Software Architecture Specification

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Course Overview

1. Software Architecture Fundamentals
2. Software Architecture Specification
3. Robust Design Strategies

Software Architecture Specification

Chapter Overview

- [2.1] Documentation requirements
- [2.2] Multifaceted perspective
- [2.3] Programming abstractions
- [2.4] Modularity
- [2.5] Architectural notation
  - [2.5.1] Components
  - [2.5.2] Connectors
  - [2.5.3] Design diagrams
  - [2.5.4] Meta level specifications

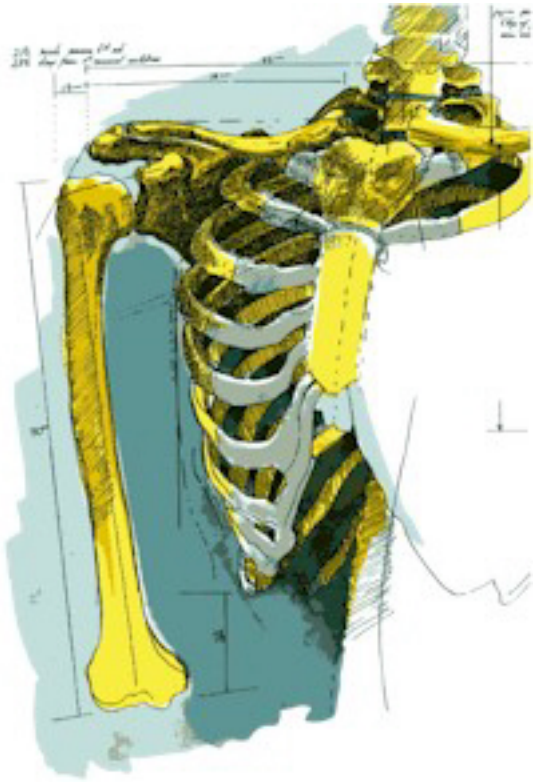
2.1 Documentation Requirements

- Key design decisions that shape the artifact we are constructing
- The rational and justification for these decisions
- Sufficient information to ensure that the final product confirms to these decisions
- Enough detail to make informed decisions about how to plan the development of the product

Documentation Strategy

Static Systems

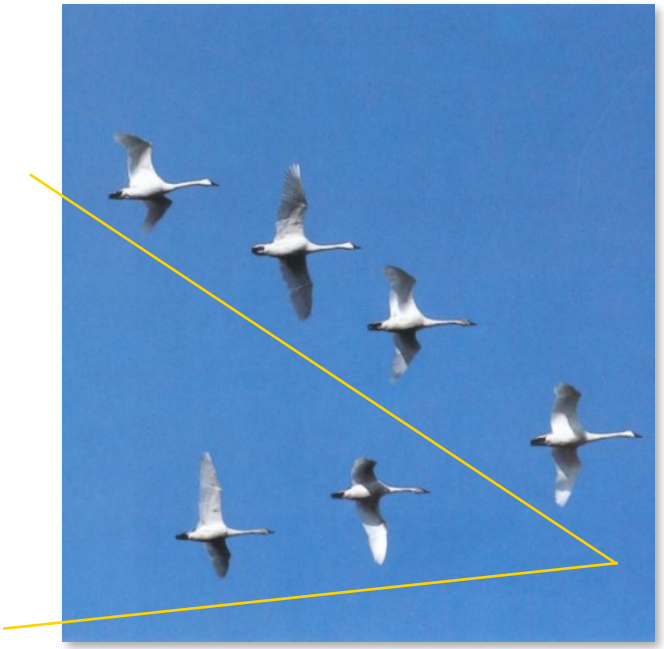
- Focus on the stable structural elements
  - system organization
- Explain local and global dynamics as overlays
  - system behavior
- Capture evaluation results
  - system analysis
- Annotate with implementation directives



Documentation Strategy

Dynamic Systems

- Focus on typical organization patterns that reveal most components and complexity
  - dynamic system organization
- Explain the evolutionary processes affecting the organization
- Highlight special and extreme cases



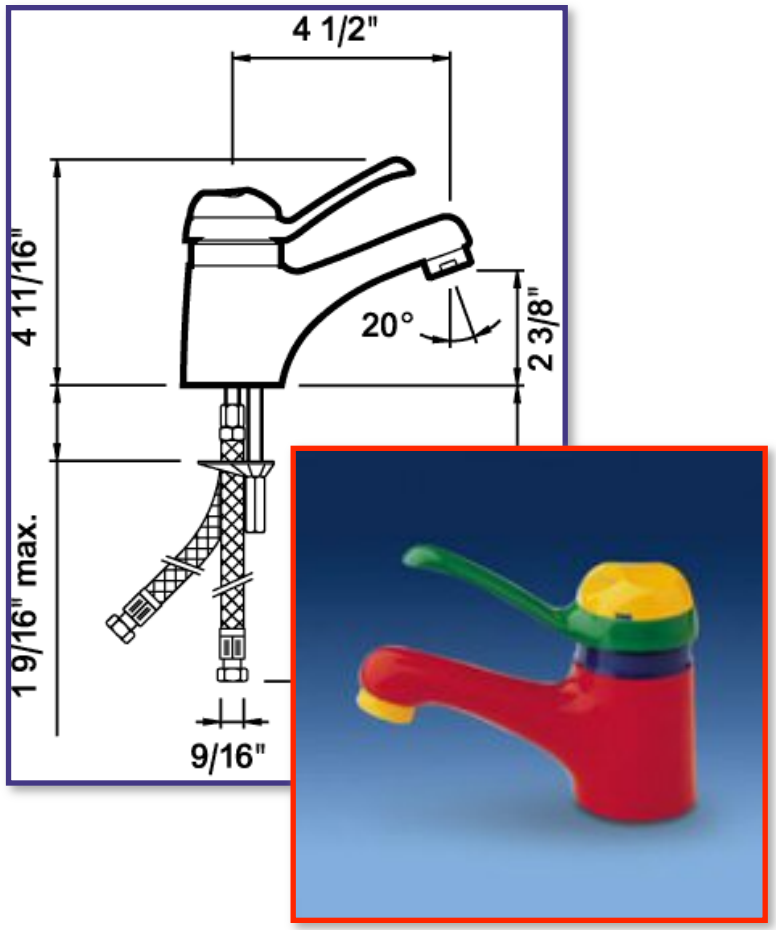
Sufficiency Criteria

An architecture is complete when all critical design issues have been addressed

- Architecture
  - as master plan
  - as management tool
  - as risk reduction program
- Modeling and analysis are critical features of a good architecture documentation
- Non-functional requirements determine the level of detail

2.2 Multiple Facets of Architecture

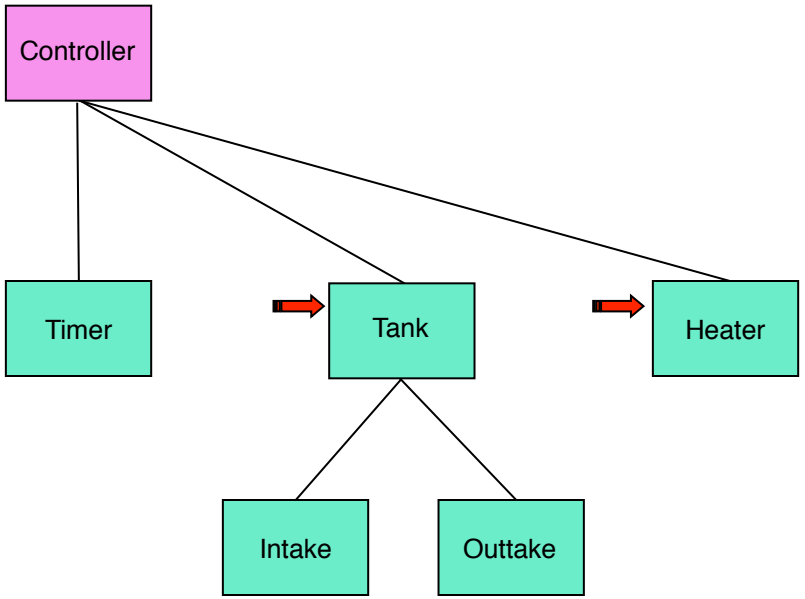
- System organization
- Component specifications
- Analytical overlays
  - behavior
  - performance
  - failure model
- Meta level specifications
- Annotations

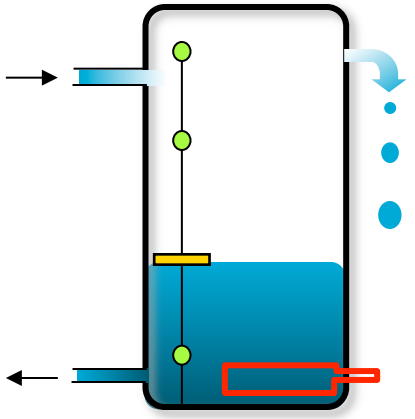


System Organization

- The core of the software architecture
- Represented as a design diagram
  - abstract view of the system structure
  - set of constraints over the system behavior
    - full behavioral specification is not feasible
- Defined in terms of
  - components making up the system
    - data, objects, threads, procedures, etc.
  - connectors constraining interactions among components
    - invocation, message passing, data access, etc.
  - actuators that trigger activity in the system
    - events, etc.
  - relations among components
    - containment, mutual dependency, coexistence, etc

Water Tank



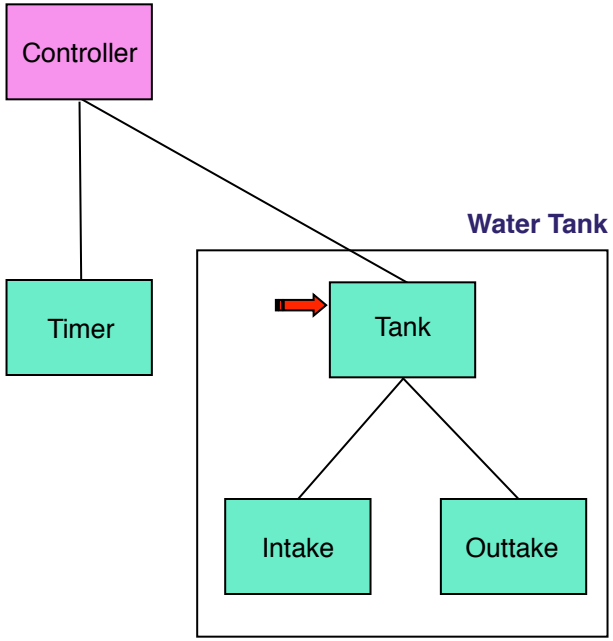


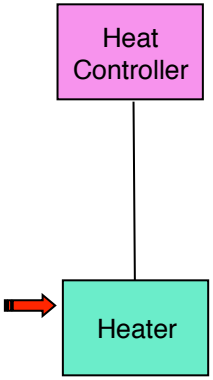
Complexity Control

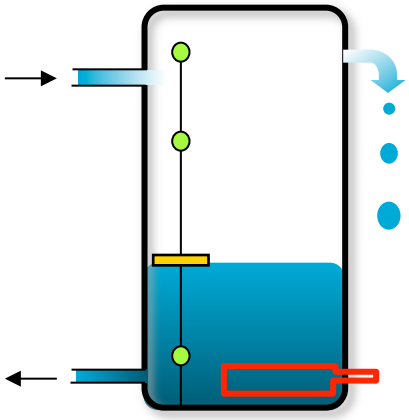
- Partition
  - separation of concerns
- Hierarchy
  - levels of abstraction
- Multiple views
  - the divide and conquer advantage
  - the price of consistency management
- Evolutionary rules
  - minimalist perspective
  - emerging structures

Water Tank

Hierarchy and partition



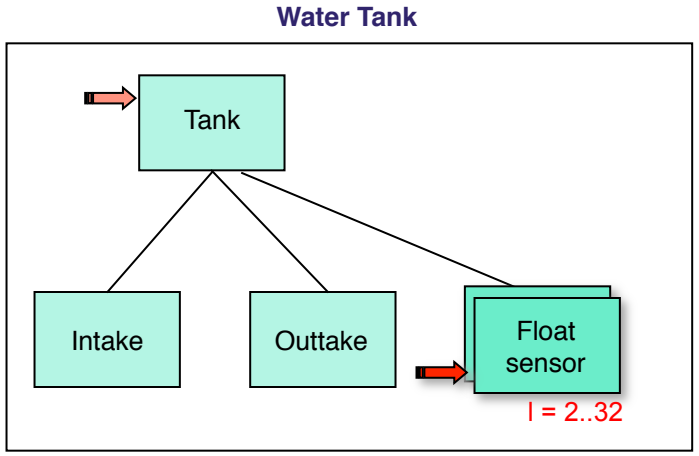


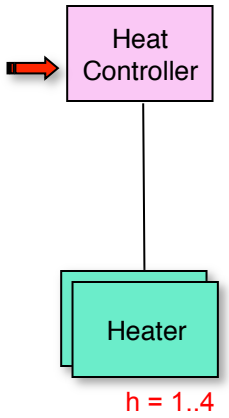


Water Tank

Configuration dynamics

- number of heating elements is $1 \leq h \leq 4$
- number of level sensors is $2 \leq l \leq 32$





Design Elements

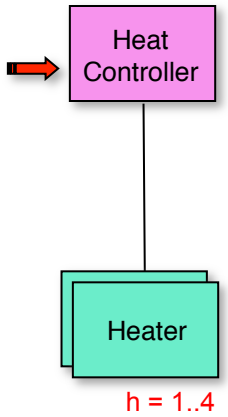
- Formally distinguished in terms of
  - components
    - software modules having direct representation in the code
  - connectors
    - abstract constructs characterizing the interactions among components
  - actuators
    - abstract mechanisms that trigger activity in the system
- Simple or composite
  - complex components may be viewed as simple at the level of architecture but composite at development time
- Characterized by
  - interface
  - behavior (state and state transitions)
- Rooted in the tradition of modular design

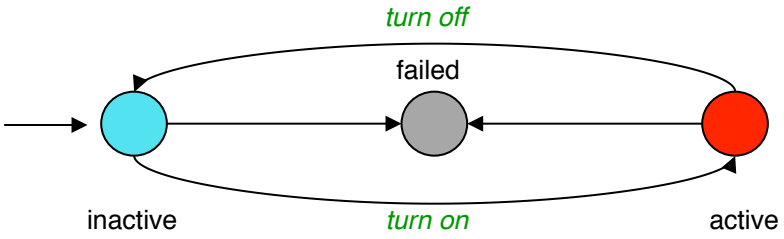
Component

- Sample component types
  - procedure
  - object
  - process (threaded object)
- Interface depends on component type and language—it is real
- Behavior reflects the component type but must be abstract

Heater

- Methods
  - turn on, turn off
  - failed, heating
- State
  - active T/F
  - failed T/F



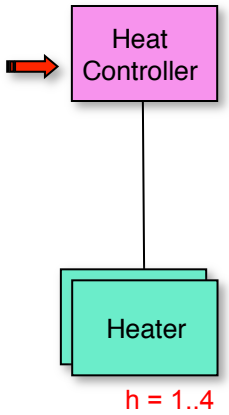


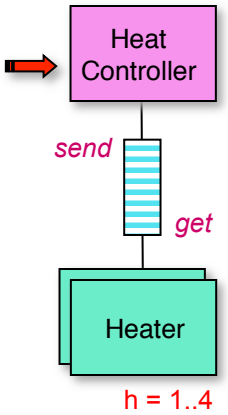
Connector

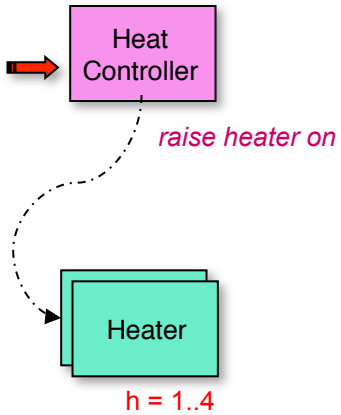
- Sample connector types
  - procedure invocation
  - message queue
- Connectors are complex specialized components

Heat Controller vs. Heater

- Possible alternatives
  - method invocation
  - message passing
  - event notification





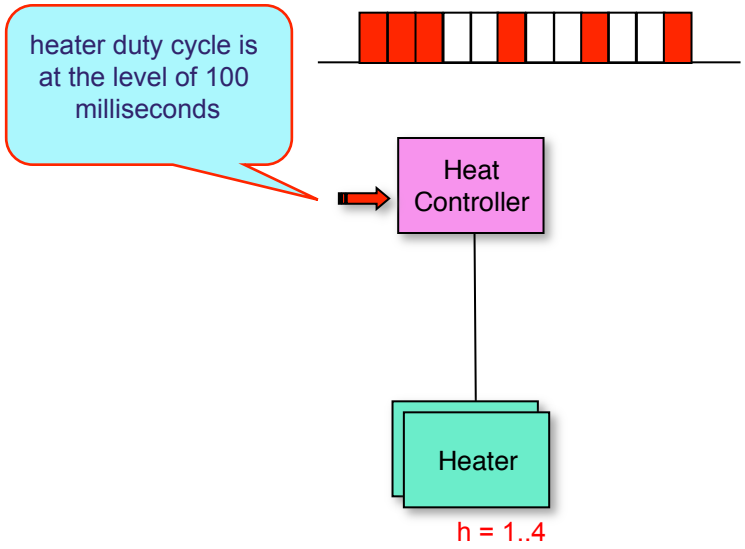


Actuator

- Actuators are events of a predefined nature that initiate activity
  - timer interrupt
  - mouse down
- Implementation is
  - language specific
  - often complex
  - distributed across the code
- Conceptually are
  - simple to understand
  - easy to analyze

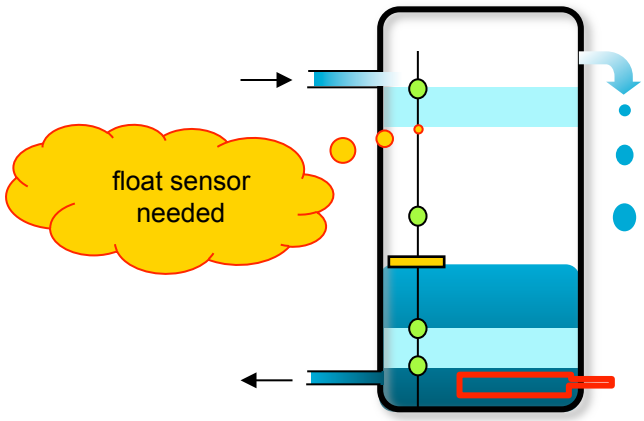
Heat Controller

- Some methods are time triggered



Analytical Overlay

- Behavior specifications not captured by the design diagram
- Analysis results and the assumptions on which they are based
- Failure models



Float sensor failure analysis

- Requirements
  - water must cover the heating element
  - water must not reach overflow outlet
- Assumptions
  - at most one float sensor fails at a time
  - sensors can be added and removed at will
  - sensors report depth when the floater is present
- Observation
  - at least four float sensors are needed

Extra Considerations

- Annotations
  - Information important in the interpretation of the architectural design
    - implementation directives
    - non-functional constraints
    - warnings
    - notions for which no notation is available
- Meta Level Specifications
  - class definitions
  - invariant properties
  - semantic constraints
  - relations
    - among classes
    - among objects
    - etc.

2.3 Programming Abstractions Revisited

- The language we speak relates to the way we think
- The way we view programming affects the kinds of systems we construct
- The history of programming languages has been a search for the “right” abstractions

Control Abstractions

Flow of control defines the order in which instructions are executed

- Sequential flow of control is built into most machines (program counter)
- Conditional jumps allow the interpreter to skip and/or repeat code segments
- if and goto statements provide a more uniform treatment by separating the condition from the flow of control transfer
- Further reductions in complexity are achieved by the shift to structured programming (if and while and other like constructs)
- exceptions provide a structured mechanism for handling error conditions (e.g., C++ throw and try/catch)

Procedural Abstractions

Procedural abstractions laid the foundation for modular design

- macro substitution offered a mechanism for naming sections of code and inserting them as needed
- subroutines (non-recursive), introduced as a memory saving device, structured the flow of control
- blocks provide an in-line structuring construct central to all modern programming languages
- procedures (recursive) encapsulate processing thus eliminating the need to look at the way they are coded (if a specification exists!)
- functions (pure) are procedures without side effects

Data Abstractions

Data is central to the representation of state

- built-in data types provide essential but primitive forms of data representation and operations on them
- programmer-defined types facilitate tailoring data selection to the specifics of the application
- strongly-typed languages improve dependability by doing strict compile-time checking
- abstract data type (ADT) is a formal characterization of a set of data structures sharing a common set of operations
- generic types (e.g., templates in C++) allow for parameterized definitions

Abstract Data Type

Provides data encapsulation and information hiding

- Defines interfaces for accessing data
- Data is accessible only through operations provided explicitly by the programmer
- Internal data representation is not visible and can change without affecting the ADT
- Creation and destruction can be automated

Abstract Specification

Unbounded stack

```
signature Stack(item)

empty() returns Stack

push(Stack, item) returns
   Stack

pop(Stack)
   returns Stack

top(Stack) returns item

is_empty(Stack)
   returns boolean
```

```
axioms

pop(push(s,x)) = s

pop(empty()) = abort

is_empty(empty())
   = true

is_empty(push(s,x))
   = false

top(push(s,x)) = x

top(empty()) = abort
```

Stack Specification in C++

```
typedef int T;
class Stack {
   public:     Stack (int size);
               ~Stack ();
               void push (const T &item);
               void pop (T &item);
               int is_empty ();
               int is_full ();
private:       int top, size;       T *list; };
```

Stack A(100), B(50);

Concurrency

Concurrency impacts the choice of components and connectors

- Concurrency is often relegated to operating systems services rather than language definition (e.g., C++)
- coroutines introduced the notion of passing the flow of control among subroutines
- concurrent process (e.g., task in Ada, thread in C++) provides for logically parallel execution
- Inter-process communication assumes a variety of forms
  - shared variables
  - message passing
  - remote procedure call
- Synchronization (mutual exclusion, barriers, etc.)

2.4 Modularity Principles

- Modularity is a complexity control method
- Modules are parts of the system
  - may be developed and tested independently
  - may be understood (usually) on their own
  - may be composed and decomposed
- Modular design is the only acceptable design practice in engineering today

Established Principles

- Separation of concerns
  - divide and conquer
- Clean abstraction
  - define simple and stable interfaces
- Information hiding
  - minimize the impact of changes
  - localize the consequence of errors

Basic Questions

- What precisely is a module?
- How should modules be selected?
- How should modules be described?
- How should modules interact?

Two Possible Answers

Function-oriented modularity

- Synonyms: action, process, transformation
- Basic idea: organize the system structure around the kinds of activities it must perform
- Rationale: a system is the functionality it supplies to the user

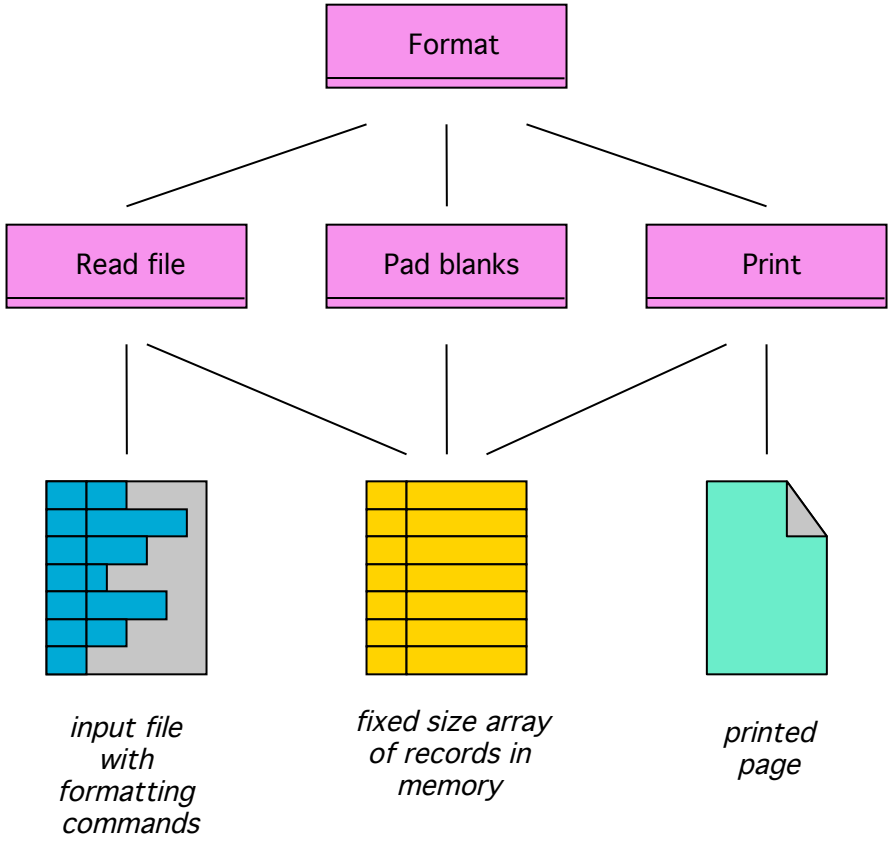
Object-oriented modularity

- Synonyms: data
- Basic idea: organize the system structure around the kinds of data it must maintain
- Rationale: functionality changes more often than the data required to support it

Function-Oriented Modularity

- Key concept:
  - procedure (procedural abstraction)
- Approach:
  - a system is organized hierarchically with procedures at one level calling procedures at the levels below
  - typically, the system is designed using top-down stepwise refinement
- Weaknesses:
  - insufficient attention is paid to data structures design
  - without encapsulation information hiding is hard to enforce
  - functionality is subject to change thus leading to design instability

Functional Decomposition



Impact of Change

- Changes often impact large sections of the code due to the lack of encapsulation of data and devices
  - the formatted text no longer fits in memory (all procedures are affected)
- Component reuse is difficult to achieve
  - the same input format is needed to implement a duplicate file command (parts of Read file need to be removed)
- Subcontracting is undermined
  - the data structures need to be redesigned (all subcontractors are affected)
- A better design could avoid these problems but the methodology does not encourage us to do it

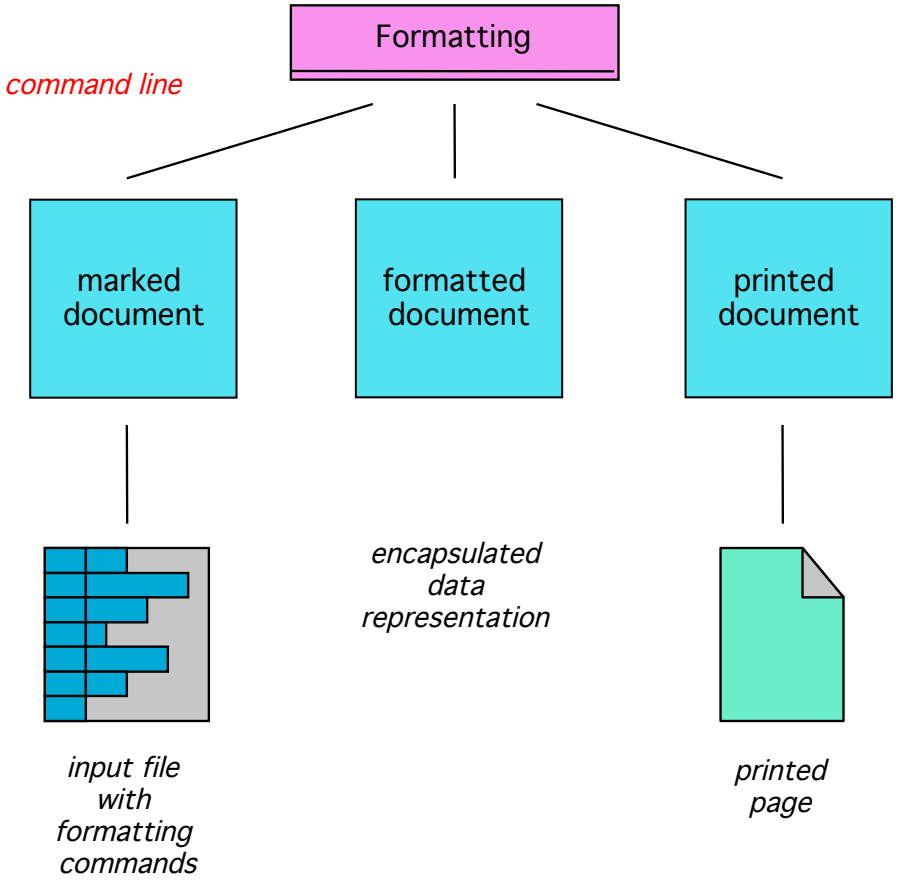
Object-oriented modularity

- Key concept:
  - abstract data type (data abstraction)
- Approach:
  - a system is organized around abstract views of the data structures it controls
  - typically, a certain degree of bottom-up design is required
- Strengths:
  - data structures are encapsulated
  - emphasis is placed on achieving generality and stability

Design Methodology Implications

- *Object-Oriented Design* is a methodology which promotes a program organization consisting of an algorithm which manipulates a set of programmer-defined objects
- The set of objects is typically static
- The software objects often correspond to objects existing in the problem domain
  - traditional data structures: integer, array, stack, queue, set, sequence, list, etc.
  - application specific data structures: radar attributes, display chain, raster image, etc.
  - interfaces to virtual devices: display, button, printer, sensor, etc.
- This form of OOD can be implemented without support from an object-oriented programming language

Object Decomposition



2.5 Architectural Notation

- Components
- Connectors and actuators
- Diagrams
- Meta-level specifications

2.5.1 Component Notation

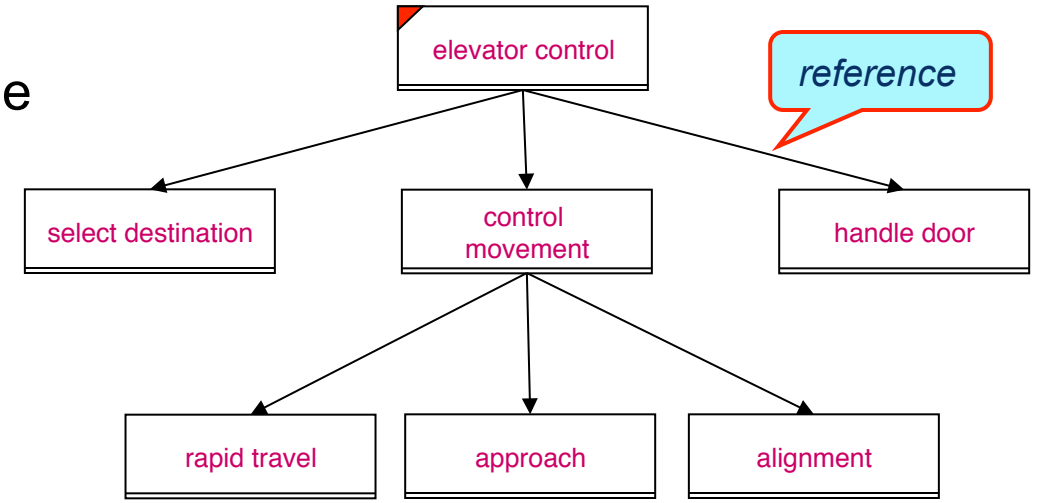
- Passive
  - procedure
  - object
- Active
  - task
  - active object
- Organizational
  - package
- External
  - devices and interfaces

Procedure

- Definition
  - encapsulates an algorithm or control process
  - executes when invoked by an active component
  - retains little if any memory of its previous execution
- Specification
  - pseudocode is recommended
  - narrative and flowcharts
- Composition
  - pure hierarchical functional composition
  - reference relation defines invocation ability

Hierarchical Processing

- Functional decomposition may be employed in order to encapsulate policy decisions and to control the complexity of
  - the processing logic
  - non-trivial methods
- The relation defining the interactions among procedures is called a reference and constraints who can invoke whom



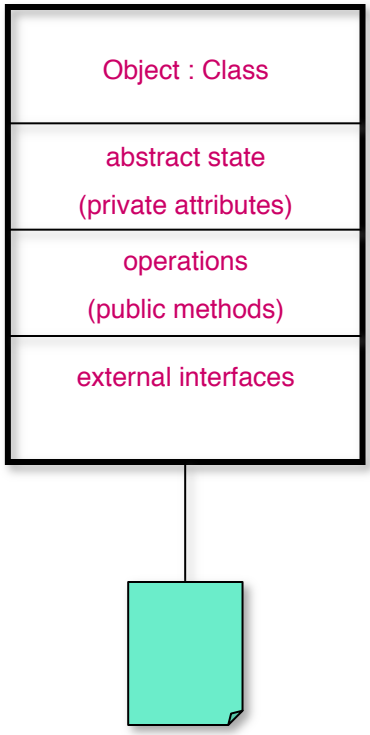
object object object object

Simple Objects

- An object is defined by the set of operations (services) it provides to its environment
- Some operations change the state of the object while others provide information about its state
- An object may be the internal abstract view of an external device and the operations that may be performed on that device
- An object may be a data structure (and its associated operations) containing information about a real-world object or some abstract concept

Notation Revisited

- A full graphical specification can capture additional details about the object
- The context in which the notation is used determines which elements are left out



Object Specification

- It is analogous to a user manual
- It must include an abstract description of the object from a user viewpoint
  - interface specification—signature
  - abstract state—private attributes
  - operations—public methods
  - functionality associated with each operation
  - encapsulated devices
  - behavior constraints (e.g., synchronization and prescribed invocation order)
- It also defines the requirements for the implementer
- It may include additional information regarding expected performance and reliability

Specification Principles

- The primary goals of an object specification are clarity and simplicity
- It must be simple and conceptually clean
- It must be presented at an abstract level
- It must be independent of any particular realization
- It must be consistent with the externally observable object behavior
- The abstract state must be clearly distinguished from data definitions which have a concrete representation in the program
- Operations must be defined in terms of the abstract state of the object

Example: Scene Manager

Let Scene S be an object that encapsulates the definition and display of a two-dimensional composition consisting of flat pictures organized in layers

Scene S: ⇐ state component, object instance

- A set of pictures initially empty.

Picture: ⇐ concept, class

- A picture is defined in terms of
  - name
  - corner coordinates
  - depth
  - pixels

Method Definition Techniques

- Narrative
- Pseudocode
- Finite state machine

Operational Specification

add_picture(P)

if a picture with the same name as P
is already part of the scene S
then **raise exception** duplicate_picture
else add P to S
endif

Axiomatic Specification

add_picture(P)

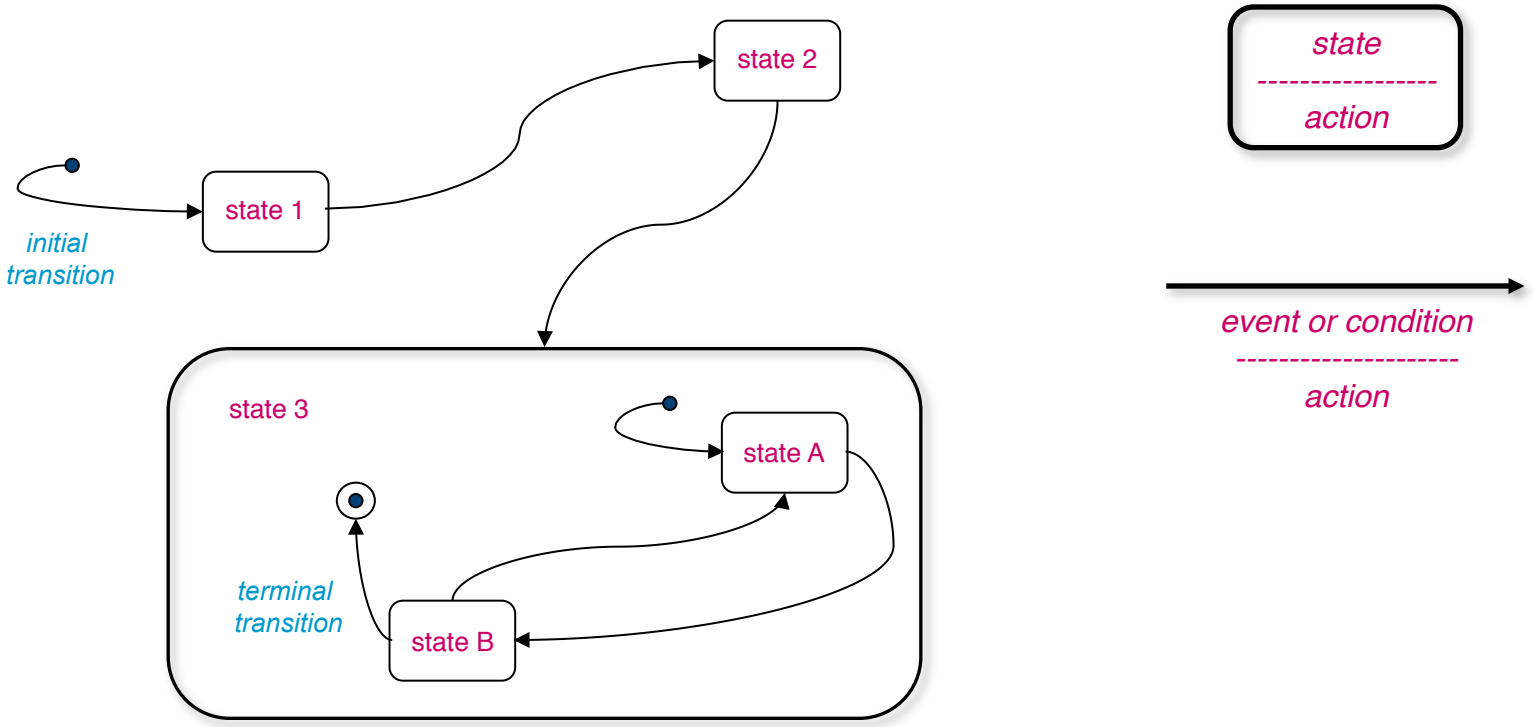
Pre: no picture with the same name as P is part of the scene S

Post: P is part of S

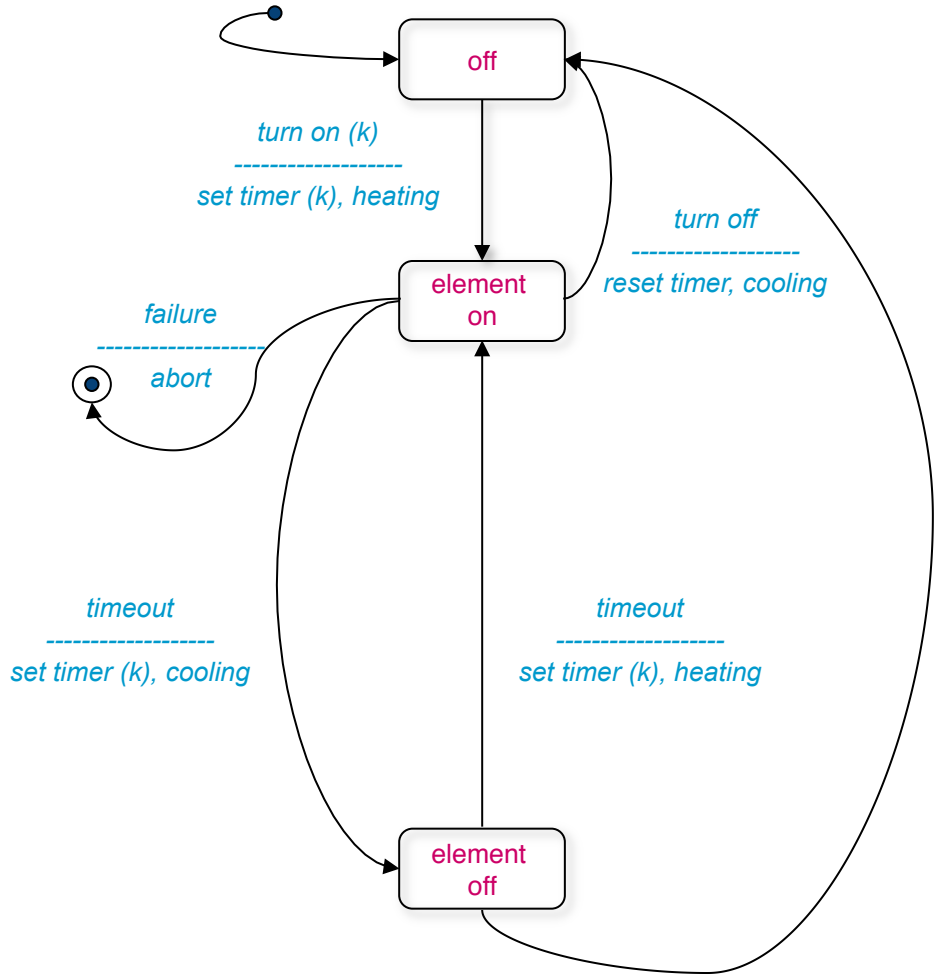
Exp: duplicate_picture

Finite State Specification

- Basic statechart notation



Example: Heating Element



Design

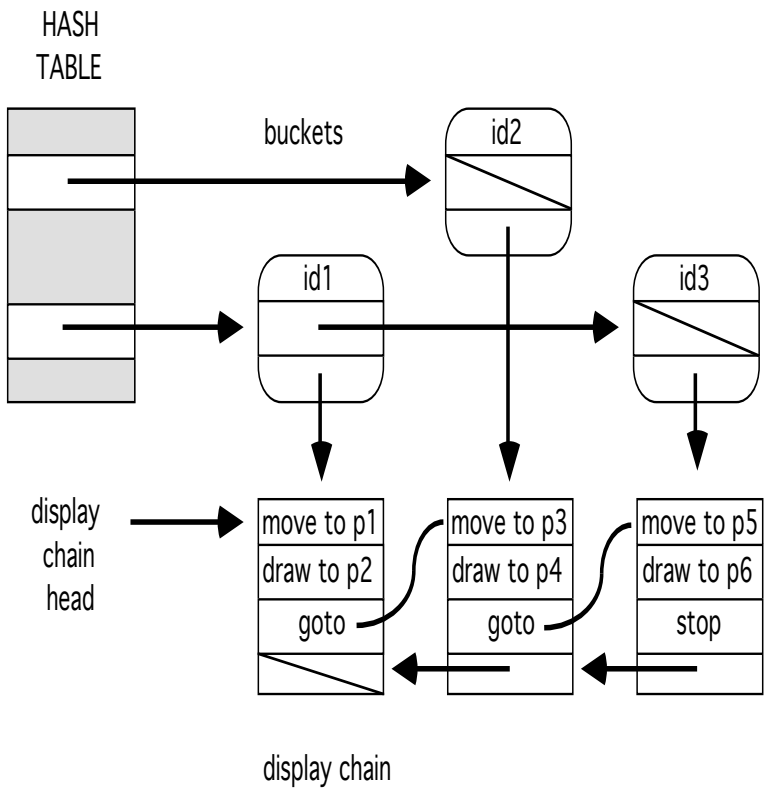
- The design documentation is a programmer's guide to the object
- It defines the coding requirements for the object
- It must include the design of the data structures and algorithms implementing the encapsulated object
  - internal data structures
  - algorithms for each operation
- It must be a faithful representation of the code

Data Structures

- They are specific to a particular realization of the object
- They must stress algorithmic efficiency
- They must be presented at a clean abstract level
- They must be consistent with the external view of the object
- They should be documented in sufficient detail so as to ensure straightforward coding but they need not be coded

Complexity Control

- Performance constraints increase complexity
- Clean presentation
  - simplifies documentation
  - increases dependability
  - facilitates analysis
- Invariant properties are critical to defining data structure integrity



Operations

- No design should be given for trivial operations
- Simple operations should be specified only in terms of pre- and post-conditions
- Complex operations should be specified by providing clearly stated algorithms
- The level of abstraction must be properly matched to the complexity of the algorithm
- An understanding of the data structures design should be assumed on the part of the reader
- The algorithms must be implementable in the target language but should not be tailored to it

Pseudocode Basics

update(picture P)

Find the layer list L associated with the depth of P.

if no such list

then raise exception no_such_picture

endif

Find a picture P’ with the same name as P in list L.

if no such picture

then raise exception no_such_picture

else replace P’ by P

endif

Relations among Objects

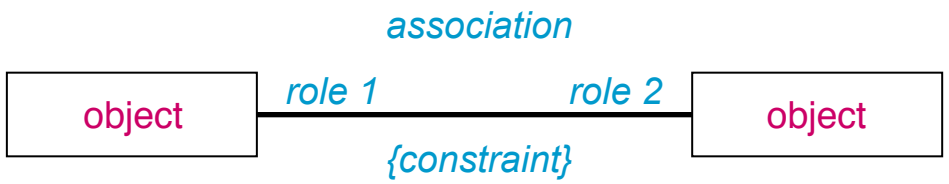
- Objects are not used in isolation
- Complicated designs entail complex relations among objects
- Design documentation, analysis, and verification benefit from a proper understanding of the relations that hold among objects
- Certain relations among objects are induced by the application and relate to semantic consistency
- Others are introduced by the design and relate to various forms of data integrity
- Still others reflect the mechanics of object composition and interaction

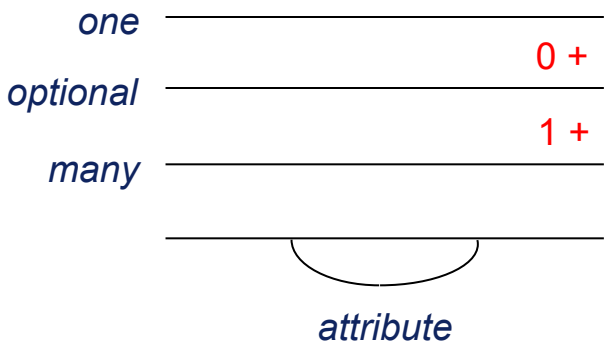
Semantic Relationships

- Semantic relationships capture integrity constraints
  - determined by essential aspects of the application (e.g., each person has a social security number)
  - introduced by the designer (e.g., the number of reserved seats stored in the flight object equals the number of booking records allocated by the reservations object)
- They play an important role in ensuring the correctness of the system
- They can be extended to include external "objects"
- They are captured by the notion of association

Associations

- They capture n-way relations among objects



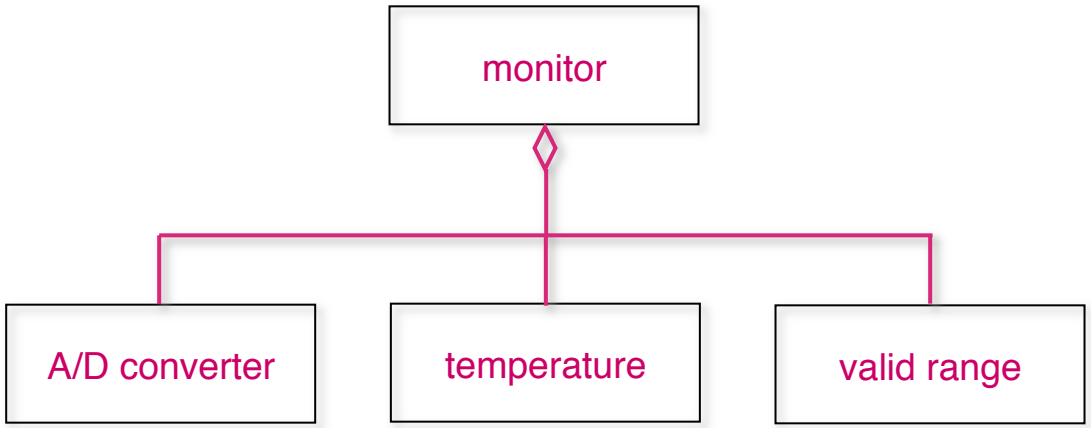


Structural Relationships

- Complex objects can be constructed from simpler ones
- The part-of relation is captured by the notion of aggregation
- It plays an important role in capturing critical aspects of the software architecture, how components are put together
- Good design practices disallow access to the subcomponents by any other objects in the system

Aggregation

- Aggregation is a special relation that
  - captures structural properties of objects
  - enables object composition

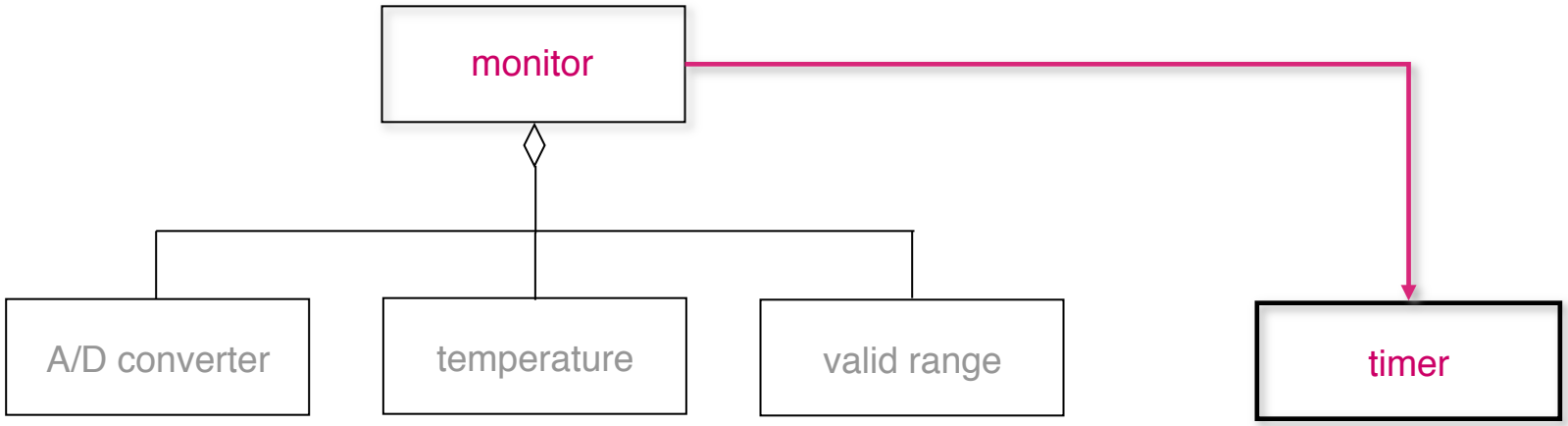


Behavioral Relationships

- Making use of the services offered by an object involves the invocation of operations on that object
- The entity invoking the operation must refer to the object
- The objects one is aware of are called its acquaintances
- Good design practices suggest that an entity ought not to know about anything it does not use
- The reference relation assumes that any object that is known is potentially accessed
- It is usually the case that a composite object references its immediately subordinate objects—there is some redundancy with the aggregation relation in this case

Reference

- Reference is another specialized relation that
  - captures run time usage of objects
  - constrains the method invocation pattern

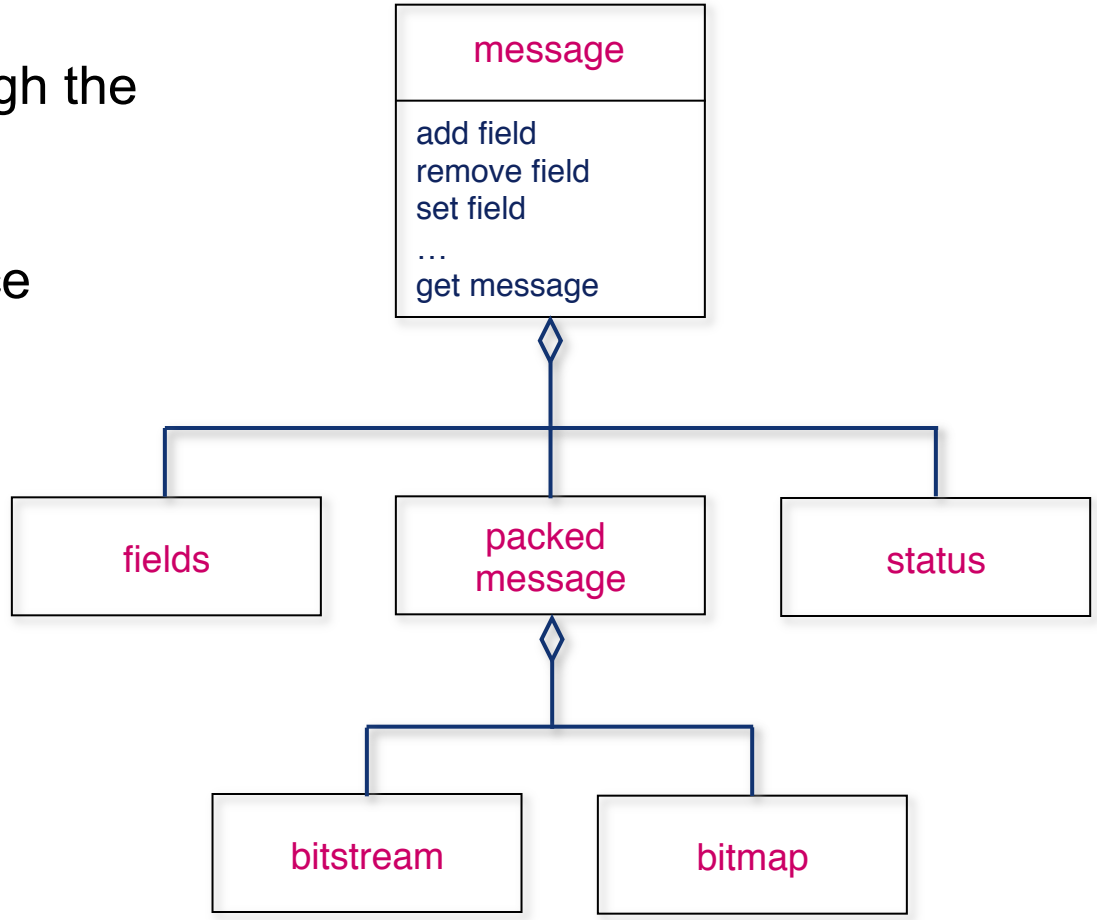


Object Composition Patterns

- Objects must be designed such that they
  - are simple to understand
  - provide a high degree of encapsulation
  - offer maximum independence among objects
- One must exercise design discipline in order to preserve these advantages while
  - faced with the complexities of real systems
  - interfacing with code which is not object-oriented
  - having access to complex and unstructured object composition methods

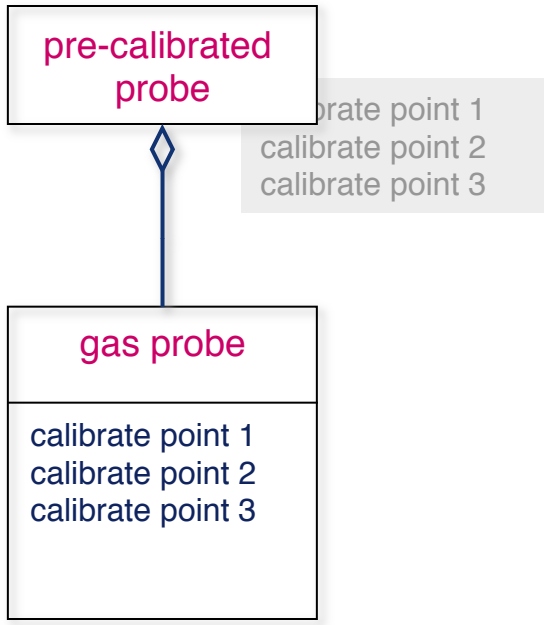
Nested Objects

- Nested objects are constructed strictly through the use of aggregation (tree structure)
- Each object can reference only its subcomponents
- It is desirable for sibling objects to be of similar complexity and level of abstraction



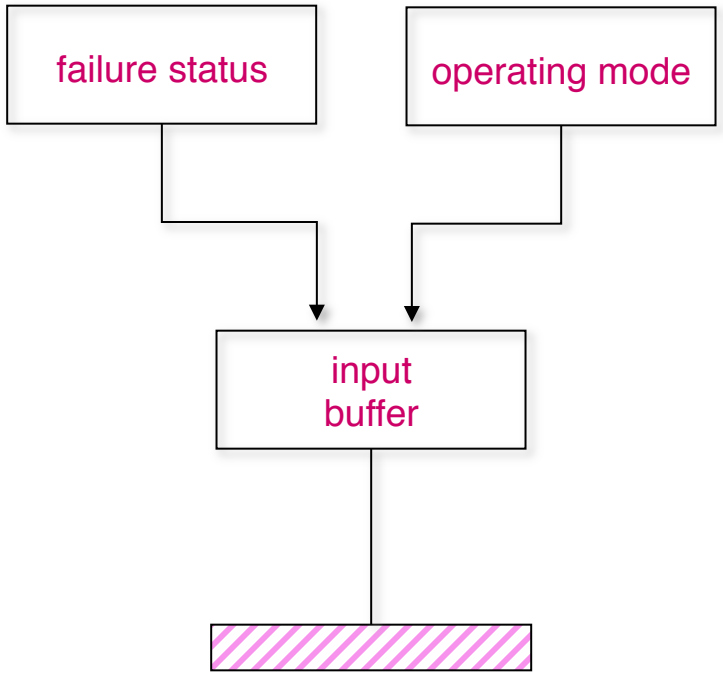
Hiding

- Hiding is an abstraction mechanism
- Hiding allows one object to project out some of the operations provided by its components
- The operations that are not hidden are delegated to the subcomponents
- A general purpose capability is tailored to a specific application



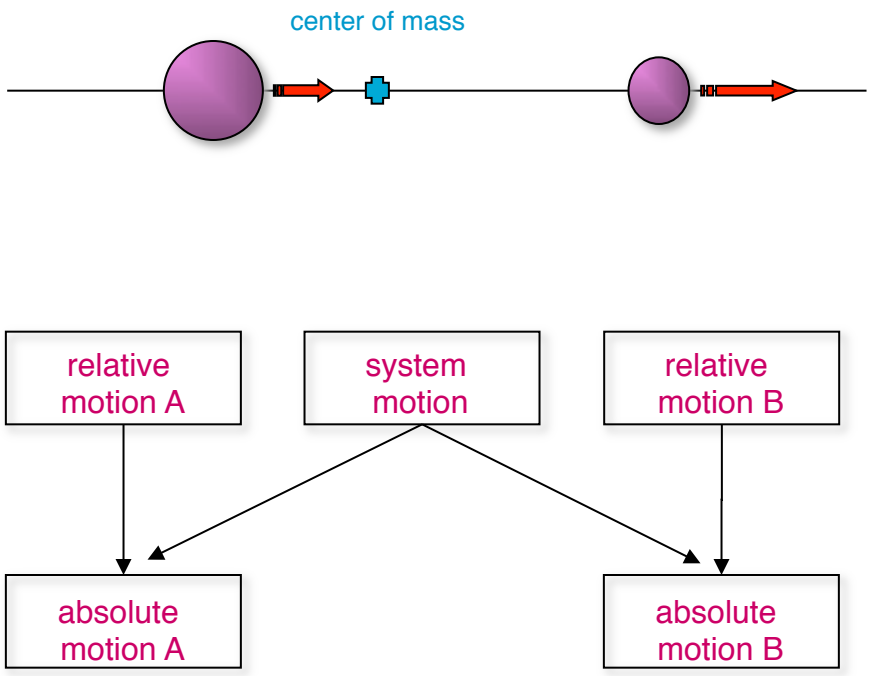
Transparent Sharing

- Object sharing occurs when two or more objects have an acquaintance (reference) in common
- Transparent sharing occurs when none of the objects involved can detect that sharing takes place
- This is often the case when one physical interface supports several logical interfaces



Mutation

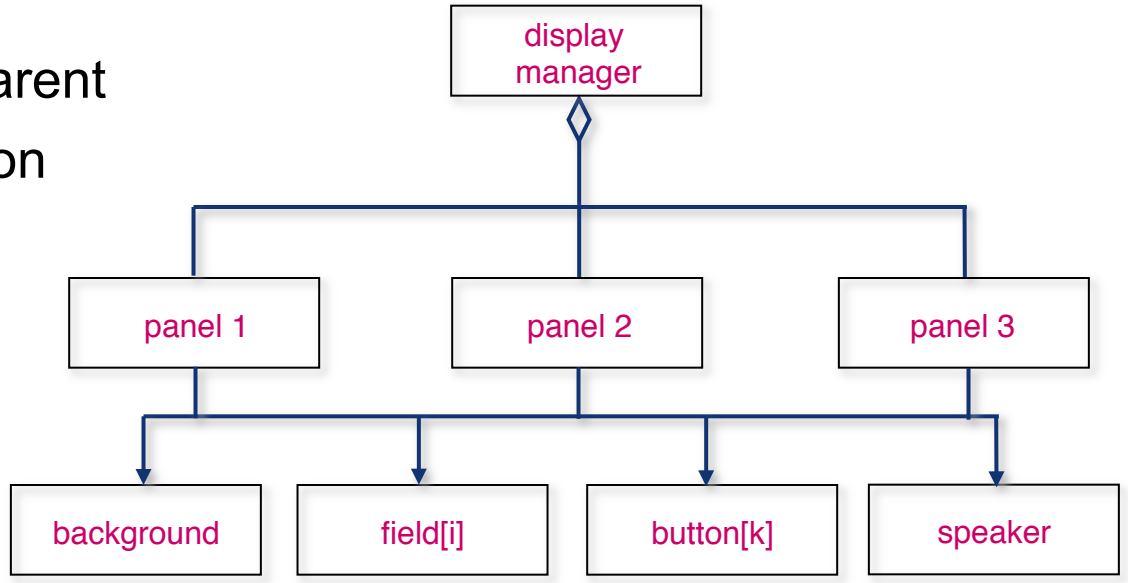
- Mutation is an abstraction pattern that relates two object layers
- It involves a change in the encapsulation of the composite state of the lower level in response to the needs of the upper levels in the design
- It is especially helpful for restructuring low level physical interfaces into more abstract ones
- The sharing of the lower level objects must be transparent



Layered Objects

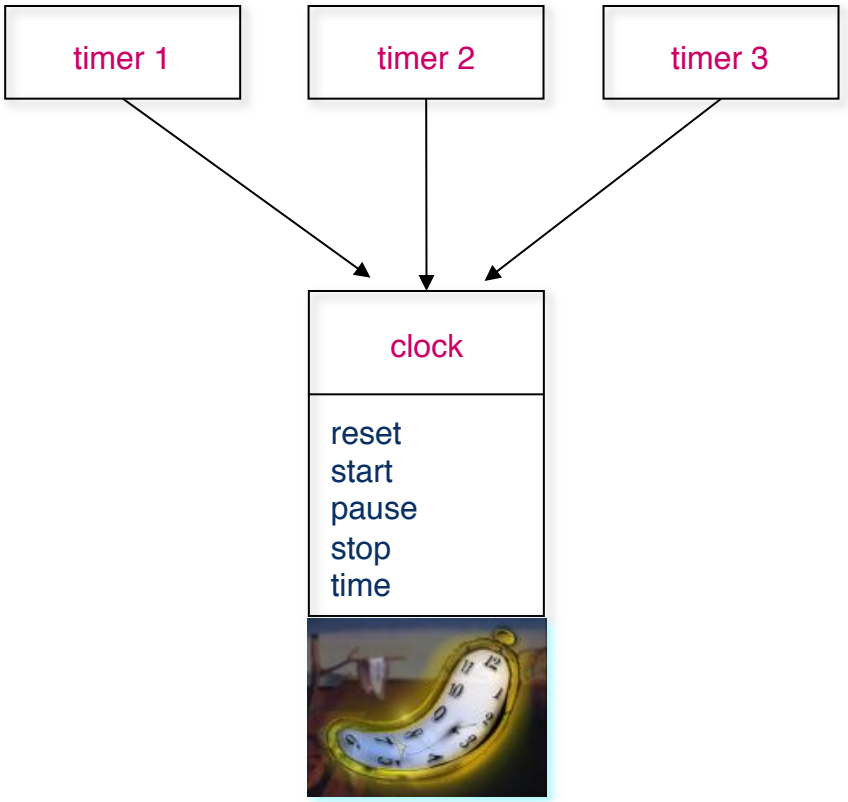
- A layered object consists of a hierarchically organized set of objects
- An object at one level can reference all objects on the level below
- Sharing is not transparent
- The level of abstraction decreases with depth

- *Dynamic restructuring*
- *One panel is active at a time*



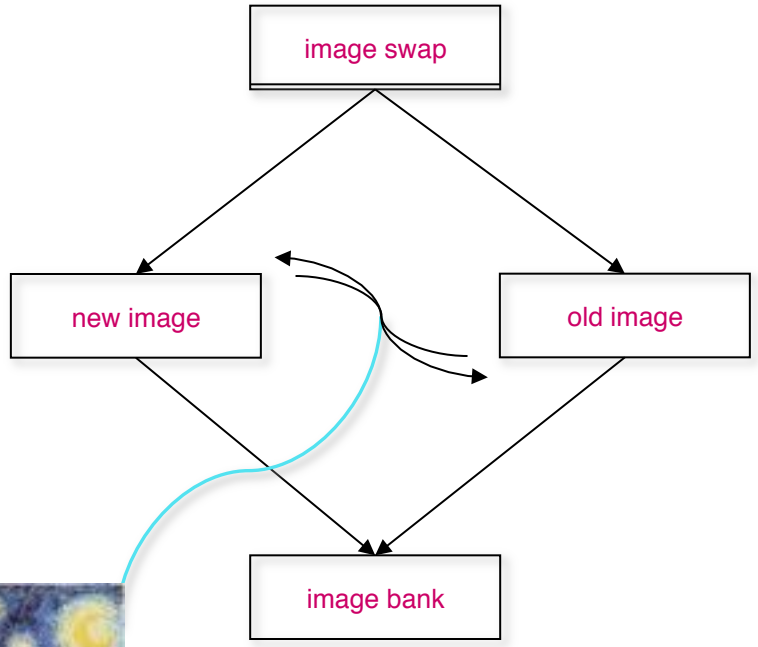
Shared Resources

- Object sharing is highly undesirable
- When sharing cannot be avoided it should be minimized, structured, and made uniform



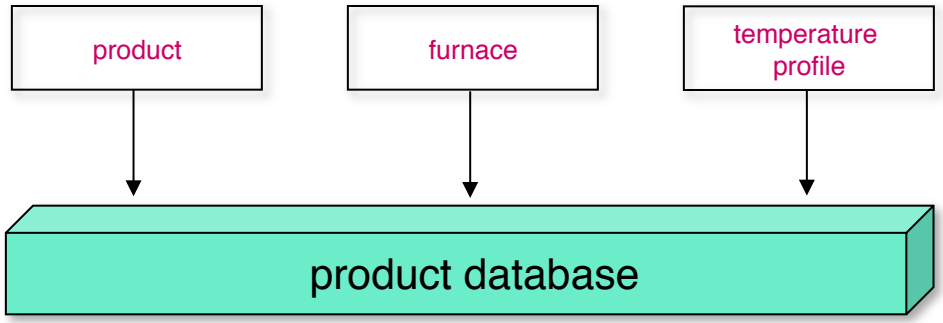
Shared Implementation

- Performance considerations often require objects which are essentially independent to be encapsulated in a single object managing their implementation
- The desire for generality may also lead to shared implementations



Object Veneer

- Legacy code need not be an impediment in the application of object-oriented design
- Existing code can be encapsulated as a set of objects which are available to the remainder of the system

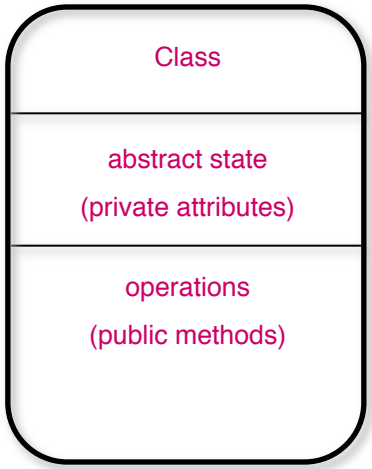


Object Generalization

- The class is a programming language construct used to extend an existing language with user-defined types
  - facilitates type checking
  - promotes encapsulation and modularity
  - encourages code reuse
  - reduces code development
- The class is an abstract concept used to characterize the set of all objects having a common signature
  - facilitates analysis
  - promotes a high-level design
  - encourages design reuse (design patterns)

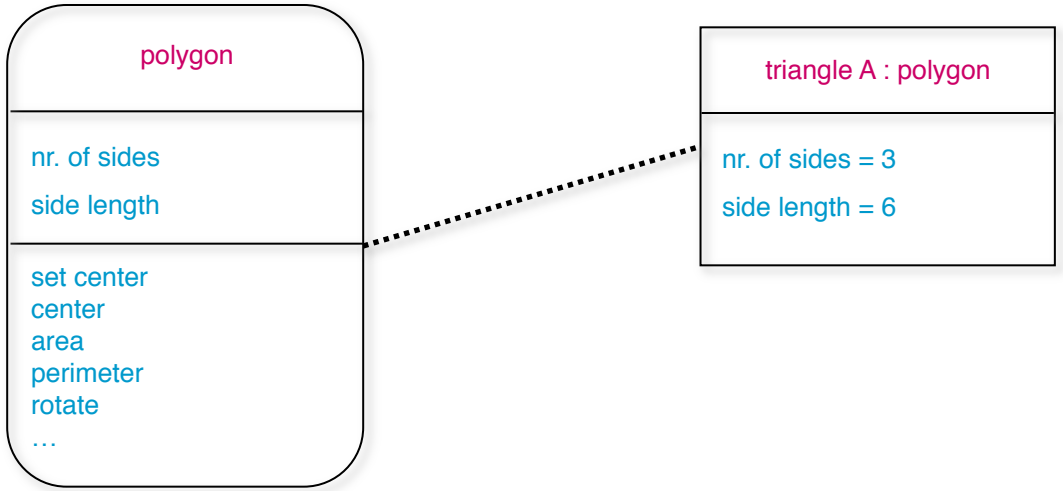
Class Definition

- A class is characterized by
  - a unique name
  - private attributes and their types (internal abstract state)
  - public methods or operations and their respective signatures (name, argument and return value types)
  - semantics of each method
- In the absence of a class concept, a new (identical) definition would be required for each object of the same type



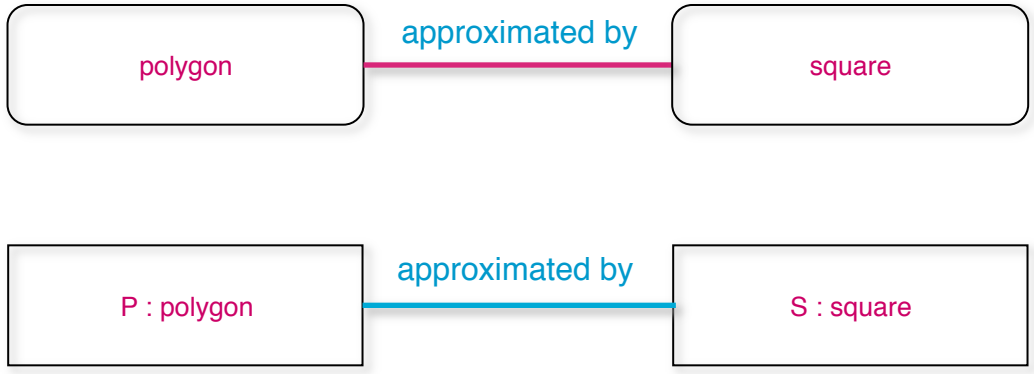
Instantiation

- The relation between a class and an object of that class is called instantiation
- Many similar objects used in the design are documented only once



Relation Transference

- Some of the relations among classes can be instantiated as relations among objects

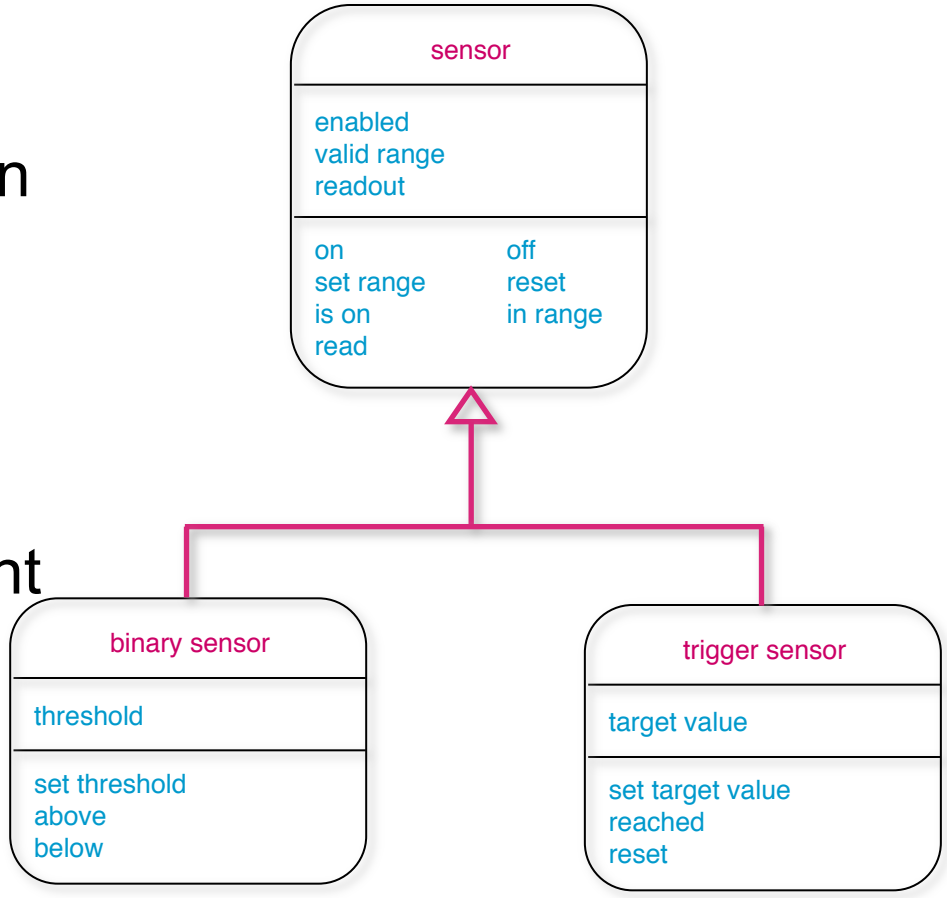


Inheritance

- New classes (subclasses or derived classes) can be defined from existing ones (superclasses or base classes)
- The subclass definition consists mainly of
  - the name of the superclass
  - the name of the class
  - additional attributes
  - additional operations
- Additional redefinition capabilities are
  - semantic redefinition of selected operations (constrained!)

Design Implications

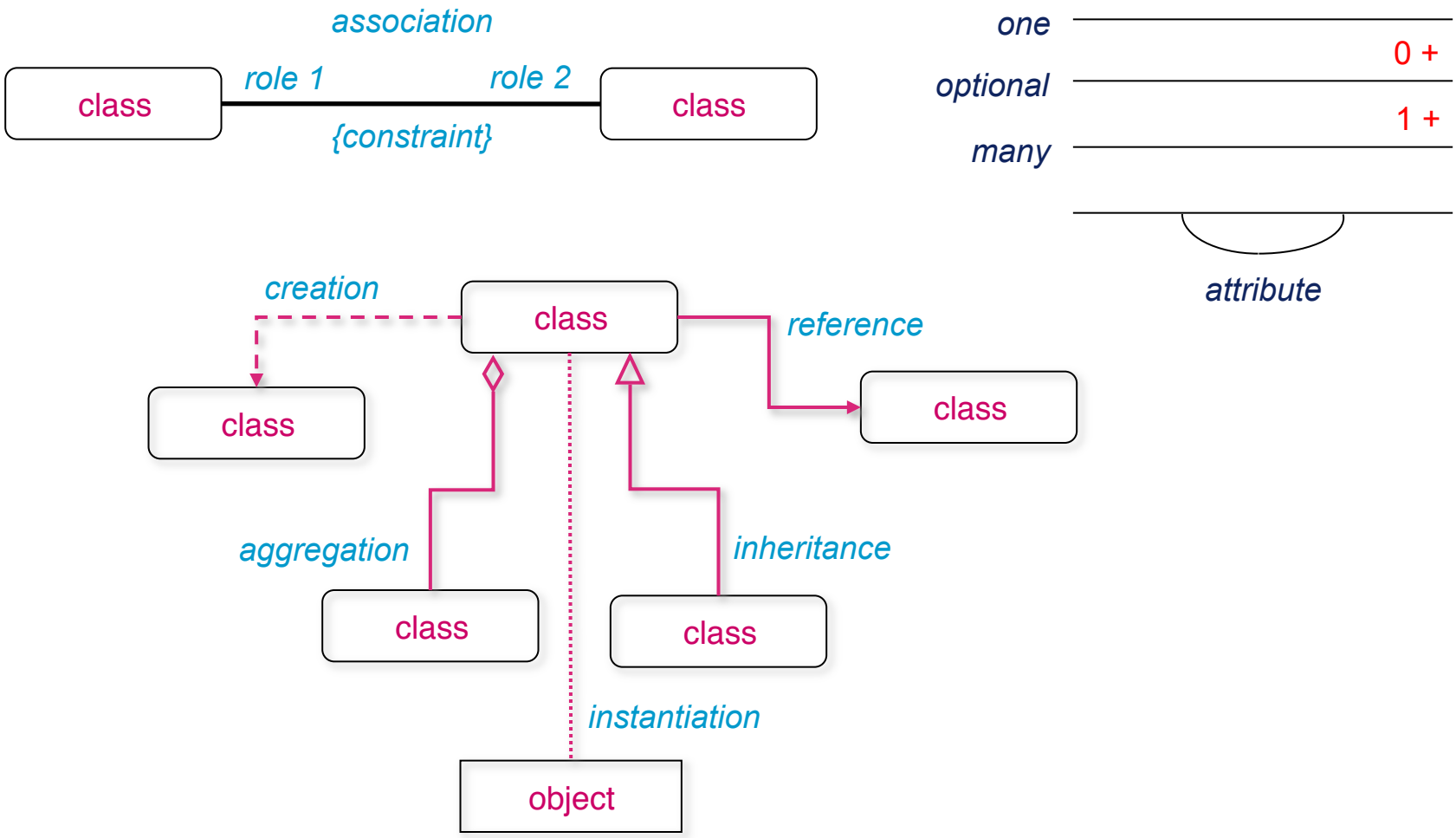
- Reduction in documentation size
- Simpler conceptualization of object definitions and their interrelations
- Effective path towards generalization
- Reduction in development time



Managing Object Complexity

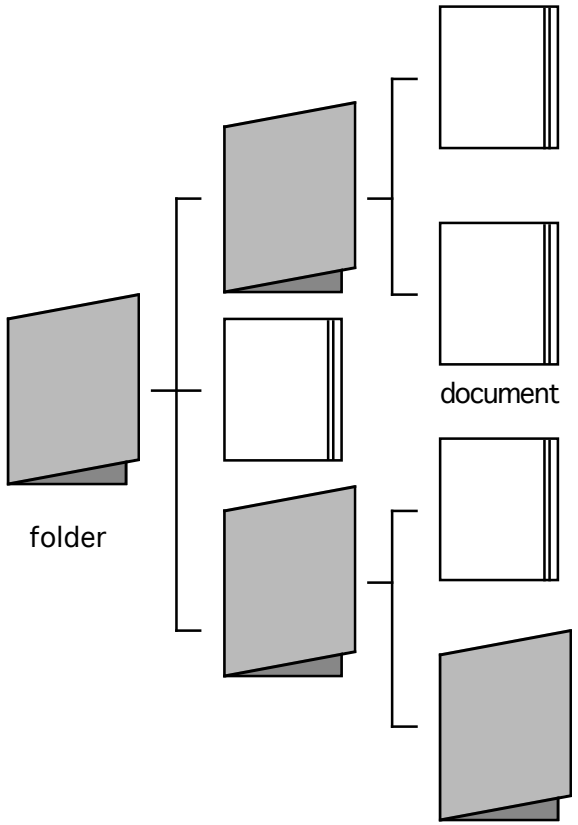
- Complicated objects require powerful object definition capabilities
- Complexity is moved to the level of class definitions
- Class diagrams employ relations such as inheritance, aggregation, reference, and more to facilitate the definition of complex classes
- Many fundamental relations among classes can be captured in diagrammatic form
- Class diagrams play an important role in object-oriented analysis
  - they do not define the architecture
  - they are ancillary meta level specifications of components (and connectors)

Class Diagrams



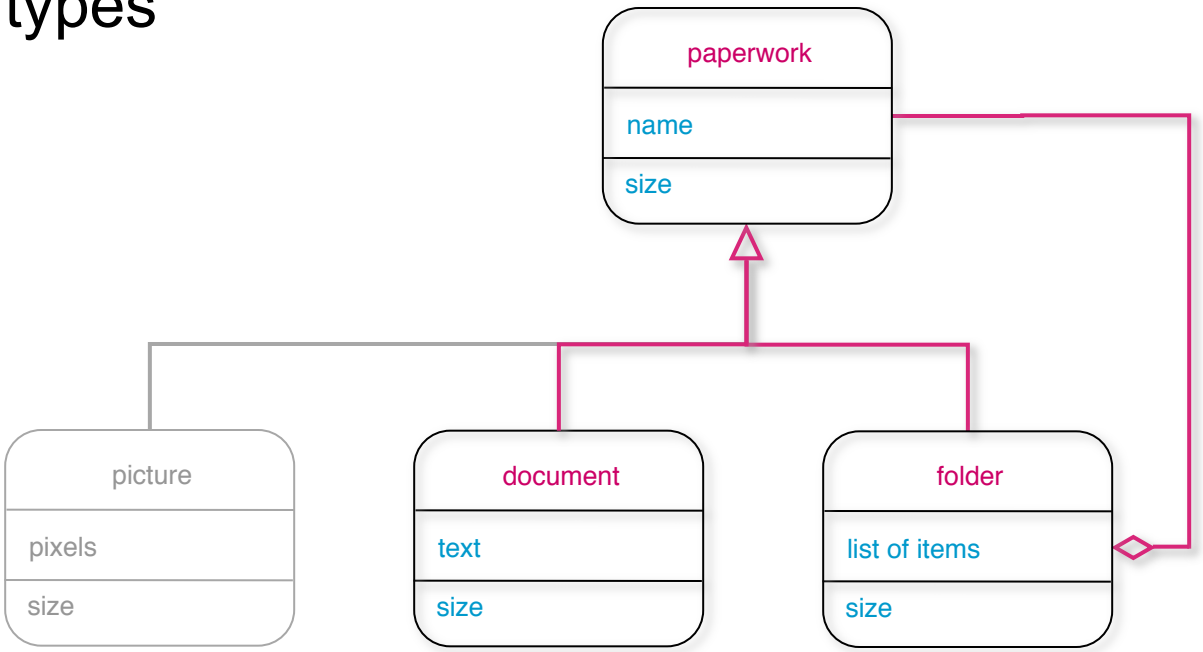
Recursive Object Structures

- Consider an application in which a folder must be able to hold other folders as well as simple documents
- The key operations needed are
  - find by name both folders and documents
  - count the total number of items in the folder



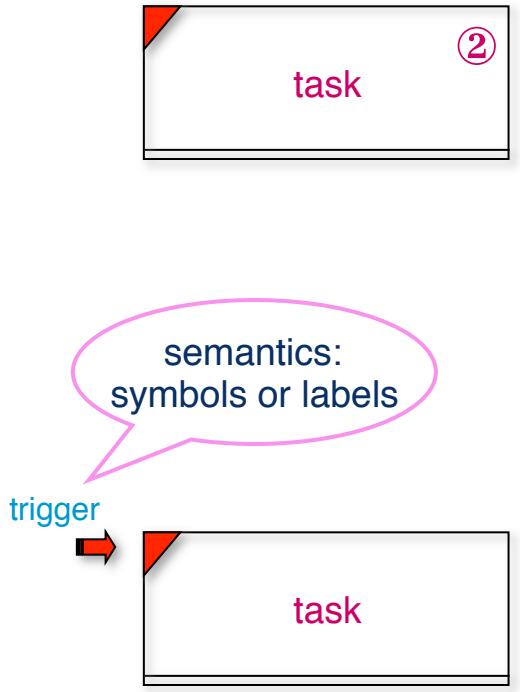
Sample Solution

- The generalization demanded by this problem accommodates future document types



Task

- A task is a sequential process having its own independent thread of control
- Its execution results in the invocation of methods on objects in the system
- Task execution may be
  - periodic, scheduled at a given priority
    - lower number represents a higher priority
  - reactive, in response to some actuator



Task Activation

- Each actuator is associated with some trigger condition
- Trigger conditions must be defined outside the diagram
- Different notations should be used for different triggers
- Implementability of the trigger mechanism must be established
- Actuators can hide complex implementation details and simplify design
- Sample trigger conditions
  - clock signal
  - timer overflow
  - system event (e.g., failure, power up)
  - application event
  - message arrival
  - system condition that can be independently assessed

Concurrency Implications

- Multitasking is both necessary and convenient
- Complicates design analysis
  - starvation due to deadlocks or priority inversion
  - missed deadlines or low performance
- Requires an understanding of
  - fundamentals of concurrency
  - system characteristics
- Special notation needs to be introduced to help design analysis

Semantics of Concurrency

- Certain concepts are fundamental to any form of concurrent processing
- In the absence of a clear definition for these concepts both design and programming become impossible

x := y +1

; or || or []

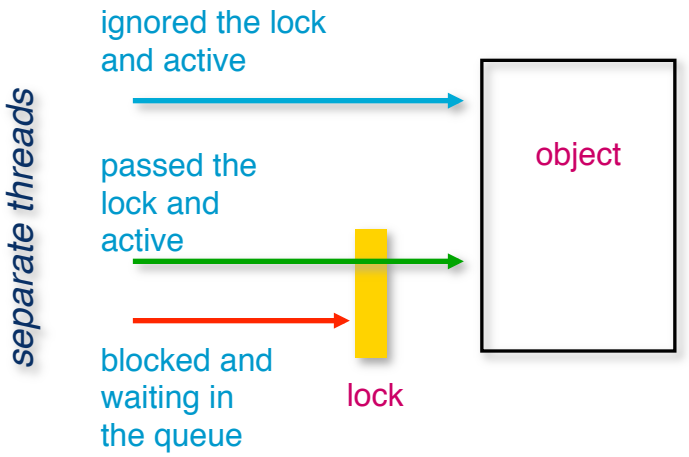
y := x + 1

- Atomicity addresses the issue of minimal guarantees of non-interference among operations
- Fairness is concerned with minimal assumptions that can be made about the scheduling of operations
- Synchronization deals with the mechanics by which concurrent operations coordinate their executions

Synchronization

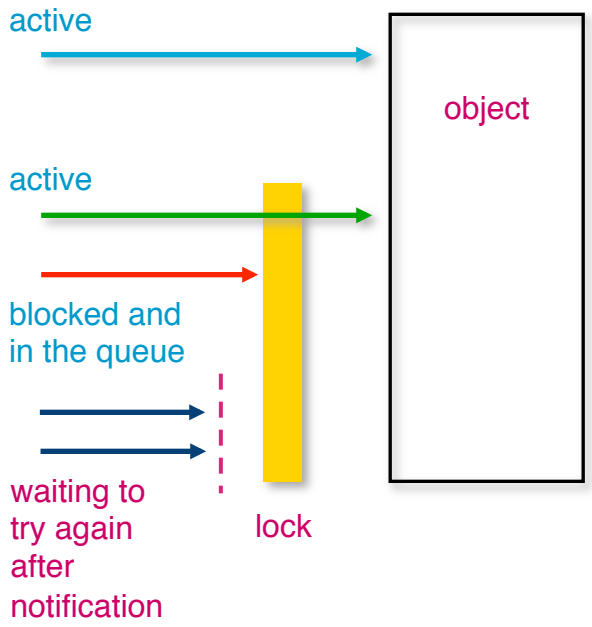
- Synchronization defines a structured mechanism for coordination among tasks
- Mutual exclusion is a general synchronization mechanism implementable in most systems
- The actual mechanics of synchronization are language specific (e.g., Ada tasks, Java synchronized methods)
- At design level it is convenient to express synchronization by specifying mutual exclusion requirements

- Java model



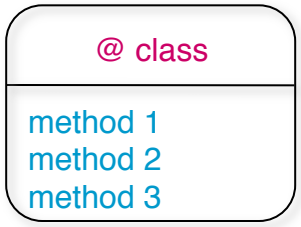
Java Notification

- The `wait(object)` operation places the thread on the wait queue
  - the object lock is released
- A time period may be specified and the thread is removed from the wait queue when the time interval expires
- The `notifyAll(object)` operation removes all the threads from the wait queue
- In both cases the released threads must be scheduled and must acquire the lock

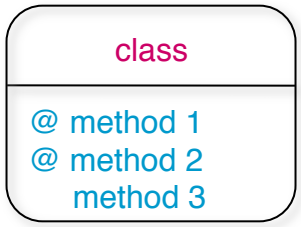


Object Level Synchronization

- The notation is the same for classes and objects and so are the semantics
- Synchronized objects specify mutual exclusion among all methods

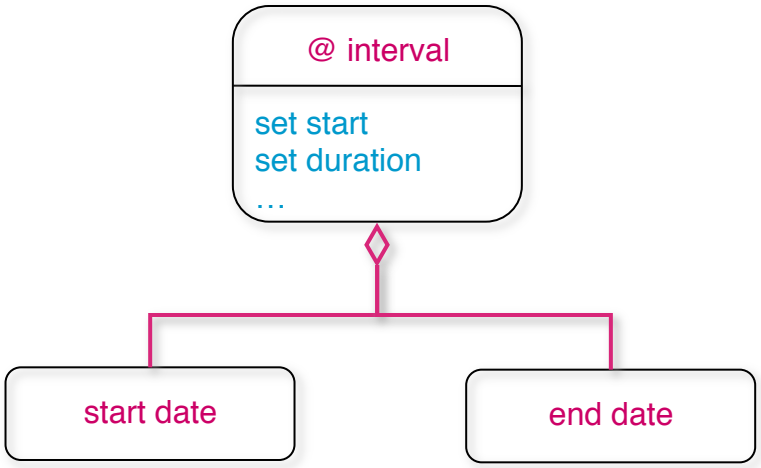


- Notation and semantics may be adjusted for different settings
- Synchronized methods limit mutual exclusion to identified methods

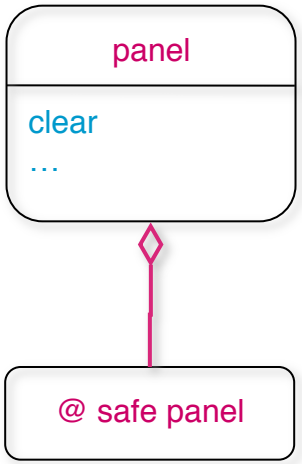


Expressiveness

- Containment

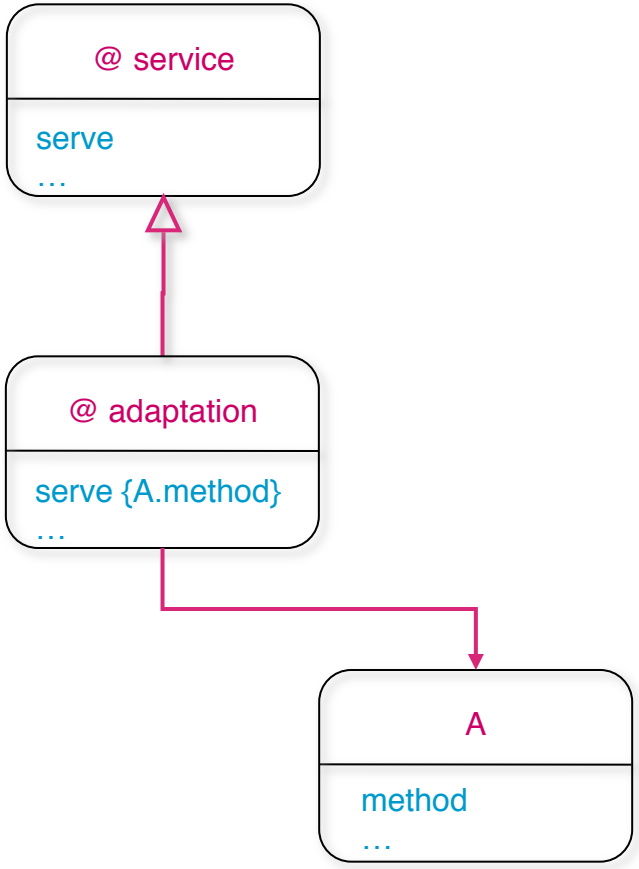


- Hidden synchronization

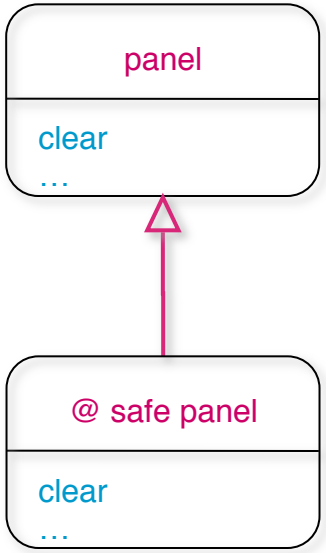


Expressiveness

- Adapter

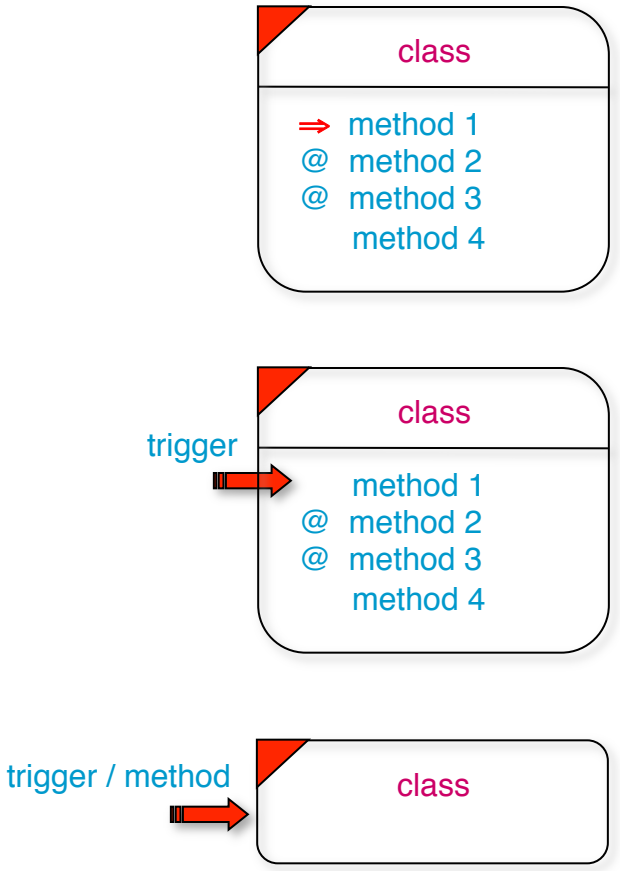


- Synchronized wrapper



Active Objects

- Exhibit behaviors equivalent to wrapping a task inside an object veneer to control the execution of a specific method
- The execution of a thread inside an active object may be periodic or reactive



2.5.2 Connectors

- Connectors relate components appearing in the design diagram
  - allow components to interact
  - constrain the nature of their interactions
  - simplify the design by abstracting complex patterns of interaction
- Connectors are specialized components
  - each component is an instance of a class
  - standard class definition methods are used
  - specialized symbols are employed to simplify design

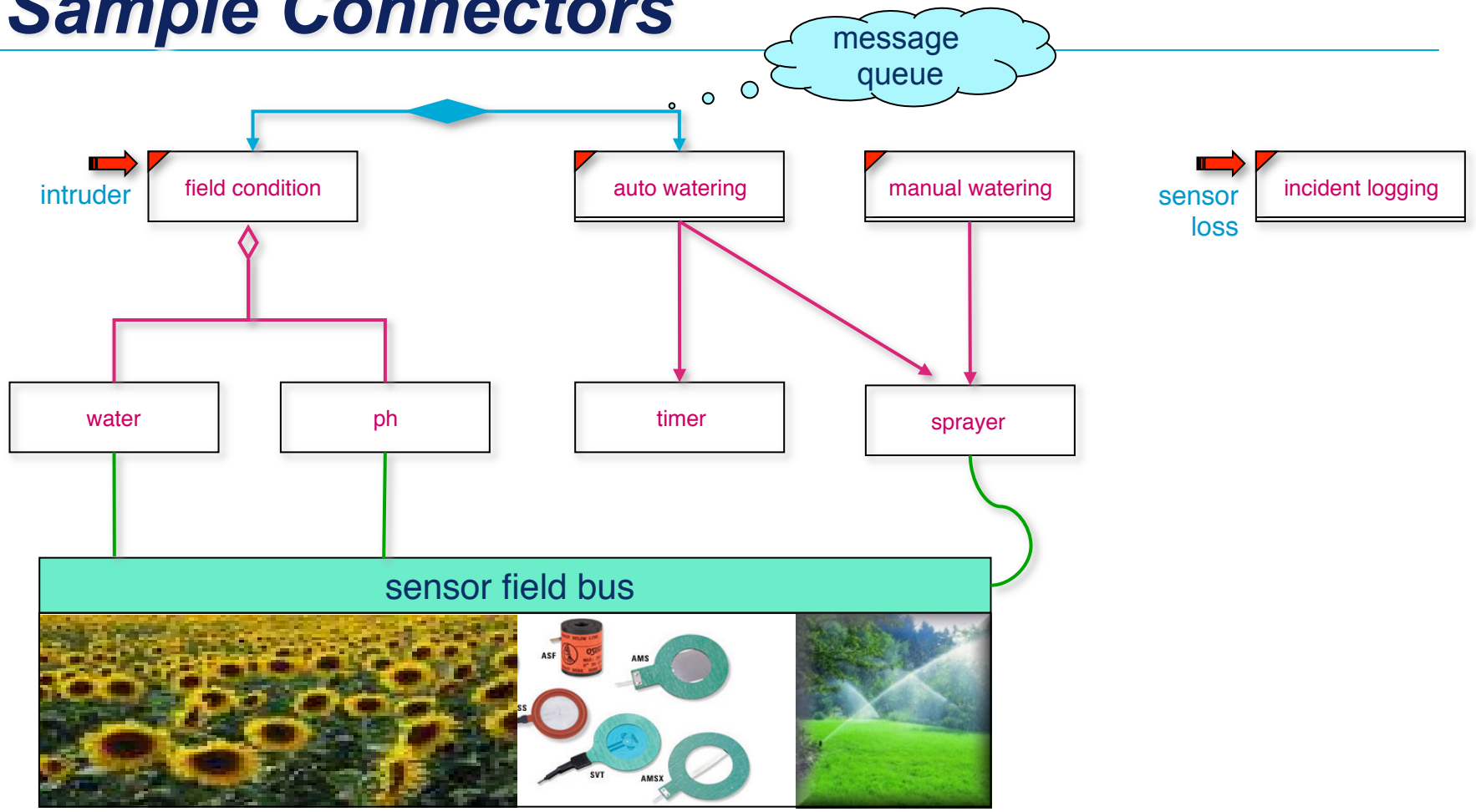
Connector Types

- Basic connectors
  - reference relation constrains method invocation patterns
  - aggregation relation is also a restricted form of reference
- Complex connectors
  - can be two-party or multi-party
  - may be specialized for a particular design
  - may use custom graphical representations
- Transparent connectors have no symbol tying the points of origin and processing
  - event notification
  - publish/subscribe

Connector Instances

- Message passing interactions
  - channels (1-1)
  - ports (n-1)
  - mailboxes (n-m)
- Software bus
- Remote procedure call
- Shared tuple spaces
- Events

Sample Connectors



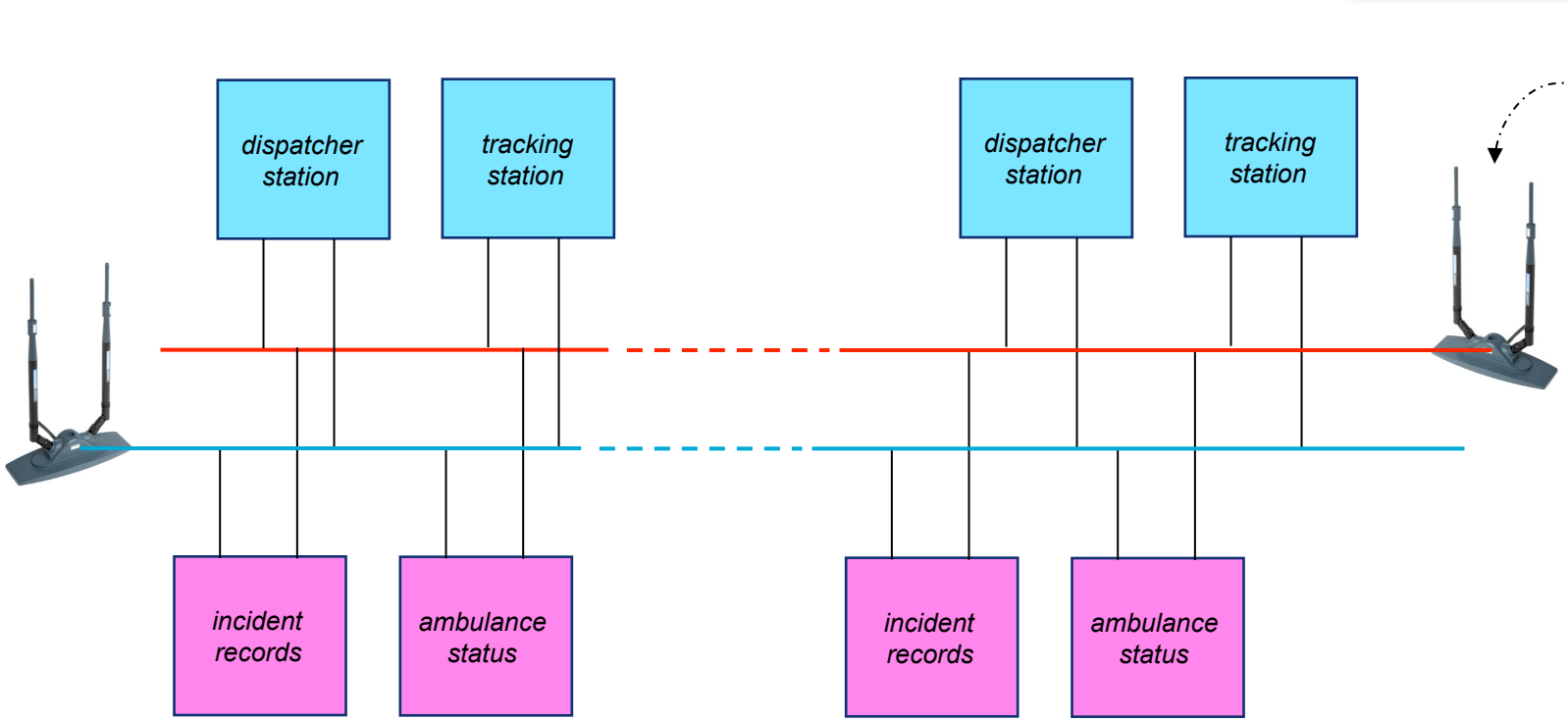
2.5.3 Design Diagrams

- The design diagram is an abstract view of the system structure and key behavior constraints
- The design diagram identifies the key software system components and the relevant connectors
- Components and connectors are defined outside the scope of the diagram
- Annotations allow one to communicate additional information for which there is no precise notation
  - implementation directives
  - timing constraints
  - software binding requirements (COTS)

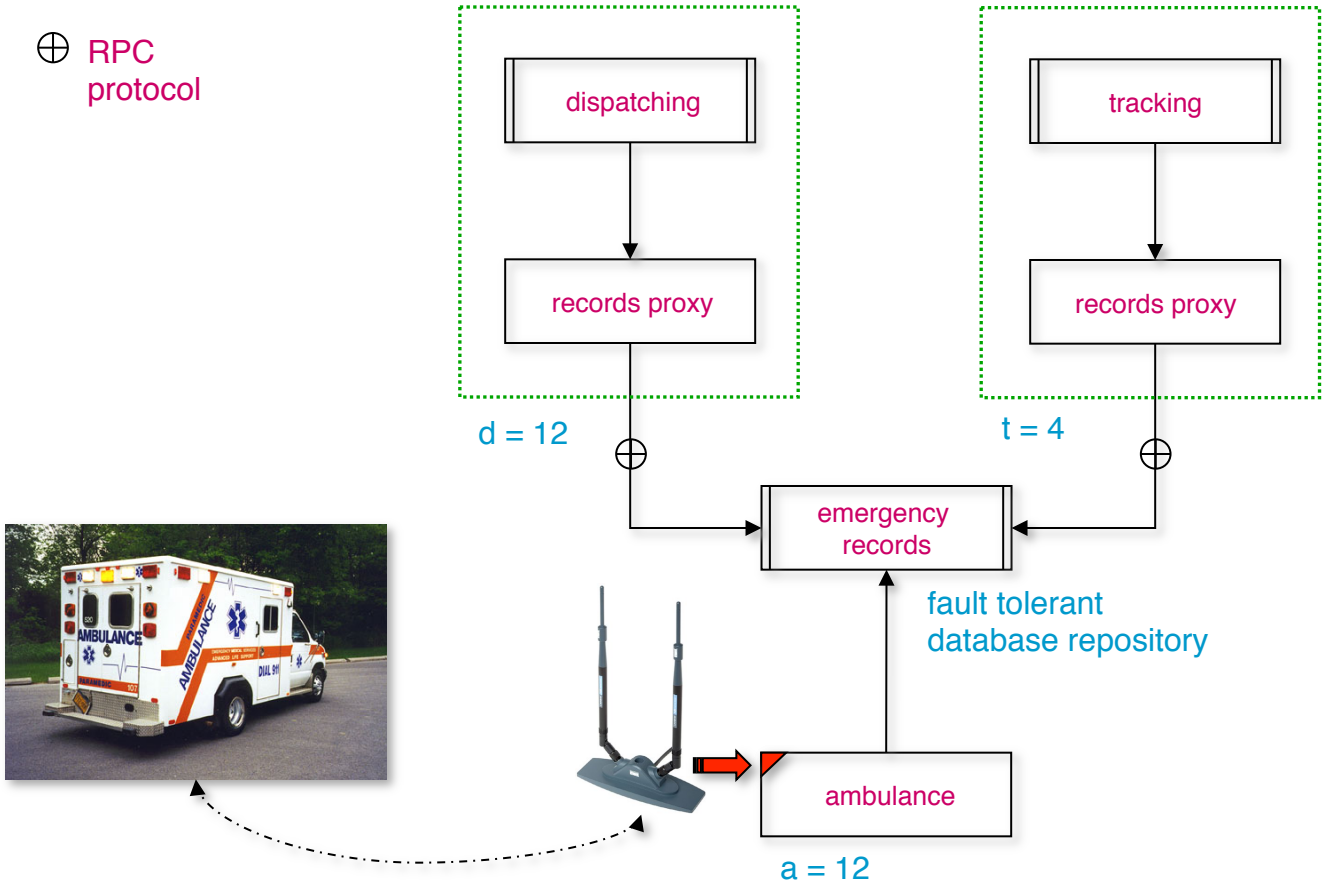
Cost Effective Design Process

- Effective design
  - focuses on early investments in creative thinking
  - delays documentation until stability is reached
- Typical stages in architectural design
  - initial diagram layout
  - diagram refinement and informal object specifications
  - informal design review
  - specification of object interfaces
  - analysis of critical design issues
  - preliminary design review
  - complete specification
  - formal architecture design review

Architectural Sketch



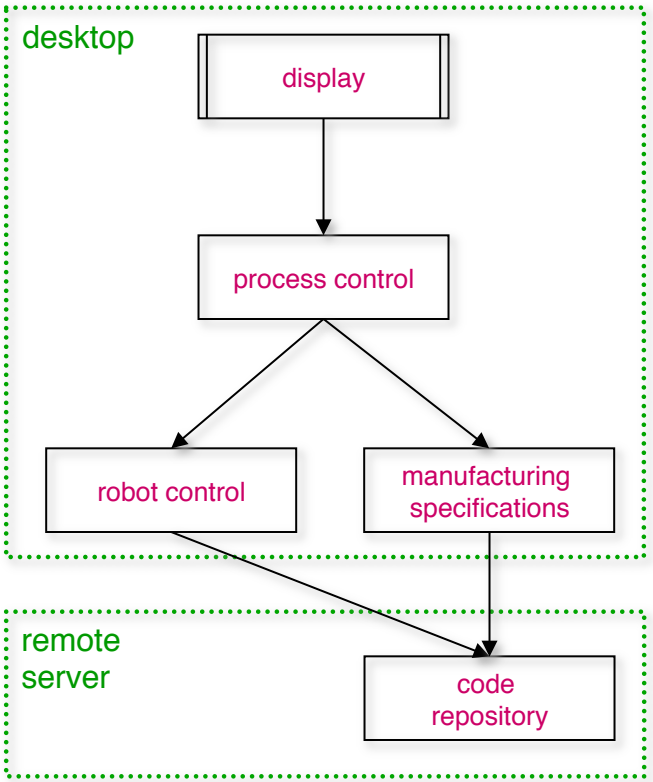
Architectural Design



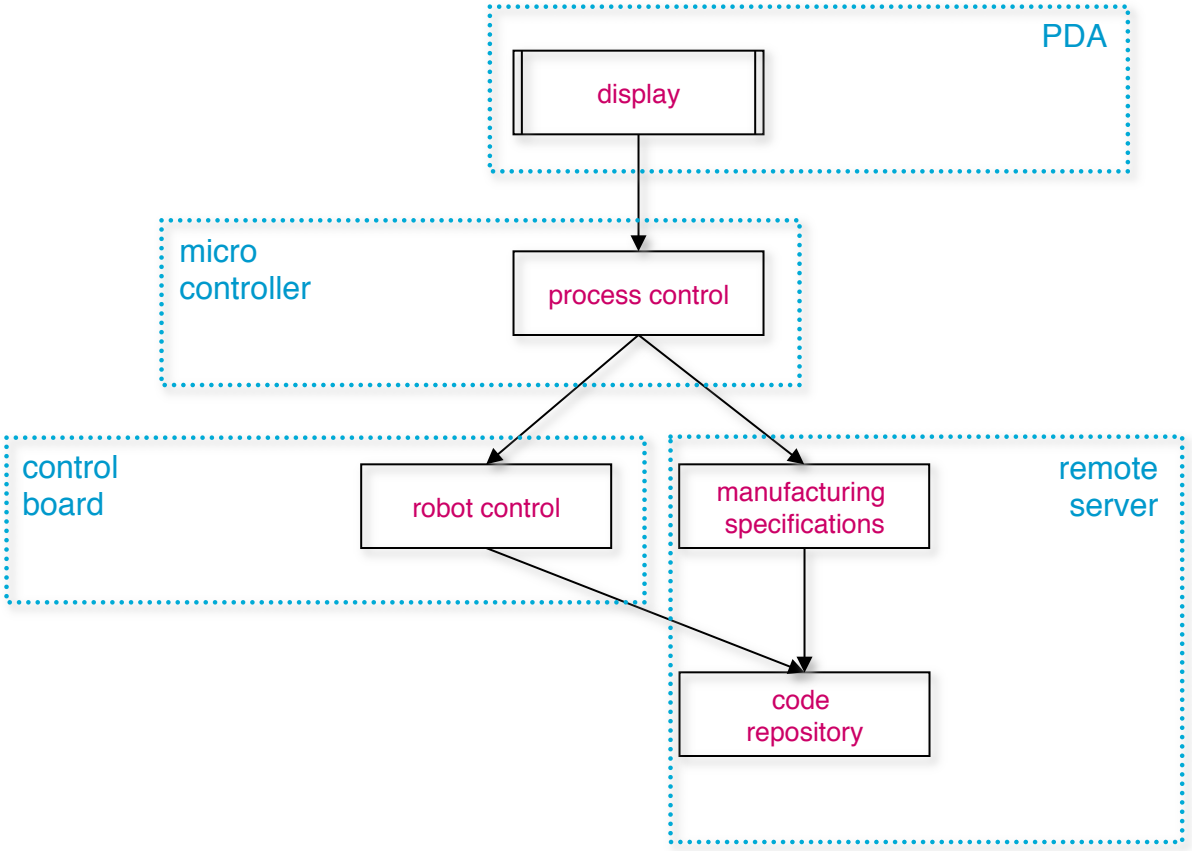
Software/Hardware Allocation

- The allocation of software components to the underlying hardware is
  - a defining feature of the architecture
  - a critical design decision affecting
    - quality of service
    - analysis and evaluation
    - software interfaces
    - coordination/communication protocols
    - maintenance procedures
- If the allocation is explicit (static or dynamic)
  - it can be captured in the form of annotations
  - each software components is mapped to exactly one hardware component
- If the allocation is transparent
  - it requires no explicit graphical notation
  - it affects analysis and evaluation

Allocation Alternatives



Allocation Alternatives

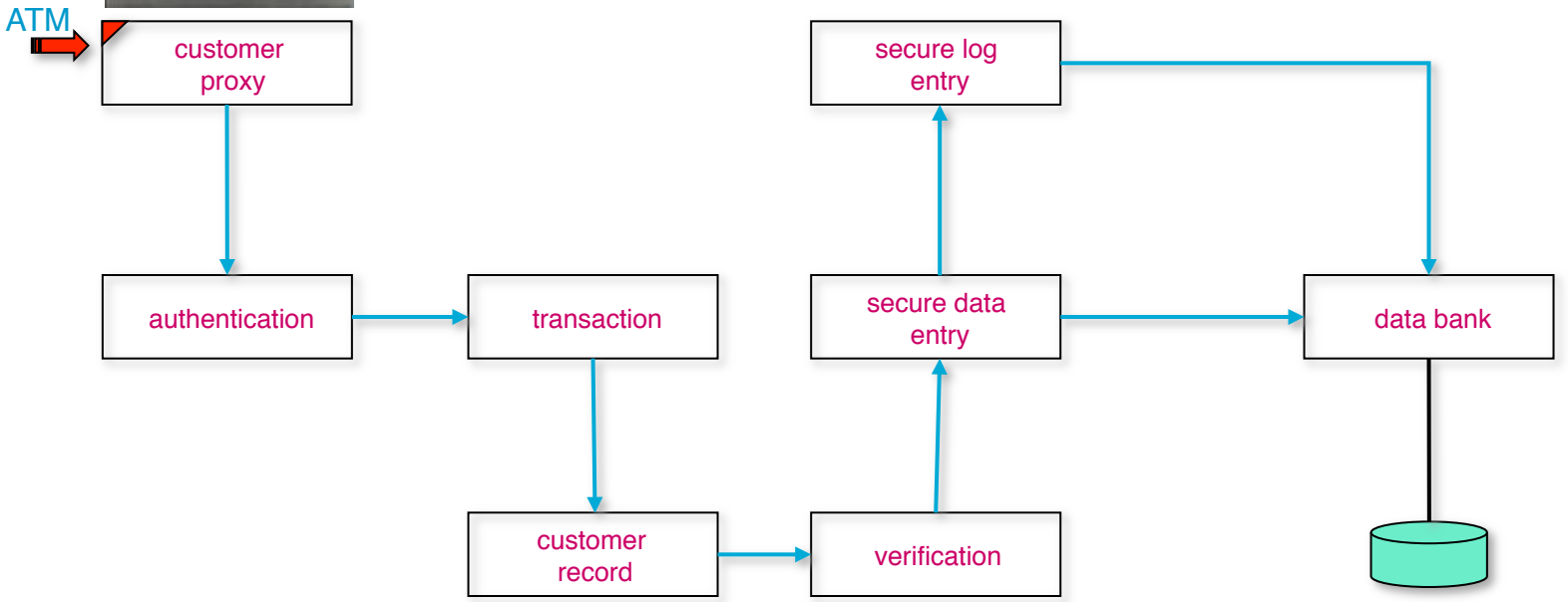


Complexity Control

- Packages may be used to define subsystems (rather than code management)
- Simple interfaces among subsystems facilitate hierarchical decomposition of the system
- Decoupling among components facilitates partitioning of the system
- Multiple views, while difficult to maintain consistent, may be critical in support of analysis
- Typical configurations can assist in providing a finite and comprehensive description of a dynamic system

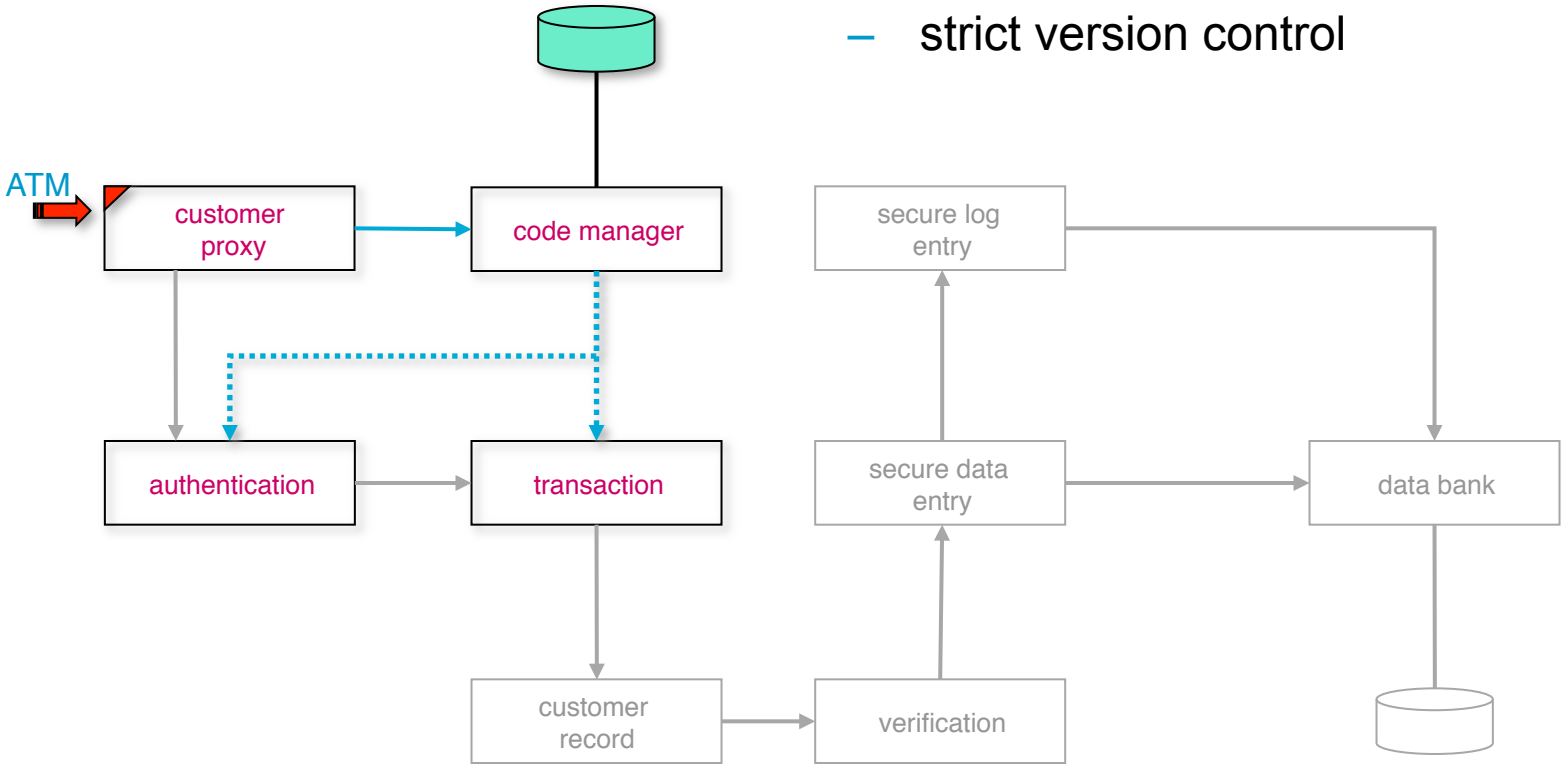
Multiple Views

- Customer service
  - sample partition



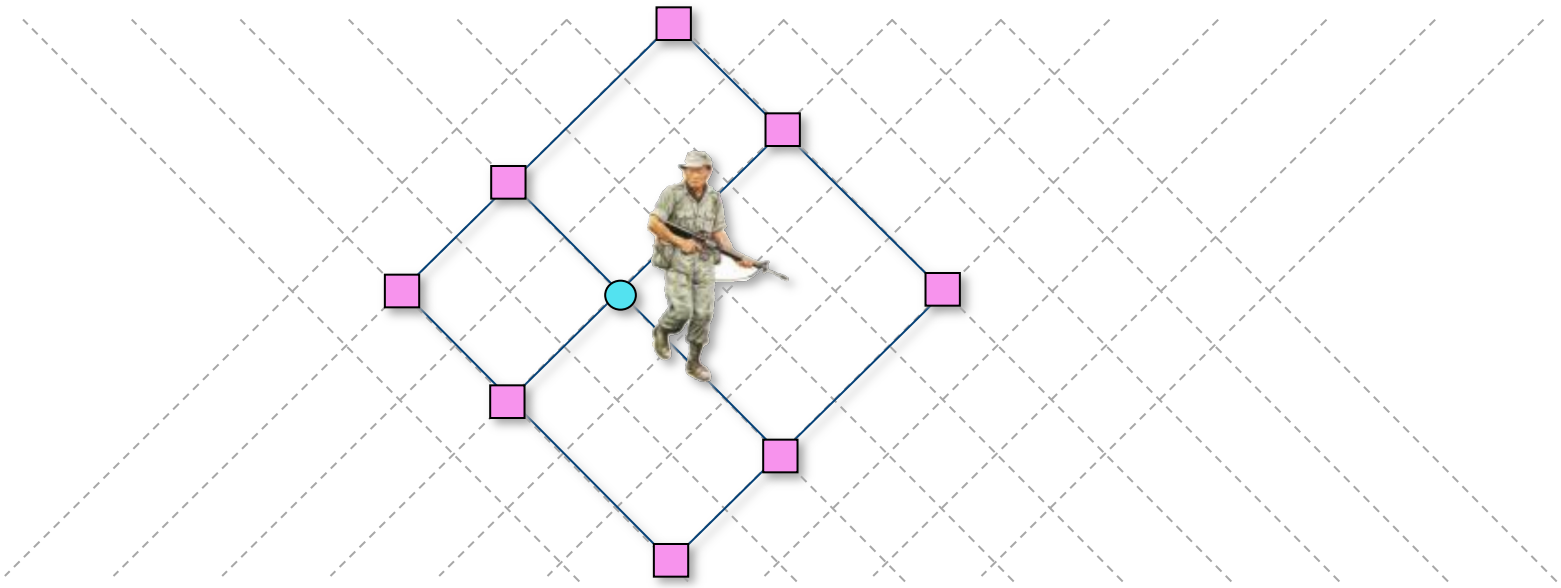
Multiple Views

- Code management
  - alternate viewpoint
  - strict version control



Dynamic Structures

- Sensor grid protection
  - mobile agent based application
  - agent cloning maintains the structure



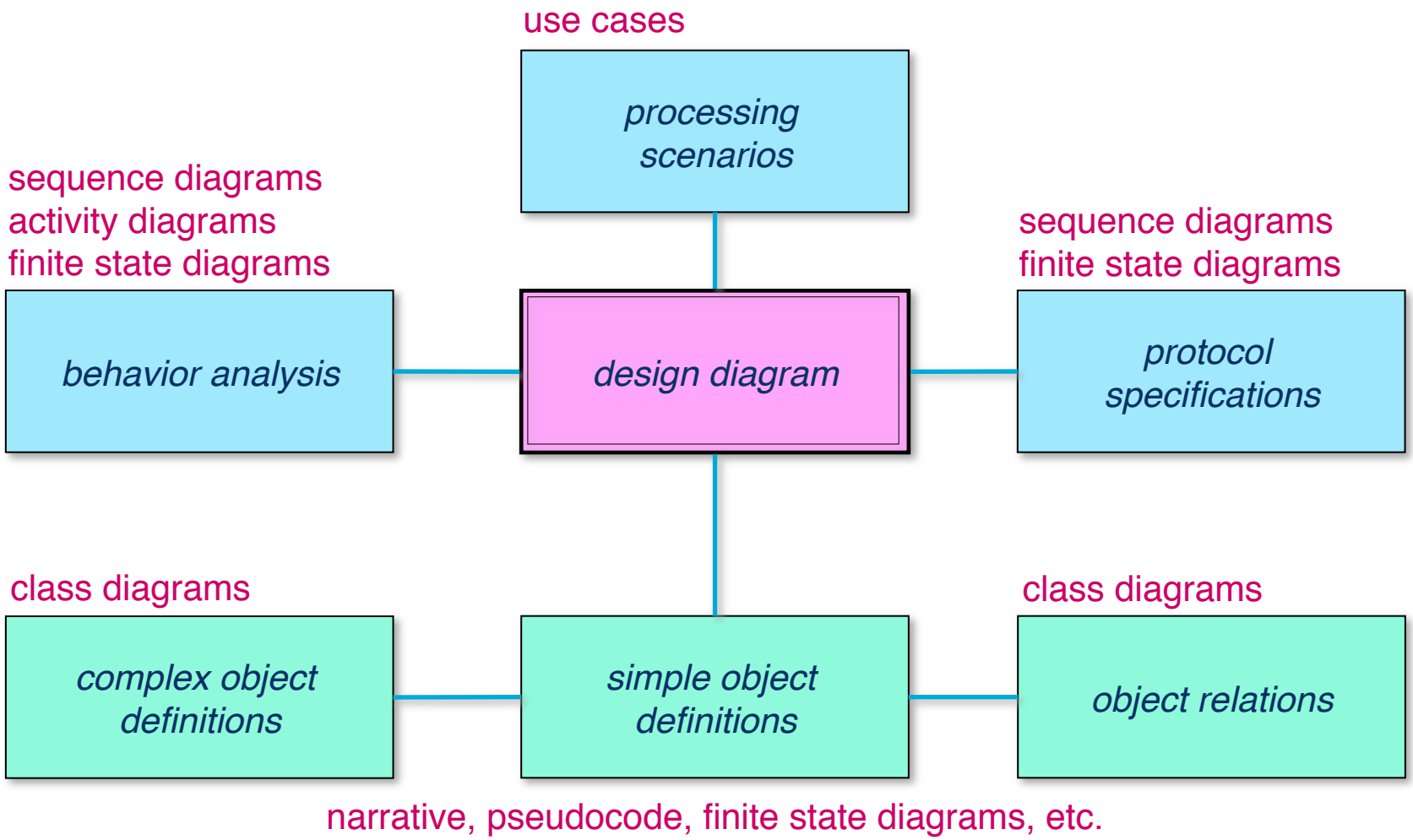
2.5.4 Meta Level Specifications

- A strict definition of the design diagram
  - enables rapid and cost effective design
  - focuses the design process on fundamentals
- Component specifications complete the picture by providing
  - precise interface specifications
  - exact behavior specifications
- Meta level specifications provide additional support for
  - definition
  - analysis
  - specification

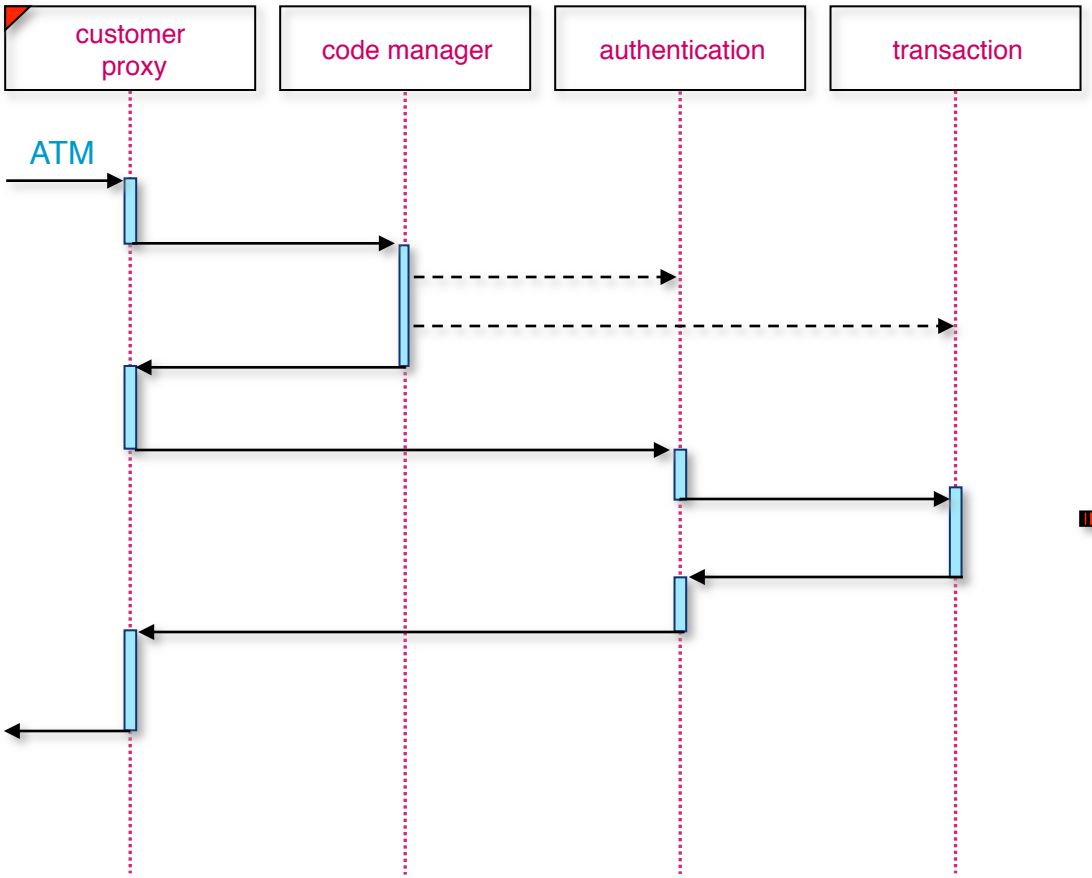
Impact on Architecture Design

- Simplify the object definition process
  - class diagrams
- Capture fundamental relationships among objects
  - class diagrams
- Define interaction protocols
  - sequence diagrams
- Formalize behavior patterns for analysis or specification
  - sequence diagrams
  - activity diagrams
- Capture interaction or processing scenarios
  - use cases
  - activity diagrams

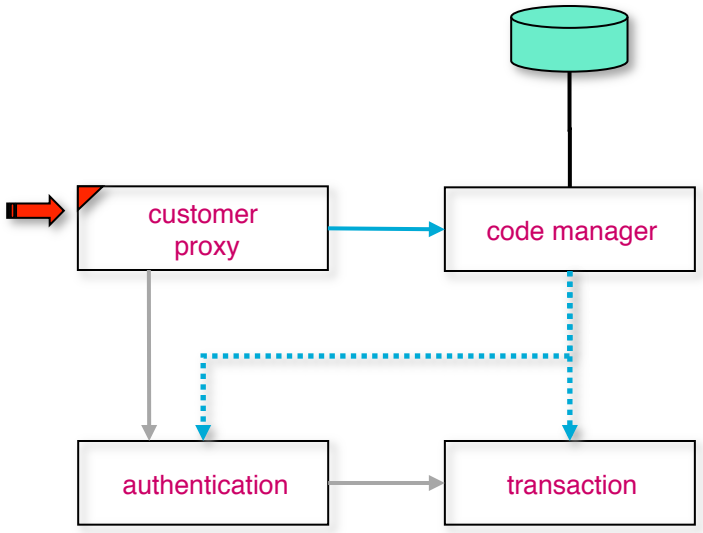
Documentation Revisited



Sequence Diagram

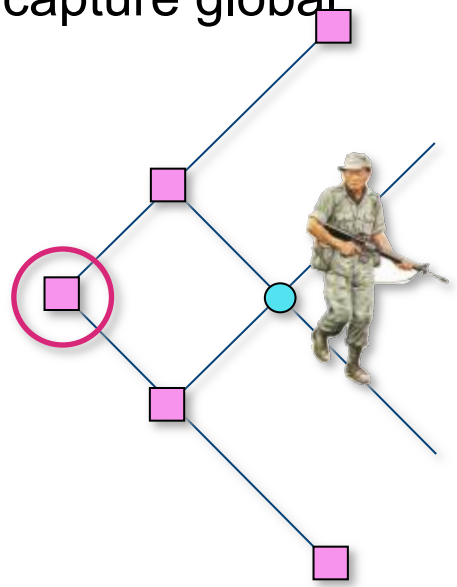


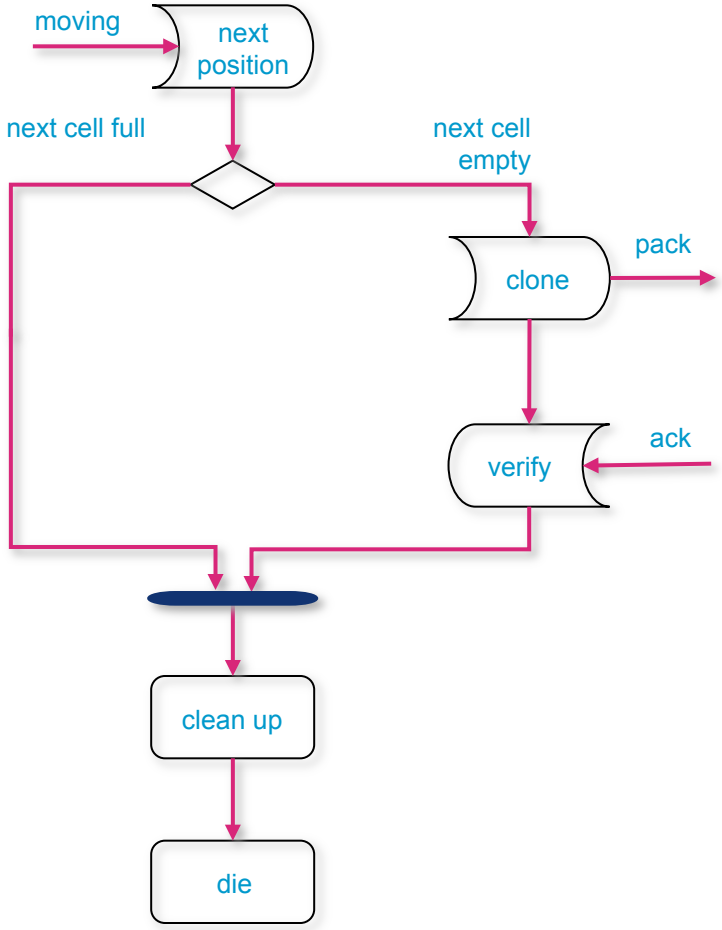
- Is the most recent code being used?
- Can authentication be bypassed?
- etc.



Activity Diagram

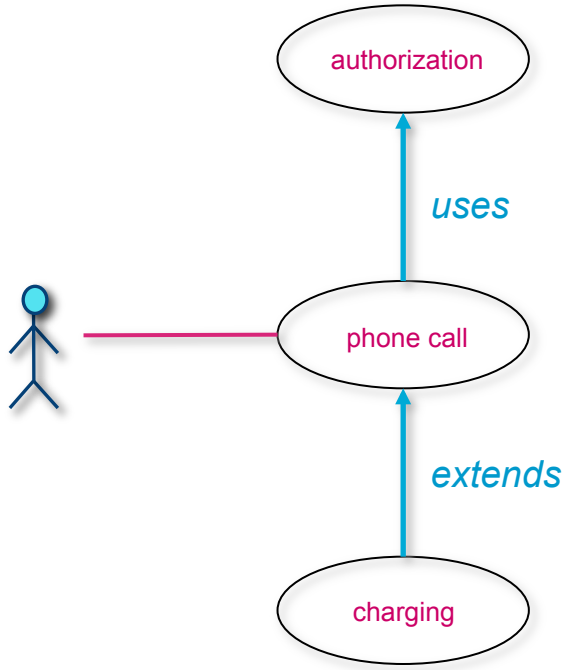
- An activity diagram is a specialized finite state machine—action termination controls transitions
- When used to describe the behavior of one object, all actions are local
- When used to capture global behavior, actions are distributed





Use Cases

- Actors
  - model the environment and the users
  - initiate activity by providing stimuli
  - can be primary or secondary
- Use cases
  - are complete courses of action initiated by actors (basic or alternative)
  - can be extended by (interrupt analogy) or use other use cases (call analogy)



Conclusions

- The development of a software architecture is a complex task
  - multiple perspectives
  - different notations
  - significant and sophisticated analysis
- The complexity of the notation and concepts should be minimized
- The design process should focus on fundamentals and on the creative activities foremost
- Precise and complete documentation is paramount but not the dominant activity