# Software Architecture and the UML

Grady Booch

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## Architecting a dog house

Can be built by one person
Requires
- Minimal modeling
- Simple process
- Simple tools

## Architecting a house

Built most efficiently and timely by a team

Requires

- Modeling
- Well-defined process
- Power tools

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## Architecting a high rise

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# Early architecture

**Progress**
- Limited knowledge of theory



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# Modern architecture

**Progress**
- Advances in materials
- Advances in analysis

**Scale**
- 5 times the span of the Pantheon
- 3 times the height of Cheops



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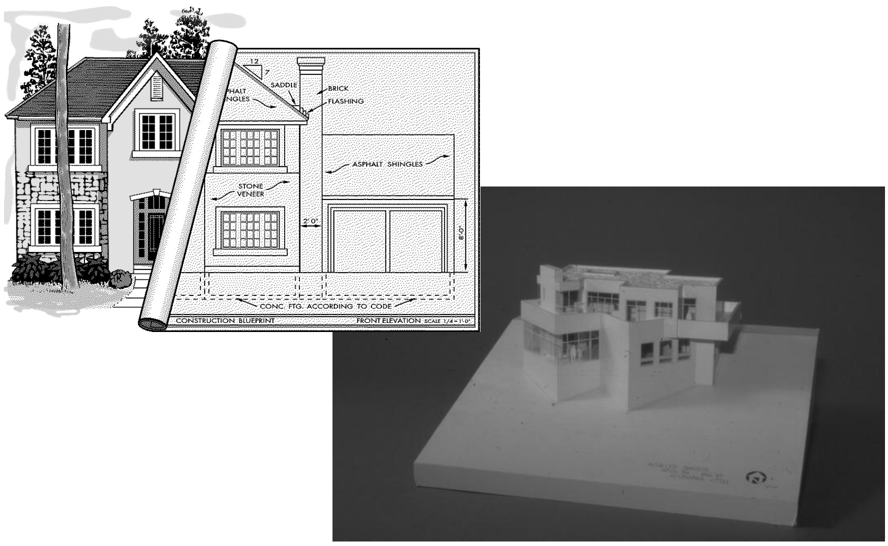
# Modeling a house






# Movements in civil architecture

- Bronze age/Egyptian (Imhotep)
- Grecian/Roman (Vitruvius)
- Byzantine/Romanesque
- Gothic
- Mannerism (Michelangelo, Palladio)
- Baroque
- Engineering/Rational/National/Romantic
- Art noveau
- Modern movement (Wright, LeCorbusier)

**Progress**
- Imitation of previous efforts
- Learning from failure
- Integration of other forces
- Experimentation

*Neufert Architect's Data*
*The Handbook of Building Types*

# Kinds of civil architecture

- Community
  - houses, flats and apartments, gardens, education, hospitals, religion
- Commerce
  - shops and stores, restaurants, hotels, office buildings, banks, airports
- Industry
  - industrial buildings, laboratories, farm buildings
- Leisure
  - sport, theaters and cinemas, museums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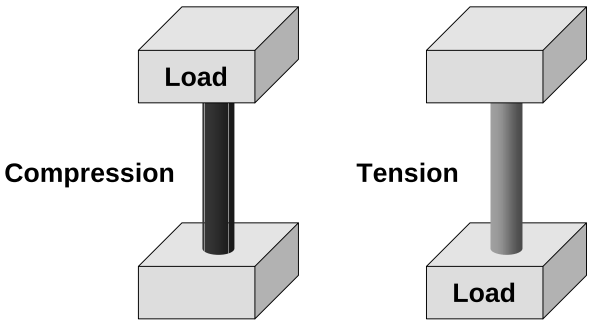
# Forces in civil architecture




**Kinds of loads**
- Dead loads
- Live loads
- Dynamic loads

**Avoiding failure**
- Safety factors
- Redundancy
- Equilibrium

**Any time you depart from established practice, make ten times the effort, ten times the investigation. Especially on a very large project.**
- LeMessuier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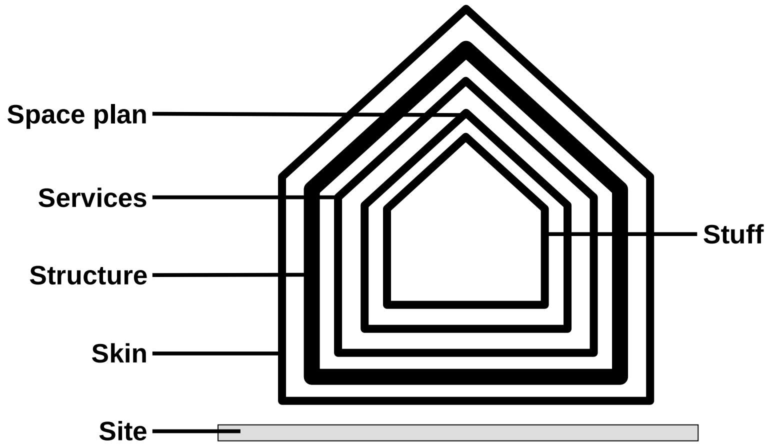
Brand, *How Buildings Learn*

# Shearing layers of change

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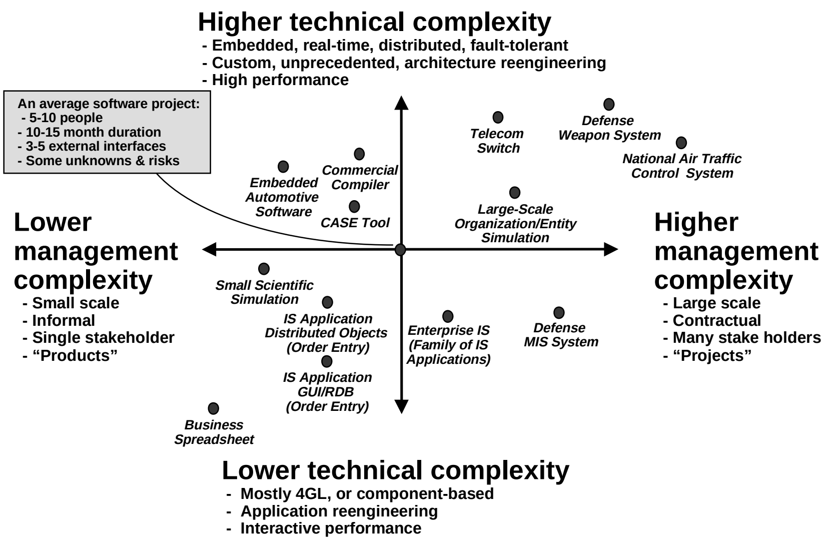
Walker Royce

# Dimensions of software complexity

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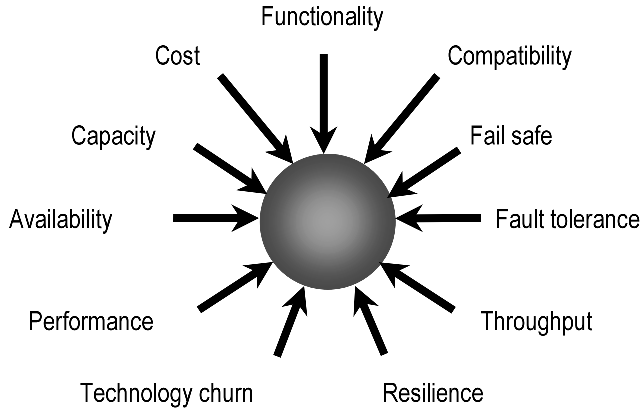
## Forces in Software



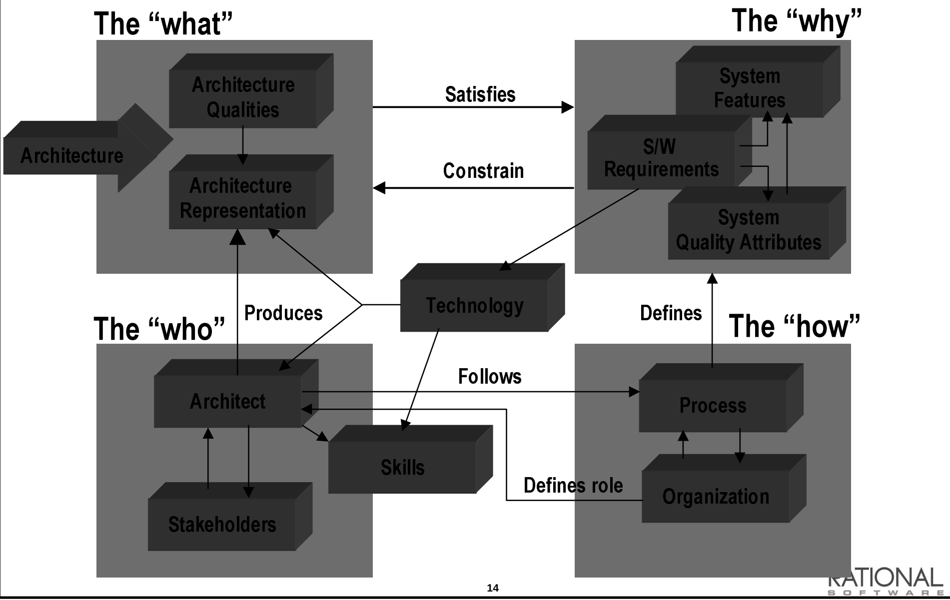

The challenge over the next 20 years will not be speed or cost or performance; it will be a question of complexity.
Bill Raduchel, Chief Strategy Officer, Sun Microsystems

Our enemy is complexity, and it's our goal to kill it.
Jan Baan



*Wojtek Kozaczynski*

## The domain of architecting



Philippe Kruchten

## We all know that ...

Architecture and design are the same thing

Architecture and infrastructure are the same thing

*<my favorite technology>* is the architecture

A good architecture is the work of a single architect

Architecture is flat, one blueprint is enough

Architecture is just structure

System architecture precedes software architecture

Architecture cannot be measured and validated

Architecture is a Science

Architecture is an Art

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Merriam Webster's Collegiate Dictionary 10th edition

## Architecture defined (again)

Architecture n (1555) 1: the art of science of building, specifically, the art or practice of designing and building structures and esp. habitable ones 2 a: formation or construction as or as if as the result of conscious act <the ~ of the garden> b: a unifying or coherent form or structure <the novel lacks ~>

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## Architecture defined (yet again)

Mary Shaw, CMU
Grady Booch,
Philippe Kruchten,
Rich Reitman
Kurt Bittner, Rational

- Software architecture encompasses the set of significant decisions about the organization of a software system
  - selection of the structural elements and their interfaces by which a system is composed
  - behavior as specified in collaborations among those elements
  - composition of these structural and behavioral elements into larger subsystem
  - architectural style that guides this organization



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## Architecture defined (continued)

Mary Shaw, CMU
Grady Booch,
Philippe Kruchten,
Rich Reitman
Kurt Bittner, Rational

- Software architecture also involves
  - usage
  - functionality
  - performance
  - resilience
  - reuse
  - comprehensibility
  - economic and technology constraints and tradeoffs
  - aesthetic concerns



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Mary Shaw, CMU

# Architectural style

- An architecture style defines a family of systems in terms of a pattern of structural organization.
- An architectural style defines
  - a vocabulary of components and connector types
  - a set of constraints on how they can be combined
  - one or more semantic models that specify how a system's overall properties can be determined from the properties of its parts

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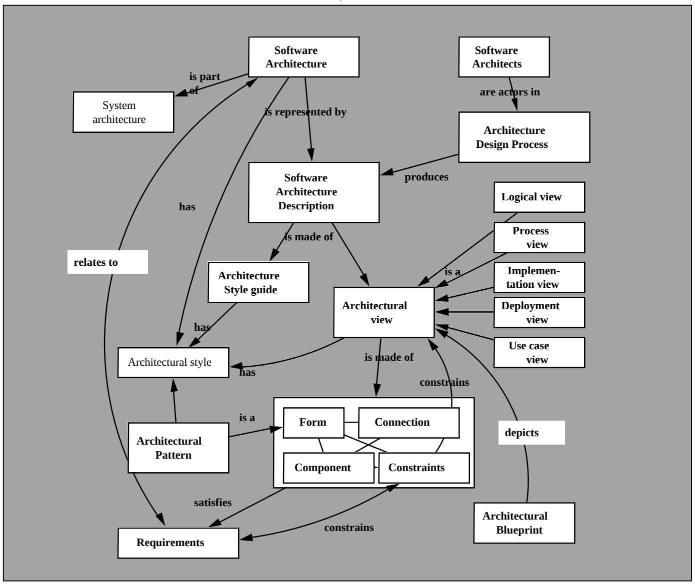
# Architecture metamodel

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## Models

- Models are the language of designer, in many disciplines
- Models are representations of the system to-be-built or as-built
- Models are vehicle for communications with various stakeholders
- Visual models, blueprints
- Scale
- Models allow reasoning about some characteristic of the real system



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## Many stakeholders, many views

- Architecture is many things to many different interested parties
  - end-user
  - customer
  - project manager
  - system engineer
  - developer
  - architect
  - maintainer
  - other developers
- Multidimensional reality
- Multiple stakeholders

  ⇒ multiple views, multiple blueprints



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## Architectural view

- An architectural view is a simplified description (an abstraction) of a system from a particular perspective or vantage point, covering particular concerns, and omitting entities that are not relevant to this perspective


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## Architecturally significant elements

- Not all design is architecture

- Main “business” classes
- Important mechanisms
- Processors and processes
- Layers and subsystems

- Architectural views = slices through models


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## Characteristics of a Good Architecture

- Resilient
- Simple
- Approachable
- Clear separation of concerns
- Balanced distribution of responsibilities
- Balances economic and technology constraints

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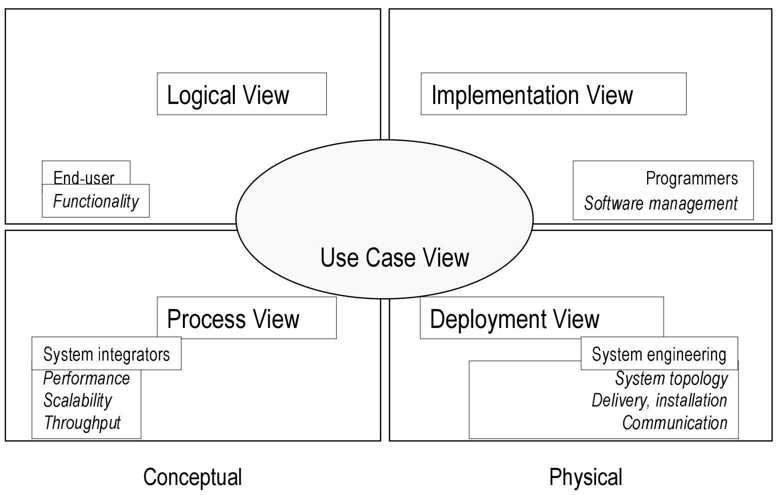
## Representing System Architecture

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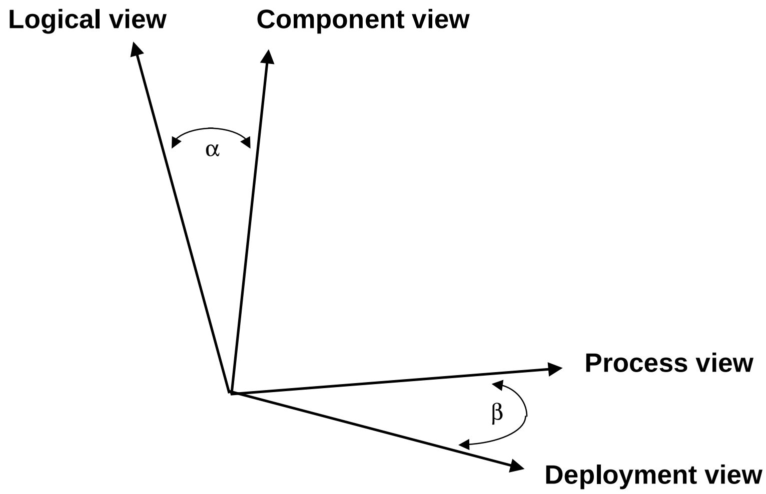
## Relation Between Views

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## How many views?

- Simplified models to fit the context
- Not all systems require all views:
  - Single processor: drop deployment view
  - Single process: drop process view
  - Very Small program: drop implementation view
- Adding views:
  - Data view, security view

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## The Value of the UML

- Is an open standard
- Supports the entire software development lifecycle
- Supports diverse applications areas
- Is based on experience and needs of the user community
- Supported by many tools



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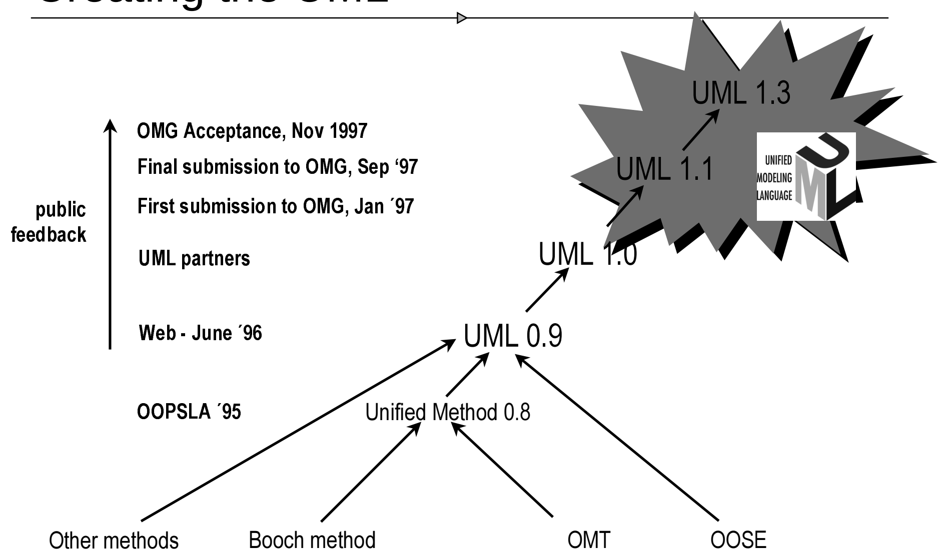
## Creating the UML



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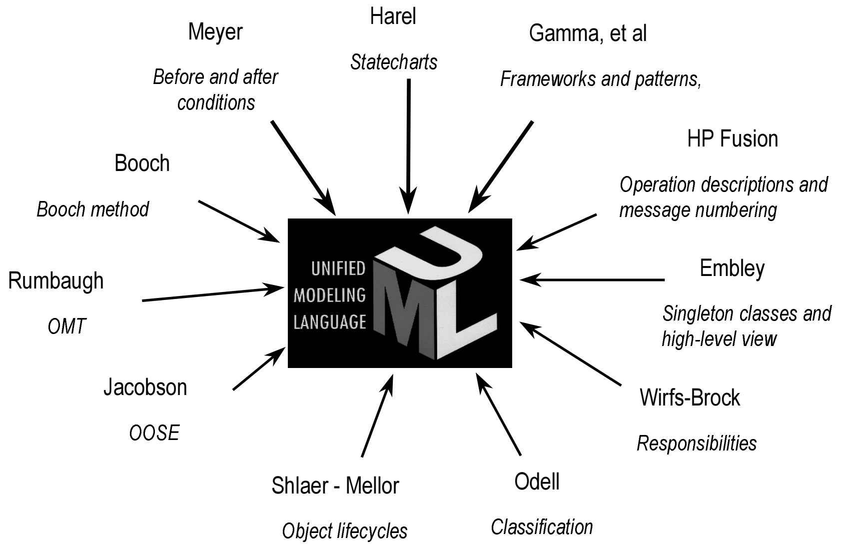
# UML Partners

- Rational Software Corporation
- Hewlett-Packard
- I-Logix
- IBM
- ICON Computing
- Intellicorp
- MCI Systemhouse
- Microsoft
- ObjecTime
- Oracle
- Platinum Technology
- Taskon
- Texas Instruments/Sterling Software
- Unisys



# Contributions to the UML



## Overview of the UML

- The UML is a language for
  - visualizing
  - specifying
  - constructing
  - documenting

  the artifacts of a software-intensive system





## Overview of the UML

- Modeling elements
- Relationships
- Extensibility Mechanisms
- Diagrams



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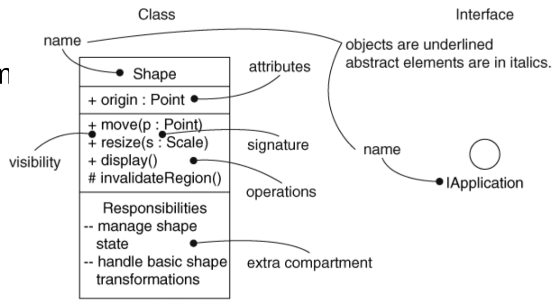
# Modeling Elements

- Structural elements
  - class, interface, collaboration, use case, active class, component, node
- Behavioral elements
  - interaction, state machine
- Grouping elements
  - package, subsystem
- Other elements
  - note

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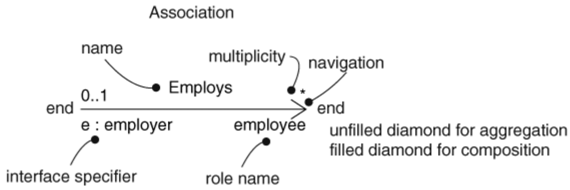
# Relationships

- Dependency
- Association
- Generalization
- Realization

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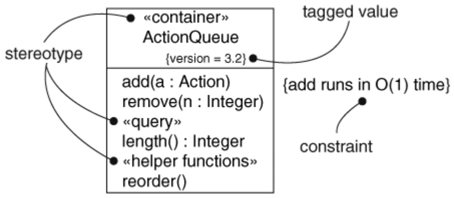
# Extensibility Mechanisms

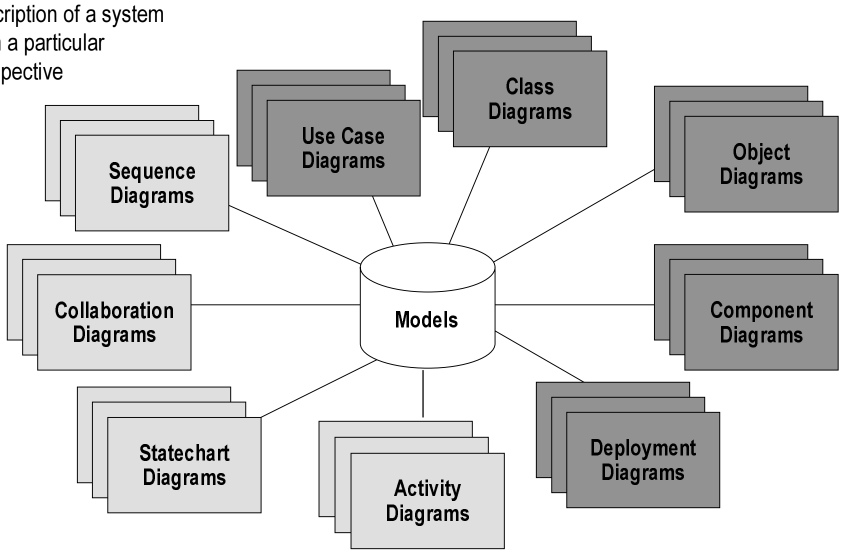
- Stereotype
- Tagged value
- Constraint






# Models, Views, and Diagrams

A ***model*** is a complete description of a system from a particular perspective



## Diagrams

- A diagram is a view into a model
  - Presented from the aspect of a particular stakeholder
  - Provides a partial representation of the system
  - Is semantically consistent with other views
- In the UML, there are nine standard diagrams
  - Static views: use case, class, object, component, deployment
  - Dynamic views: sequence, collaboration, statechart, activity

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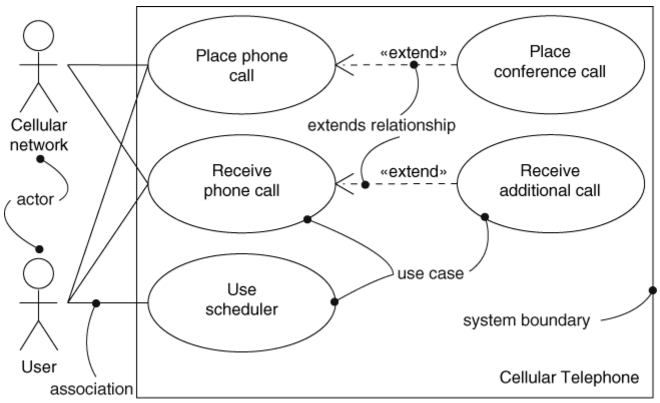
## Use Case Diagram

- Captures system functionality as seen by users

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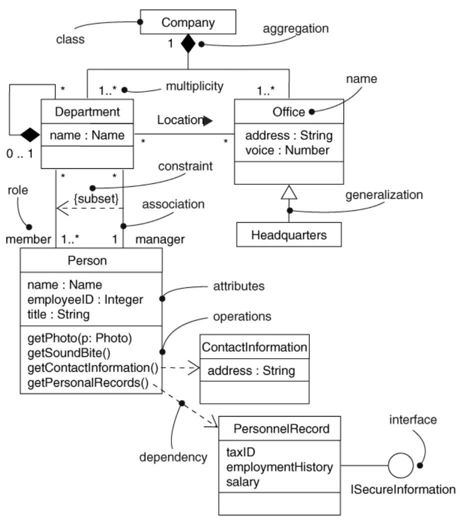
## Use Case Diagram

- Captures system functionality as seen by users
- Built in early stages of development
- Purpose
  - Specify the context of a system
  - Capture the requirements of a system
  - Validate a system's architecture
  - Drive implementation and generate test cases
- Developed by analysts and domain experts



## Class Diagram

- Captures the vocabulary of a system



## Class Diagram

- Captures the vocabulary of a system
- Built and refined throughout development
- Purpose
  - Name and model concepts in the system
  - Specify collaborations
  - Specify logical database schemas
- Developed by analysts, designers, and implementers



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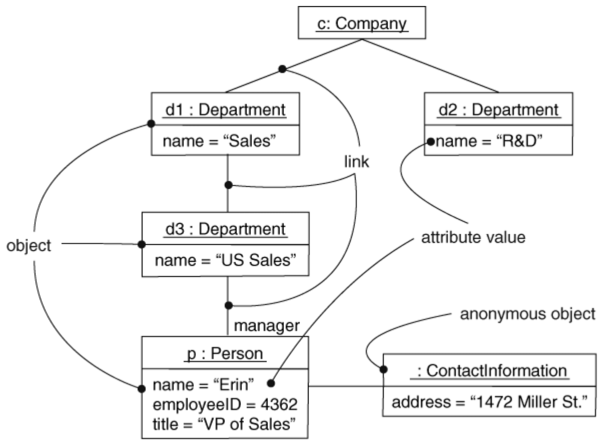
## Object Diagram

- Captures instances and links



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## Object Diagram

- Shows instances and links
- Built during analysis and design
- Purpose
  - Illustrate data/object structures
  - Specify snapshots
- Developed by analysts, designers, and implementers



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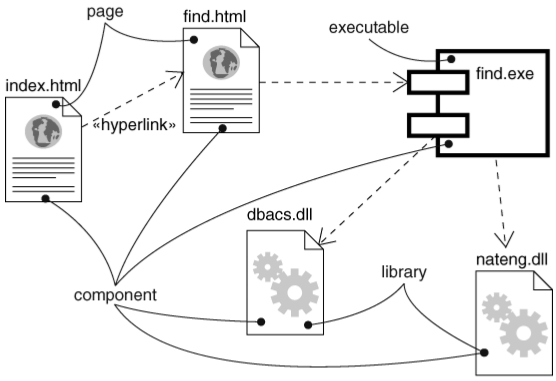
## Component Diagram

- Captures the physical structure of the implementation



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## Component Diagram

- Captures the physical structure of the implementation
- Built as part of architectural specification
- Purpose
  - Organize source code
  - Construct an executable release
  - Specify a physical database
- Developed by architects and programmers

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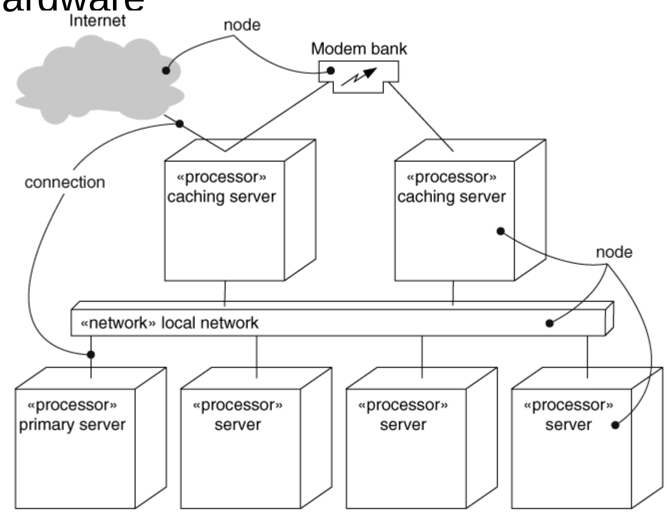
## Deployment Diagram

- Captures the topology of a system's hardware

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## Deployment Diagram

- Captures the topology of a system’s hardware
- Built as part of architectural specification
- Purpose
  - Specify the distribution of components
  - Identify performance bottlenecks
- Developed by architects, networking engineers, and system engineers



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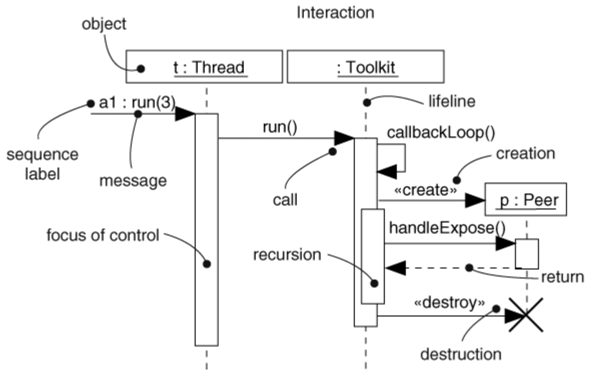
## Sequence Diagram

- Captures dynamic behavior (time-oriented)



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## Sequence Diagram

- Captures dynamic behavior (time-oriented)
- Purpose
  - Model flow of control
  - Illustrate typical scenarios



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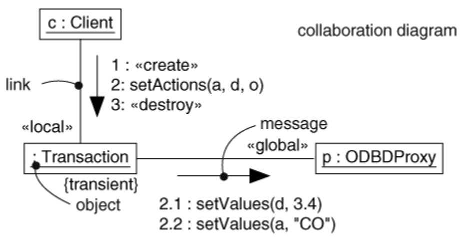
## Collaboration Diagram

- Captures dynamic behavior (message-oriented)



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## Collaboration Diagram

- Captures dynamic behavior (message-oriented)
- Purpose
  - Model flow of control
  - Illustrate coordination of object structure and control



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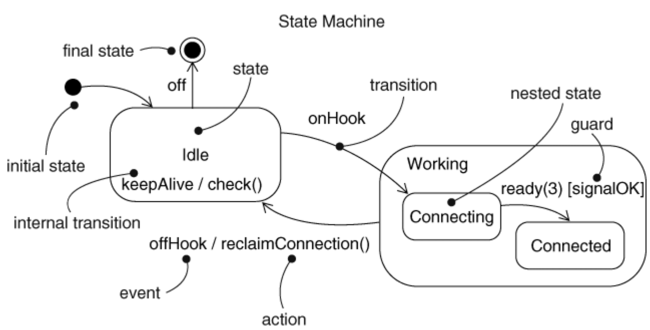
## Statechart Diagram

- Captures dynamic behavior (event-oriented)



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## Statechart Diagram

- Captures dynamic behavior (event-oriented)
- Purpose
  - Model object lifecycle
  - Model reactive objects (user interfaces, devices, etc.)

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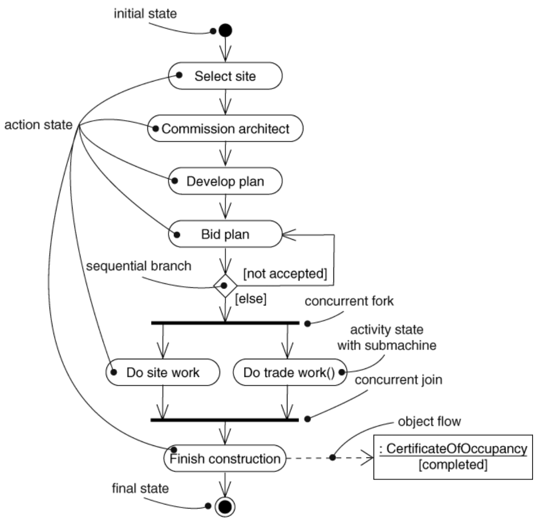
## Activity Diagram

- Captures dynamic behavior (activity-oriented)

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# Activity Diagram

- Captures dynamic behavior (activity-oriented)
- Purpose
  - Model business workflows
  - Model operations

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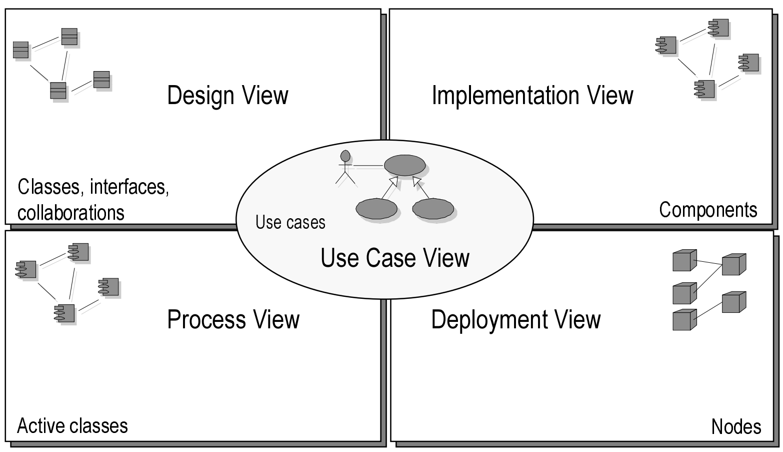
# Architecture and the UML




Organization
Package, subsystem

Dynamics
Interaction
State machine

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## Software engineering process

A set of partially ordered steps intended to reach a goal. In software engineering the goal is to build a software product or to enhance an existing one.

- Architectural process
  - Sequence of activities that lead to the production of architectural artifacts:
    - A software architecture description
    - An architectural prototype



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## Rational Unified Process

- Iterative
- Architecture-centric
- Use-case driven
- Risk confronting



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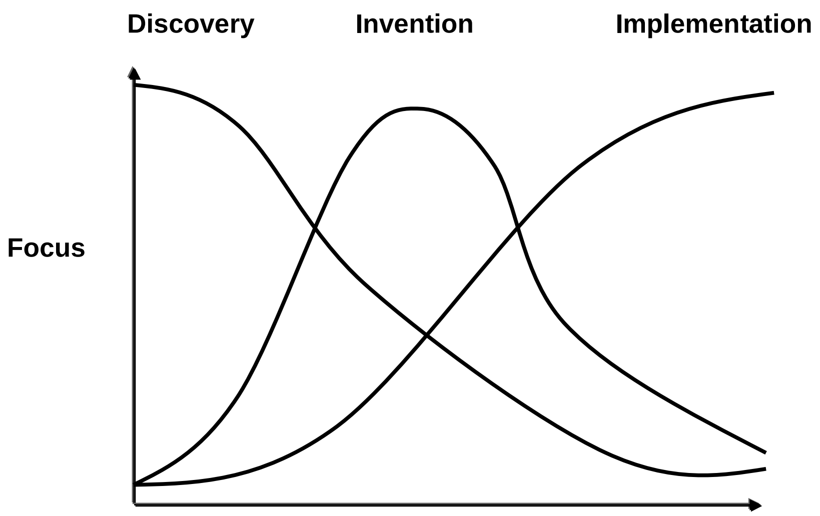
## Focus over time



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## Key concepts

- Phase, Iterations
- Process Workflows
  - Activity, steps
- Artifacts
  - models
  - reports, documents
- Worker: Architect

**When does architecture happen?**

**What does happen?**

**What is produced?**

**Who does it?**



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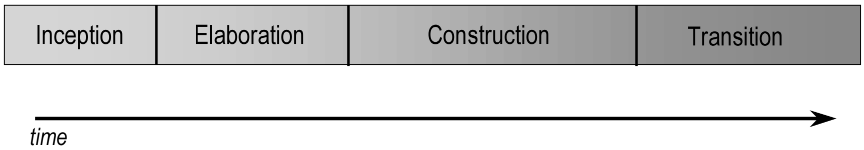
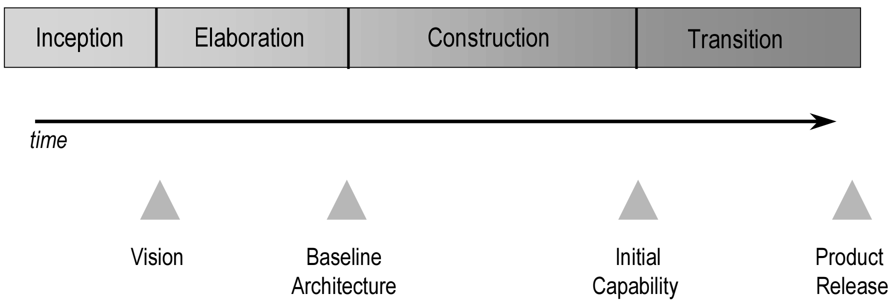
## Lifecycle Phases



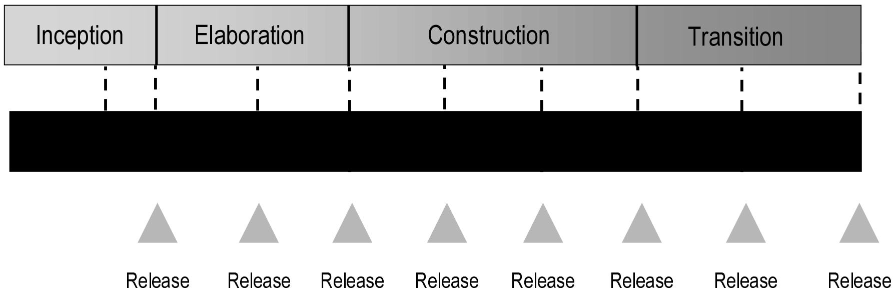

- Inception — Define the scope of the project and develop business case
- Elaboration — Plan project, specify features, and baseline the architecture
- Construction — Build the product
- Transition — Transition the product to its users



## Major Milestones



## Phases and Iterations




An iteration is a sequence of activities with an established plan and evaluation criteria, resulting in an executable release



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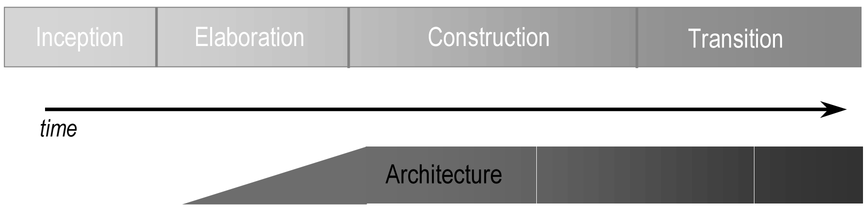
## Architecture-Centric

- Models are vehicles for visualizing, specifying, constructing, and documenting architecture
- The Unified Process prescribes the successive refinement of an executable architecture



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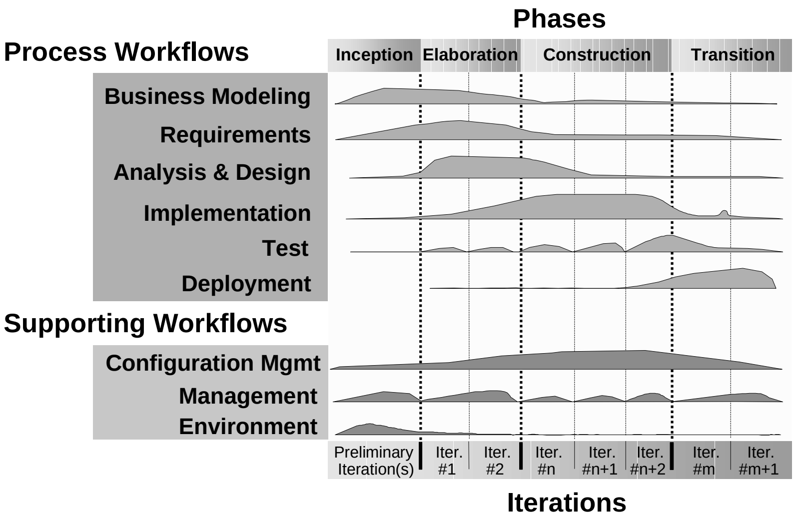
# Unified Process structure



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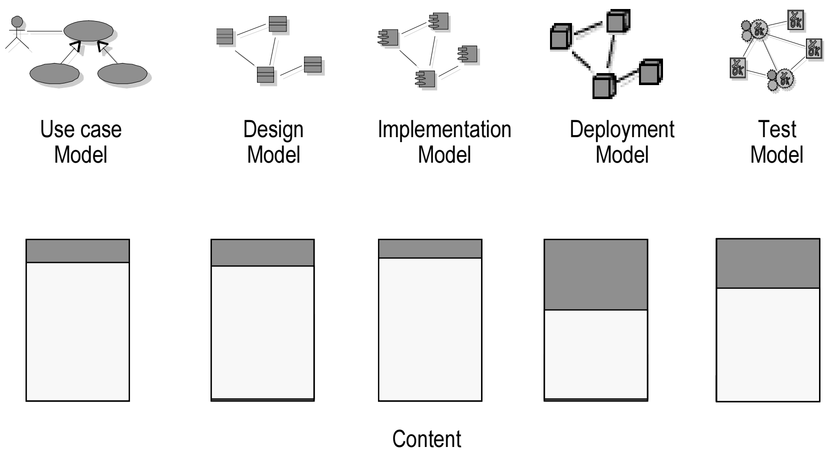
# Architecture and Iterations



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## Architectural design

- Identify, select, and validate "architecturally significant" elements
- Not everything is architecture
  - Main "business" classes
  - Important mechanisms
  - Processors and processes
  - Layers and subsystems
  - Interfaces
- Produce a Software Architecture Documen

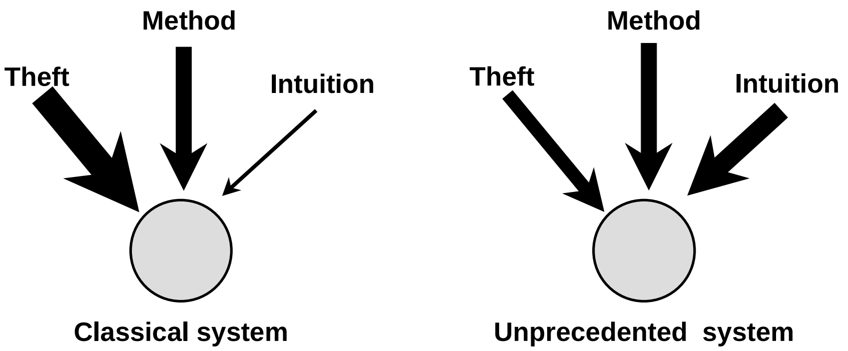


## Architectural design workflow

- Select scenarios: criticality and risk — Use case view
- Identify main classes and their responsibility — Logical view
- Distribute behavior on classes
- Structure in subsystems, layers, define interfaces — Implementation view
- Define distribution and concurrency — Deployment view — Process view
- Implement architectural prototype
- Derive tests from use cases
- Evaluate architecture

***Iterate***

## Sources of architecture

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## Patterns

- A pattern is a solution to a problem in a context
- A pattern codifies specific knowledge collected from experience in a domain
- All well-structured systems are full of patterns
  - Idioms
  - Design patterns
  - Architectural patterns

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daVinci

## Mechanisms

- Screws
- Keys
- Rivets
- Bearings
- Pins, axles, shafts
- Couplings
- Ropes, belts, and chains
- Friction wheels
- Toothed wheels
- Flywheels
- Levers and connecting rods
- Click wheels and gears
- Ratchets
- Brakes
- Pipes
- Valves
- Springs
- Cranks and rods
- Cams
- Pulleys
- Engaging gears



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*Design Patterns*
Gamma et al

## Design patterns

- Creational patterns
  - Abstract factory
  - Prototype
- Structural patterns
  - Adapter
  - Bridge
  - Proxy
- Behavioral patterns
  - Chain of responsibility
  - Mediator
  - Visitor
- Mechanisms are the soul of an architecture



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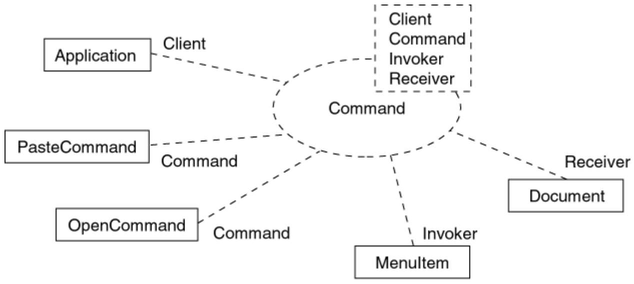
## Modeling a design pattern



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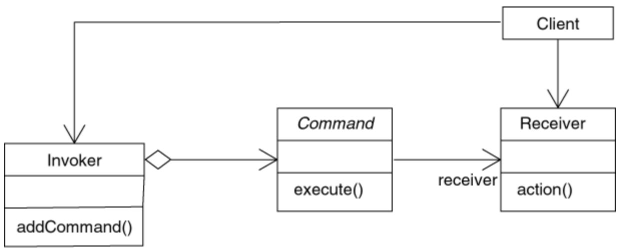
## Modeling a design pattern (cont.)



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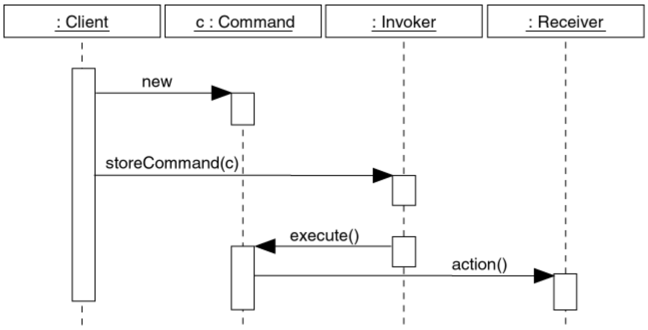
## Modeling a design pattern (cont.)



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## Architectural patterns

*Software Architecture*
Shaw and Garlan
*Buschmann et al*
*A System of Patterns*
Buschman et al
Booch

- Distributed
- Event-driven
- Frame-based
- Batch
- Pipes and filters
- Repository-centric
- Blackboard
- Interpreter
- Rule-based

- Layered
- MVC
- IR-centric
- Subsumption
- Disposable



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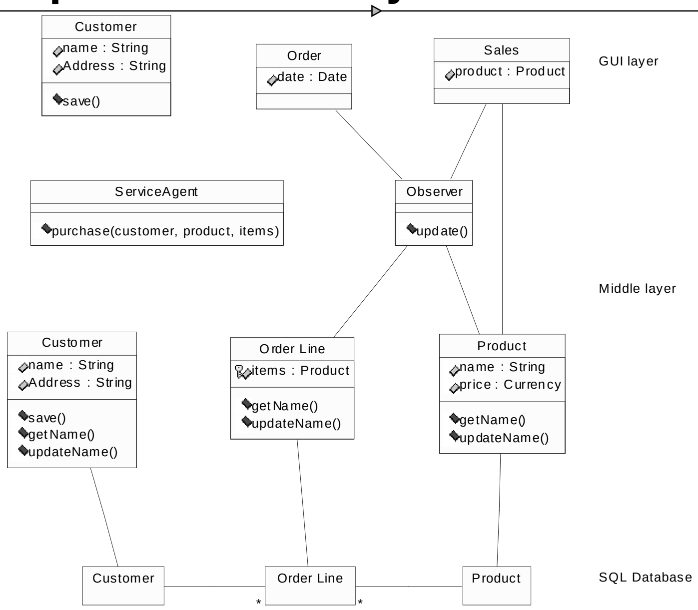
# Complex business system



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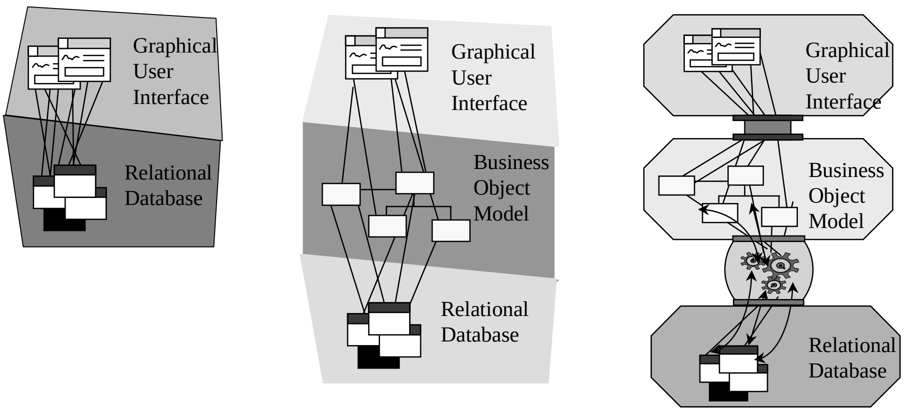
# Logical application architecture



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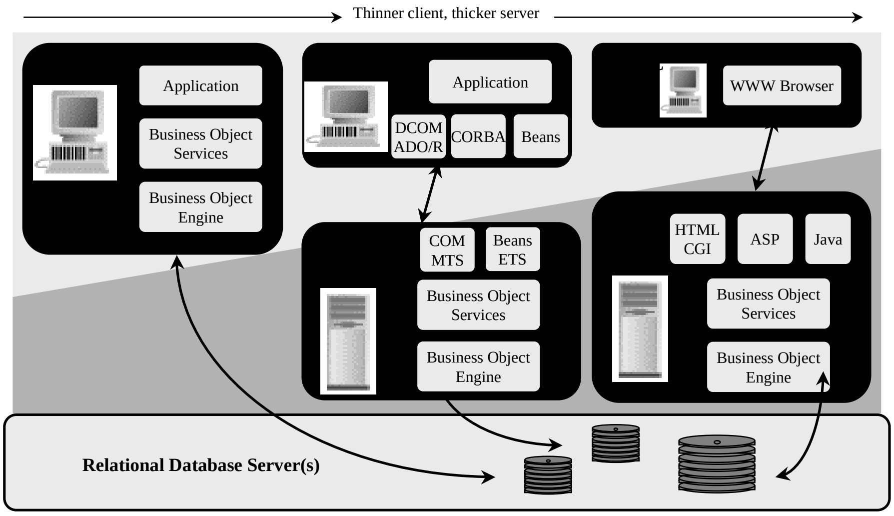
# Physical application architecture



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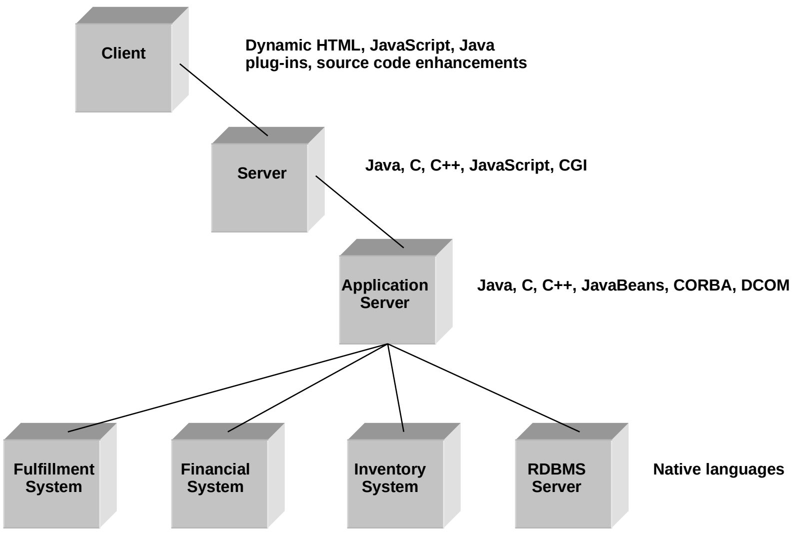
*The Second Wave*
Paul Dreyfus, Netscape

# Complex Internet system



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## Who are the architects?

- Experience
  - software development
  - domain
- Pro-active, goal oriented
- Leadership, authority
- Architecture team
  - balance





## Architect

- Not just a top level designer
  - Need to ensure feasibility
- Not the project manager
  - But “joined at the hip”
- Not a technology expert
  - Purpose of the system, “fit”,
- Not a lone scientist
  - Communicator

## Software architecture team charter

- Defining the architecture of the software
- Maintaining the architectural integrity of the software
- Assessing technical risks related to the software design
- Proposing the order and contents of the successive iterations
- Consulting services
- Assisting marketing for future product definition
- Facilitating communications between project teams

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## Architecture is making decisions

The life of a software architect is a long (and sometimes painful) succession of suboptimal decisions made partly in the dark.

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# Futures

- ADL: Architecture Description Languages
  - UML, UniCon, LILEAnna, P++, LEAP, Wright, µRapid
- Standardization of concepts
  - IEEE Working Group on Architecture
  - INCOSE Working Group on System Architecture
- Systematic capture of architectural patterns



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