Ch.12 Design Concepts

- **Design**
  - *Mitch Kapor, the creator of Lotus 1-2-3, presented a "software design manifesto" in Dr. Dobbs Journal. He said:*
  - *Good software design should exhibit:*
    - *Firmness*: A program should not have any bugs that inhibit its function.
    - *Commodity*: A program should be suitable for the purposes for which it was intended.
    - *Delight*: The experience of using the program should be pleasurable one.

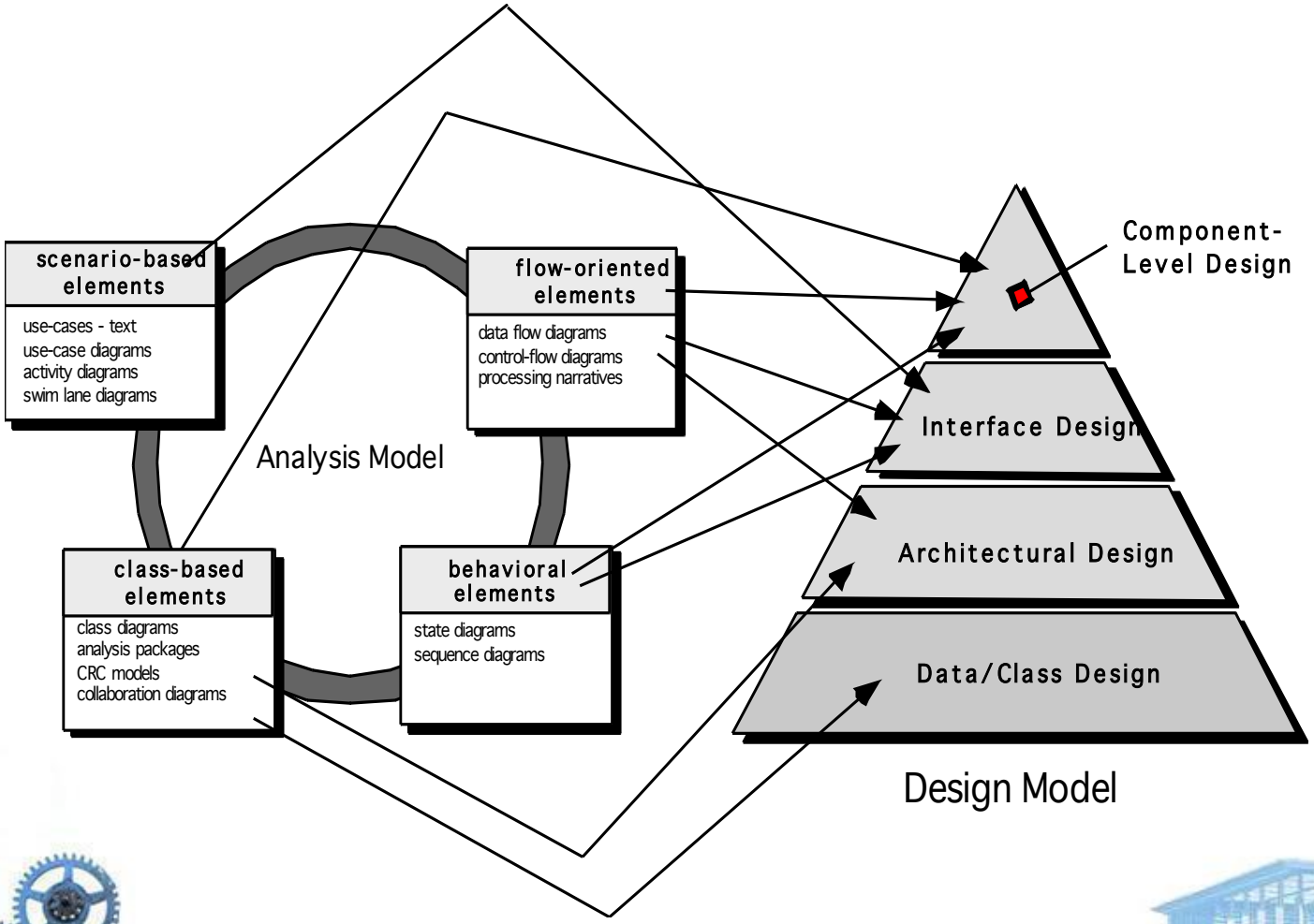
- **Software Design**

  - Encompasses the set of principles, concepts, and practices that lead to the development of a high quality system or product
  - Design principles establish and overriding philosophy that guides the designer as the work is performed
  - Design concepts must be understood before the mechanics of design practice are applied
  - Software design practices change continuously as new methods, better analysis, and broader understanding evolve

- **Software Engineering Design**

  - Data/Class design – transforms analysis classes into implementation classes and data structures
  - Architectural design – defines relationships among the major software structural elements
  - Interface design – defines how software elements, hardware elements, and end-users communicate
  - Component-level design – transforms structural elements into procedural descriptions of software components

- **Analysis Model -> Design Model**



- **Design and Quality**

  - *the design must implement all of the explicit requirements* contained in the analysis model, and it must accommodate all of the implicit requirements desired by the customer.
  - *the design must be a readable, understandable guide* for those who generate code and for those who test and subsequently support the software.
  - *the design should provide a complete picture of the software*, addressing the data, functional, and behavioral domains from an implementation perspective.

Quality Guidelines

- *A design should exhibit an architecture* that (1) has been created using recognizable architectural styles or patterns, (2) is composed of components that exhibit good design characteristics and (3) can be implemented in an evolutionary fashion
- *A design should be modular;* that is, the software should be logically partitioned into elements or subsystems
- *A design should contain distinct representations* of data, architecture, interfaces, and components.
- *A design should lead to data structures that are appropriate* for the classes to be implemented and are drawn from recognizable data patterns.
- *A design should lead to components that exhibit independent functional characteristics.*
- *A design should lead to interfaces that reduce the complexity* of connections between components and with the external environment.
- *A design should be derived using a repeatable method* that is driven by information obtained during software requirements analysis.
- *A design should be represented using a notation* that effectively communicates its meaning.

Design Principles

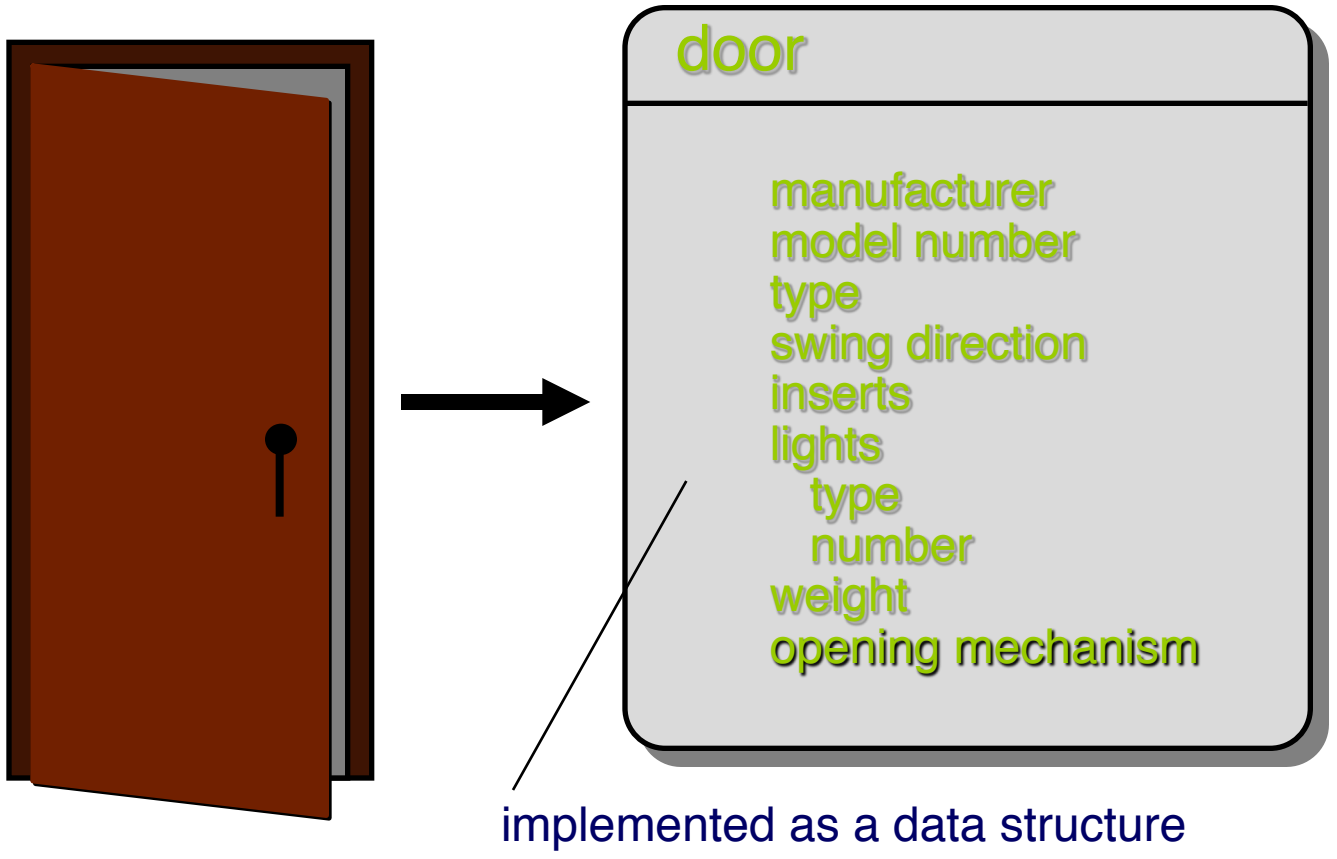
- The design process should not suffer from ‘tunnel vision.’
- The design should be traceable to the analysis model.
- The design should not reinvent the wheel.
- The design should “minimize the intellectual distance” [DAV95] between the software and the problem as it exists in the real world.
- The design should exhibit uniformity and integration.
- The design should be structured to accommodate change.
- The design should be structured to degrade gently, even when aberrant data, events, or operating conditions are encountered.
- Design is not coding, coding is not design.
- The design should be assessed for quality as it is being created, not after the fact.
- The design should be reviewed to minimize conceptual (semantic) errors.

From Davis [DAV95]

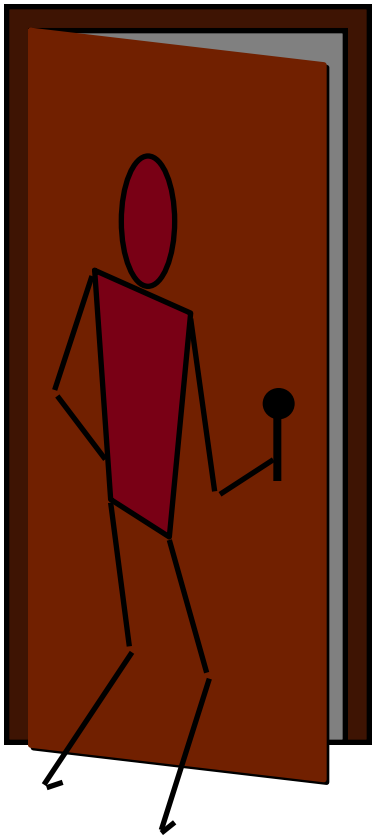
Fundamental Concepts

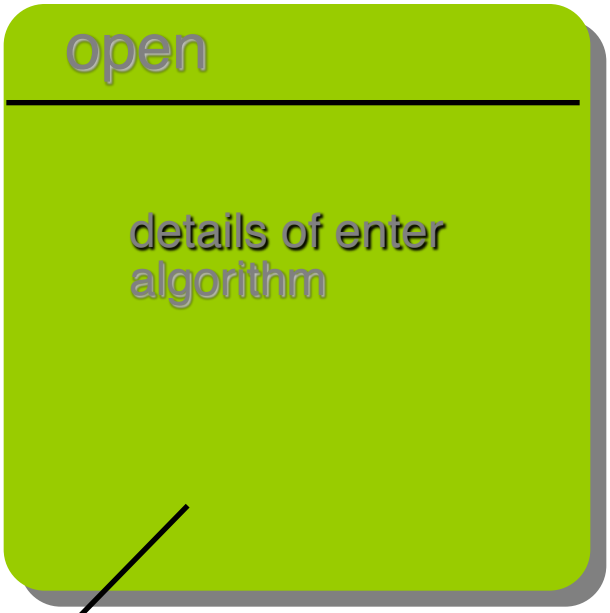
- *Abstraction*—data, procedure, control
- *Architecture*—the overall structure of the software
- *Patterns*—"conveys the essence" of a proven design solution
- *Separation of concerns*—any complex problem can be more easily handled if it is subdivided into pieces
- *Modularity*—compartmentalization of data and function
- *Hiding*—controlled interfaces
- *Functional independence*—single-minded function and low coupling
- *Refinement*—elaboration of detail for all abstractions
- *Aspects*—a mechanism for understanding how global requirements affect design
- *Refactoring*—a reorganization technique that simplifies the design
- *OO design concepts*—Appendix II
- *Design Classes*—provide design detail that will enable analysis classes to be implemented

- **Data Abstraction**



- **Procedural Abstraction**





implemented with a "knowledge" of the object that is associated with enter

- **Architecture**

"The overall structure of the software and the ways in which that structure provides conceptual integrity for a system." [SHA95a]

- *Structural properties.* This aspect of the architectural design representation defines the components of a system (e.g., modules, objects, filters) and the manner in which those components are packaged and interact with one another. For example, objects are packaged to encapsulate both data and the processing that manipulates the data and interact via the invocation of methods
- *Extra-functional properties.* The architectural design description should address how the design architecture achieves requirements for performance, capacity, reliability, security, adaptability, and other system characteristics.
- *Families of related systems.* The architectural design should draw upon repeatable patterns that are commonly encountered in the design of families of similar systems. In essence, the design should have the ability to reuse architectural building blocks.

- **Patterns**

Design Pattern Template

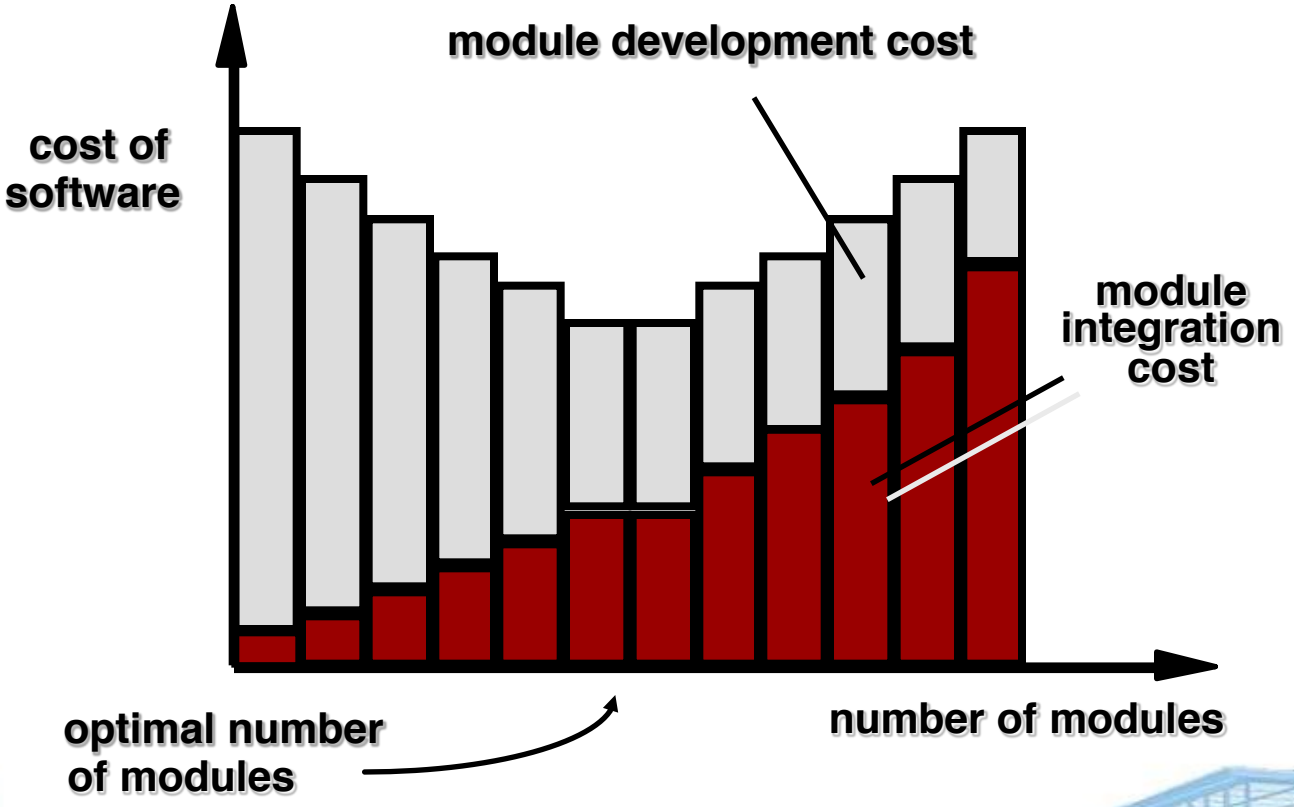
- *Pattern name*—describes the essence of the pattern in a short but expressive name
- *Intent*—describes the pattern and what it does
- *Also-known-as*—lists any synonyms for the pattern
- *Motivation*—provides an example of the problem
- *Applicability*—notes specific design situations in which the pattern is applicable
- *Structure*—describes the classes that are required to implement the pattern
- *Participants*—describes the responsibilities of the classes that are required to implement the pattern
- *Collaborations*—describes how the participants collaborate to carry out their responsibilities
- *Consequences*—describes the “design forces” that affect the pattern and the potential trade-offs that must be considered when the pattern is implemented
- *Related patterns*—cross-references related design patterns

- **Separation of Concerns**
  - Any complex problem can be more easily handled if it is subdivided into pieces that can each be solved and/or optimized independently
  - A *concern* is a feature or behavior that is specified as part of the requirements model for the software
  - By separating concerns into smaller, and therefore more manageable pieces, a problem takes less effort and time to solve.

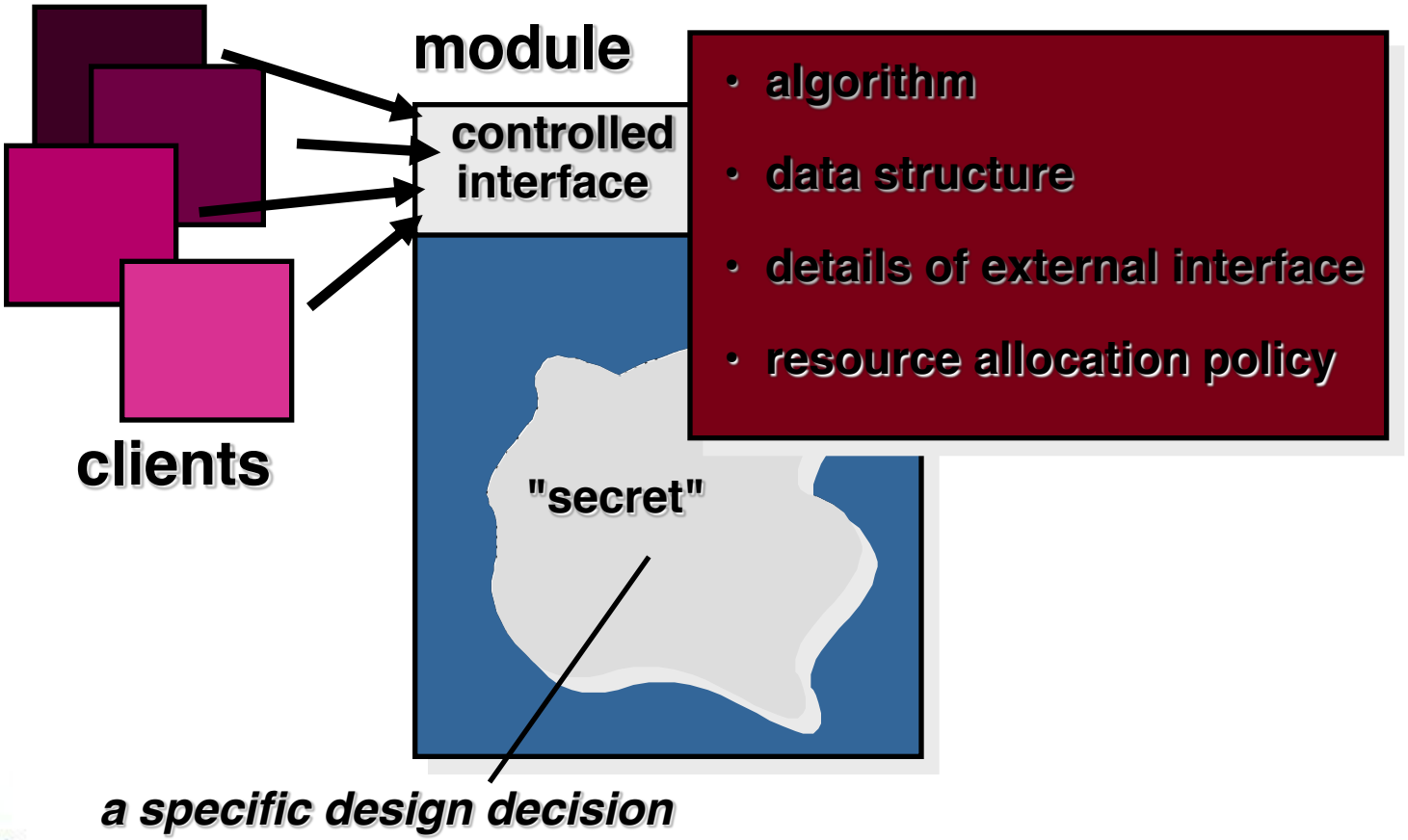
- **Modularity**
  - "modularity is the single attribute of software that allows a program to be intellectually manageable" [Mye78].
  - Monolithic software (i.e., a large program composed of a single module) cannot be easily grasped by a software engineer.
    - The number of control paths, span of reference, number of variables, and overall complexity would make understanding close to impossible.
  - In almost all instances, you should break the design into many modules, hoping to make understanding easier and as a consequence, reduce the cost required to build the software.

- **Modularity: Trade-offs**

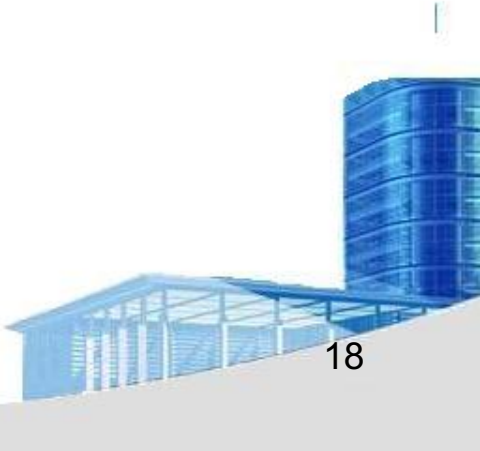
What is the "right" number of modules for a specific software design?



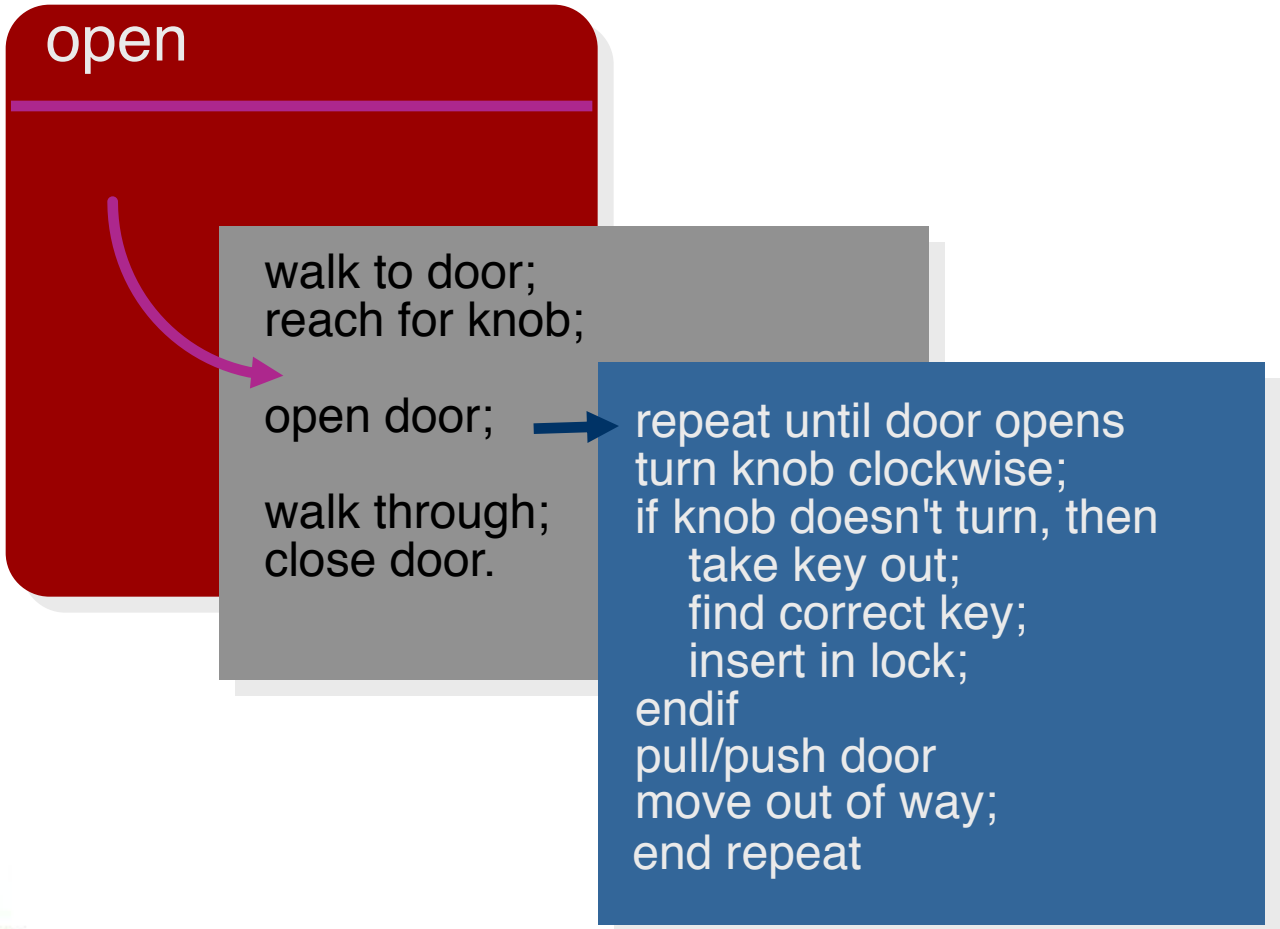
- **Information Hiding**



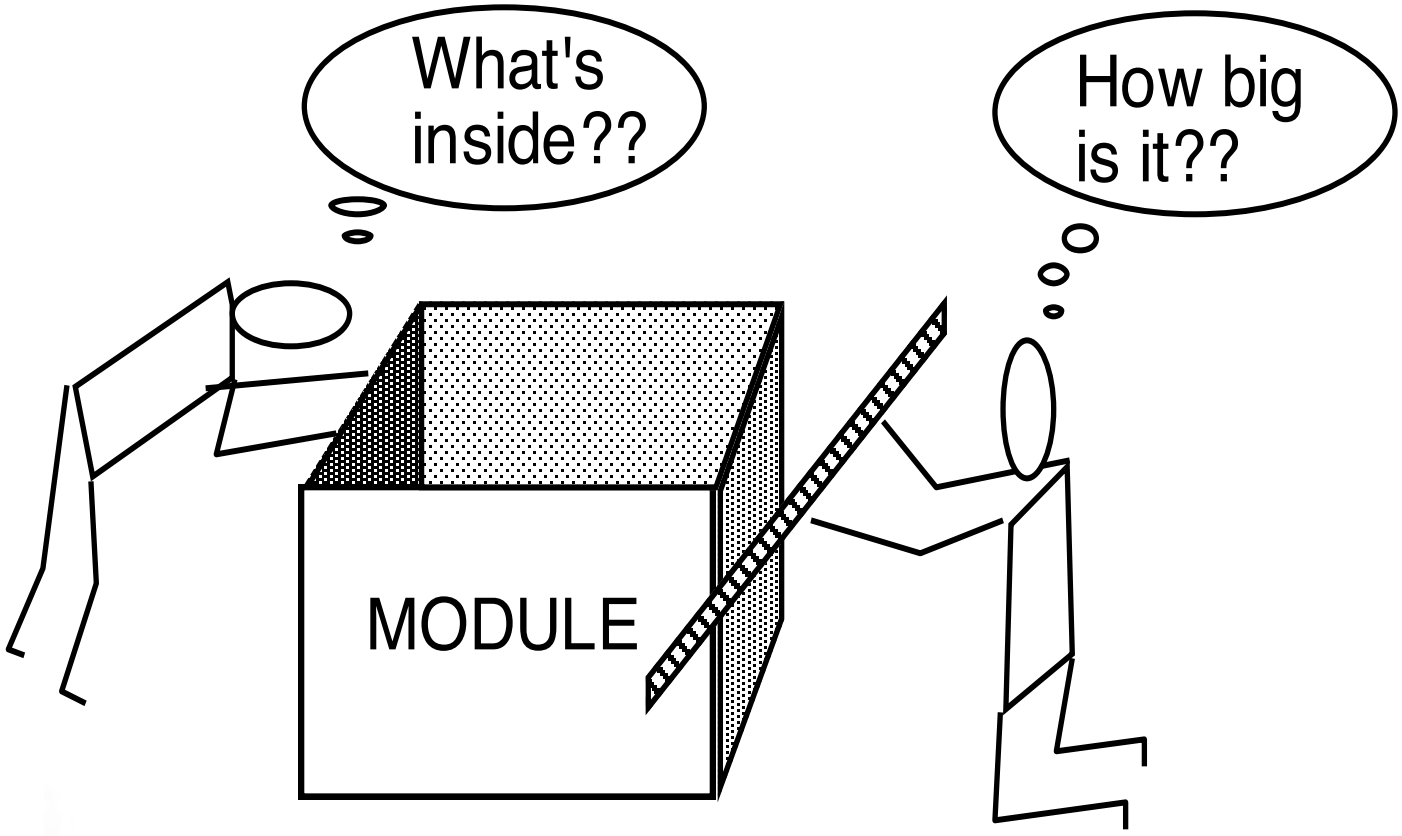
- **Why Information Hiding?**
  - reduces the likelihood of “side effects”
  - limits the global impact of local design decisions
  - emphasizes communication through controlled interfaces
  - discourages the use of global data
  - leads to encapsulation—an attribute of high quality design
  - results in higher quality software



- **Stepwise Refinement**



- **Sizing Modules: Two Views**



- **Functional Independence**
  - Functional independence is achieved by developing modules with "single-minded" function and an "aversion" to excessive interaction with other modules.
  - *Cohesion* is an indication of the relative functional strength of a module.
    - A cohesive module performs a single task, requiring little interaction with other components in other parts of a program. Stated simply, a cohesive module should (ideally) do just one thing.
  - *Coupling* is an indication of the relative interdependence among modules.
    - Coupling depends on the interface complexity between modules, the point at which entry or reference is made to a module, and what data pass across the interface.

- **Aspects**
  - Consider two requirements, A and B. Requirement A crosscuts requirement B “if a software decomposition [refinement] has been chosen in which B cannot be satisfied without taking A into account. [Ros04]
  - An *aspect* is a representation of a cross-cutting concern.

- **Aspects—An Example**
  - Consider two requirements for the *SafeHomeAssured.com* WebApp. Requirement A is described via the use-case *Access camera surveillance via the Internet.* A design refinement would focus on those modules that would enable a registered user to access video from cameras placed throughout a space. Requirement B is a generic security requirement that states that a registered user must be validated prior to using *SafeHomeAssured.com*. This requirement is applicable for all functions that are available to registered SafeHome users. As design refinement occurs, A* is a design representation for requirement A and B* is a design representation for requirement B. Therefore, A* and B* are representations of concerns, and B* cross-cuts A*.
  - An aspect is a representation of a cross-cutting concern. Therefore, the design representation, B*, of the requirement, a registered user must be validated prior to using *SafeHomeAssured.com*, is an aspect of the SafeHome WebApp.

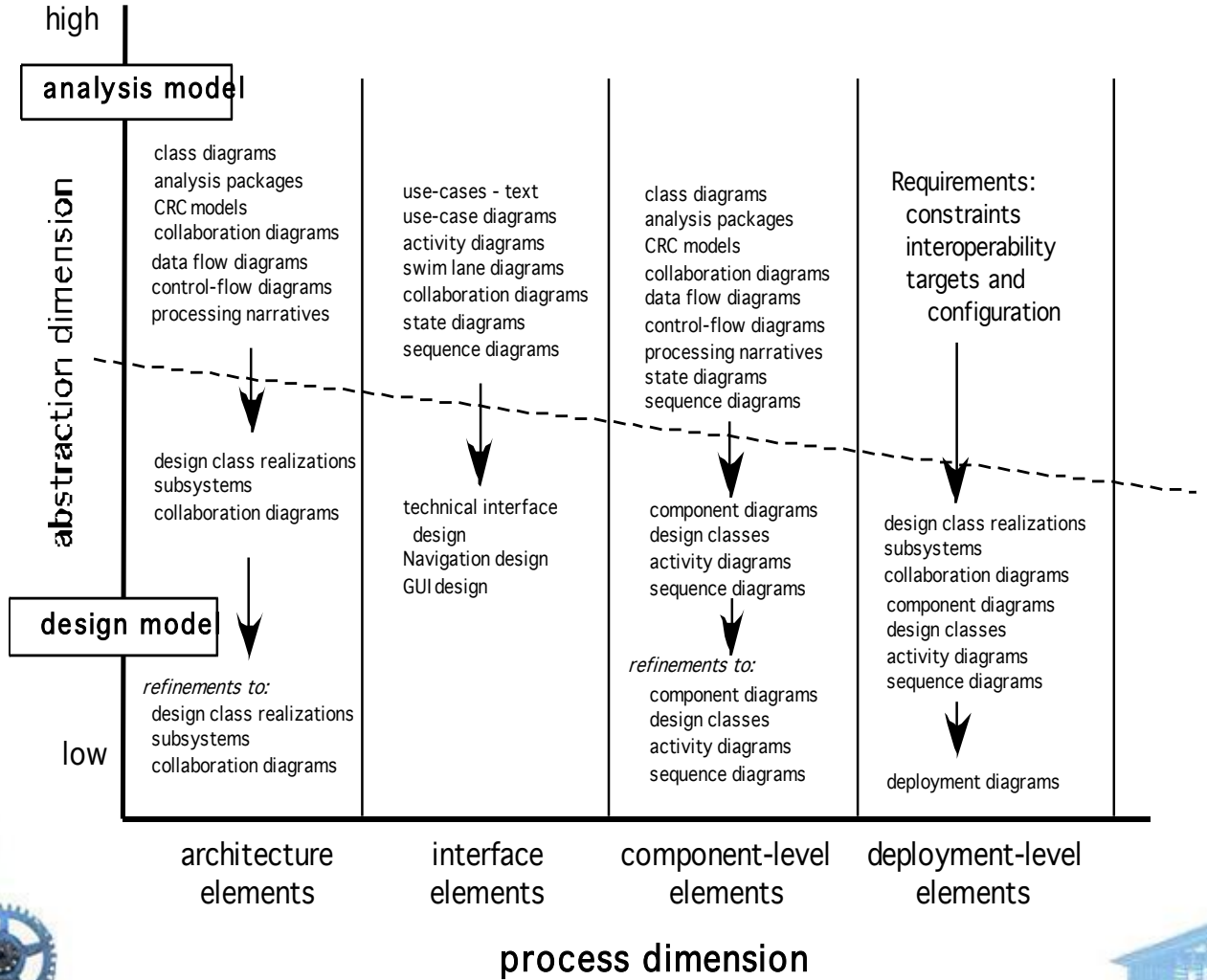
- **Functional Independence**
  - Fowler [FOW99] defines refactoring in the following manner:
    - *"Refactoring is the process of changing a software system in such a way that it does not alter the external behavior of the code [design] yet improves its internal structure."*
  - When software is refactored, the existing design is examined for
    - redundancy
    - unused design elements
    - inefficient or unnecessary algorithms
    - poorly constructed or inappropriate data structures
    - or any other design failure that can be corrected to yield a better design.

- **OO Design Concepts**
  - *Design classes*
    - Entity classes
    - Boundary classes
    - Controller classes
  - *Inheritance*—all responsibilities of a superclass is immediately inherited by all subclasses
  - *Messages*—stimulate some behavior to occur in the receiving object
  - *Polymorphism*—a characteristic that greatly reduces the effort required to extend the design

- **Design Classes**
  - Analysis classes are refined during design to become *entity classes*
  - *Boundary classes* are developed during design to create the interface (e.g., interactive screen or printed reports) that the user sees and interacts with as the software is used.
    - Boundary classes are designed with the responsibility of managing the way entity objects are represented to users.
  - *Controller classes* are designed to manage
    - the creation or update of entity objects;
    - the instantiation of boundary objects as they obtain information from entity objects;
    - complex communication between sets of objects;
    - validation of data communicated between objects or between the user and the application.

- **Design Class Characteristics**
  - *Complete* - includes all necessary attributes and methods) and sufficient (contains only those methods needed to achieve class intent)
  - *Primitiveness* – each class method focuses on providing one service
  - *High cohesion* – small, focused, single-minded classes
  - *Low coupling* – class collaboration kept to minimum

- **The Design Model**



- **Design Model Elements**
  - *Data elements*
    - Data model --> data structures
    - Data model --> database architecture
  - *Architectural elements*
    - Application domain
    - Analysis classes, their relationships, collaborations and behaviors are transformed into design realizations
    - Patterns and “styles” (Chapters 9 and 12)
  - *Interface elements*
    - the user interface (UI)
    - external interfaces to other systems, devices, networks or other producers or consumers of information
    - internal interfaces between various design components.
  - *Component elements*
  - *Deployment elements*

- **Data Modeling**
  - examines data objects independently of processing
  - focuses attention on the data domain
  - creates a model at the customer's level of abstraction
  - indicates how data objects relate to one another

- **What is a Data Object?**
  - a representation of almost any composite information that must be understood by software.
    - composite information—something that has a number of different properties or attributes
  - can be an *external entity* (e.g., anything that produces or consumes information), *a thing* (e.g., a report or a display), *an occurrence* (e.g., a telephone call) or *event* (e.g., an alarm), *a role* (e.g., salesperson), *an organizational unit* (e.g., accounting department), *a place* (e.g., a warehouse), or *a structure* (e.g., a file).
  - The description of the data object incorporates the data object and all of its attributes.
  - A data object encapsulates data only—there is no reference within a data object to operations that act on the data.

- **Data Objects and Attributes**

  - A data object contains a set of attributes that act as an aspect, quality, characteristic, or descriptor of the object

object: automobile

attributes:
- **make**
- **model**
- **body type**
- **price**
- **options code**

- **What is a Relationship?**
  - Data objects are connected to one another in different ways.
    - A connection is established between **person** and **car** because the two objects are related.
  - A person owns a car
  - A person is insured to drive a car
  - The relationships *owns* and *insured to drive* define the relevant connections between ***person*** and ***car***.
  - Several instances of a relationship can exist
  - Objects can be related in many different ways

- **Architectural Elements**
  - The architectural model [Sha96] is derived from three sources:
    - **information about the application domain** for the software to be built;
    - **specific requirements model elements** such as data flow diagrams or analysis classes, their relationships and collaborations for the problem at hand, and
    - **the availability of architectural patterns** (Chapter 16) **and styles** (Chapter 13).

- **Interface Elements**
  - Interface is a set of operations that describes the externally observable behavior of a class and provides access to its public operations
  - Important elements
    - User interface (UI)
    - External interfaces to other systems
    - Internal interfaces between various design components
  - Modeled using UML communication diagrams (called collaboration diagrams in UML 1.x)

- **Interface Elements**

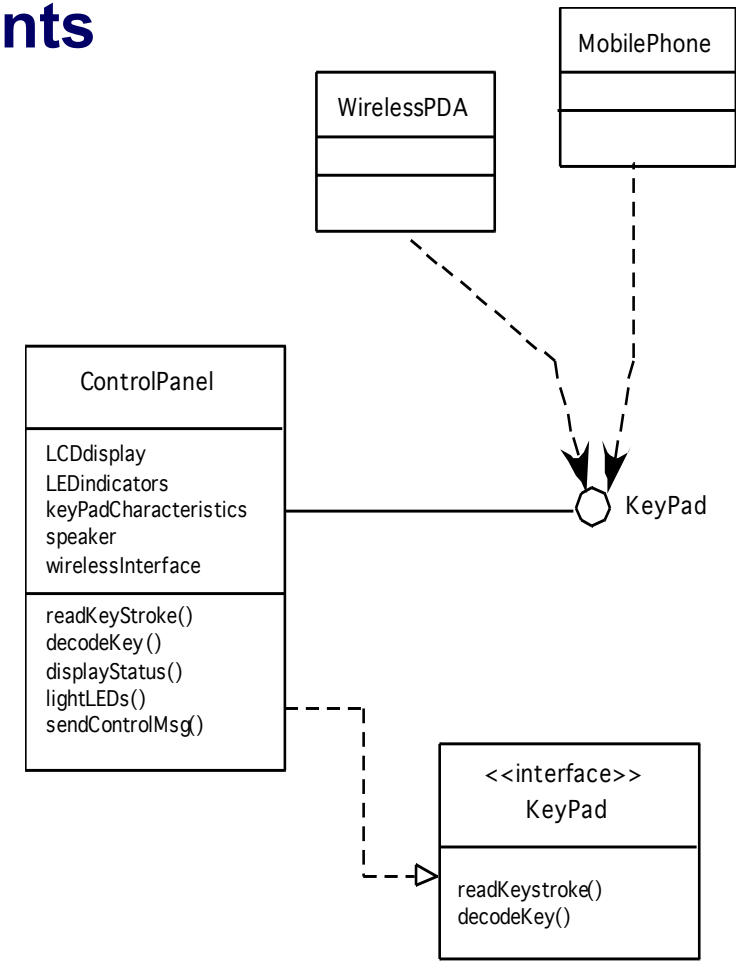
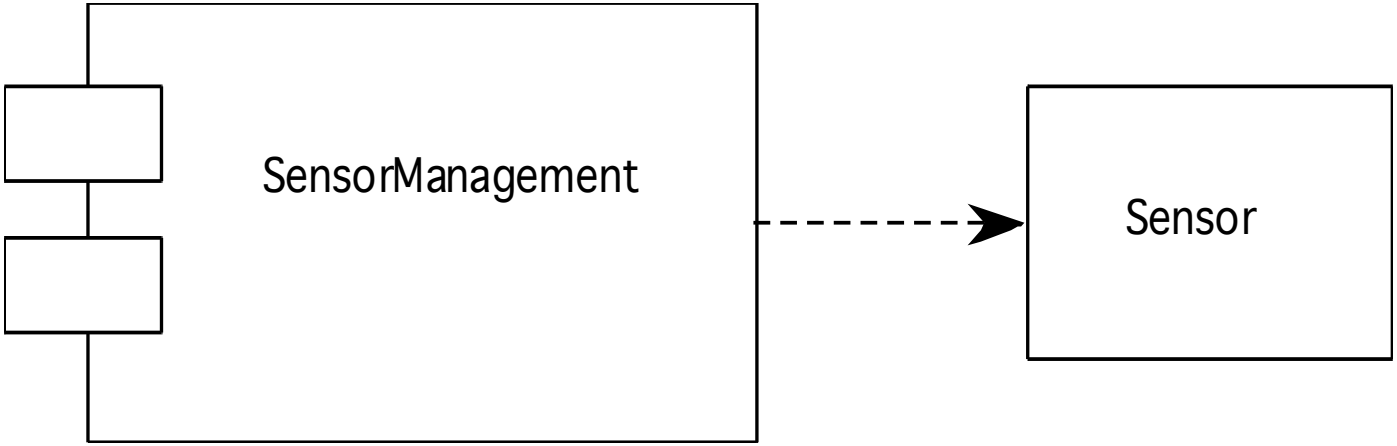


Figure 9.6 UML interface representation for **ControlPanel**

- **Component Elements**
  - Describes the internal detail of each software component
  - Defines
    - Data structures for all local data objects
    - Algorithmic detail for all component processing functions
    - Interface that allows access to all component operations
  - Modeled using UML component diagrams, UML activity diagrams, pseudocode (PDL), and sometimes flowcharts

- **Component Elements**



- **Deployment Elements**
  - Indicates how software functionality and subsystems will be allocated within the physical computing environment
  - Modeled using UML deployment diagrams
  - *Descriptor form* deployment diagrams show the computing environment but does not indicate configuration details
  - *Instance form* deployment diagrams identifying specific named hardware configurations are developed during the latter stages of design

- **Deployment Elements**

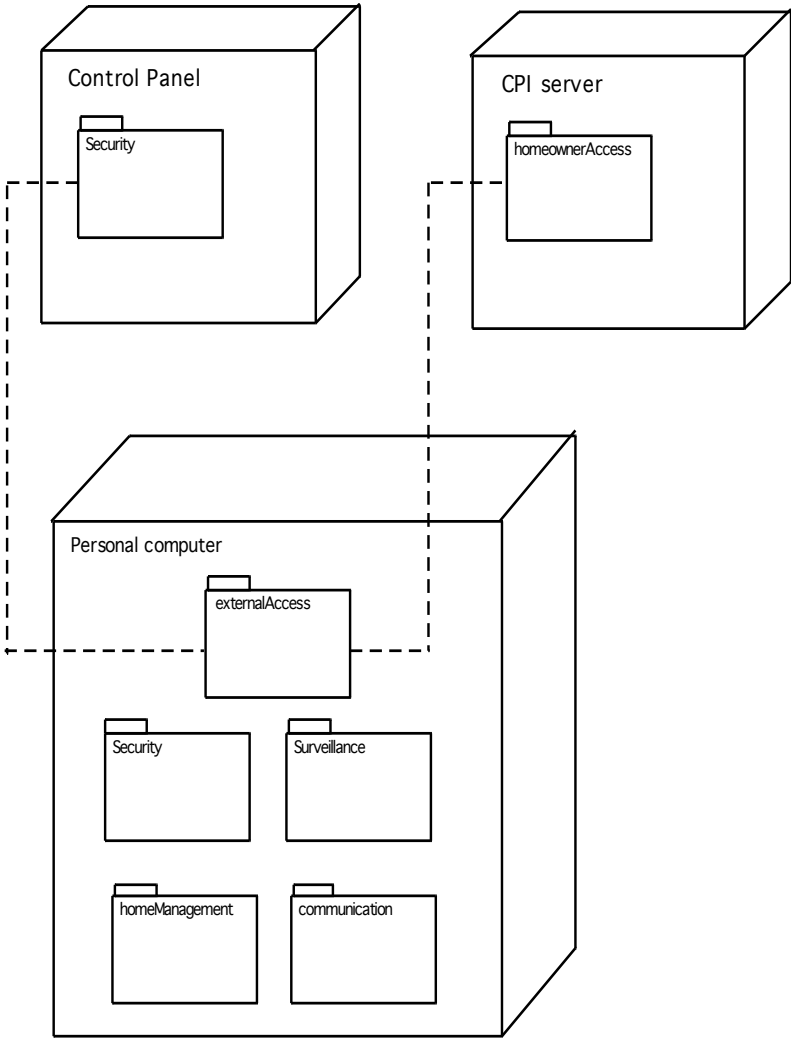


Figure 9.8 UML deployment diagram for *SafeHome*