
CH1 - Introduction

- **Software:** Computer programs & associated documentation
- **Software engineering:** concerned with theories, methods, tools for software development
  - Fundamental activities: software specification, development, validation, evolution
  - A part of system engineering (hardware + software + process engineering)
- Often: Software costs > computer system / hardware cost
- Software maintenance cost > development cost
- Software products: "Generic" or "customized"
- Essential attributes of good software:
  - **Maintainability:** Critical attribute. To be able to evolve with changing needs
  - **Dependablity:** Security, reliability, safety. Should not cause damage in case of failure
  - **Efficiency**
  - **Acceptability:** Compatible with other systems, understandable, usable

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Application Types

Stand-alone

- Run on a local machine (e.g.g a PC).
- Need not to be connected to a network

- Has all required functionality

Interactive transaction-based

- Accessed by users externally, runs on remote computer
- Web app.s (e.g e-commerce app.s)

Embedded control systems

- Controls and manages HW

Batch processing systems

- Processes individual inputs in large batches

Data collection systems

- Collect data using sensors, send to other systems to process

Entertainment systems

Modelling & simulation systems

- Developed by scientists & engineers for modeling
- Usually includes many separate interacting objects

Systems of systems

- Composed of other software systems

- Web-based systems: Distributed & complex. Need "agile development": impractical to specify all the requirements for such systems in advance.

- Service-oriened systems: All components considered as replaceable services. Allows rapid configurations & incremental updates as new services become available.

CH2 - Software Processes

- "Software process": Structured set of activities required to develop a software system

- Many different ones but alll involve: Specification, design & implementation, validation, evolution

- Approaches:

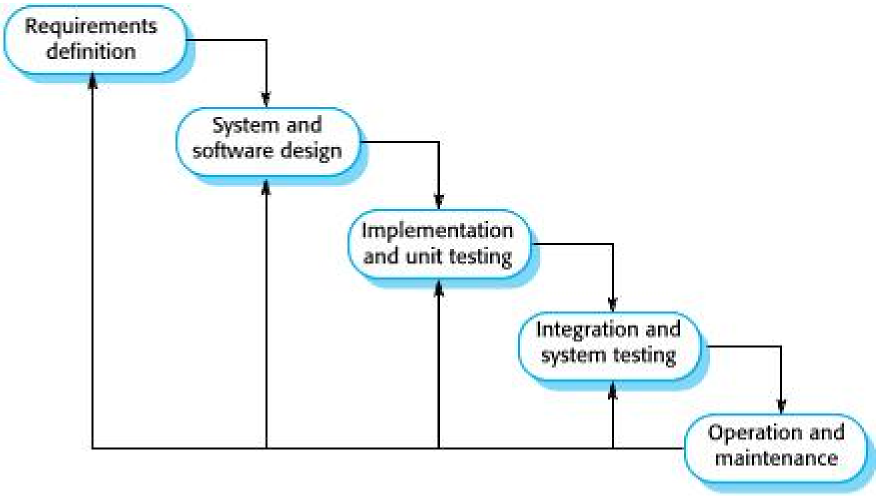
  - "Plan driven process": all activities planned in advance, progress is measured against the plan

  - "Agile process": Incremental planning, easier to change process to changing requirements

  - Often, elements from both approaches are used.

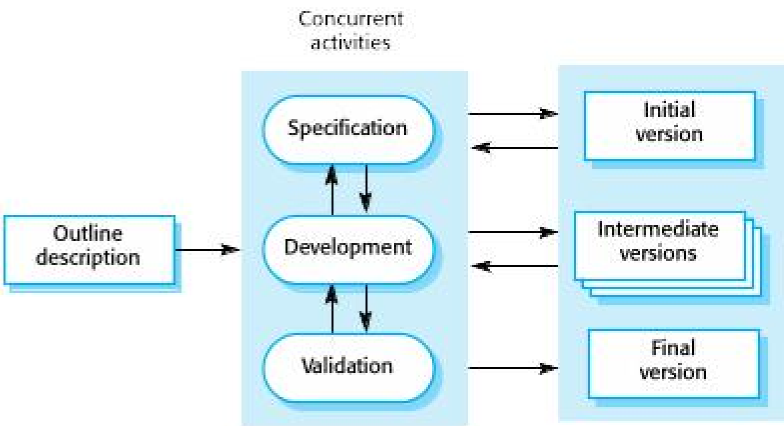
Software Process Models

The Waterfall Model



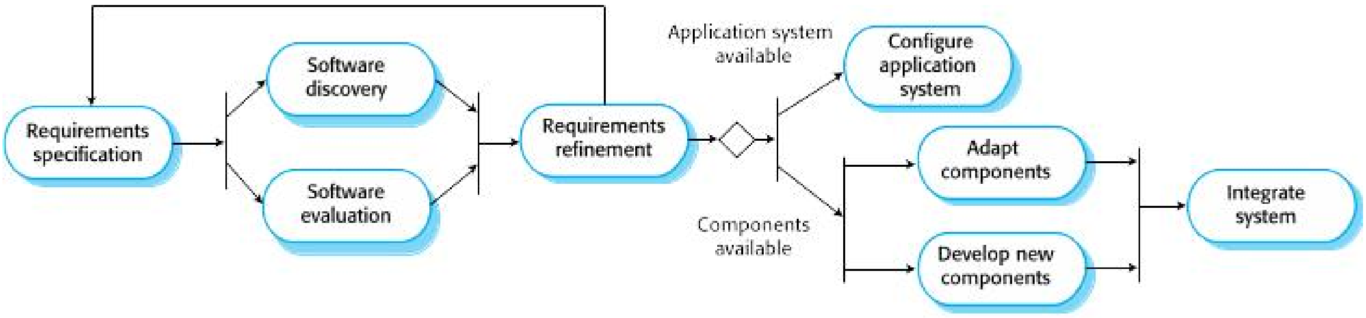
- Plan-driven
- Separate identified phases
- Drawback: a phase has to be completed before moving onto next, hard to accomodate changes
  - Only appropriate when the requirements are well understood & changes will be limited
- Mostly used for large system engineering projects where a system is developed at several sites

Incremental Development



- Cost of making changes reduced
- Easier to get customer feedback
  - Customers can comment on demonstrations
  - Customers can be provided with useful software earlier
- Drawbacks:
  - Regular changes may corrupt project structure - incorporating changes becomes harder and costlier as time progresses
  - Cost-ineffective to document each system version -> Measuring progress is hard

Integration & Configuration (Reuse-oriented SW. Eng.)

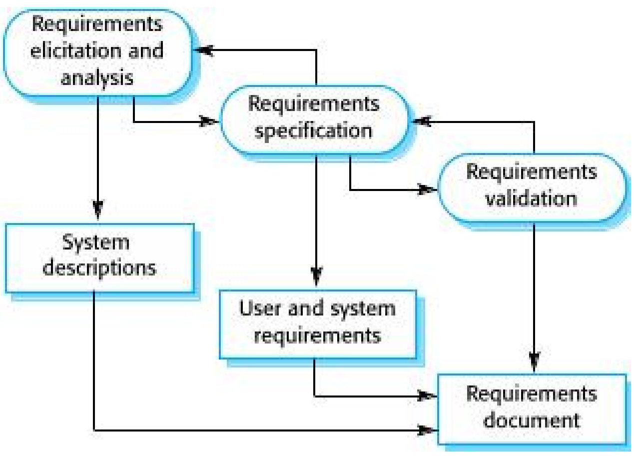


- Based on software reuse - reused elements can be configured according to requirements
- Standard approach for many business system types
- Faster delivery
- Less SW developed from scratch -> Reduced risks & costs
- Drawbacks:
  - Some requirements are likely to be unsatisfied
  - Lost control over the evolution of reused components

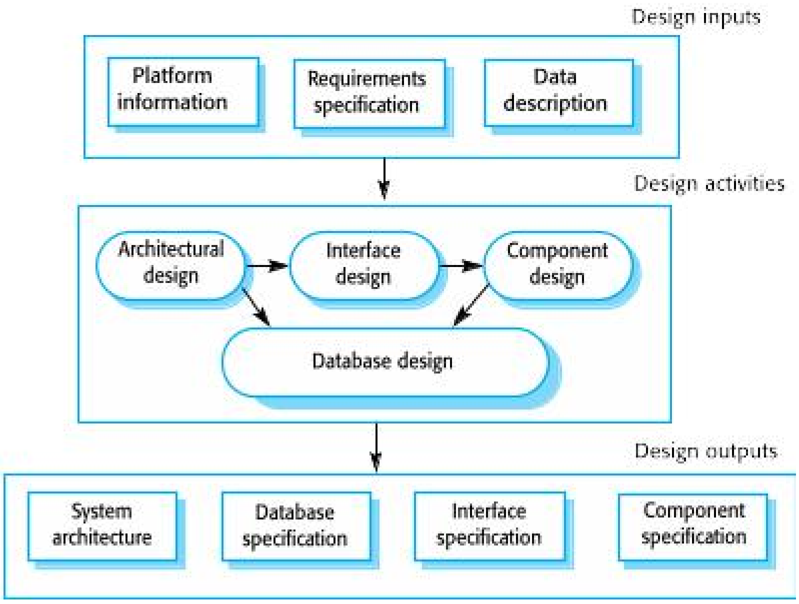
Process Activities

- Can be ordered sequentially or interleaved according to the model

Requirements Engineering Process



Software Design & Implementation

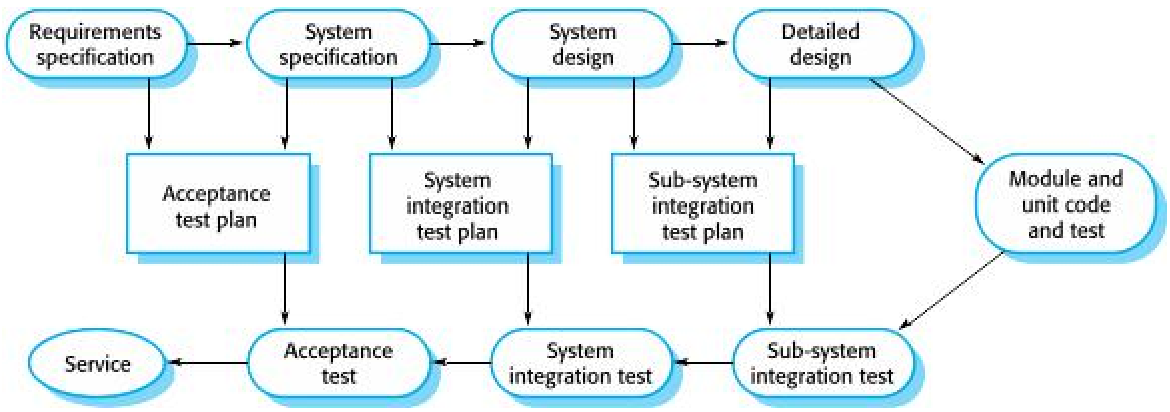


- Design: Creating software structure
  - Architectural, database, interface (between components), component selection & design
- Implementation: translating the structure into an executable
  - Design & implementation can be closely related or interleaved

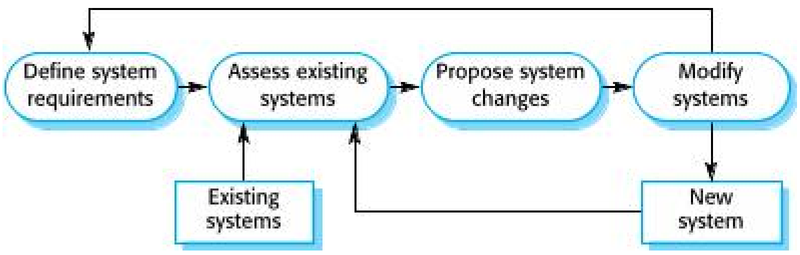
Software Validation

- Testing: Most common verification & validation activity

- V-model: Testing phases in a plan-driven software process:

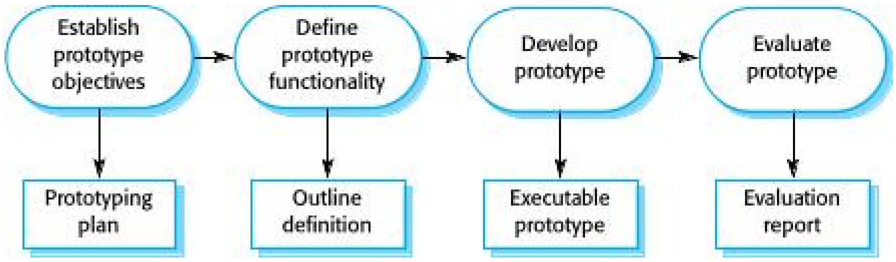


System Evolution



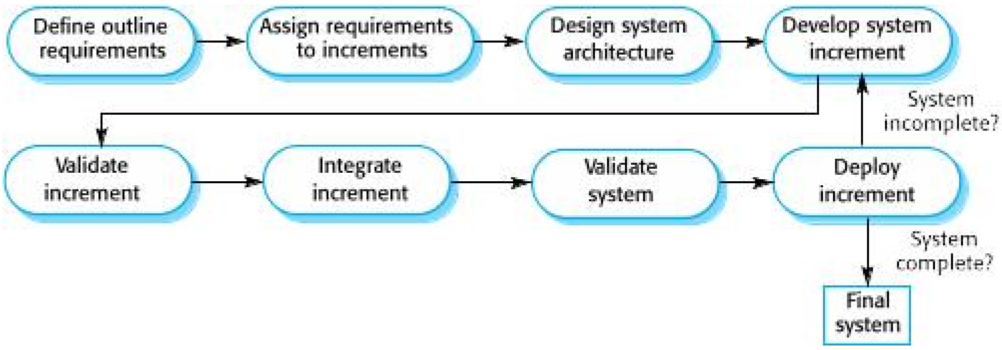
- Change anticipation: Possible changes can be anticipated without much rework
- Change tolerance: Process is designed so that changes are applied without much cost

Software Prototyping



- Discarded after development: usually unstructured, undocumented and not standard-compliant

Incremental Development & Delivery



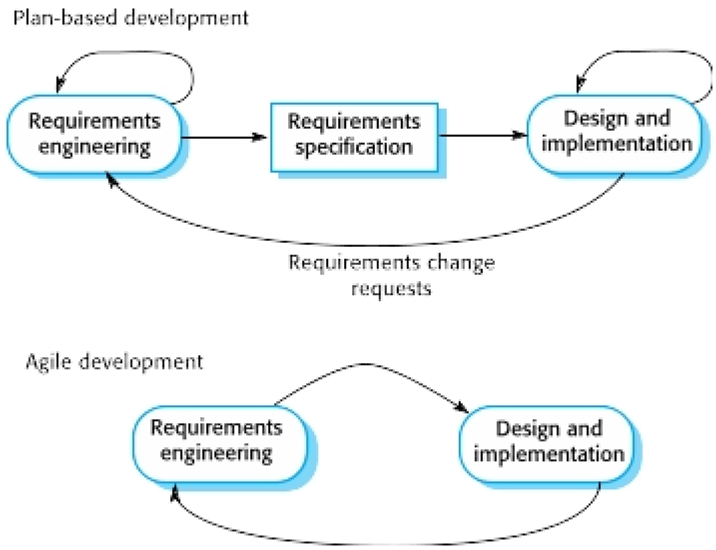
- Early increments serve as prototypes
- Requirements are not changed throughout the development of an increment
- Highest priority services receive most testing
- Specification is developed toghether with the SW itself
  - May contradict procurement models of some organizations

Process Improvement

- Process maturity approach: ? Agile approach: focus on iterative development & reduction of overheads. Emphasis on rapid functionality delivery & adapting to requirement changes
- improvement cycle: Change -> Measure -> Analyze -> Change ...
- Process metrics:
  - Taken time to complete activities
  - Required resources for activities
  - Number of occurrences of a specific event (e.g. an error)
- SEI capability maturity model:
  1. Initial: uncontrolled

2. Repeatable: Defined & used product management procedures
3. Defined: Defined & used process management procedures
4. Managed: Defined & used quality management strategies
5. Optimising: Defined & used process improvement procedures

CH3 - Agile SW Development



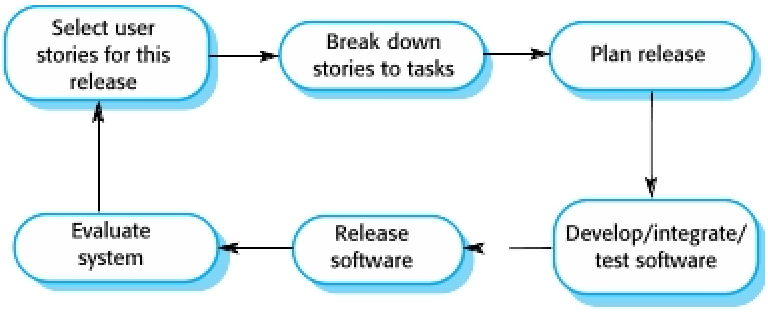
- Program specification, design and implementation are inter-leaved
- The system is developed as a series of versions or increments with stakeholders involved in version specification and evaluation
- Frequent delivery of new versions for evaluation
- Extensive tool support (e.g. automated testing tools) used to support development.
- The aim is to reduce overheads in the SW process, to be able do respond quickly to changing requirements without excessive rework.
    - e.g Minimal documentation - focus on working code

Principles

- Customer involvement: Evaluating iterations, provide and prioritize requirements
- Incremental delivery
- People over processes: Skill of the team should be recognized - members should develop their own ways of working without prescripted processes
- Embrace change
- Maintain simplicity

Agile development techniques

Extreme programming (XP)



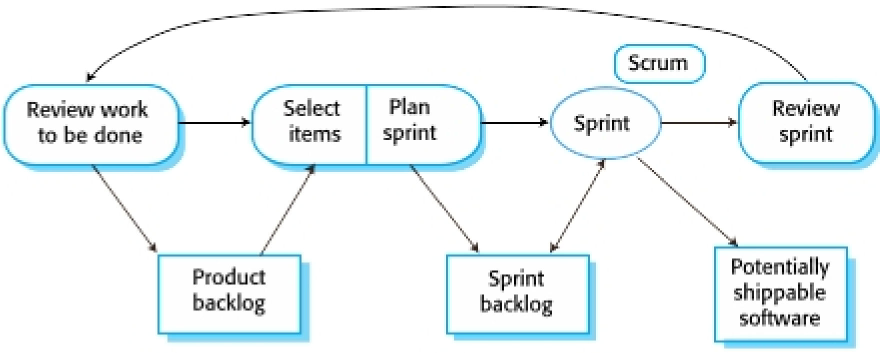
- "Extreme" iterative development:
  - New versions may be built several times per day
  - Increments are delivered to customers every 2 weeks
  - All tests must be run for every build and the build is only accepted if tests run successfully.
- Has a technical focus - usually not easy to integrate with management practice
- XP practices:
  - Incremental planning: Requirements recorded onto "story cards" -> Broken down into "Tasks"
  - Minimal useful set of functionality is developed first, frequent small releases. Functionality added incrementally.
  - Minimum design to satisfy current requirements is carried out
  - Test-first development: A functionality's test framework is implemented earlier than the functionality itself
  - Constant refactoring: All developers are expected to refactor code as soon as possible, even if there is no immediate need
    - Improves software understandability & reduces need for documentation
    - Well-structured code -> Changes are easier to make
    - Changes requiring architecture refactoring are much more expensive
  - Collective ownership: Everyone works on everything, no islands of expertise develop
  - Pair programming
    - Helps develop collective ownership
    - Informal review process
    - Encourages refactoring & sharing of knowledge
  - Continuous integration: After each task is completed, it is integrated & tested (must pass the test)
    - Test-driven development clarifies the requirements to be implemented
    - Tests are written as programs rather than data -> they can be executed automatically after integrating each new functionality
  - The customer should be available full-time as a member of the development team

        - Customer may be reluctant - may feel that providing requirements was enough

    - Large amounts of overtime are not acceptable: Reduces productivity & quality on long term

Agile Project Management

Scrum



- Agile method focusing on managing iterative development rather than agile practices
- "product backlog": a "TODO list", may be feature definitions, SW. requirements, user stories, supplementary tasks (e.g user documentation, architecture definition), etc.
- "scrum"s: daily meetings reviewing progress and daily tasks, ideally short f2f meeting including whole team
- "velocity": estimate of backlog covering rate of the team
- 3 phases:
    - Initial: plan outline, establish objectives (choose from backlog), design architecture
    - "Sprint cycles" of developing increments
        - fixed length (~2-4 weeks)
    - Project closure: wrap-up & complete documentation (e.g system help frames)
- Team is isolated from distractions & customer communication. Only the "scrum master" handles communication with the customer.
- Benefits:
    - Breaks down product into managable chunks
    - Unstable requirements do not hold up
    - Whole team has visibility on everything
    - Customers see on-time increment delivery, can provide feedback
        - Establishes customer-developer trust

Scaling Up Agile Methods

- Agile methods are successful for small & medium sized projects with small teams
    - "Scaling up": Agile methods for large SW systems with large teams
    - "Scaling out": Introducing agile methods to a large, experienced organization

Practical problems

- Agile is informal -> incompatible with legal approach to contracts in large companies
- Agile is more approporiate for new software rather than maintenance
  - In large companies usually: Maintenance cost > development cost
- Agile is more approporiate for small co-located teams
  - SW development involves worldwide distributed teams
  - Design documents may be needed for distributed teams
    - If not available: IDE support for visualisation & program analysis is essential
  - Cross-team communication mechanisms are needed
- Agile works best when team has high skill level, but large companies have a wide range of skill level
- Software contracts are based around specifications; however, agile interleaves specification and development
  - Contract based on time rather than functionality is required for agile -> considered risky
- Maintenance problems:
  - Lack of SW documentation
    - Also needed if system is subject to external regulation
  - Customers are kept involved in development
    - Diverse set of stakeholders in large systems -> hard to involve them all in development
  - Need to keep the original team
    - Problem for long-lifetime systems
- Prioritizing changes may be difficult: Multiple stakeholders have different priorities
- Incremental delivery: Can be hard for business planning and marketing

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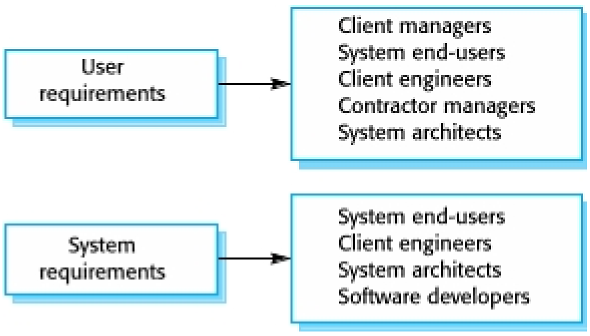
- Several integrated systems: Significant amount of development on system configuration rather than development
- Completely incremental approach to requirements engineering is impossible
- Continuous integration practically impossible. However, frequent system builds & regular releases are essential
- Multi-team Scrum:
  - Releases are aligned
  - Each team has their own scrum masters and product owners
  - Each team chooses "product architect"s to design & evolve overall system architecture
  - "scrum of scrums" are done where representatives of each team meet and discuss progress

CH4 - Requirements Engineering

- Req. eng: Establishing services a customer requires from a system & its operation and development constraints
- System requirements: Desctiptions of the system services & constraints. Generated during requirements engineering.
- "Requirement": Ranges from an abstract statement of a service / system constraint to a detailed functional specification
  - Dual function: May be the basis for a bid for a contract or for the contract itself
- User requirements: Statements in natural language + diagrams of services & operational constraints
  - Must be understandable by the end-users & customers without technical knowledge
- System requirements: Structured document, detailed descriptions of system functions, services, operational constraints.
  - Defines things to be implemented -> May be a part of a contract
- Readers of requirements specification types:



- "Stakeholder": Any person or organization who is affected by the system in some way and thus has a legitimate interest
  - End users, system managers, system owners, external stakeholders
- Agile methods use incremental requirements engineering and may express requirements as "user stories"
  - Practical for business systems
  - Problematic for systems requiring pre-delivery analysis (e.g critical systems) or systems developed by multiple teams

Functional & Nonfunc. Requirements

- **Functional requirements:** Statements of system services, describing system's reactions to particular inputs and situations
  - May state what the system should not do
  - Depends on SW type, expected users & type of system where the SW is used
  - Functional user req.s: May be high-level statements of what the system should do
  - Functional system req.s: describes system services in detail

- **Non-functional requirements:** Constraints on system services or func.s

    - Timing constraints, development process constraints, standards, etc.
    - Often apply to the system as a whole, rather than individiual features
    - May be more critical than functional requirements
    - May be difficult to state precisely, which may be difficult to verify
        - "Goals" (general intentions of the user) can be specified instead
        - A "verifiable nonfunc. req." uses some measure that can be tested objectively
            - Speed: operation time, response time, refresh rate etc.
            - Size
            - Ease of use
            - Reliability: Failure rate, availability etc.
            - Robustness: Recovery from failure
            - Portability: Target-dependent statement rate
    - A single nonfunc. requirements may generate several related
    - Product requirements: execution speed, reliability etc.
    - Organizational requirements: Consequence of organizational policies & procedures (e.g standards, implementation requirements etc.)
    - External requirements: interoperability requirements, legal requirements etc.

- **Domain requirements:** System constraints from the operation domain

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- In principle: Requirements should be complete & consistent:
    - Completeness: include descriptions of all required system facilities
    - Consistency: No conflicts in the descriptions of the system facilities
    - Complexity of environment & system -> impossible to produce a complete and consistent requirements document

Requirements Engineering Process

- An iterative activity in which req. elicitation, analysis, validation and management are interleaved

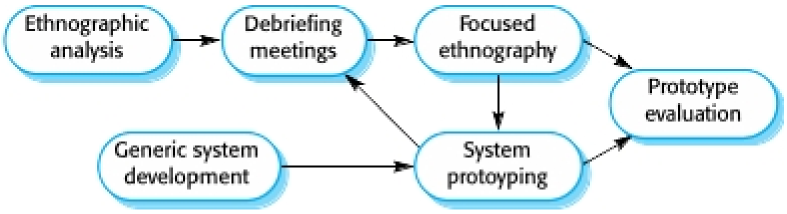
Req.s Elicitation / Discovery

- Technical staff works with stakeholders to find out about application domain, system services & system's operational constraints

- Stages (in a cycle):

    - Req.s discovery
        - Getting info. from stakeholders about the required & existing systems
            - Interviewing:
                - closed (pre-determined questions) or open, or mixed
                - Not good for understanding domain requirements: Stakeholder can unintentionally overlook them since they are already familiar with the domain

      - Ethnography: Social scientist analyzing how people work



        - Important social & organizational factors can be observed
        - Effective for understanding existing processes
        - Cannot identify new features to be added to a system
    - Specifying user & system requirements from the gathered info.
  - Req.s classification & organization
  - Req.s prioritization & negotiation
    - Conflicts are resolved here
  - Req.s specification
    - Req.s are documented here

- Problems:

  - Stakeholders may have unstable decisions
  - Stakeholders express req.s in their own terms
  - Stakeholders' req.s may conflict
  - Organizational & political factors may influence the req.s
  - Stakeholders & business environment may change -> Req.s change during analysis process

- User stories: Real-life system usage examples

  - Practical situation -> stakeholders can relate and comment

- Scenarios: Structured form of user stories

  - Should include starting situation, normal event flow, what can go wrong, state when scenario finishes, other concurrent activities

Requirements specification

- Process of documenting the req.s

- Requirements are written using natural language + diagrams & tables

- Problems with NL:

  - Lack of clarity: Hard to be precise without being complex
  - Functional & nonfunc. req.s may get mixed up
  - Several req.s can be expressed together

- Form-based specifications: Definition of function/entity, description of inputs, outputs, computations, pre & post conditions, any side effects of the function

- Tabular specification: Supplements NL

  - Useful when there are alternative courses of action

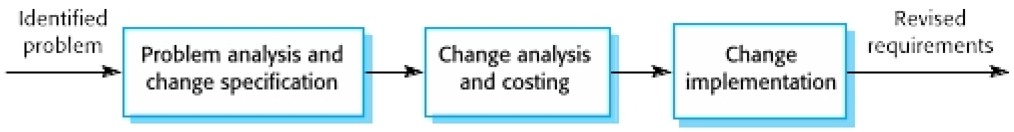
- Use-cases: Identifies an interaction and involved actors
    - A set of use-cases should describe all possible interactions with the system
- SW Req. document should describe "what" the system should do rather than "how" it should do
- Incremental development -> Less detail in req.s document

Requirements Validation

- Validating that the requirements define the system that the customer really wants
- Important: Errors in req.s are costly
- Check:
    - Validity (whether system provides func.s tht best supports customer's needs)
    - Consistency
    - Completeness
    - Realism (whether implementation with given budget & tech is possible)
    - Verifiability (whether the req.s can be tested)
- Techniques:
    - Reviews (systematic manual analyses)
        - Both client and contractors should be involved
        - Formal or informal
        - Check: Verifiability, comprehensibility, traceability (whether origin of the req. is clear), adaptability (whether the req. can be changed wtihout large impact on other req.s)
    - Prototyping
    - Test-case generation

Requirements Management

- Managing changing req.s during req. engineering and system development
    - New req.s emerge as system is being developed and after is deployed
- Req.s mng. planning:
    - Req.s identification: Needed so that a req. can be cross-referenced with other req.s
    - Change management process: Set of activities to assess impacr & cost of changes
    - Traceability policies: Define relationships between req.s
    - Tool support



CH5 - System Modeling

- Representing system using a graphial notation - almost always based on UML
- Models of existing systems are used during req. eng. to clarify its purpose & as a basis for strengths and weaknesses -> Lead to req.s for new system
- Models of new systems are used during req. eng. to explain req.s to other stakeholders
  - Engineers use it to discuss design proposals & document system for implementation
- Model driven engineering: Possible to implement system (partially or completely) from model

System Perspectives

- External perspective: Model context or environment
- Interaction perpective: Model interactions between system & environment or between system components
- Structural perspective: Model organization of system or the structure of processed data
- Behavioral perspective: Model how the system responds to events

UML Diagram Types

- Activity diagrams
- Use-case diagrams: Shows system - environment interactions
- Sequence diagrams: Shows actor - system interactions and interactions between system components
- Class diagrams: Shows object classes and the associations inbetween
- State diagrams: Shows the system's reactions to internal & external events

Context Models

- Shows system's operational context & boundaries
  - Social and organizational concerns affects the boundary
  - Boundary position profoundly affects system req.s
  - Simply shows other systems in the environment, not how it is used or developed
    - Process models show how they are used
      - UML Activity diagrams may be used to define process models
- Architectural model: Shows relationship among systems

Interaction Models

- Use-case and sequence diagrams may be used to model inter-system and inter-component interactions

Use-case Diagrams

- Each use case represents a discrete task that involves external interaction with a system
  - Actors in a use case may be people or other systems

- Represented as a diagram for overview and also in a more detailed textual form

Sequence Diagrams

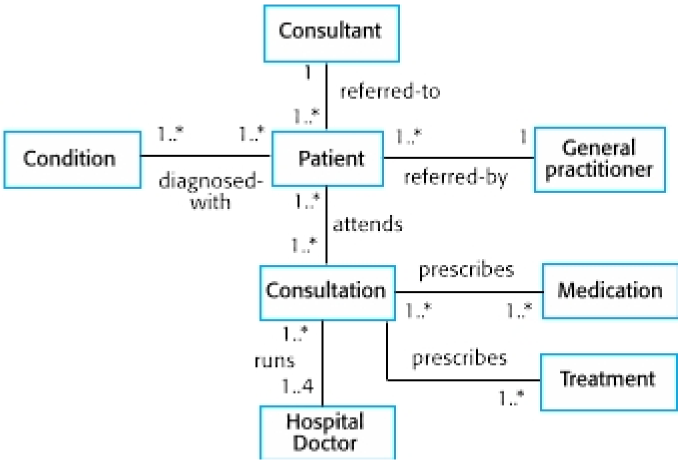
- Part of UML showing sequence of interactions taking place during a particular use-case

Structural Models

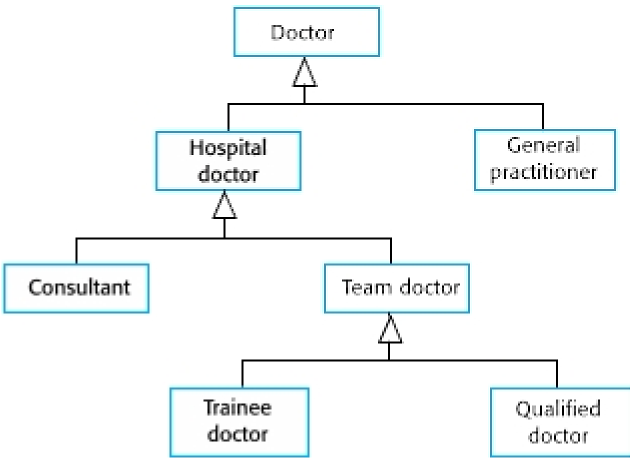
- Display system organization in terms of its components and their relationships
- Static models: show structure of system design, dynamic models: show system organization during execution
- Created when system architecture is being created & discussed

Class Diagrams

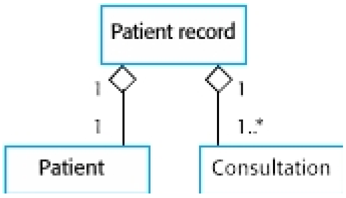
- Object Class: General definitiob of one kind of system obejct
    - During early stages of SW engineering: objects represent an entity in the real world



- Generalization: Base class - Derived class relation

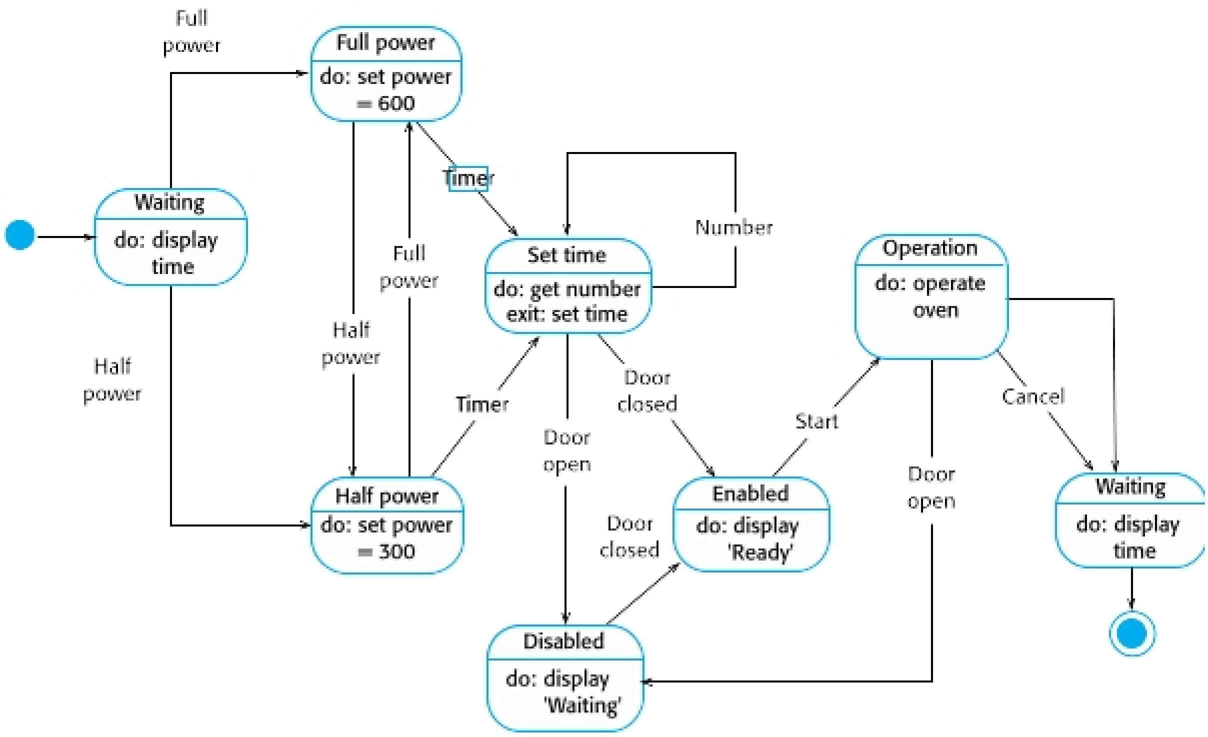


- Aggregation association: Class is composed of other classes
    - Subclasses do not depend on aggregating class to be able to exist - similar to an "array - array element" relation



Behavioral models

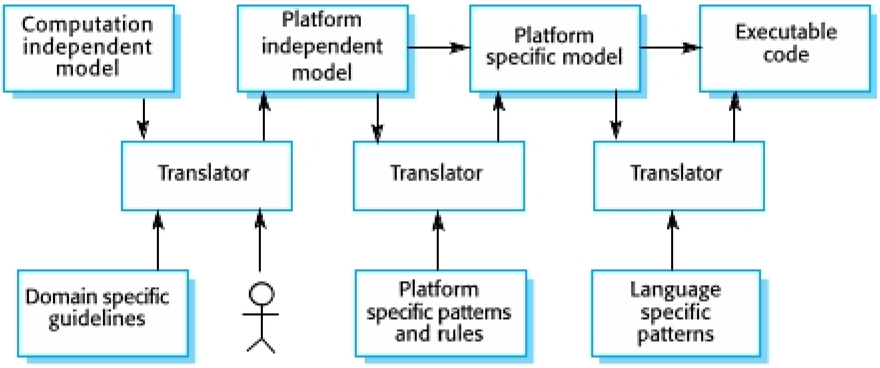
- Models a system's dynamic behavior during execution
  - Show expected response to environmental stimulus
- Types of environmental stimuli:
  - Data: input to be processed by system
  - Events: Trigger system processing
    - May or may not have associated data
- Data-driven models: Show sequence of actions in processing input & generating associated output
  - Most busines systems are data-driven, minimal external event processing
  - Shows end-to-end processing in a system -> Useful in req.s analysis
- Event-driven models: Shows system's response to external & internal events
  - Most real-time systems are event-driven, minimal data processing
  - Based on assumption that a system has finite states & events/stimuli cause transition between states
  - State machine models: Show system's responses to internal & external events



- Statechart in UML are used to represent state machine models

Model-Driven engineering

- Principal outputs of development are models rather than programs
  - Programs are later generated from models
  - Increases abstraction: Engineers no longer have to be concerned with details related to programming languages or execution platforms
  - Method is still in developments
  - Cheaper code generation but developing translators for new platforms may be expensive
- Model-driven architecture (MDA): Model a system using a subset of UML modules, at different levels of abstraction, generate implementation from model. In principle, it is possible to generate a working program without manual intervention.
  - Computation-independent model (CIM) / Domain model: Model important domain abstractions in a system
  - Platform-independent model (PIM): Model operation without referencing implementation
    - Usually described using UML to show response to stimuli & static system structure
  - Platform-specific model (PSM): Transformation of PIMs for specific platforms
    - Can be layered according to added details



- Iterative approach of MDA suggests agile, however up-front modeling contradicts.
  - Can be used in agile if PIM-to-program transformation can be fully automated
- MDA has limited adoption:
  - Limited tool availability for model conversion between abstraction levels
  - The abstractions that are useful for discussions may not be the right abstractions for implementation
  - For most complex systems, req. eng, security, dependability, backwards compatibility, testing etc. are more significant problems than implementation
  - Prevalance of agile has diverted attention away from MDA

CH6 - Architectural Design

- Concerned with overall structure & organization of a SW system
  - Results with an "architectural model" identifying relation between system components -> Critical link between design and req.s engineerings
  - Early stage of agile processes

- Refactoring architecture affects many system components -> expensive
- Architectural abstraction:
  - Small scale: arch. of individual programs & its components
  - Large scale: arch. of large systems involving other systems & programs
- Explicit architecture benefits:
  - Used for discussion & communication with stakeholders
  - Analyzing system for wherher it can meet its nonfunc. requirements
  - An architecture can be reused for other systems
- Box & line diagram representations of architecture: Very abstract but good for communication with stakeholders

Architecture and system characteristics

- Performance: Localize crititcal operations, minimize communications, use "larger" components
- Security: Use layered architecture with critical assets in the inner layers
- Safety: Localise safety-critical features in a small number of sub-systems.
- Availability: Include redundant components and mechanisms for fault tolerance.
- Maintainability: Use replacable components

Architectural views

- Relate different views using use-cases & scenarios:
  - Logical view: Show key abstractions in the system as objects & object classes
  - Process view: Show how the system is composed of interacting processes at run-time
  - Development view: Show how the SW is decomposed for development
  - Physical view: Show how HW & SW components are distributed across processors in system
- Represent views with UML or architectural description lang.s (ADLs)

Architectural patterns

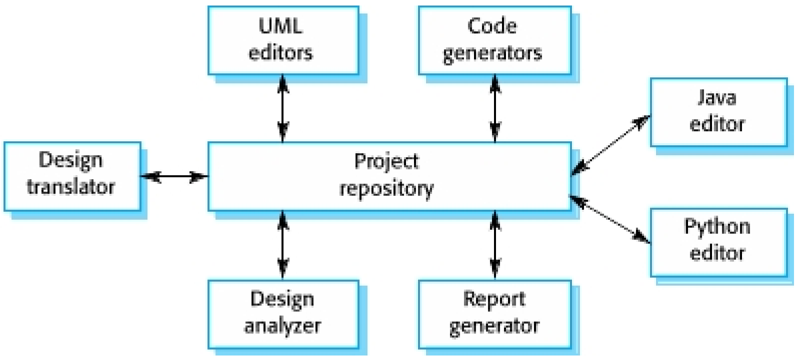
- Patterns: means of representing, sharing, reusing knowledge
  - architectural pattern: stylized description of good design practice, which has been tried and tested in different environments
  - Should include info. about when they are useful and when they are not
  - May be represented using tabular & graphical descriptions

Layered architecture

- Used to model sub-systems interface

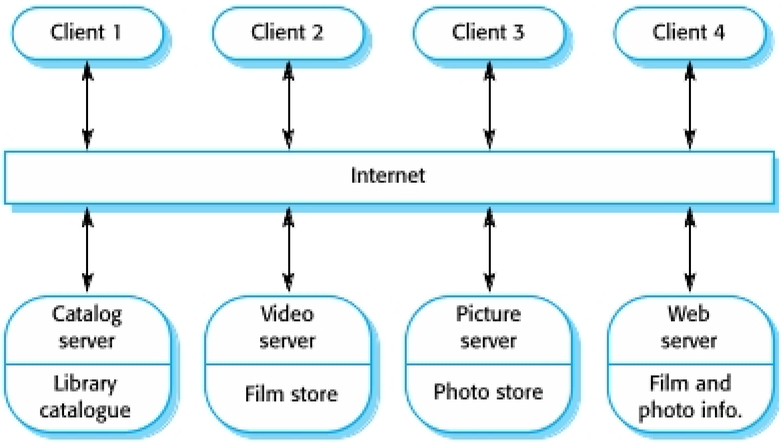
    - Organizes system into a set of "abstract machine" layers
        - Each provides a set of services
    - Supports incremental development
        - A layer changes -> only adjacent layers affected
    - Example: layers from OS to the user interface

Repository architecture



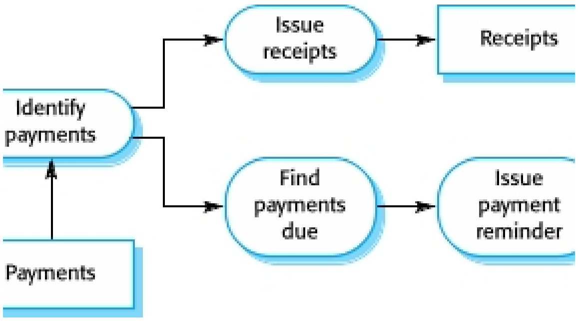
- Efficient data sharing mechanism when large amounts of data is shared among subsystems
    - Shared data held in central database instead of each subsystem maintaining their own databases

Client-server architecture



- Distributed system model which shows how data and processing is distributed across a range of components
    - Can be implemented on a single computer
    - Set of stand-alone "servers" providing specific services, "clients" calling these services & "network" providing clients access to the servers

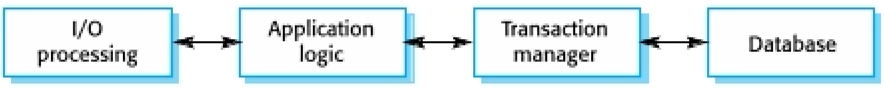
Pipe & Filter architecture



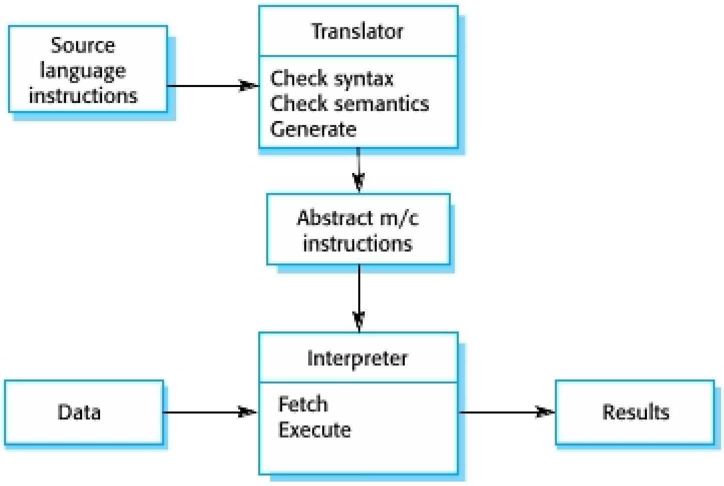
- Input -> functional transformations -> output
- If transformations are sequential: "batch sequential model", used extensively in data processing systems
- Not very suitable for interactive systems

Application architectures

- Architecture for a type of system that may be configured and adapted to fulfill specific requirements.
- Used as:
    - A starting point for architectural design.
    - A design checklist.
    - Way of organising the work of the development team.
    - Means of assessing components for reuse.
    - To discuss application types.
- Two widely used generic app. architectures:
    - Transaction processing systems

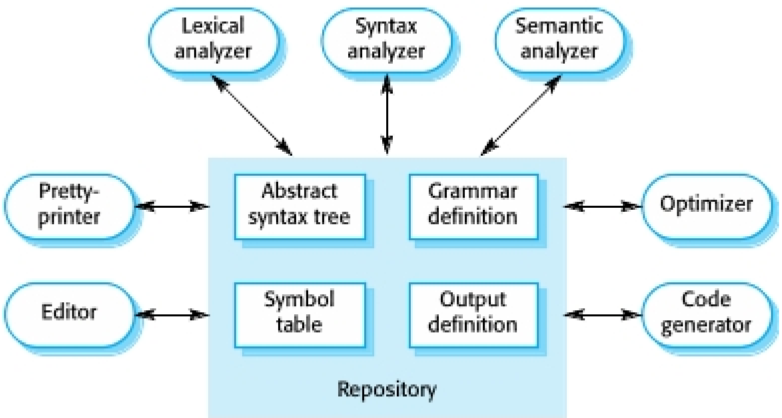


        - Data centered app.s provessing user requests & updating info in a system database
        - Users make asynchronous requests for service which are then processed by a transaction manager
        - E-commerce sys.s, reservation sys.s, etc.
    - Language processing systems

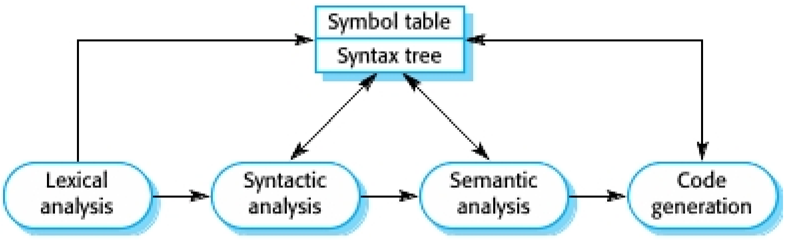


- App.s where user specifies intentions in a formal language, which is processed & interpreted by the system
- Compilers, command interpreters etc.
- Compiler components:
  - Lexical analyzer: Converts language tokens to internal form
  - Symbol table: holds info. about names of entities used in text
  - Syntax analyzer
  - Syntax tree: internal structure of the program being compiled
  - Semantic analyzer: Uses info. from syntax tree & symbol table to check semantic correctness of text
  - Code generator: "Walk" syntax tree to generate abstract machine code

  Repository compiler architecture:

  Pipe & filter compiler architecture:



Information systems architecture

- Can be organized in layers
  - Layers: UI, User communications, info. retrieval, system database...
  - Transaction-based since interaction with these systems generally involves database transactions

CH7 - Design & Implementation

- Implementation: Realizing the design as a program

- Developing a modifiable "off the shelf system": design process is concerned with the configuration features

Object-Oriented Design With UML

- Involve developing a number of different system models - may not be cost-effective for small systems

- Common activities include:

1) Defining system context & interactions

- Defines relationship between software and external environment

- Establishes system boundaries - helps decide which features to implement

- **System context model:** Demonstrates other systems

- **Interaction model:** e.g. Use case model & descriptions

2) Designing system architecture

- Organize components in an architectural pattern (e.g. layered, client-server...)

3) Identifying object classes

- Relatively difficult & an iterative process
  - Considering tangible entities & scenerio based analysis (as in use case model) helps

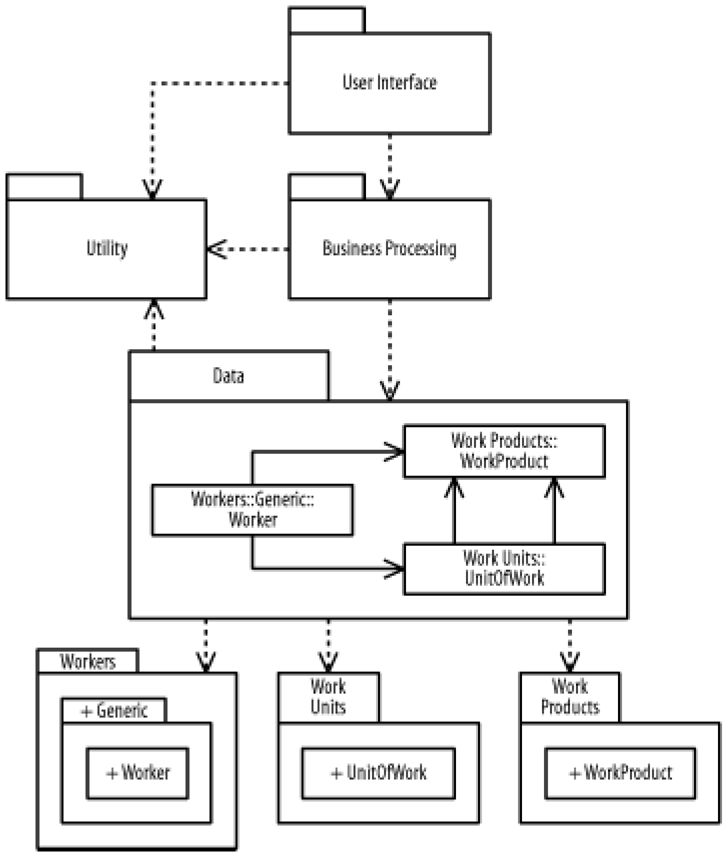
- In the system's verbal description: Generally objects & attributes correspond to nouns, operations & services correspond to verbs

4) Developing design models

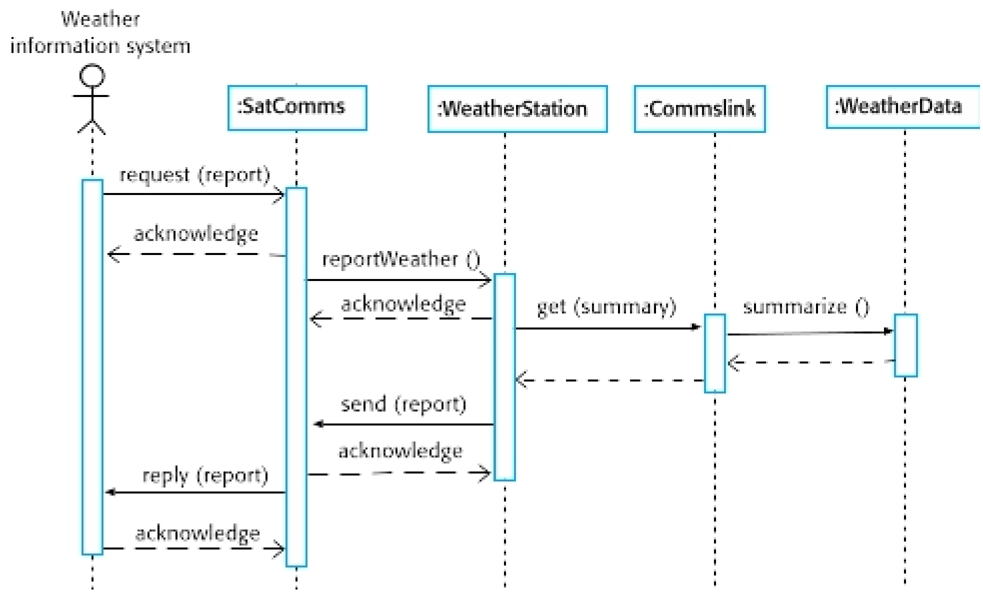
- **Design model:** Shows relations between objects/object classes
  - **Structural model:** Describes static structure of object classes & relationships
  - **Dynamic model:** Describes dynamic interactions between objects

Examples:

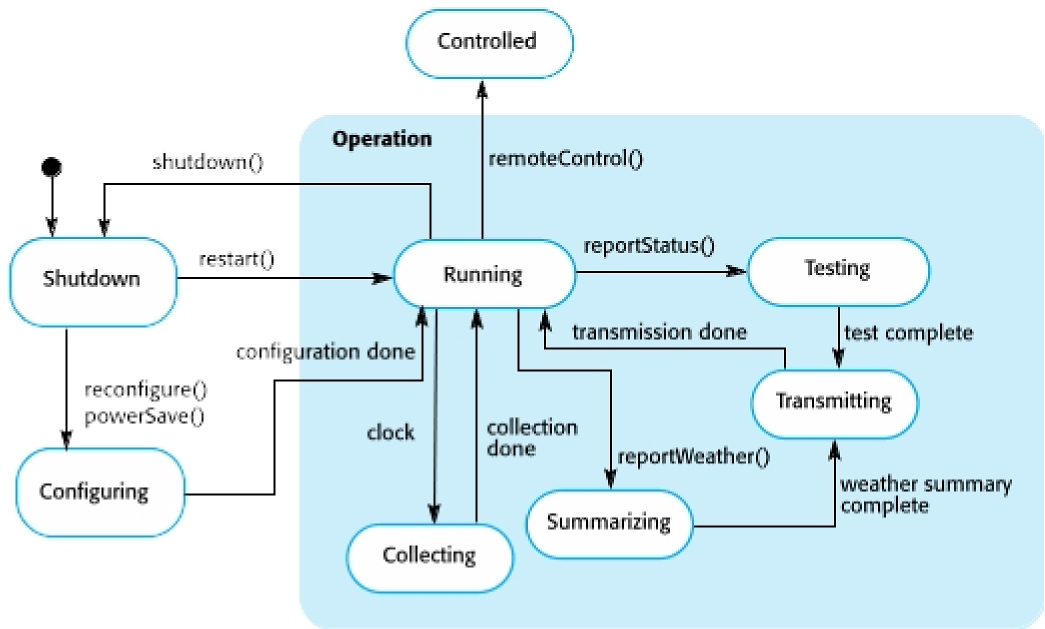
- **Subsystem models:** Show logically related groups of objects
  - Shown with "packages" in UML



- **Sequence models:** Show sequence of object interactions



- **State diagrams:** Show objects' response to service requests & triggered state transitions
    - Useful for modeling run-time behavior
    - Not needed / Unnecessarily complex for most objects



- Also use case models, aggregation models, generalisation models... etc

5) Specifying object interfaces

- Specifying interafaces allows designing objects in parallel

- UML: Class diagrams

Design Patterns

- Ways of reusing abstract knowledge: a description of a problem and the essence of its solution
- Consists of:
    - Name
    - Problem description
    - Solution description (as a template for design)
    - Consequences (& trade-offs)
- Pattern examples: Observer, Façade, Iterator, Decorator...

Implementation Issues

Reuse

- Existing code should be used as much as possible
- Reuse costs:
    - **Searching** for reusable software
    - **Buying** reusable software
    - **Adaptation** of reusable software
    - **Integrating** reusable software with each other

Reuse levels

- **Abstraction level:** Reuse knowledge of successful abstractions
- **Object level:** Reuse objects from an existing library
- **Component level:** Reuse collections of objects & object classes
- **System level:** Reuse entire application systems

Configuration management

- Supporting the system integration process so that all developers can access the project code and documents in a controlled way, find out what changes have been made, and compile and link components to create a system

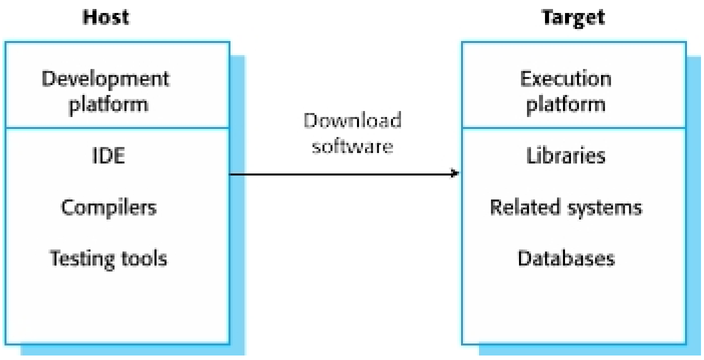
Config. man. activities

- Version management
- System integration (Define versions of used components)
- Problem tracking
- Release management

Host-Target Development

- Consider development & execution platform differences

- Sometimes more or less the same (e.g. Java Virtual Machine)
- Sometimes different (e.g embedded systems): Need simulations & testing



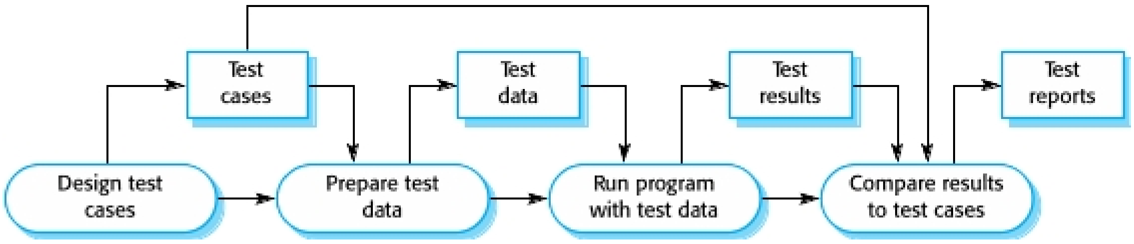
Open Source Developnent

- Avaliable source & volunteers are invited do particitpate in development
- Open source business: Selling support for software rather than software product itself
  - Intention: Cheaper & quicker development and forming a community of users
- Licensing: Open source sofware need not be freely used & manipulated. Restrictions may apply

CH8 - Software Testing

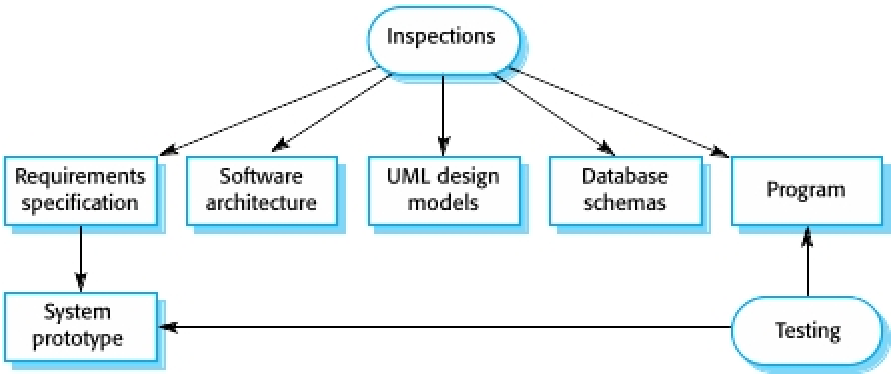
Program Testing

- Executing program with artificial data
- **Defect/Verification testing:** Discover possible defects before putting the program into use
  - Can use deliberately obscure test cases
  - Does not guarantee absence of errors
  - "Are we building the product right?"
- **Validation testing:** Demonstrate program to developers & customers
  - At least one test for each requirement in SRS
  - "Are we building the right product?"
- Verification & Validation (V&V) confidence dependss on softwaree purpose, user expectations, marketing environment
  - Early publishing to market is sometimes more important than finding defects



Software inspection

- **Software inspection:** static verification, **software testing:** dynamic verification



- Doesn't require execution
- Can check conformance with a standard
- Unlike testing, incomplete program can be verified without additional costs
- Unlike testing, cannot check performance, usability etc.
- Both inspections and testing should be used in V&V

Testing stages:

1) Development Testing

Unit testing

- Testing components individually (for defects)
- Example units:
  - Functions/Methods of an object
  - Object classes
  - Composite components & their interfaces
- Testing object classes: Inheritance is more difficult to test as tested information is not localized
- Should be automated whenever possible
  - Setup, call, assertion (checking) stages

Choosing unit testing cases:

- 2 unit test case types:
    - Normal operation (usual cases)
    - Abnormal inputs (edge cases)
- **Partition testing:** Process inputs with similar characterstics together, test inputs from each "equivalence class"
- **Guideline-based testing:** Tests reflecting previous experience, common errors, edge cases
    - Forcing system to generate all errors
    - Force input buffer overflow
    - Repeat same input multiple times
    - ... etc.

Component testing

- Testing composite components & showing that the component interface behaves in accordance with specification
- Assume unit tests within component are completed
- Interface types:
    - **Parameter interfaces:** Passed data between methods/procedures
    - **Shared memory intercafes:** Block of memory shared among methods/procedures
    - **Procedural interfaces:** Encapsulated procedure set of a sub-system to be called by other sub-systems
    - **Message passing interfaces**: Service requests among sub-systems
- Interface errors:
    - **Interface misuse:** A component calls another component erroneously
    - **Interface misunderstanding:** A caller component makes wrong assumptions about the called component
    - **Timing errors:** Caller and called components operate at different speeds and out-of-date or premature information is accessed

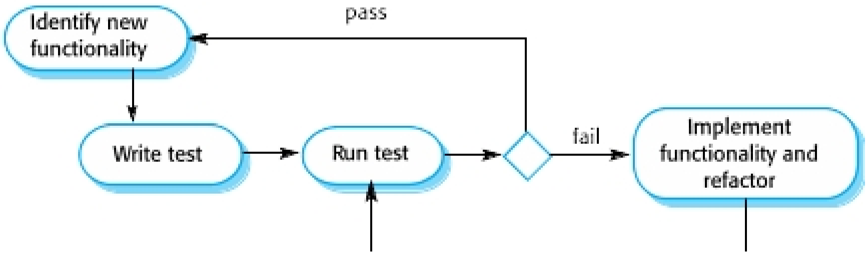
System testing

- Integrate components to create a system version & test it
    - Teams developing different components may come toghether for testing. Some companies have separate testing teams for system testing
- Test interaction and compatibility between components
    - "Emergent behavior" of the system

- Use-cases can be used as a basis as they usually force component interaction
- Exhaustive testing is impractical: Policies defining test coverages may be developed

Test-driven Development

- Write tests before increments, aim to pass tests during development. Do not move on to next increment until test is passed
  - Introduced as part of agile



Benefits

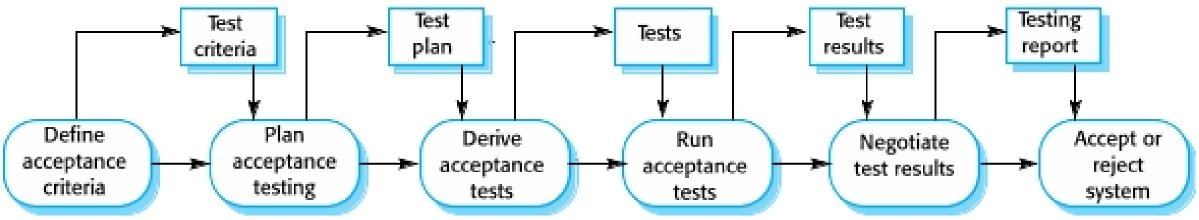
- **Code coverage:** every code segment is tested at least once
- **Regression testing:** Test suite is developed incrementally with the program - It can always be checked whether new code introduces new bugs
- **Simplified debugging**
- **System documentation:** Tests form a documentation describing what the code should be doing

2) Release Testing

- Testing a release which is for outside development team
- A form of system testing, except:
  - A team separate than development team should be responsible for testing
  - System testing focuses on verification, release testing focuses on validation
- Shows system delivers its specified functionality, performance and dependability, does not fail during normal use
- Usually black-box where tests are derived from system specification
- **Requirements-based testing:** Examine each requirement & develop test/s for them
- **Scenario testing:** Devise usage scenarios & use them to develop tests
- **Performance testing:** Testing emergent properties of system (e.g performance, reliability)
  - Steadily increase load until performance becomes unacceptable
  - Stress testing: Deliberately overload system to test failure behavior

3) User testing

- Users / customers provide input & system testing advice
- Essential since influences from user's working environment cannot be exactly replicated in a testing environment
    - User's environment affects reliability, performance, usability, robustness of a system
- **Alpha testing:** Users and developers work together
- **Beta testing:** A release is available to the users for them to experiment with and raise problems to developers
- **Acceptance testing:** Customers test whether system can be accepted from system dev.s & deployed.
    - Primarily for custom systems

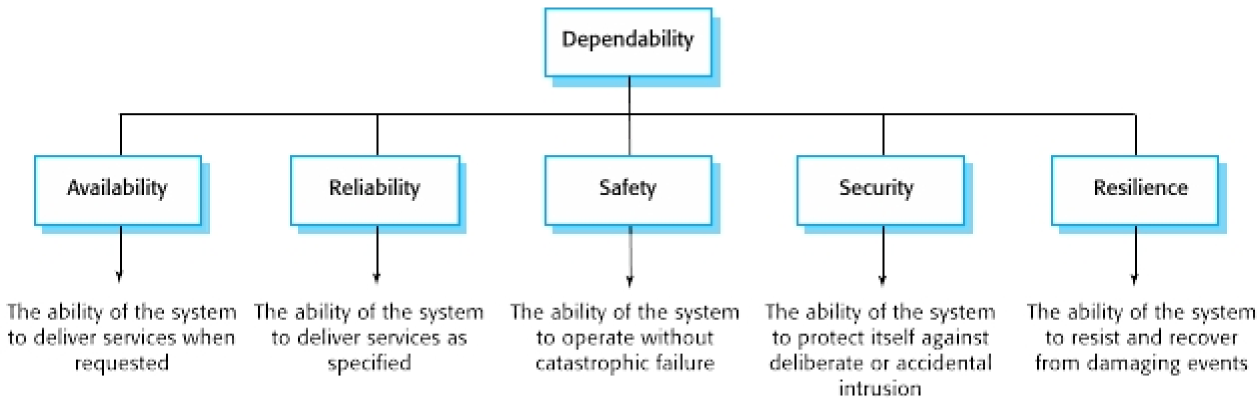


    - In agile: Tests are defined by the user/customer. No separate acceptance testing process
        - Main problem is whether the user working with the team can represent a general user

CH10 - Dependable Systems

- Dependability: Reflects user's degree of trust in a system
- Failure causes:
    - Hardware failure
    - Software failure (erroneous specification, design or implementation)
    - Operational failure (mistakes by human operators)

Dependability Properties

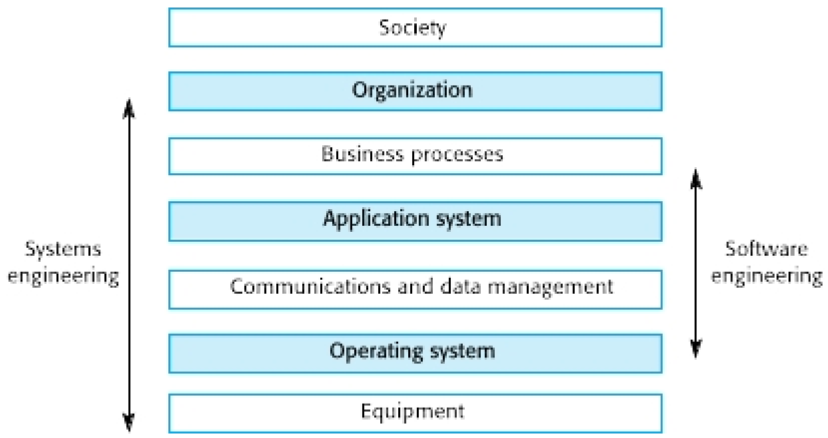


Also:

- **Repairability:** Extent to which system can be repaired in case of failure

- **Maintainability:** Extent to which system can be adapted to new requirements
- **Error tolerance:** Extent to which system can avoid or tolerate user input errors
- Dependability costs increase exponentially as required dependability level increases
    - V&V is expensive
    - Dependability can be compromised depending on social & political factors

Sociotechnical Systems

- Software systems are components of broader systems with social & organizational purpose
- 

    - Equipment: HW
    - Communications & data mgmt.: Middleware providing access to db.
    - Application systems: Specific functionality to meet some organization requirements.
    - Society: Laws, regulation, culture affecting operation of the system
- **Holistic ("bütünsel") system design:** Consider other layers of socio-tehnical system for dependability. A failure in a layer should not propogate to others

Regulation & compliance

- Companies developing safety-critical systems (e.g. nuclear systems, medical devices, air traffic systems) have to produce an extensive safety case showing that regulations are followed
    - Sometimes as expensive to prepare documentation as to develop system itself

Redundancy & diversity

- **Redundancy:** Keep multiple versions of critical components for backup
- **Diversity:** Provide same functionality in multiple ways to lower chance of failure in the same way
- Redundant and diverse components should be independent to avoid common ("ortak") failures
- Redundancy & diversity in process activities: Activities such as V&V should depend on multiple approaches: Provides "cross-checking" and avoids development process errors
    - e.g Use testing, manual inspections, static analysis together for verification (fault finding)

Disadvantages

- R&D increases system complexity
- Increases chances of error - unanticipated interactions & dependencies possible between redundant components
- Some advocate simplicity & extensice V&V instead of R&D

Dependable Processes

- Software processes designed to produce dependable software

Dependable Process Characteristics:

- **Well-defined:** A model is explicitly defined & it is shown that the team follows the process model
- **Repeatable:** does not depend on individual skills, can be applied by different peoples
- **Auditable:** Understandable by outsiders who check whether standards are followed & make suggestions to improve the process
- **Diverse:** Should include R&D activities for V&V
- **Documentable**
- **Robust:** Able to recover from errors
- **Standardized:** SW development standards covering SW production & documentation should be available

Dependable Process Activities:

- Requirements reviews to check completeness & consistency
- Req.s management
- Formal specification: Mathematical model of SW
- System modeling: Explicitly documented SW design as graphical models
- Design & program inspections
- Static analysis, automated source code checking
- Test planning & management

Dependable Processes & Agile

- Conflicts with agile:
    - Dependable SW usually requires certification, need process and document documentation
    - Up-front requirements analysis is essential to ensure safety and security
    - Agile aims to minimize documentation and in agile, requirements are developed along with the system

- Instead of "pure agile" an agile process incorporating techniques (such as iterative development, test-first development, user-developer co-operation) can be used

Formal methods & Dependability

- Formal methods: Approaches to SW development based on mathematical representation
- Reduces fault count -> main application area is dependable systems engineering
- **Verification-based formal approaches:** Prove different SW system representations and the program implementing it are equal
- **Refinement-based formal approaches:** Systematically transform a system's representation into a lower-level one
  - e.g. specification -> implementation
  - If transformation is correct, representations are equivalent

Benefits

- Formal specification development requires deatiled req.s analysis -> helps detect req.s problems
- Formal language: allows automatic analysis of specifications
- Formal verification: May reduce program testing costs

- Formal methods are impractical:
  - Stakeholders cannot assess whether formal specifications accurately represent their requierements
  - Easier to assess costs but harder to assess benefits of formal specification
  - SW engineers are unfamiliar with formal methods
  - Hard to upscale for large systems
  - Not compatible with agile

CH11 - Reliability Engineering

- System faults do not necessarliy result in system errors
  - Faults may be transient
  - Faulty code portion may never be executed
  - Removing a fault not necessariy improves system reliability
- Errors do not necessarily lead to system failures
  - Error can be corrected by built-in error detection and recovery
  - Built-in protection facilities can prevent failure
- Achieving reliability:

    - **Fault avoidance:** Use development techniques to minimise possibility of mistakes or "trap" them before a system fault
    - **Fault detection & removal:** Use V&V to increase fault detection & removal probability before deployment
    - **Fault tolerance** Use runtime techniques to ensure fault do not resutl in errors, or errors do not reult in system failures
- Exponential fault removal costs

Availability & Reliability

- Can be quantitatively expressed
- **Reliability:** Probability of no failures for a given time, environment and purpose
- **Availability:** At a given time, probability of a system to deliver requested services

Reliability perception

- Formal reliability description may not reflect user's perception of reliablitty
    - Assumptions about user's environment may not hold
    - Perceived reliability is more important in practice
- Users adapt their behavior to avoid system features that may fail for them

Availability perception

- Expressed as a percentage
- Does not consider service outage length or number of affected users

Reliability Requirements

...