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Use Cases

- **use case**: informally: text story of an actor using a system to meet goals
  - emphasises user goals and perspective
    - who is using the system?
    - what are their typical scenarios of use?
    - what are their goals?
  - formally: collection of related success/failure scenarios that describe an actor using the SuD to support a goal
  - primarily capture functional requirements
  - define a contract of how a system will behave
- **SuD:** system under discussion
- **actor:** something with behaviour; e.g. person, computer system, organisation
- **scenario/use case instance:** specific sequence of actions/interactions between actors and SuD

Level of Detail

- **brief:** terse one-paragraph summary of the main success scenario
- **casual:** informal multi-paragraph format covering various scenarios
- **fully dressed:** formal writing of each step and variations in detail, with supporting material

Use case variants

- **main success scenario:** ideal use case; mandatory element
  - “happy path”, typical flow
  - usually has no conditions/branching
- **alternative scenario:** optional, enhances understanding, provides some alternative behaviour
  - covered in Extensions section when fully dressed

Actors

- **primary actor:** has user goals fulfilled through using services of SuD

- **supporting actor:** provides a service to SuD to clarify external interfaces/protocols
  - typically a computer system (e.g. payment authorisation system) but can be an organisation or person
- **offstage actor:** has an interest in behaviour of the use case, but is not primary/supporting
  - e.g. tax agency
  - important to include to ensure all stakeholder requirements are captured

Importance

- influences design, implementation, project management
- key source of information for OO analysis/testing
- use cases should be strongly driven by project goals

Use case Model

- **Use case model:** model of system functionality/environment
  - *primarily:* set of *written* use cases
  - *optionally:* includes UML use case diagram

Use case Diagram

- show primary actors on LHS
- show supporting actors on RHS

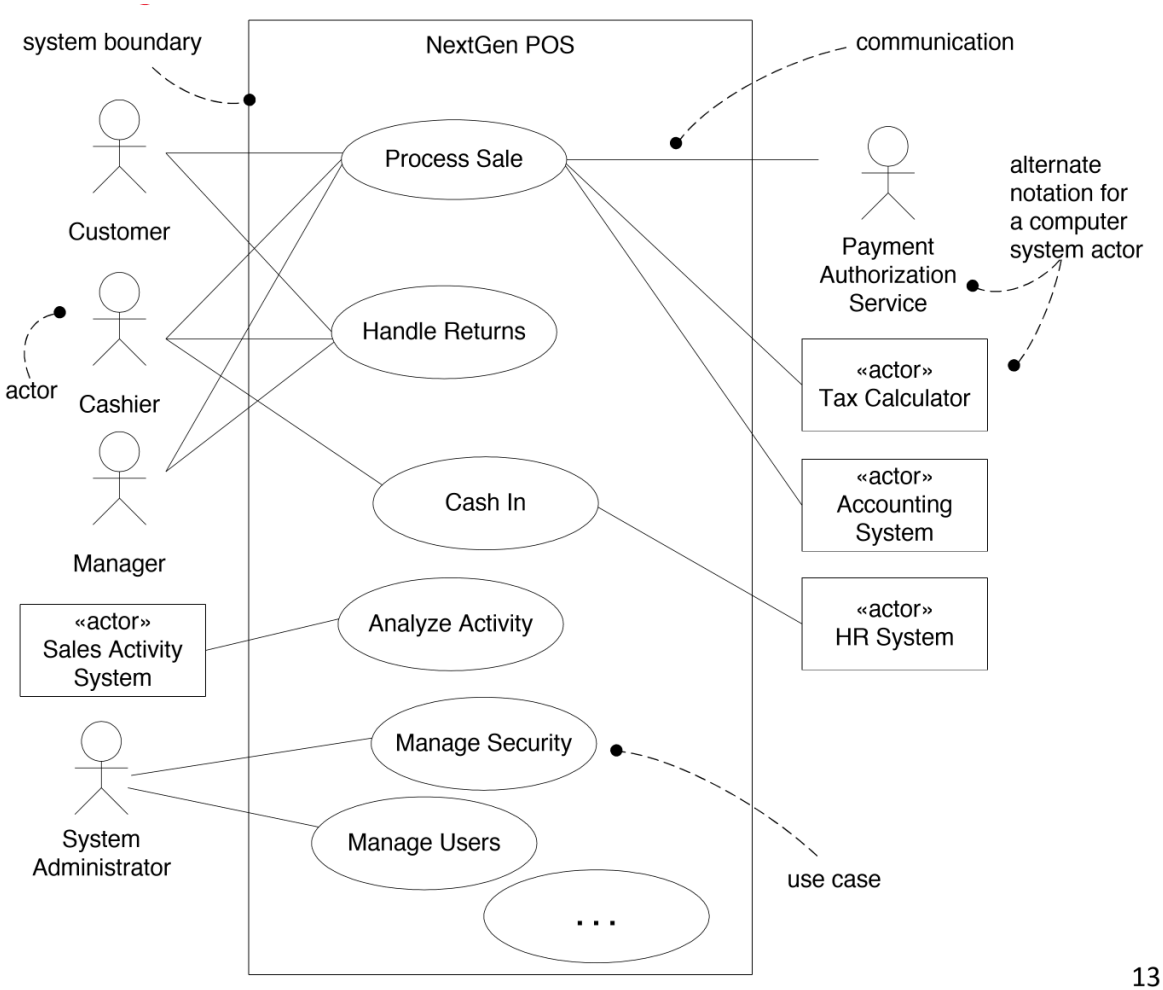

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Figure 1: Use case diagram

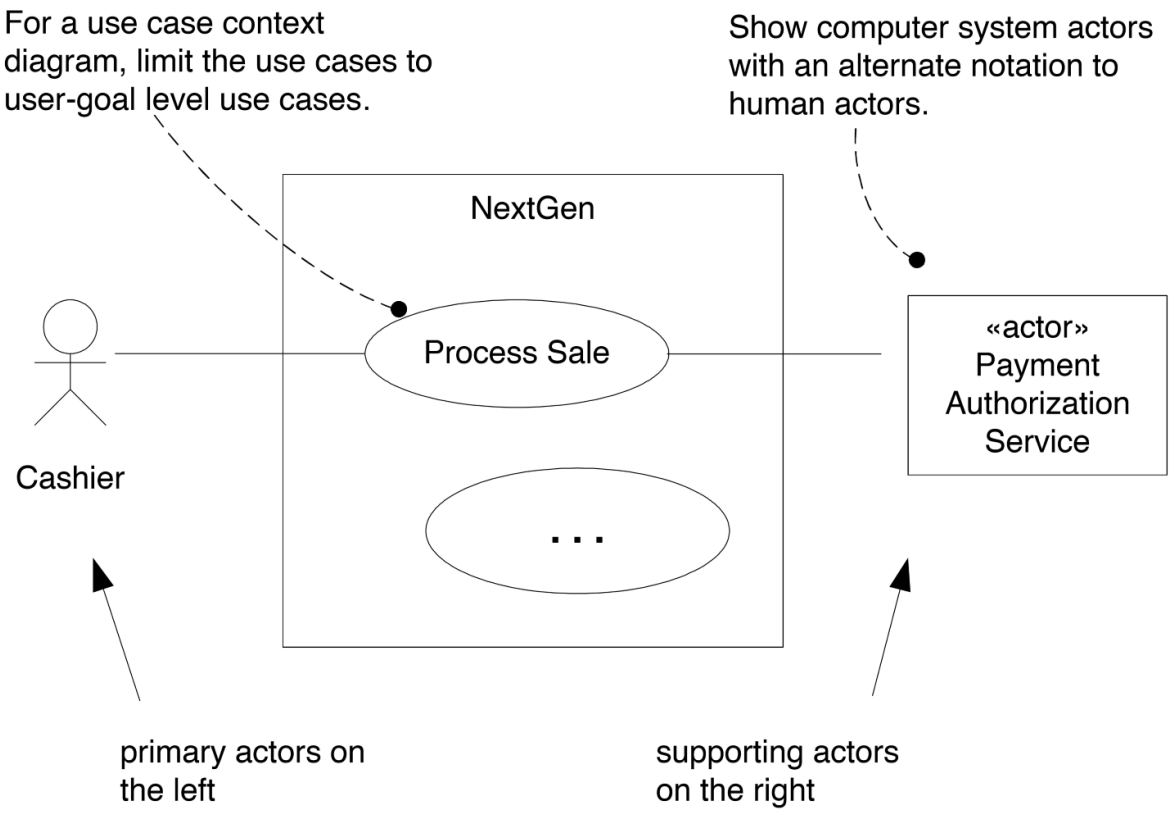

Figure 2: Use case notation

Relevance of Use cases

To check whether use-cases are at the right level for application requirements analysis, you can apply a number of tests.

- **Boss test:** your boss must be happy if, when asking you what you have been doing, you respond with the use case
- **Elementary business process test:** a value-adding process undertaken by one person in one location in response to a business event
- **Size test:** tasks shouldn't be a single step. They shouldn't be too many steps.
  - Fully dressed: 3-10 pages

Example:

- negotiate a supplier contract: much broader/longer than an EBP
- handle returns: OK with the boss. Seems like EBP. Good size.
- Log in: fails boss test

- Move piece on game board: single step - fails size test.

Include relationship

- used to reduce repetition in multiple use cases
- refactor common part of use cases into subfunction use case

```
Extensions:

6b. Paying by credit: Include Handle Credit Payment.
```

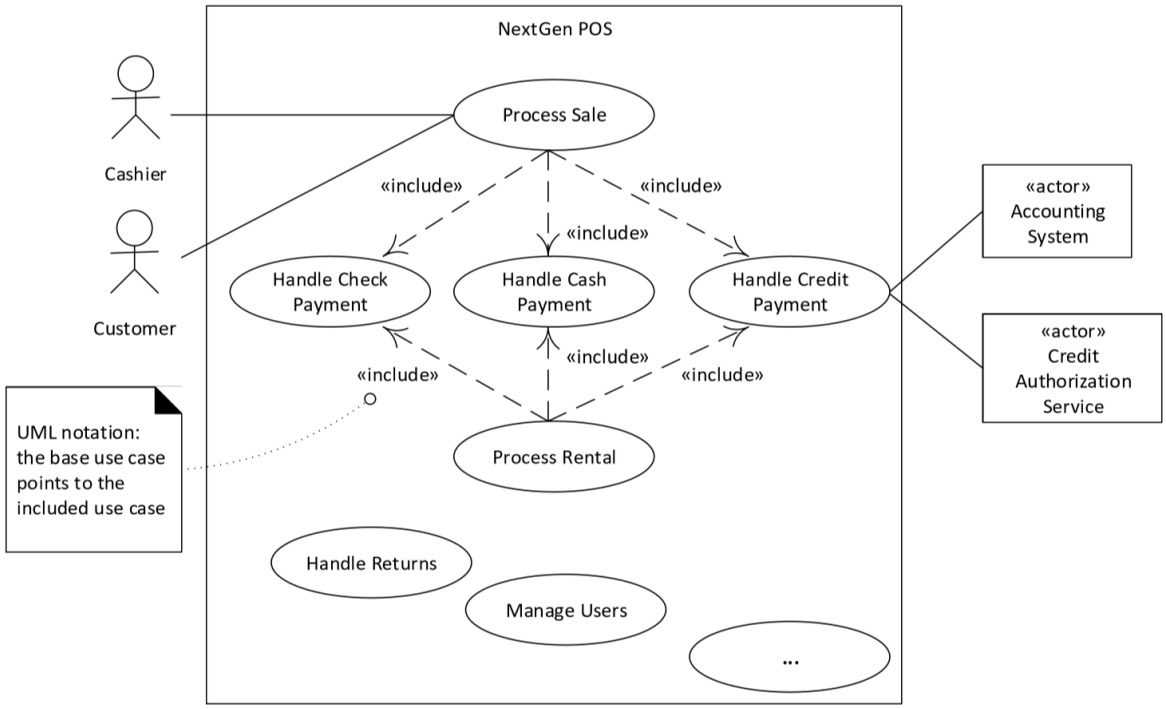

Figure 3: Use case include relationship

Extend relationship

- used to add new extensions/conditional steps to a use case
  - base case is complete without the extension
  - extension relies on base case
  - base case doesn't know about extension
- extension analogous to wrapper or subclass

- used infrequently: most often when you cannot modify the original
- where possible, modify use case text instead

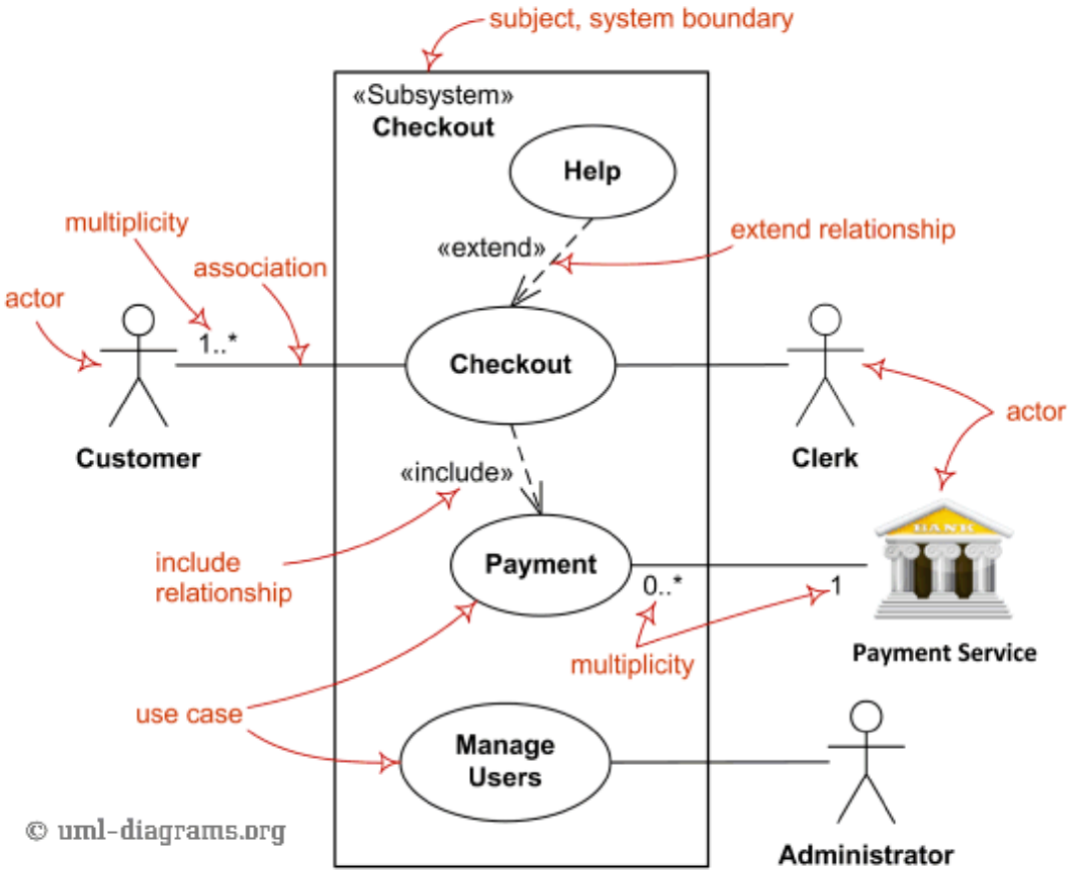

Figure 4: Use case extend and include

OO Analysis

- **OO analysis:** creating description of domain from OO perspective
  - analyse use cases and identify objects/concepts in problem domain
  - concepts/behaviours captured in Domain models and Sequence diagrams
  - abstract level of intention
  - intended to help understand the domain
- domain models and system sequence diagrams are the primary artefacts

Domain Models

- **domain model:** representation of real-situation conceptual classes
  - not a software object
  - shows noteworthy domain concepts/objects
  - is an OO artefact
  - focus on explaining things and products important to the particular business domain
- represented visually using UML class diagram: show conceptual classes, attributes and associations
- **no method signatures** defined
- visual dictionary of noteworthy abstractions, domain vocabulary, information content of the domain
- should be recognisable to a non-programmer from the domain
- captures **static context** of system
- attribute or class?
  - if X not considered a number/text in the real world, X is probably a conceptual class, not an attribute
- don't use attributes as foreign keys: show the association

Identifying conceptual classes

Approaches:

- noun phrase analysis: use carefully, but often suggestive
- use published category list/existing models for common domains

Associations

- **association:** relationship between classes indicating a meaningful/interesting connection
- include associations when
  - significant in the domain
  - knowledge of the relationship needs to be preserved

Attributes

- **attribute:** logical data value of an object

- include when requirements suggest a need to remember information
- do not show visibility: this is a design detail

Creating a Domain Model

1. find conceptual classes
2. draw as classes in UML class diagram
3. add associations and attributes

Description Class

- **description class:** contains information that describes something else
- used when:
  - groups of items share the same description
  - items need to be described, even when there are currently no instances

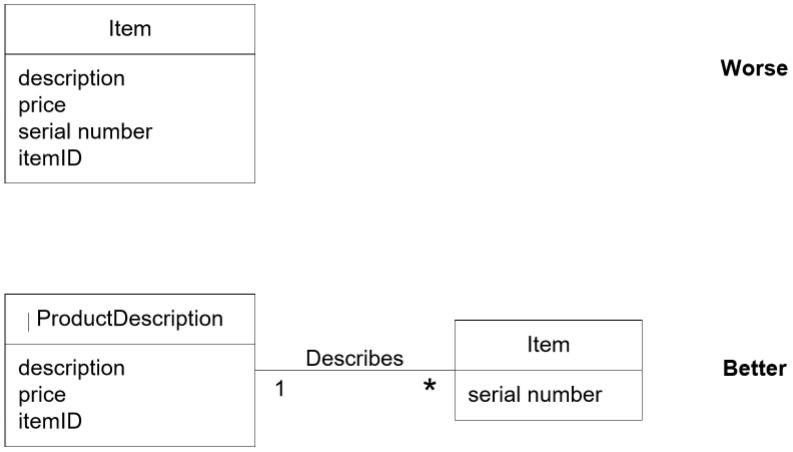

Figure 5: Description class example 1

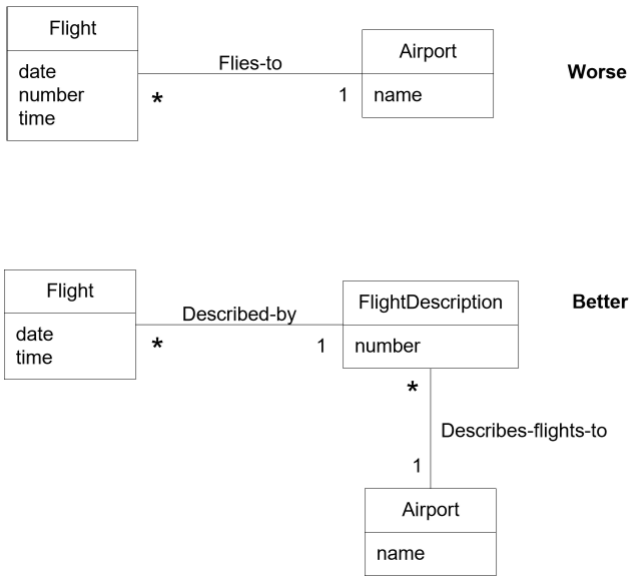

Figure 6: Description class example 2

System Sequence Diagrams

- **system sequence diagram:** shows chronology of system events generated by external actors
- captures **dynamic context of system**
- one SSD for one scenario of a use case
- helps identify external input events to the system (i.e. system events)
- indicates events design needs to handle
- treat system as a black box: describe what it does without describing implementation details
- choose system events that don't tie you to an implementation
  - events should remain abstract: show intent, not the means
  - e.g. `enterItem` better than `scan`
- all external actors (human or not) for the scenario are shown
- can show inter-system interactions, e.g. POS to external credit payment authoriser

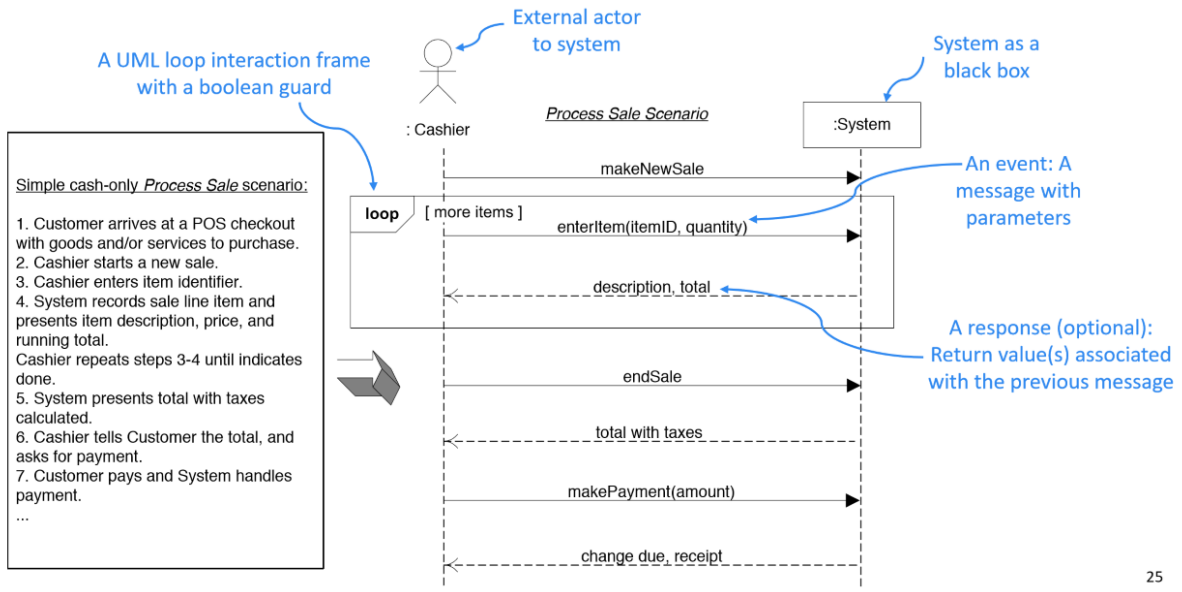

Figure 7: System Sequence Diagram

Object-Oriented Design Models

OO Domain Models

- **Analysis:** investigation of problem and requirements
- **OO Software Analysis:** finding and describes objects/concepts in the problem **domain**

OO Design Models

- **Design:** conceptual solution that meets the requirements of the problem
- **OO Software Design:** defining software objects and their collaboration

Input Artefacts to OO design

- **Use case text** describes functional requirements that design models must realise
- **Domain models** provide inspiration for software objects in design models
- **System sequence Diagram** indicates an interaction between users and system

OO Software Design

- process of creating conceptual solution: defining software objects and their collaboration
- **architecture**
- **interfaces**: methods, data types, protocols
- assignment of **responsibilities**: principles and patterns

Output Artefacts of OOSD

- Static model: Design class diagram
- Dynamic model: Design sequence diagram

Static Design Models

- **static design model:** representation of software objects, defining class names, attributes and method signatures
  - visualised via UML class diagram, called **design class diagram**

Comparison to Domain models

- Domain model: conceptual perspective
  - noteworthy concepts, attributes, associations in the domain
- Design model: implementation perspective
  - roles and collaborations of software objects
- Domain models **inspire** design models to **reduce the representational gap**
  - talk the same language in software and domain

Dynamic Design Models

- **dynamic design model:** representation of how software objects **interact** via messages
  - visualised as **UML Sequence diagram** or **UML Communication diagram**

- **Design Sequence diagram:** illustrates sequence/time ordering of messages between software objects
  - helpful in assigning responsibilities to software objects

SSD vs DSD

- System Sequence Diagram treats the system as a black box, focusing on interactions between actors and the system
- Design sequence diagram illustrates behaviours **within** the system, focusing on interaction between software objects

Lifeline Notation

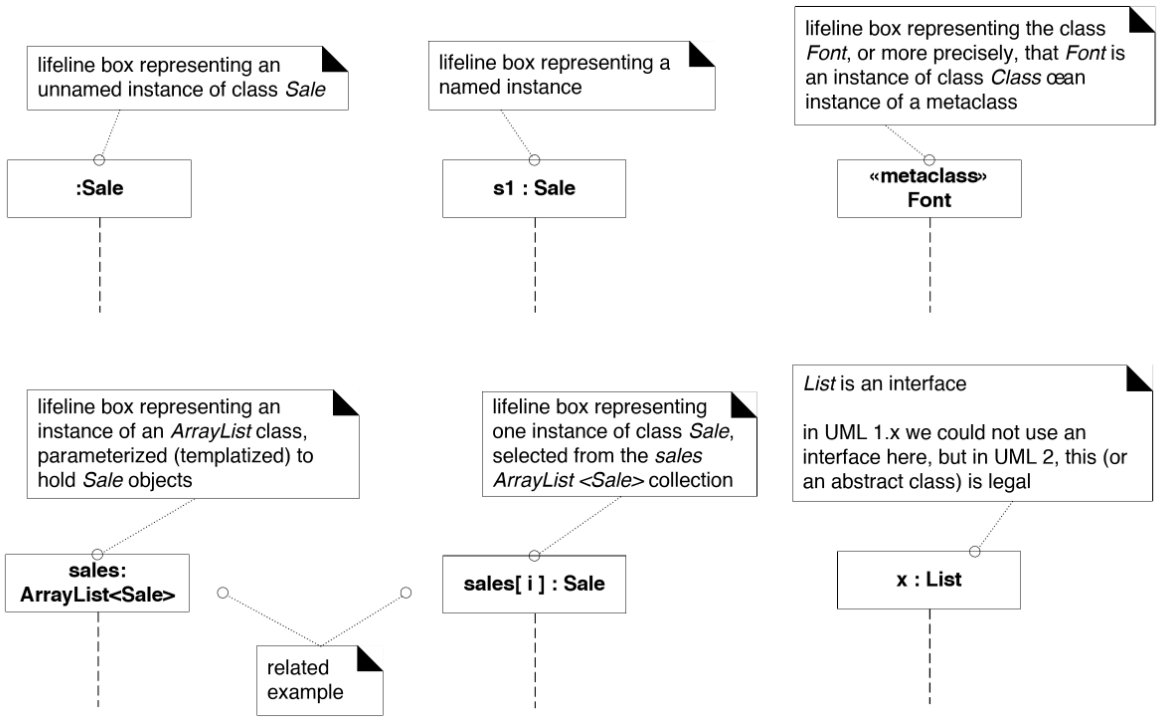

Figure 8: Lifeline Notation

Reference frames

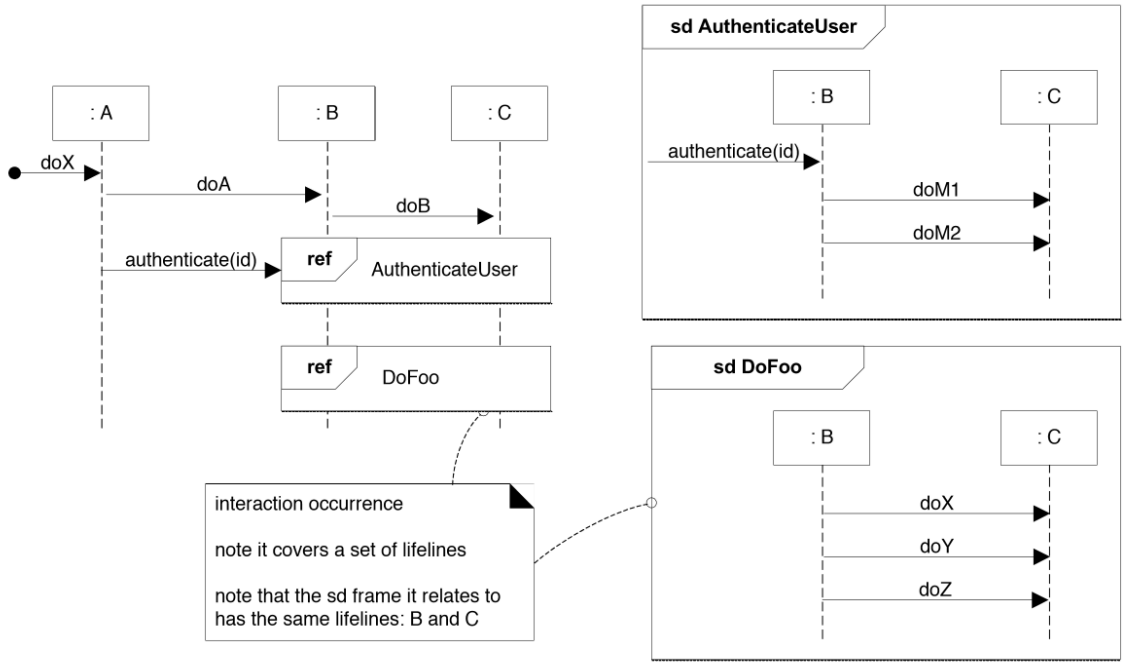

Figure 9: Reference Frames

Loop frames

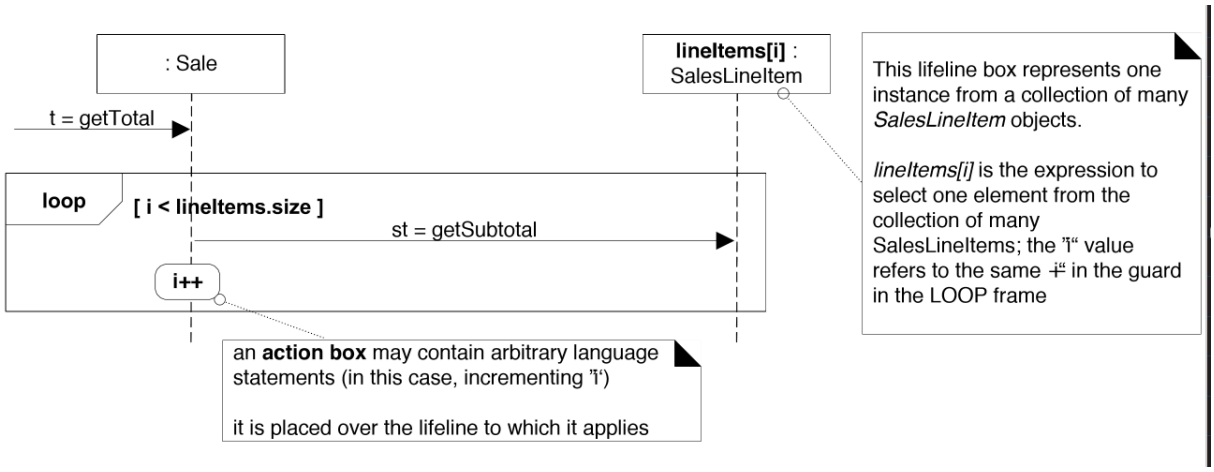

Figure 10: Loop Frame

OO Implementation

- **Implementation:** concrete solution that meets the requirements of the problem
- **OO Software Implementation:** implementation in OO languages and technologies

Translating design models to code

- build least-coupled classes first, as more highly coupled classes will depend on these
- use `Map` for key-based lookup
- use `List` for growing ordered list
- declare variable in terms of the interface (e.g. `Map` over `HashMap`)

Visibility

- **visibility:** ability of an object to see/refer to another object
- objects require visibility of each other in order to cooperate
- e.g. for `A` to send a message to `B`, `B` must be visible to `A`

Achieving visibility

`A` can get visibility of `B` in 1 of 4 ways:

1. `B` is an attribute of `A`
2. `B` is a parameter of a method of `A`
3. `B` is a (non-parameter) local object in a method of `A`
4. `B` has global visibility

State Machines

- **state machine:** behaviour model capturing dynamic behaviour of an object in terms of
  - **states:** condition of an object at a moment in time
  - **event:** significant/noteworthy occurrence that causes the object to change state
  - **transition:** directed relationship between two states, such that an event can cause the object to change states per the transition
- visualised via **UML State machine diagram**

When to apply state machine diagrams?

- **state-dependent object:** reacts differently to events depending on its state
  - e.g. elevator
- **state-independent object:** reacts uniformly to all events
  - e.g. automatic door
- **state-independent w.r.t a particular event:** responds uniformly to a particular event
  - e.g. microwave state-independent w.r.t cancel
- Consider state machines for **state-dependent objects with complex behaviour**
- Domain guidance:
  - business information systems: state machines are uncommon
  - communications/control: state machines are more common (e.g. Berkeley socket)

UML Details

- **transition action:** action taken when a transition occurs
  - typically represents invocation of a method
- **guard:** pre-condition to a transition
  - if false, transition does not proceed

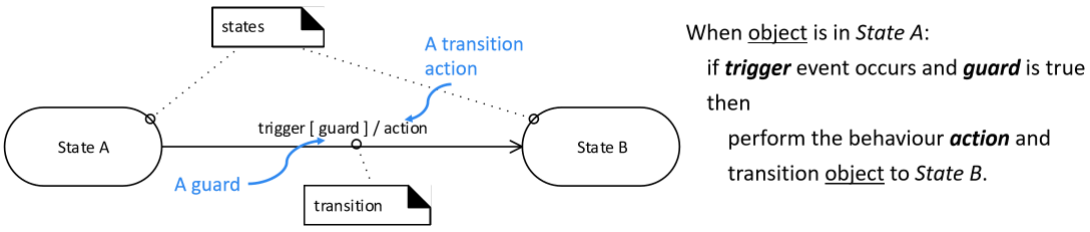

Figure 11: Transition actions and guards

- **nested states:** substates inherit transitions of the superstate

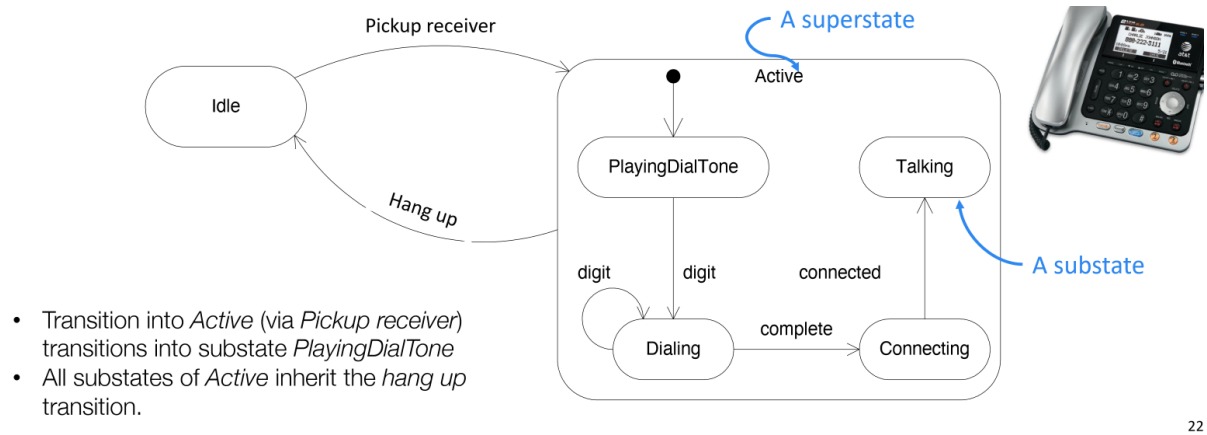

Figure 12: Nested States

- **choice pseudostates:** dynamic conditional branch
  - can have as many branches as needed
  - can use an `[else]` branch to follow if no other guards are true

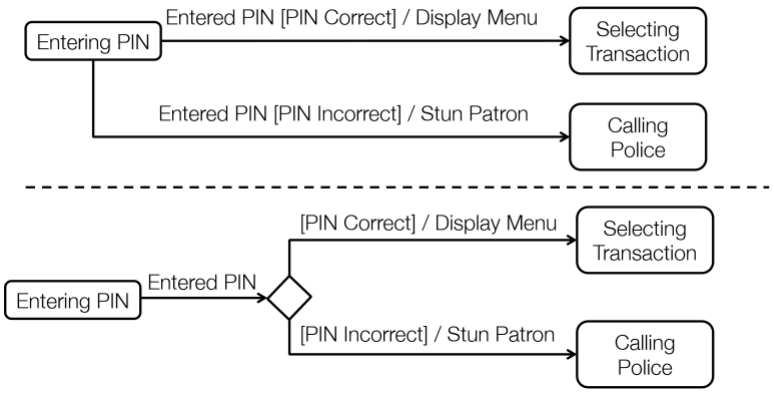

Figure 13: Choice Pseudostate

Implementation Details

- use an enumeration for states

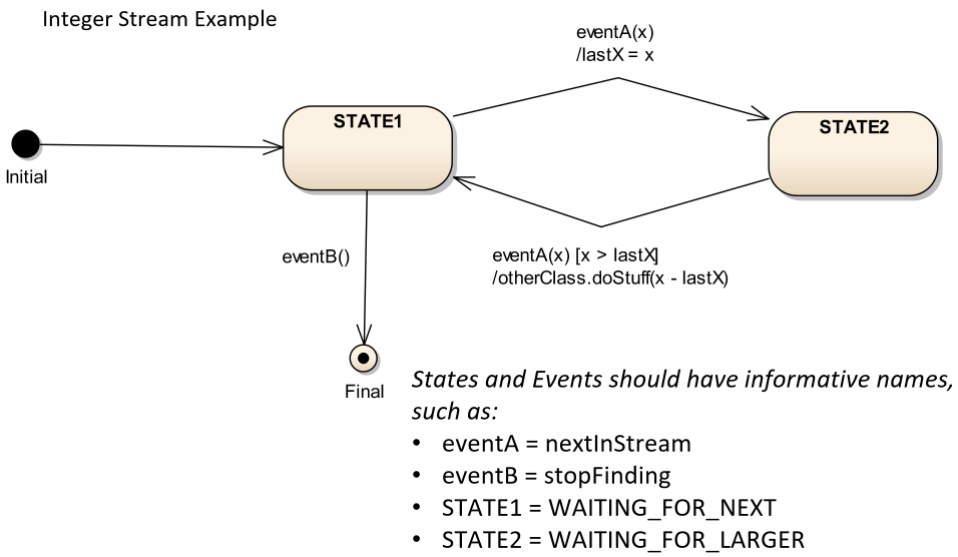

Figure 14: Implementation

```
public class IncreasingPairFinder {
  // enum for all the states of the state machine
  enum State { STATE1, STATE2, FINAL }
  // initialise to start state
  State state = State.STATE1;
  int lastX;

  // trigger
  public void eventA(int x) {
    if (state == State.STATE1) {
      // action
      lastX = x;
      // transition
      state = State.STATE2;
    } else if (state == State.STATE2) {
      // condition
      if (x > lastX) {
        // action
        otherClass.doStuff(x - lastX);
        // transition
        state = State.STATE1;
      }
    }
  }

  public void eventB() {
    if (state == State.STATE1) {
      state = State.FINAL;
    }
```

```
30     }
31 }
```

Architecture

- Larman: Chs 13, 33

Software Architecture

- **software architecture:** large scale organisation of the elements in a software system
- **descisions:**
  - **structural elements:** what are the components of the system?
  - **interfaces:** what interfaces do elements expose?
  - **collaboration:** how do the elements work together according to the business logic?
  - **composition:** how can elements be grouped into larger subsystems?

Architectural Analysis

- **architectural analysis:** process of identifying **factors** that will influence the architecture, understand their variability and priority, and resolve them
  - identify and resolve non-functional requirements in the context of functional requirements
  - challenge: what questions to ask, weighing the trade-offs, knowing the many ways to resolve architecturally significant factors
- **goal:** reduce risk of missing critical factor in the design of a system
  - focus effort on high priority requirements
  - align the product with business goals

Architectural analysis identifies and analyses:

- **architecturally significant requirements:** are those which can have a significant impact on the system design, especially if they are not accounted for early in the process
- **variation points:** variation in existing current system/requirements
  - e.g. multiple tax calculator interfaces that need to be supported
- **potential evolution points:** speculative points of variation that may arise in the future, but are not captured in existing requirements

Architecturally significant functional requirements

- Auditing
- Licensing
- Localisation
- Mail
- Online help
- Printing
- Reporting
- Security
- System management
- Workflow

Architecturally significant Non-functional Requirements

- Usability
- Reliability
- Performance
- Supportability

Effects of requirements on design

- the answer to the following questions significantly affects the system design
- how do reliability and fault-tolerance requirements affect the design?
  - e.g. POS: for what remote services (tax calculator) will fail-over to local services be allowed?
- how do the licensing costs of purchased subcomponents affect profitability?
  - e.g. more costly database server weighed against development time

Steps

- start early in *elaboration* phase
- **architectural factors/drivers:** identify and analyse architectural factors
  - architectural factors are primarily non-functional requirements that are architecturally significant

  - overlaps with requirements analysis
  - some should have been identified during the *inception* phase, and are now investigated in more detail
- **architectural decisions:** for each factor, analyse alternatives and create solutions, e.g.:
  - remove the requirement
  - custom solution
  - stop the project
  - hire an expert

Priorities

- **inflexible constraints**
  - must run on Linux
  - budget for 3rd party components is X
  - legal compliance
- **business goals**
  - demo for clients at tradeshow in 18 months
  - competitor driven window of opportunity
- **other goals**
  - extendible: new release every 6 months

Architectural Factor Table

- documentation recording the influence of factors, their priorities, and variability

Fields

- Factor
- Measures, quality scenarios
- Variability: current, future evolution
- Impact of factor to
  - stakeholders
  - architecture
  - other factors
- Priority for success
- Risk

Technical Memo

- records alternative solutions, decisions, influential factors, and motivations for noteworthy issues/decisions

Contents

- Issue
- Solution summary
- Factors
- Solution
- Motivation
- Unresolved Issues
- Alternatives Considered

Logical Architecture

- **logical architecture:** large-scale organisation of software classes into **packages, subsystems** and **layers**
- **deployment architecture:** mapping of system onto physical devices, networks, operating systems, etc.
  - not a part of logical architecture

Layered architecture

- **layers:** coarse-grained grouping of classes, packages, or subsystems that has cohesive responsibility for a major aspect of the system
  - very common
  - vertical division of a system into subsystems
- e.g.
  - UI
  - application logic/domain objects
  - technical services: general purpose objects/subsystems e.g. interfaces with DB
- **strict layered architecture:** each layer only calls upon the services of the layer directly below it
  - common in network protocol stacks

- **relaxed layered architecture:** higher layer calls upon several lower layers
  - common in information systems
- **partitions:** horizontal division of parallel subsystems within a layer
- **benefits:**
  - prevent high coupling: changes don't ripple through entire system, and hard to divide work
  - promote reuse: application logic is distinct from UI
  - ability to change underlying technical services

UML Package Diagram

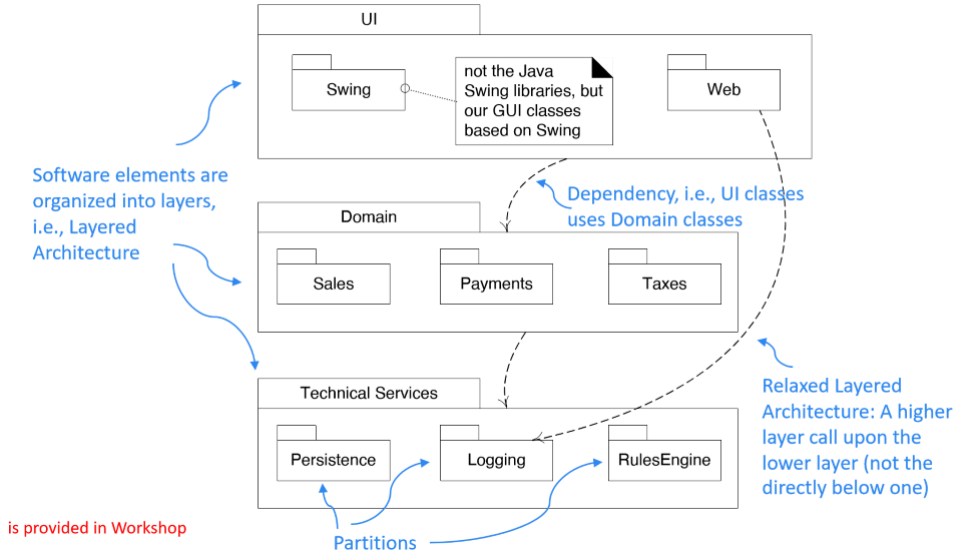

Figure 15: Layers and Partitions

Information Systems - Typical Logical Architecture

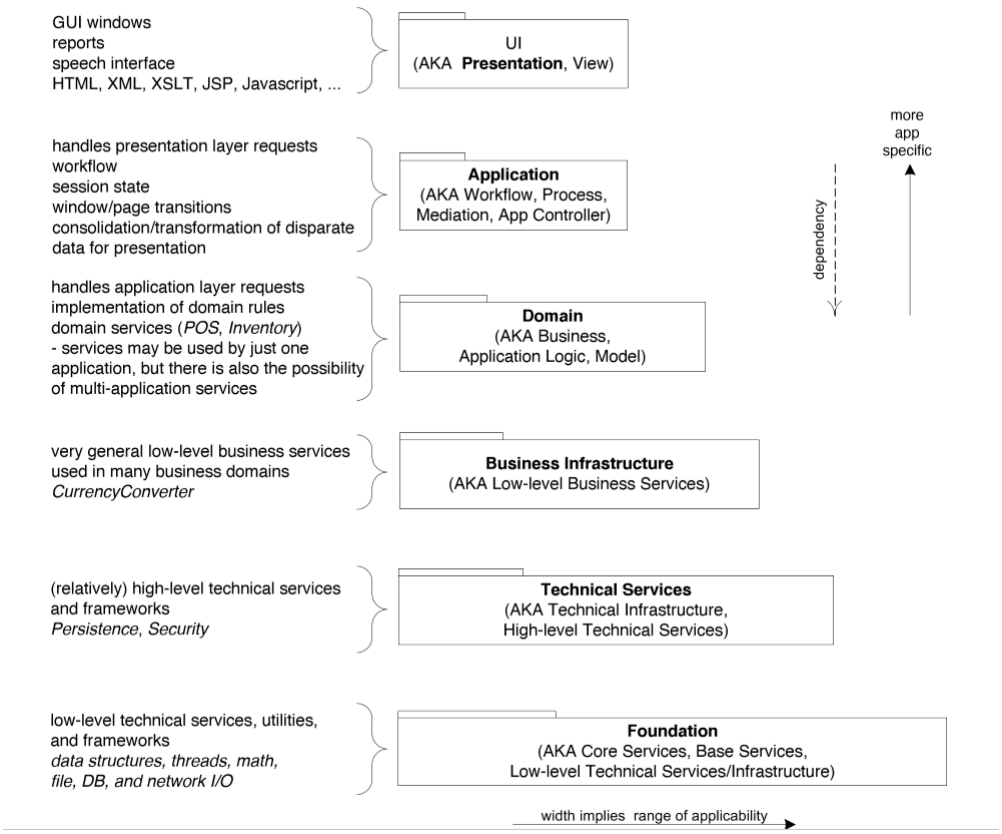

Figure 16: IS Logical Architecture

UML Component Diagram - Implementation View

- **component:** modular part of a system that encapsulates its contents, and is replaceable within its environment
  - can be a class, but can also be external resources (e.g. DB) and services
- **component diagram:** show how to implement software system at a high level
  - initial architectural landscape of the system
  - defines behaviour: provided/required interfaces

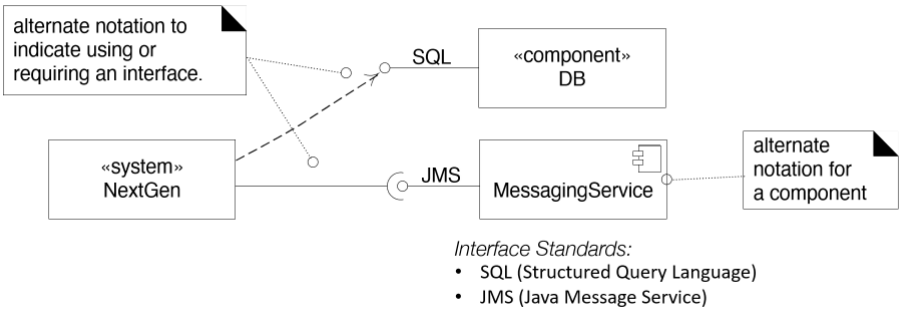

Figure 17: UML Components

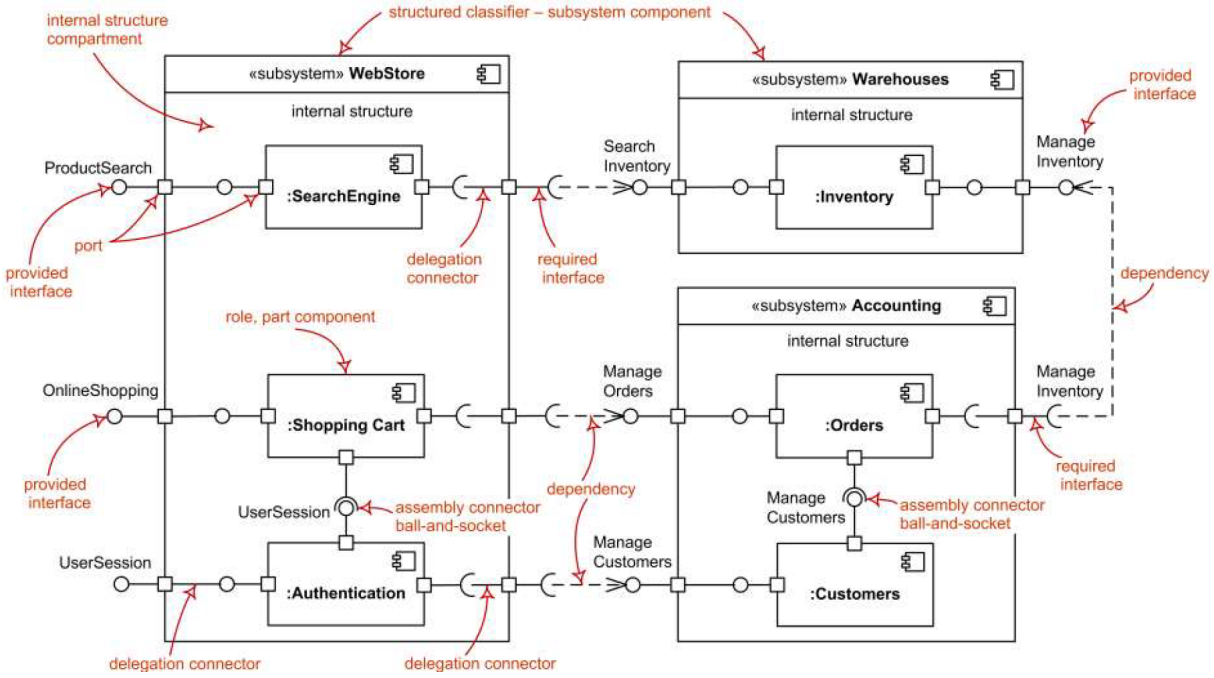

Figure 18: UML Components 2

Architectural Improvement

Strategies Options that might be considered: buy, build, modify

- **Buy**: Use COTS
  - pros: short development time, low starting cost
  - cons: business differences, control over software, long term cost

- **Build:** build a new system from the ground up
  - pros: built-for-purpose for current needs
  - cons: high cost, long timeline, high risk for transition
- **Modify:** modify existing solution
  - pros: simpler transition, control of software
  - cons: cost and delay tradeoff
- Challenge: planning and executing an acceptable path

Handling issues: some ideas

- responsiveness: host system locally, reduce Internet communications
- reliability: update networking
- modifiability: remove old/redundant systems
- functionality: add high priority, low complexity features

Modelling and Design in the Software Process

- Larman: Chs 4, 8, 12, 14
- **Unified Process:** iterative/incremental software development

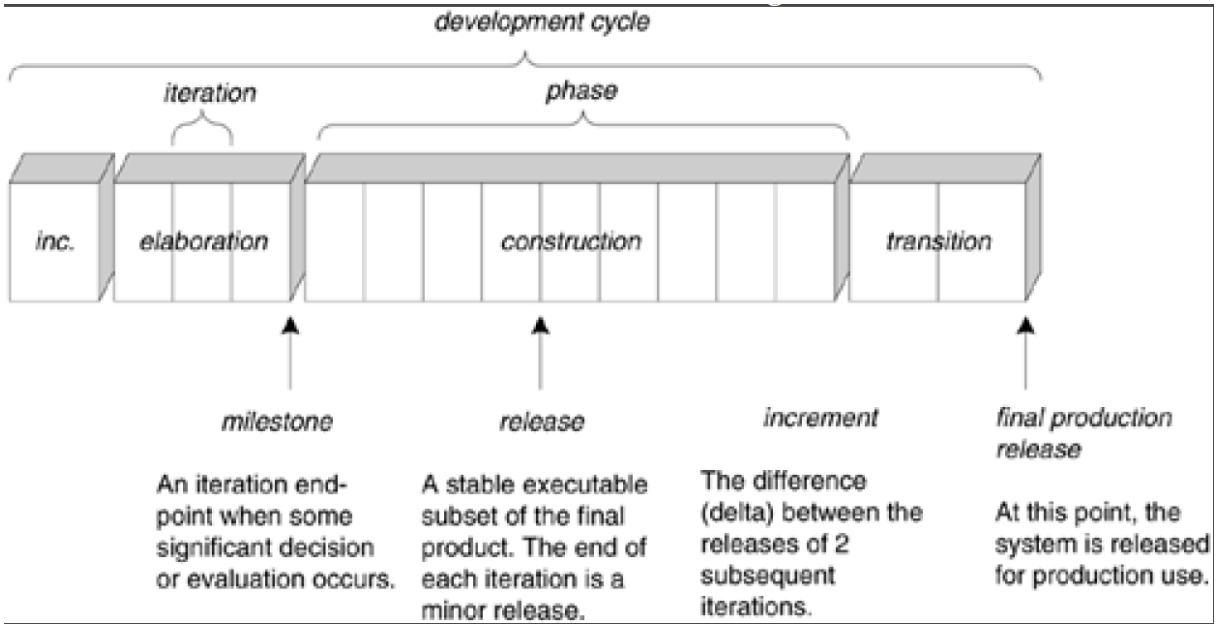

Figure 19: Unified Process

Inception

- **inception:** initial short step to establish common vision and basic scope
- not the time to detail all requirements, and create high fidelity estimates/plans: this happens in elaboration
- answering questions:
  - vision, business case, RoM cost estimates
  - buy/build?
  - Go/no go?
  - Agreement from stakeholders on vision and value?
- how much UML? Probably only simple UML use case diagrams
- should last ~ 1 week
- artefacts should be brief and incomplete

Artefacts

[Bold means mandatory]

- **Vision and business case:** high level goals and constraints, executive summary, business case
- **Use case model:** functional requirements. Most use cases name, ~ 10% detailed.
- Supplementary specification: architecturally significant **non-functional requirements**
- glossary
- risk list and mitigation plan
- prototypes, proof of concept
- **iteration plan:** what to do in 1st elaboration iteration
- phase plan: low fidelity guess of elaboration phase duration and resources
- development case: artefacts and steps for the project

You're doing it wrong:

1. more than a few weeks spent
2. attempted to define most requirements
3. expect estimates to be reliable
4. defined the architecture
5. tried to sequence the work: requirements, then architecture, then implement
6. you don't have a business case/vision
7. you wrote all uses cases in detail
8. you wrote no use cases in detail

Elaboration

- **elaboration:** initial series of iterations for
  - building core architecture
  - resolving high-risk elements
  - defining most requirements
  - estimating overall schedule/resources
- after elaboration
  - core, risky software architecture is programmed/tested
  - majority of requirements are discovered/stabilised
  - major risks mitigated/retired
- start production-quality programming and testing for a subset of requirements, **before** requirements analysis is complete
- work on varying scenarios of the same use case over several iterations: gradually extend the system to ultimately handle all functionality required

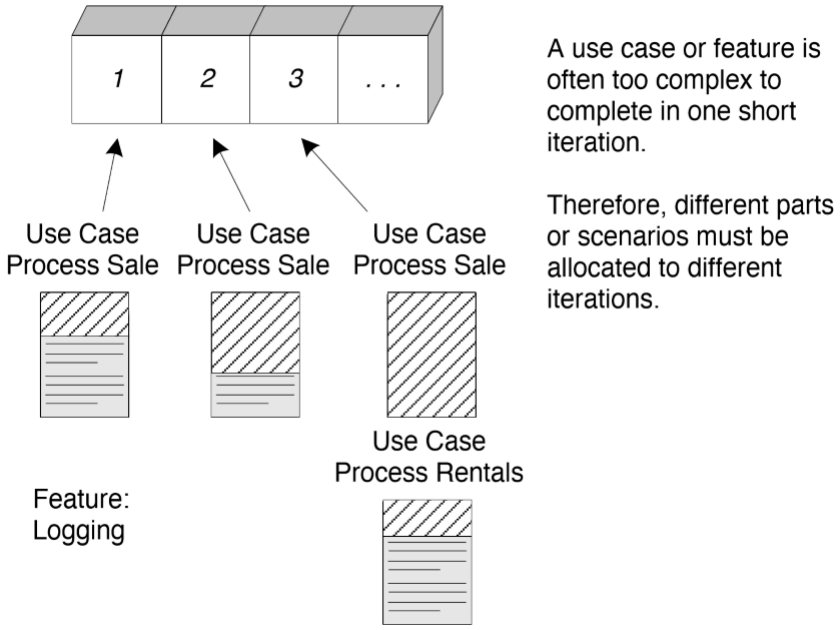

Figure 20: Spreading use cases across Iterations

- usually 2+ iterations of 2-6 weeks each, with a fixed end date
- produces the **architectural baseline**

- test early, often, realistically
- adapt based on feedback from tests, users, developers

Artefacts

- domain model
- design model
- software architecture document
- data model
- use-case storyboards, UI prototypes

You're doing it wrong:

1. more than a few months long
2. only has 1 iteration
3. most requirements were defined before elaboration
4. risky elements/core architecture are not being addressed
5. not production code
6. considered requirements/design phase, preceding implementation
7. attempt to design fully before programming
8. minimal feedback/adaptation
9. no early/realistic testing
10. architecture is speculatively finalised, before implementation