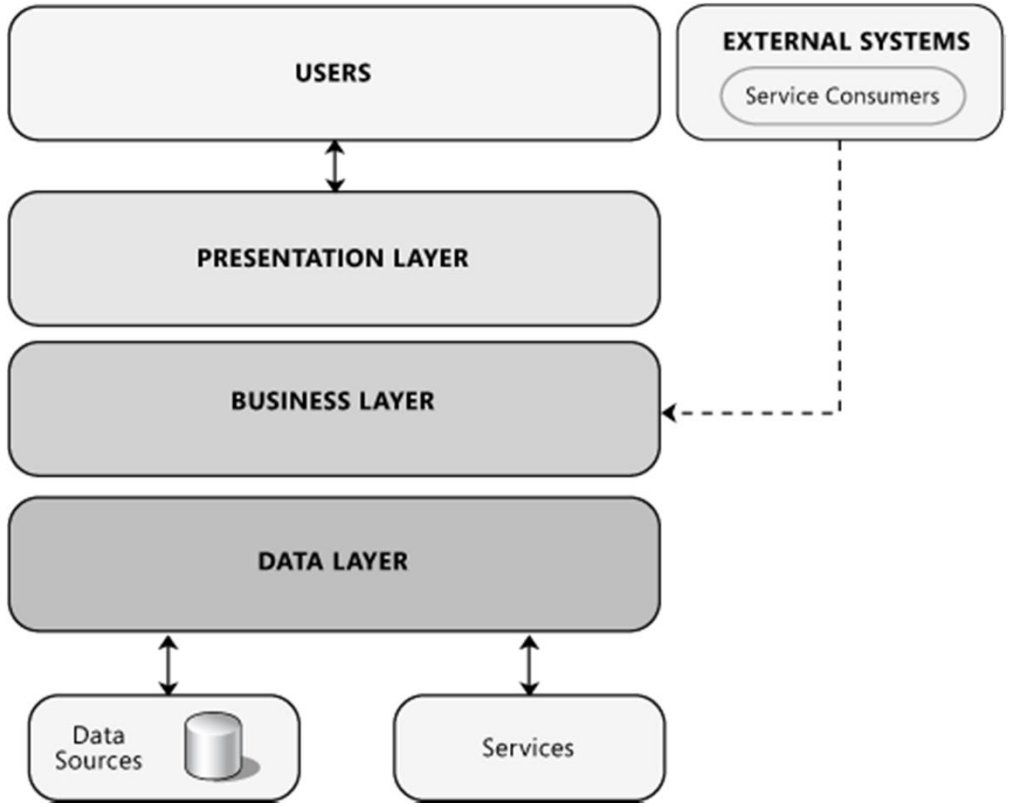
Layered Architectural Style

- Grouping of related functionality into distinct layers, stacked vertically on top of each other
- Functionality in each layer related by a common role or responsibility (e.g. presentation, business logic, data access)
- Communication between layers is explicit & loosely coupled
- Only dependencies on the N-1th layer allowed

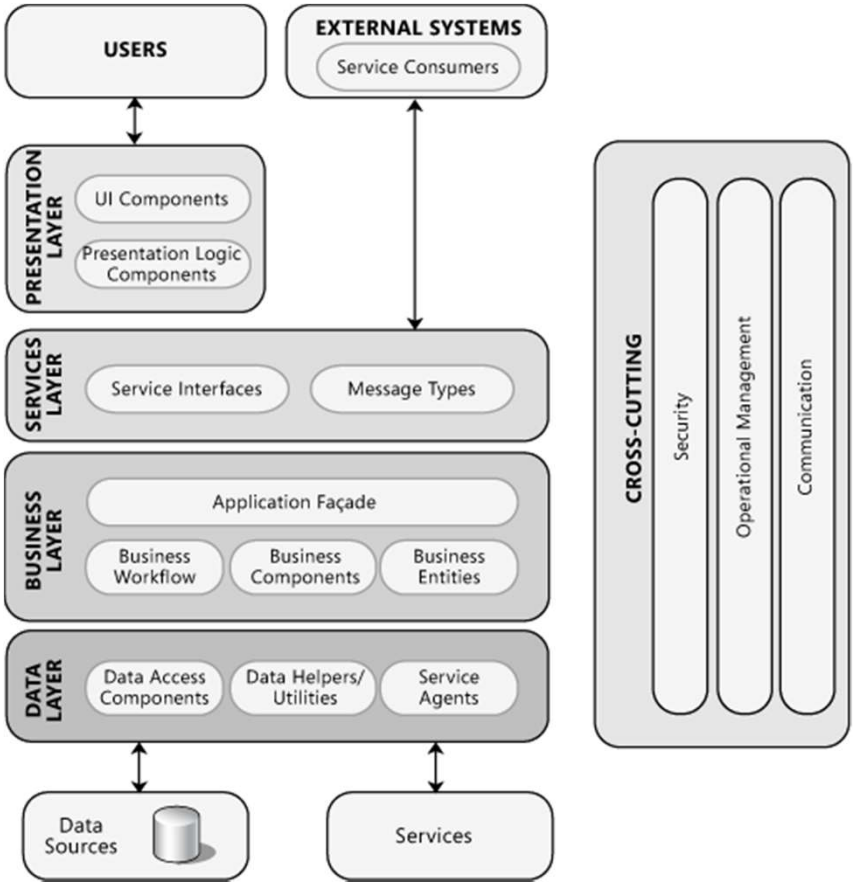
Layered Architectural Style

- Common Principles:
  - Abstraction
  - Encapsulation
  - Clearly defined functional layers
  - Reusable
  - Loose coupling

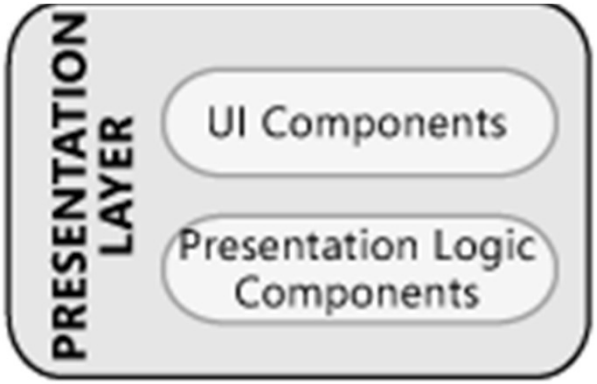
Logical View of 3-Layer Application



More Detailed Architecture



Presentation Layer



- UI Components
  - Visual Elements aka "Controls"
- Presentation Logic Components
  - Logical behavior of the UI
  - UI flow, Validation, Calculation, ..
  - Use appropriate patterns (Model-View-Controller, Model-View-Presenter, …)

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Presentation Layer Technologies

- Swing
- JavaServer Faces
- JavaFX
- …

Challenges at Presentation Layer

- Validation
- Navigation
- Exception management
- Composition
- Communication
- Caching

Service Layer

- Important separation:
  - Hides internal implementation
- Service contracts
- Message types
- Translator components

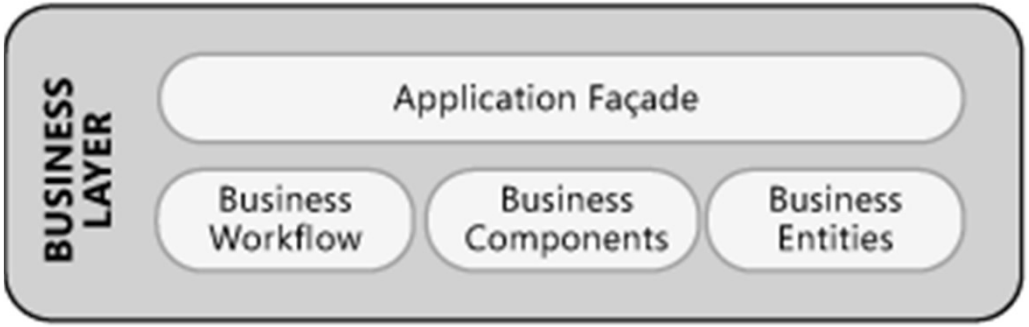
Services Design

- Application-scoped
- Extensibility
- Design service contracts separately
- Compose message types of standard elements
- Assume invalid requests
- Detect & manage repeated messages
- Manage messages arriving out of order

Service Layer Technologies

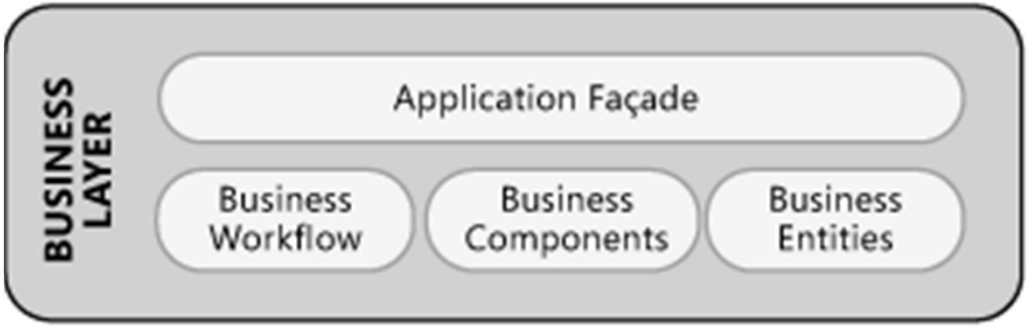
- Protocols:
  - SOAP, REST, …
- Frameworks / Infrastructure:
  - JAX-WS
  - JAX-RS
  - …

Business Layer



- Application façade:
  - Simplified interface
  - Hides complexity
  - Combines multiple operations & components
  - Just forwards calls, does security checks, …

Business Layer

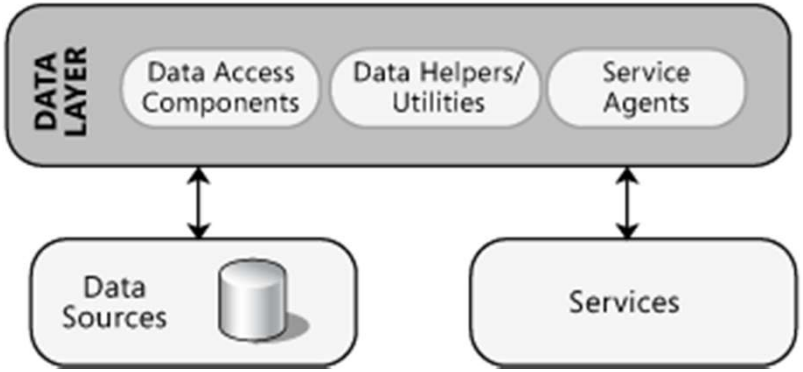


- Business logic components:
  - Business workflow components
  - Business components
  - Business entity components

Business Layer

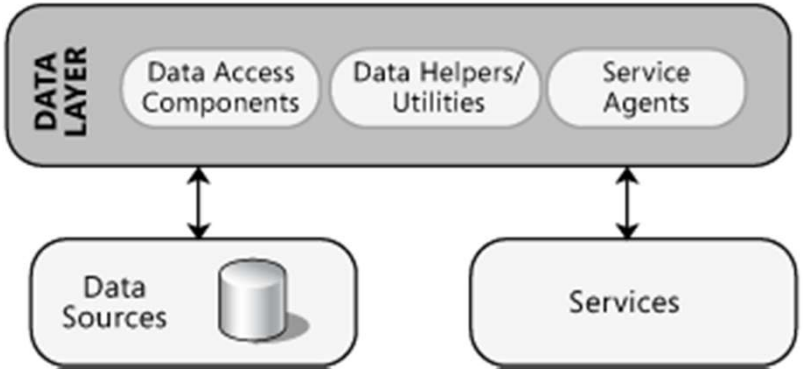
- Business workflow components:
  - Perform business processes
  - Orchestration between multiple steps
  - Long running processes
- Business components
  - Encapsulate logic, calculation, validation, …
- Business entity components
  - Store data (e.g. Customer, Order)
  - Sometimes also: validation & logic

Data Layer



- Access data sources of different kinds:
  - Relational
  - NoSQL
  - Services

Data Layer



- Data access components
  - Encapsulate data source specific access code
  - Grouped by source types
  - e.g. CustomerDbAccess, BookingXmlWriter
- Service agents
  - Encapsulate access to service proxies
  - Similar to data access components

Data Exchange via Layer Boundaries

- Predefined contracts (interfaces)
- Known to both sides
- Contract versioning:
  - Side by side:
    - Multiple parallel deployments
  - Inheritance:
    - Single deployment
    - Old contracts still exist
  - Translators / Adapters:
    - Translate old format to new one
- Technology independent DTOs

Application Archetypes

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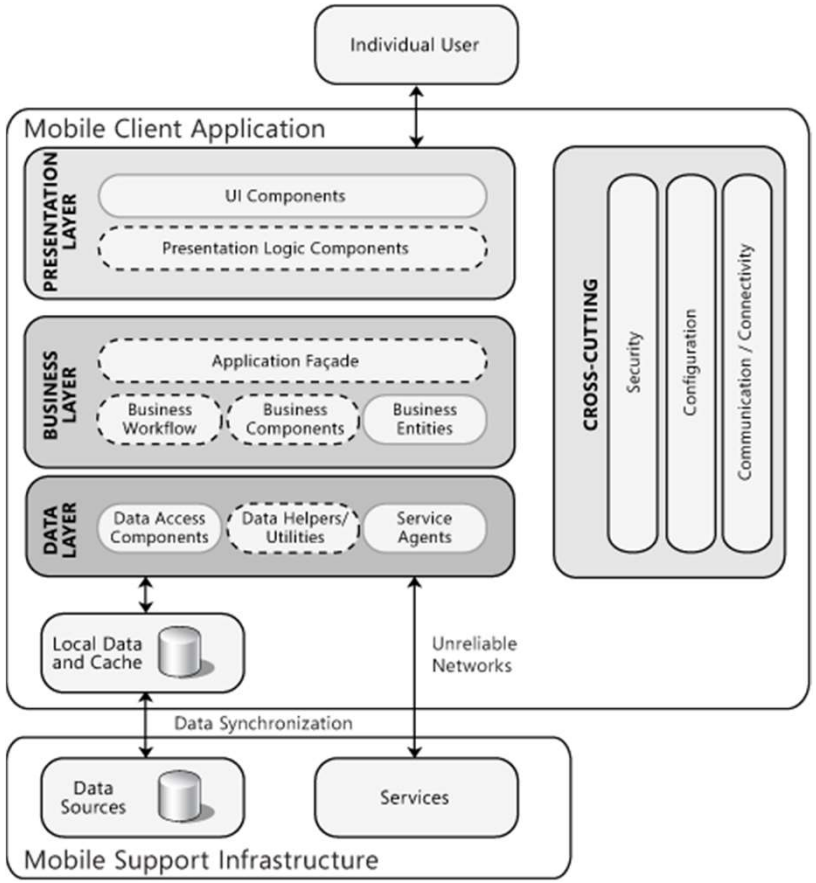
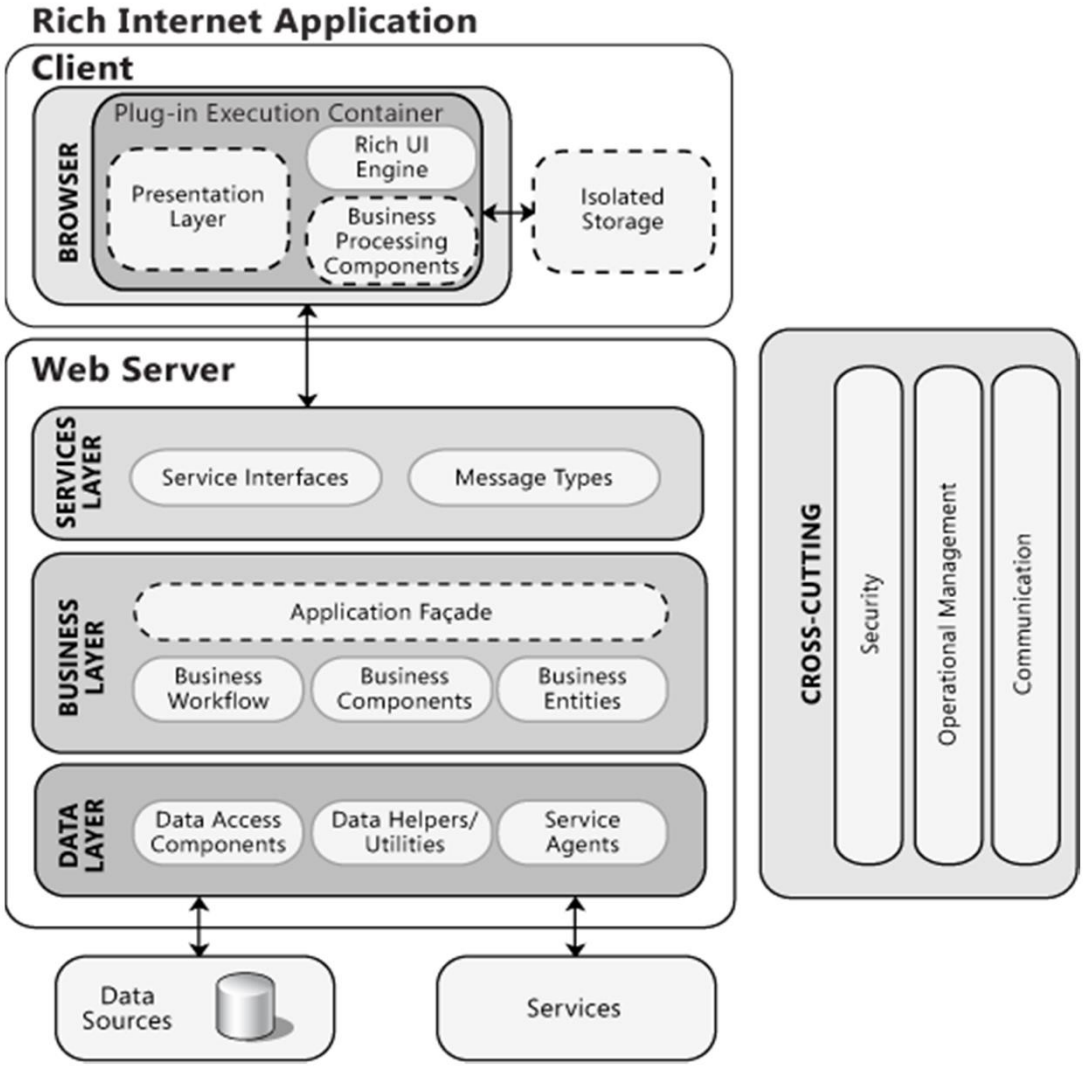
Common Application Archetypes

- Mobile applications
- Rich Internet applications
- Service applications
- Web applications

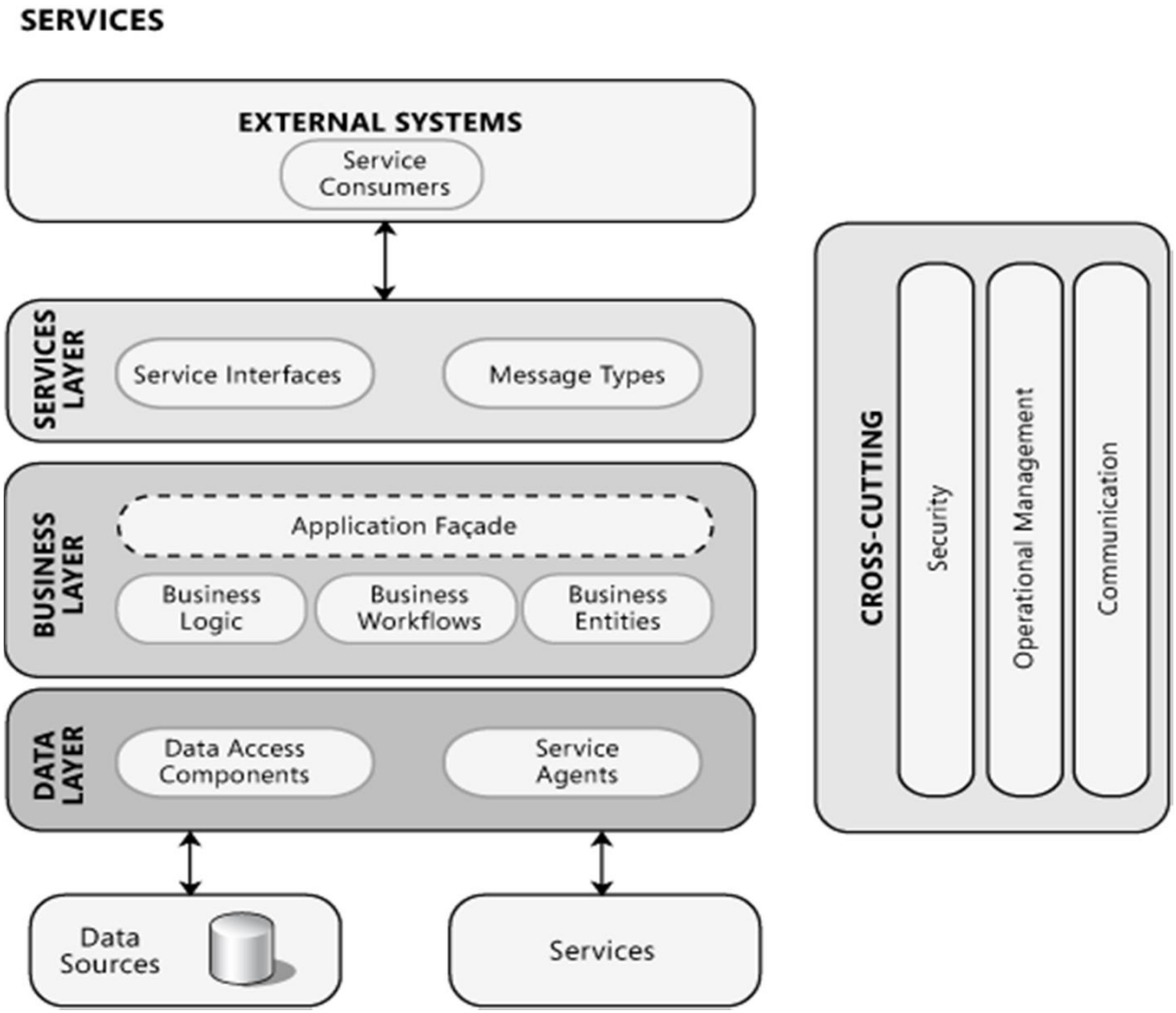
Mobile Application



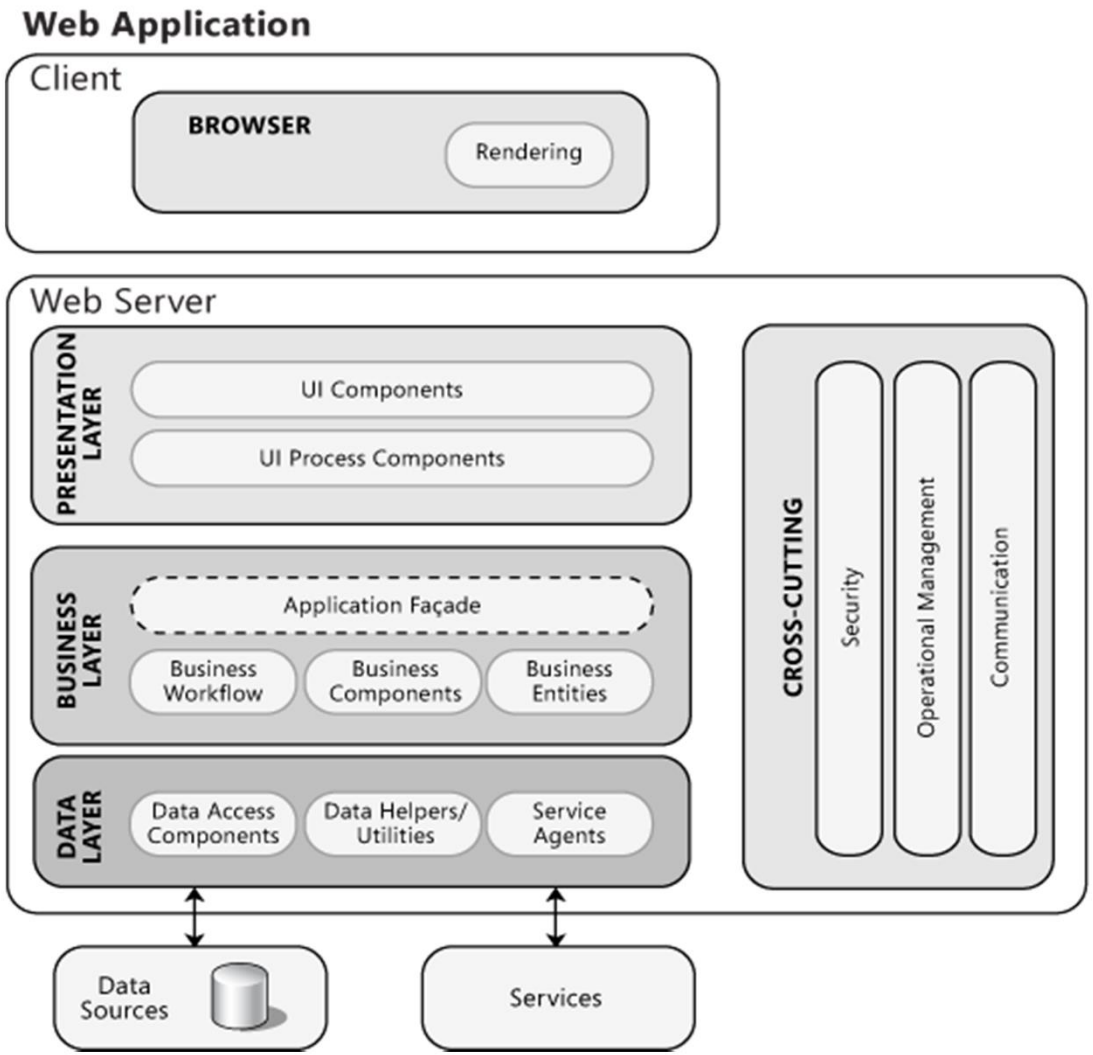
Rich Internet Application



Service Application



Web Application



Architectural Documentation

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Why is Documentation Important?

- Others can understand and evaluate the design.
- Others in the team can learn from the architecture by digesting the thinking behind the design.
- We can do analysis on the design, perhaps to assess its expected performance.

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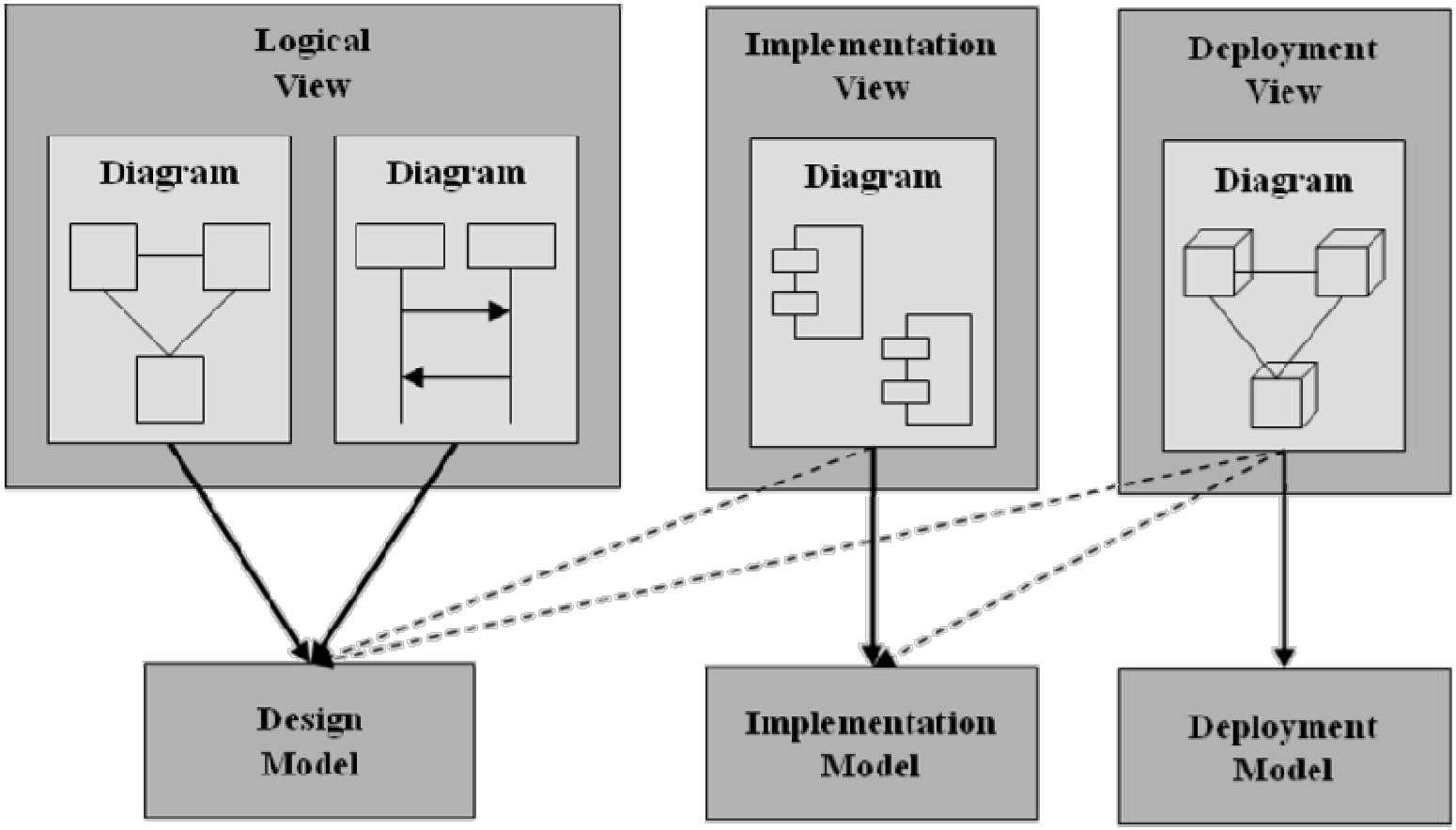
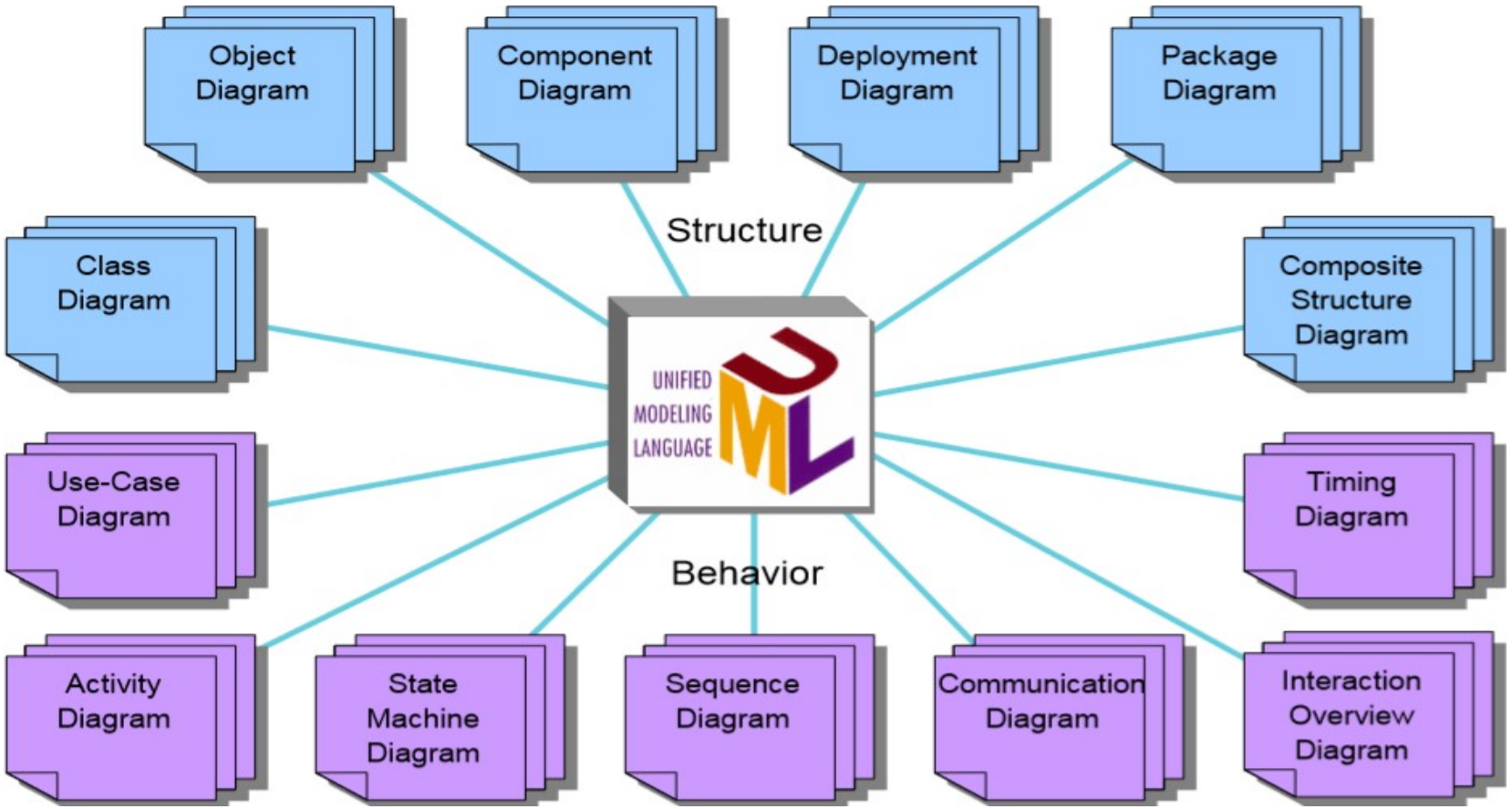
Challenges

- It exists no unique and generally accepted standard.
- Describing complex matters in an understandable way is time consuming and itself complex.
- Architecture is not a static thing.

Views, Diagrams and Models



Architectural Documentation Using UML



Design Patterns (dt. Entwurfsmuster)

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What is a Design Pattern?

- general, reusable solution to a commonly occurring problem in software design
- description or template for how to solve a problem
- formalized best practices that developers can use to solve common problems
- defines a vocabulary
- most famous are Gang of Four (GoF) patterns described in "Design Patterns: Elements of Reusable Object-Oriented Software", 1994
  - creational patterns
  - structural patterns
  - behavioral patterns

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Pattern Documentation (used by GoF)

- Pattern Name and Classification
- Intent
- Also Known As
- Motivation (Forces)
- Applicability
- Structure
- Participants
- Collaboration
- Consequences
- Implementation
- Sample Code
- Known Uses
- Related Patterns

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Creational Patterns

- Abstract Factory
- Builder
- Factory Method
- Prototype
- Singleton

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Structural Patterns

- Adapter
- Bridge
- Composite
- Decorator
- Facade
- Flyweight
- Proxy

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Behavioral Patterns

- Chain of Responsibility
- Command
- Interpreter
- Iterator
- Mediator
- Memento
- Observer
- State
- Strategy
- Template Method
- Visitor

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Many More Patterns

- Data Access Object (DAO)
- Dependency Injection (DI) or Inversion of Control (IoC)
- Front Controller
- Method Chaining
- Null Object
- Read-Write Lock
- …

Software Components

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Software Element

- contains sequences of program statements that describe computations to be performed by machine

Software Component

- software element that conforms to component model and can be independently deployed and composed without modification according to composition standard

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Component Model

- defines specific interaction and composition standards
- guideline on how to construct an individual component

Elements of Component Model

- interfaces
- naming
- meta data
- interoperability
- composition
- evolution support
- packaging and deployment

Interface

- abstraction aimed at software reuse
- not a constituent part of component, but serves as contract
- elements
  - operations
  - parameters and their types
  - return values and their types
  - exceptions
  - pre- and post-conditions
  - …

Naming

- uniquely identifiable components and interfaces
  - standardized naming schema
  - hierarchical name spaces

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Meta Data

- for composition tools and reflective programs

Interoperability

- communication channels for components
  - inside processes
  - across processes and over the network

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Composition

- combination of two or more components

Evolution Support

- components might have to be replaced by newer versions
  - modified and new interfaces
  - co-existence of different versions of one component

Packaging and Deployment

- packaging might include
  - program code (binary vs. source)
  - configuration data
  - other components
  - additional resources
- used for installation and configuration

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Component Model Implementation

- set of executable software elements required to support execution of components that conform to model

Interaction Standard

- components may have explicit context dependencies on operating system, software components or some other software elements
- specifies type of explicit context dependencies components may have

Composition Standard

- defines how components can be composed to create larger structure and how producer can substitute one component to replace another that already exists within the structure

Software Component Infrastructure

- set of interacting software components designed to ensure that software system using those components and interfaces will satisfy clearly defined performance specifications

Performance Specification

- defines functional requirements for product, environment in which it must operate, and any interface and interchangeability requirements
- provides criteria for verifying compliance

Component-Based Software Lifecycle

- lifecycle process for software component
  - business rules
  - business process modeling
  - design
  - construction
  - continuous testing
  - deployment
  - evolution
  - subsequent reuse
  - maintenance

Component Platforms

- Common Object Request Broker Architecture (CORBA)
- Microsoft .NET Framework
- Jakarta Enterprise Edition
- Spring Framework
- …