Chapter 9
Design Engineering

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Roadmap of SEPA covered in CS550

- Ch 1 – Ch 5
  - 1. Intro to SE
  - 2. A Generic View of Process
  - 3. Process Models
  - 4. An Agile View of Process
  - 5. SE Practice
  - 6. System Engineering

- Ch 7- Ch 9
  - 7. Requirement Engineering
    - Req. eng tasks
    - Req. elicitation
    - Developing use-cases
    - Building the analysis model
  - 8. Building the Analysis Model
  - 9. Design Engineering

SafeHome Project
- Use-case diagram
- Use-cases
- Activity diagram

- Ch 10 – Ch 14
  - 10. Creating an Architectural Design
  - 11. Modeling Component-Level Design
  - 12. Performing UI Design
  - 13. Testing Strategies
  - 14. Testing Tactics

SafeHome Project
- Class diagram
- CRC cards
- Sequence diagram
- State diagram

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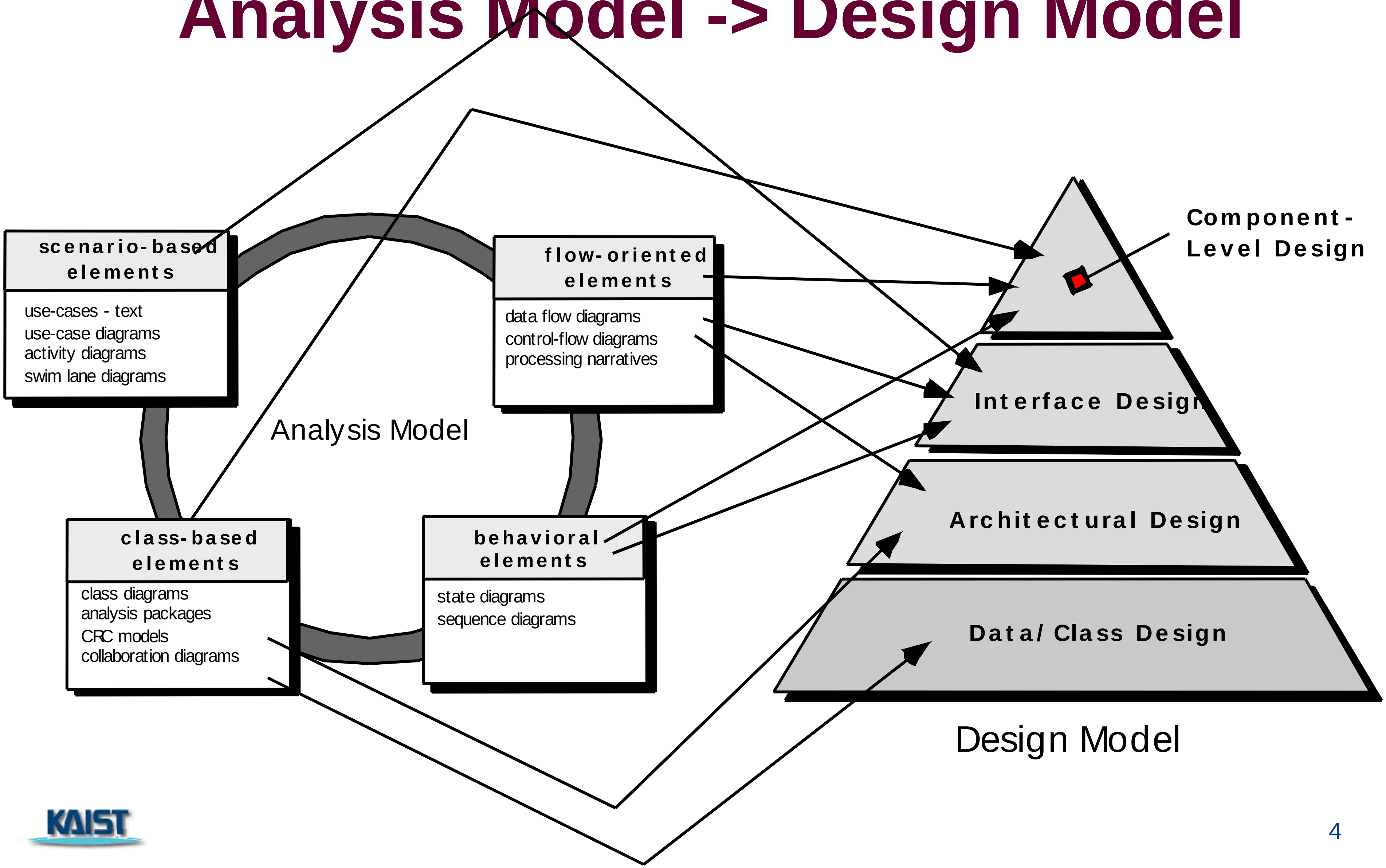
Overview of Ch 9. Design Engineering

- 9.1 Design within the Context of SE
- 9.2 Design Process and Design Quality
- 9.3 Design Concepts
  - Abstraction
  - Architecture
  - Patterns
  - Modularity
  - Information Hiding
  - Functional Independence
  - Refinement
  - Refactoring
  - Design Classes
- 9.4 Design Model
  - Data Design Elements
  - Architectural Design Elements
  - Interface Design Elements
  - Component-level Design Elements
  - Deployment-level Design Elements
- 9.5 Pattern-based SW Design
  - Describing a Design Pattern
  - Using Patterns in Design
  - Frameworks

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.

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Quality Guidelines

1. A design should exhibit an architecture which
   1. has been created using recognizable architectural styles or patterns,
   2. is composed of components that exhibit good design characteristics
   3. can be implemented in an evolutionary fashion
2. A design should be modular
3. A design should contain distinct representations of data, architecture, interfaces, and components.
4. A design should lead to data structures that are
   1. appropriate for the classes to be implemented
   2. drawn from recognizable data patterns.
5. A design should lead to components that exhibit independent functional characteristics.
6. A design should lead to interfaces that reduce the complexity of connections between components and with the external environment.
7. A design should be represented effectively for communicating its meaning.

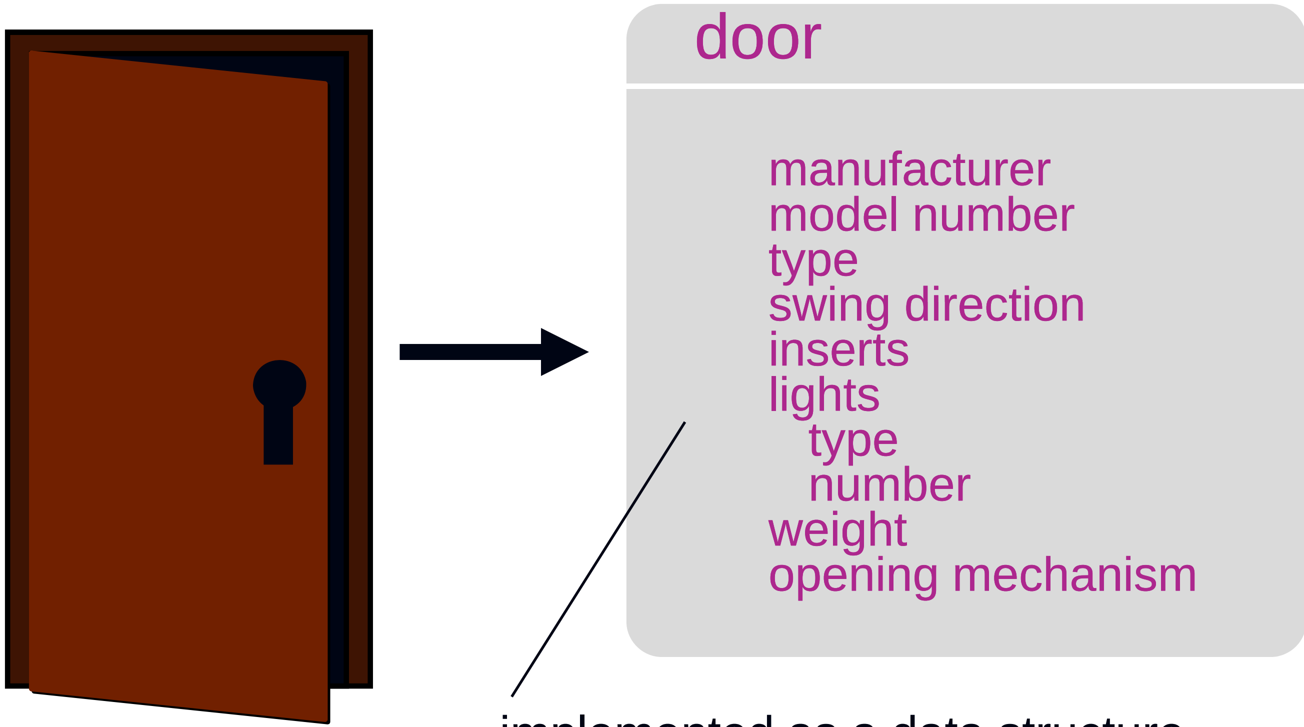
Quality Attributes – FURPS [GRA87]

- Functionality
  - Assessed by evaluating feature set and capabilities of the program and generality of the functions that are delivered
- Usability
  - Assessed by considering human factors, overall aesthetics
- Reliability
- Performance
- Supportability
  - Maintainability
  - Compatibility, ease of configuration, ease of installation, etc

Fundamental SW Design Concepts

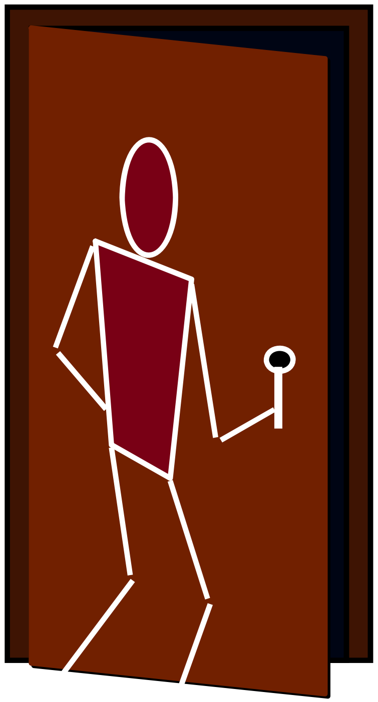
- Abstraction
  - data, procedure
- Patterns
  - “conveys the essence” of a proven design solution
- Modularity
  - compartmentalization of data and function
- Hiding
  - controlled interfaces
- Functional independence
  - single-minded function (cohesion) and low coupling
- Refinement
  - elaboration of detail for all abstractions
- Refactoring
  - a reorganization technique that simplifies the design

Data Abstraction



implemented as a data structure

Procedural Abstraction



open

details of enter algorithm

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

Design Patterns

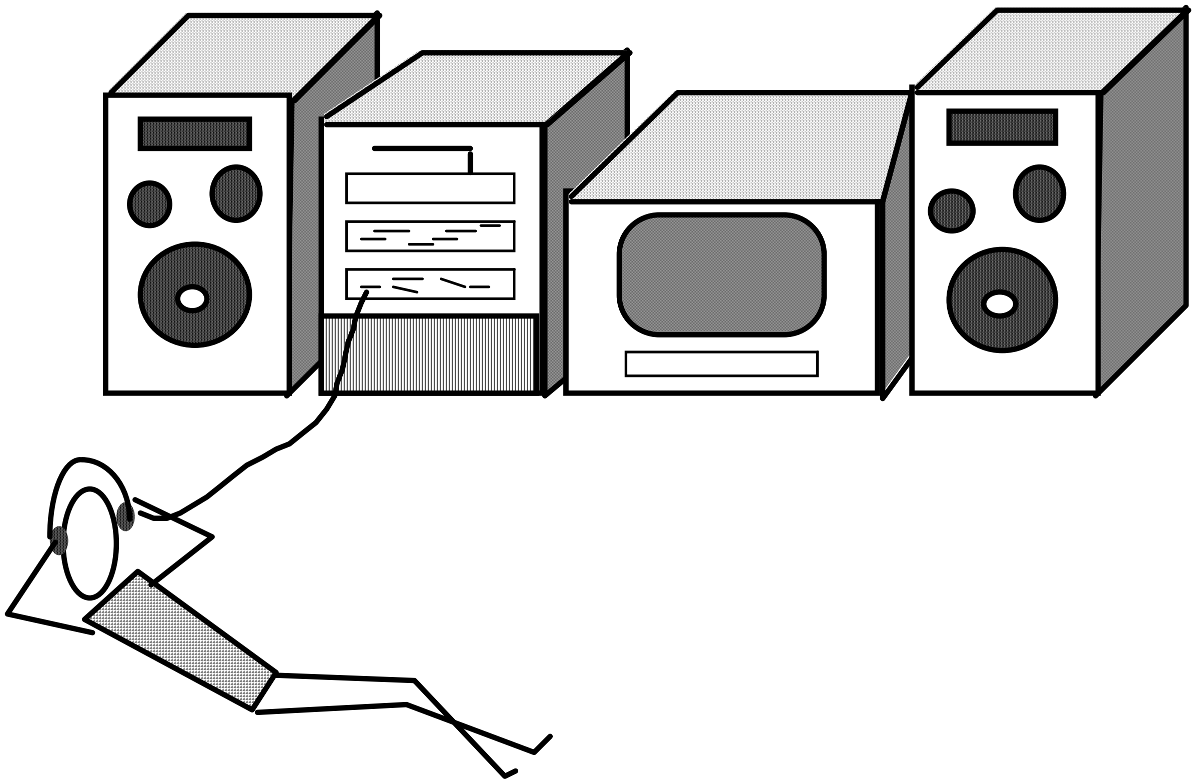
- The best designers in any field have an ability to see
  - patterns that characterize a problem
  - patterns that can be combined to create a solution
- A design pattern may also consider a set of design forces.
  - *Design forces* describe non-functional requirements (e.g., ease of maintainability, portability) associated the software for which the pattern is to be applied.
- The pattern characteristics (classes, responsibilities, and collaborations) indicate the attributes of the design that may be adjusted to enable the pattern to accommodate a variety of problems.
- Levels of abstraction
  - Architectural patterns
  - Design patterns
  - Idioms (coding patterns)

Design Patterns Template

- ***Pattern name***
  - describes the essence of the pattern in a short but expressive name
- ***Intent***
  - describes the pattern and what it does
- ***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
- ***Related patterns*****—cross-references related design patterns**

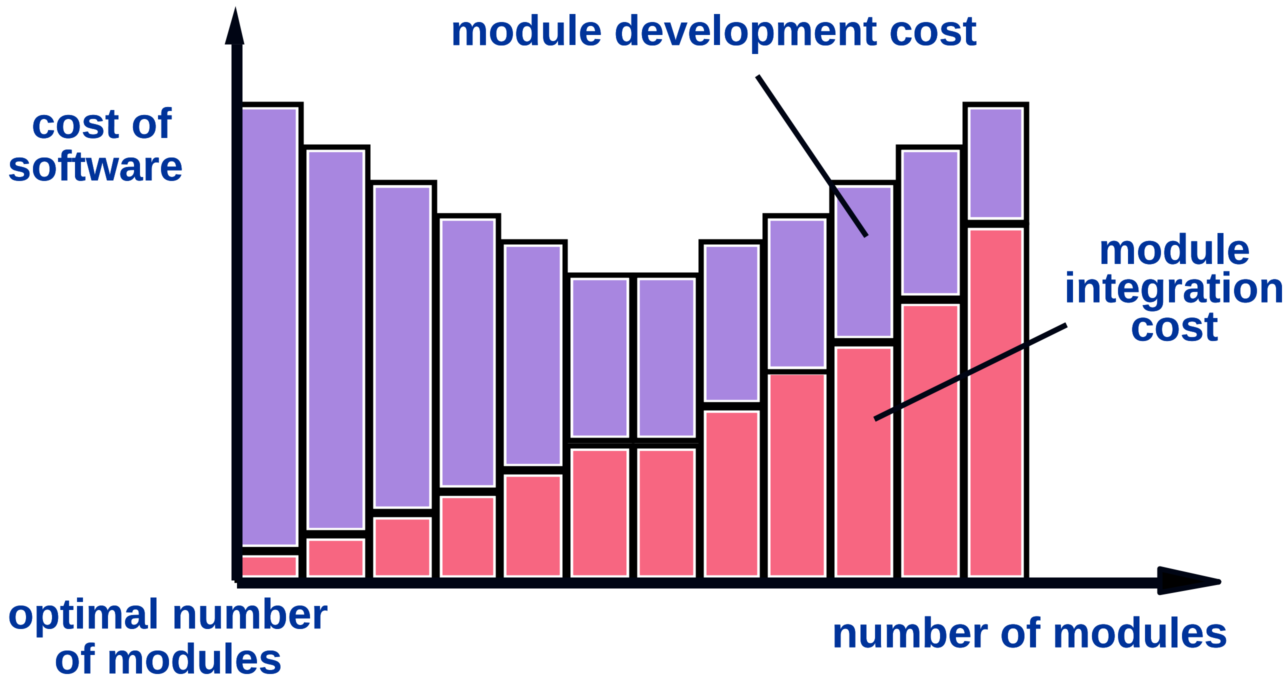
Modular Design

easier to build, easier to change, easier to fix ...

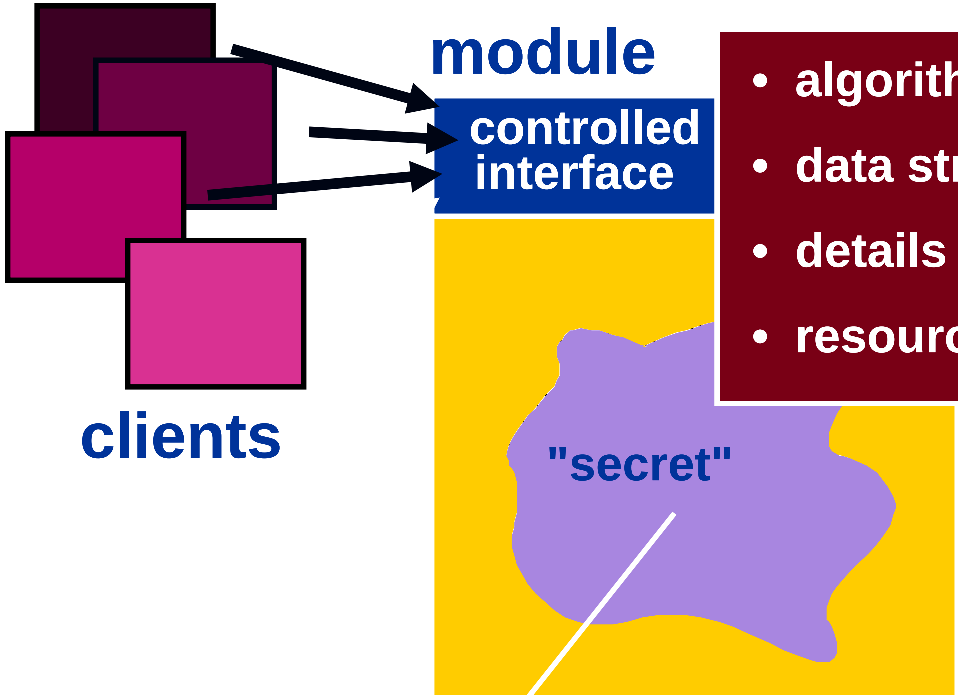


Modularity: Trade-offs

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



Information Hiding



- algorithm
- data structure
- details of external interface
- resource allocation policy

a specific design decision

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

open

walk to door;
reach for knob;

open door;

walk through;
close door.

repeat until door opens
turn knob clockwise;
if knob doesn't turn, then
    take key out;
    find correct key;
    insert in lock;
endif
pull/push door
move out of way;
end repeat

Refactoring

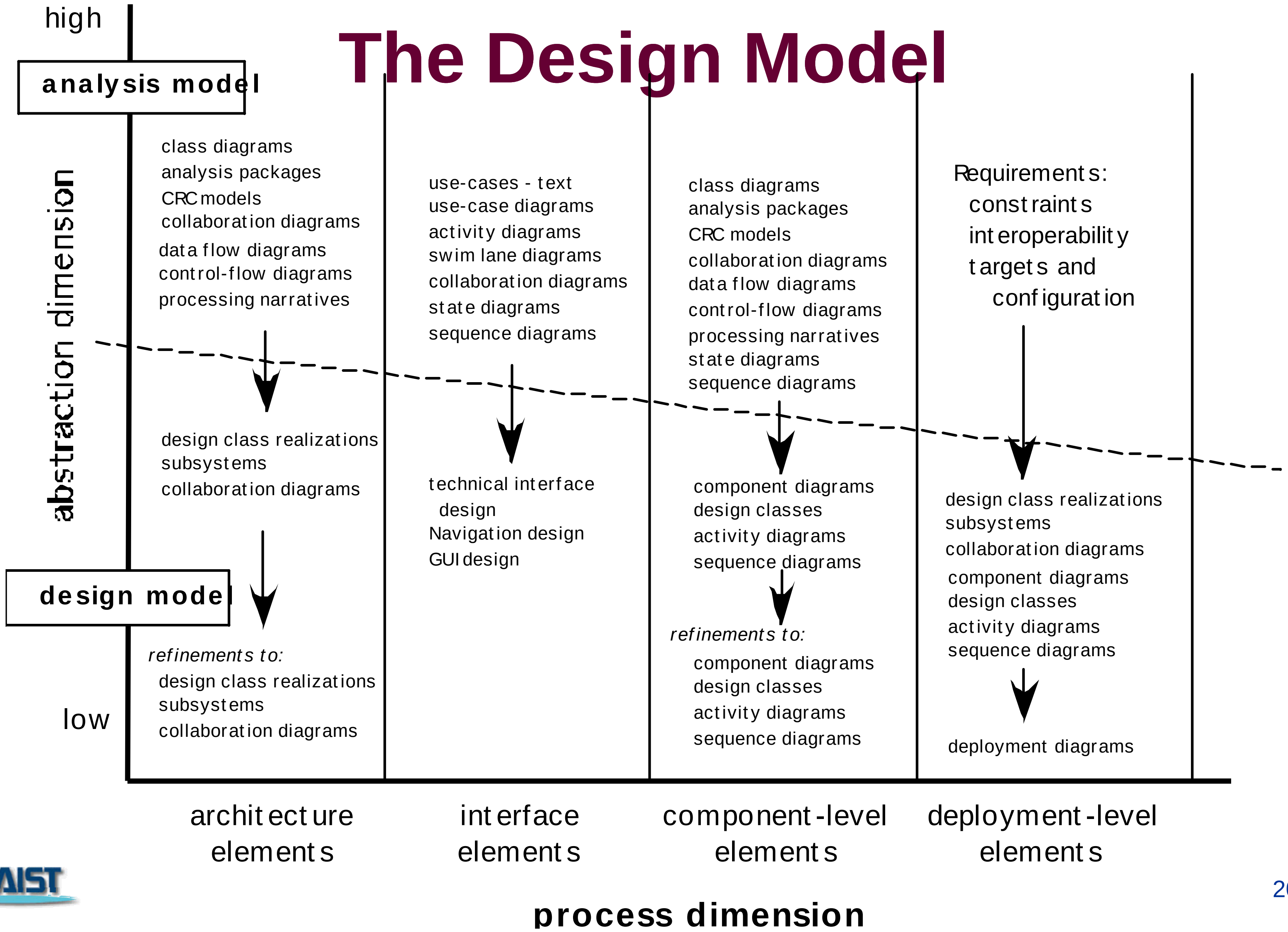
- Fowler [FOW99] defines refactoring in the following manner:
  - "Refactoring is the process of changing a software system in such a way that it does not alter the external behavior of the code [design] yet improves its internal structure."
- When software is refactored, the existing design is examined 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.

Functional Independence

COHESION - the degree to which a module performs one and only one function.

COUPLING - the degree to which a module is "connected" to other modules in the system.

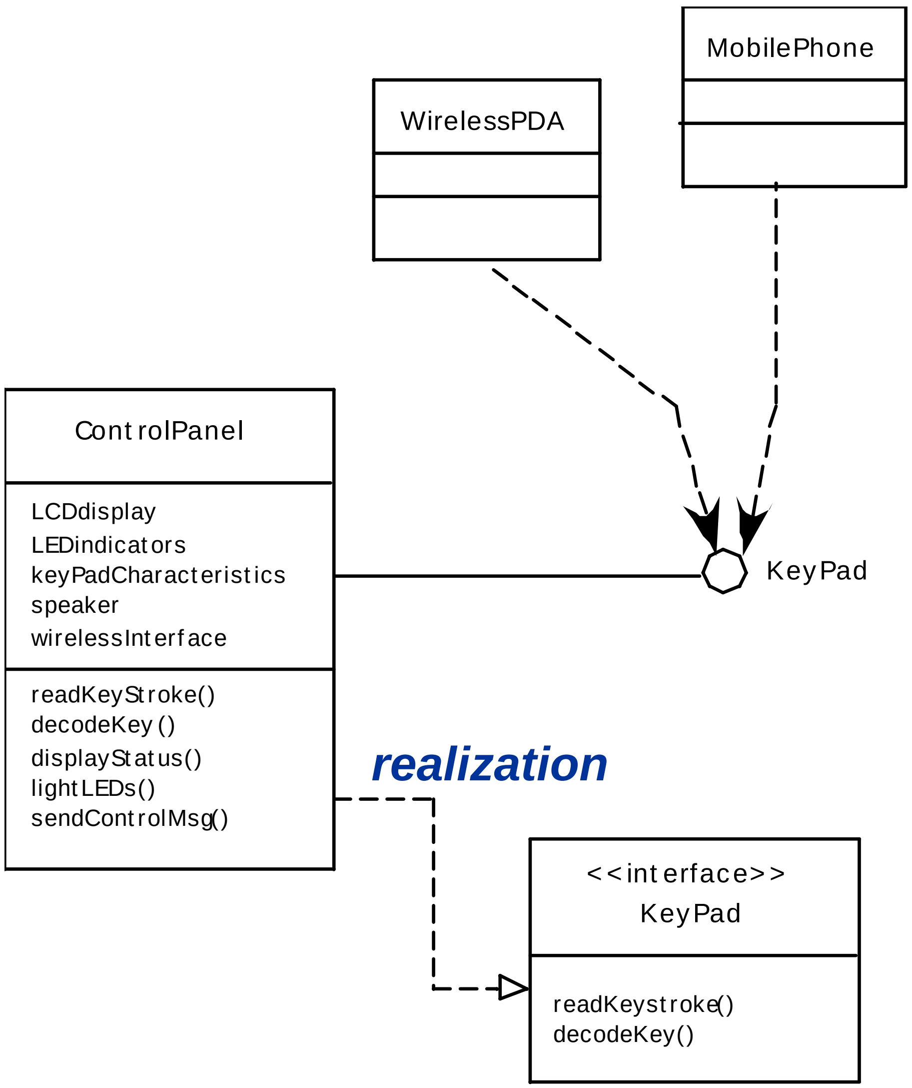
The Design Model



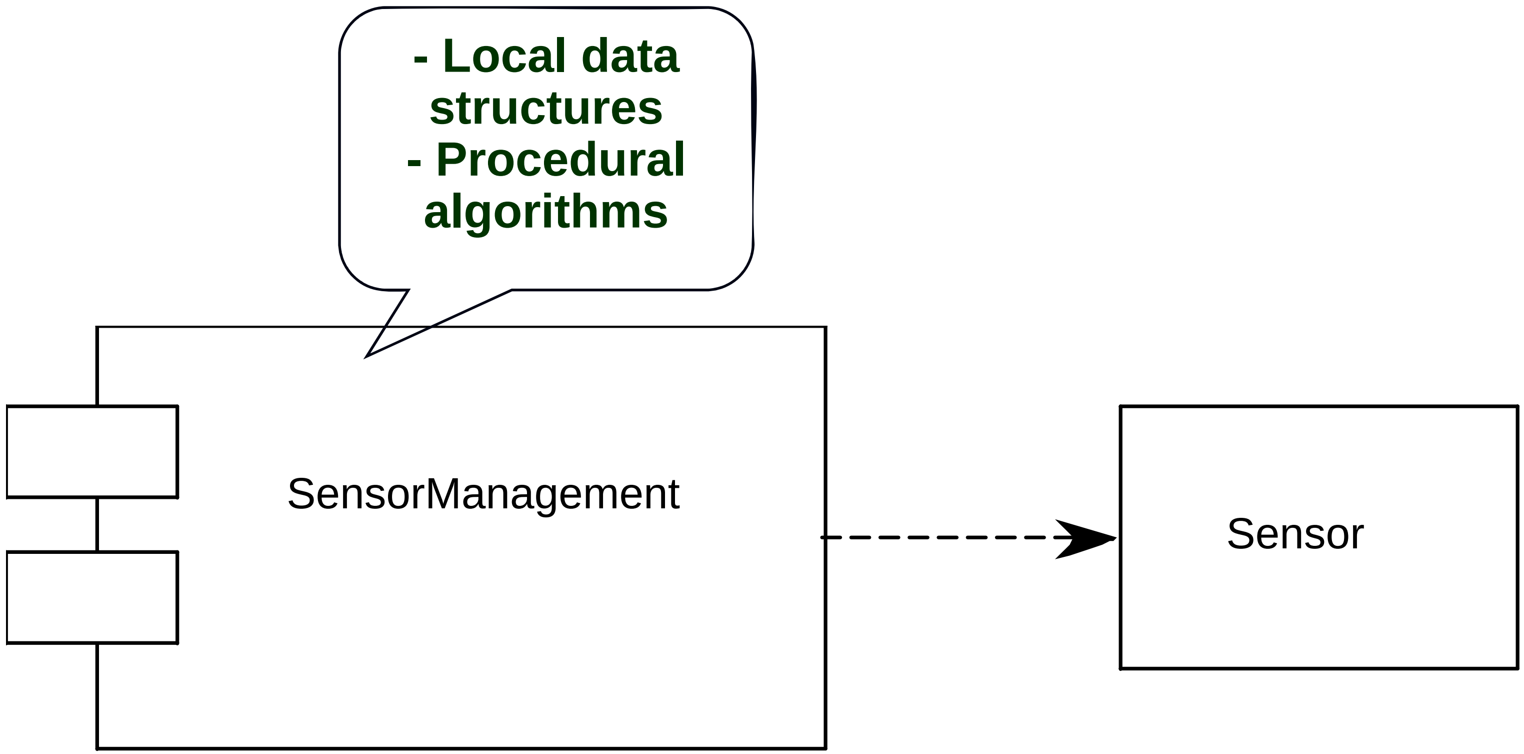
Design Model Elements

- Data elements
  - a model of data and/or information that is represented at a high level of abstraction (the customer/user's view of data)
  - Refined into more implementation-specific representations
- Architectural elements
  - Application domain
  - Analysis classes, their relationships, collaborations and behaviors are transformed into design realizations
  - Patterns and "styles" (Chapter 10)
- 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

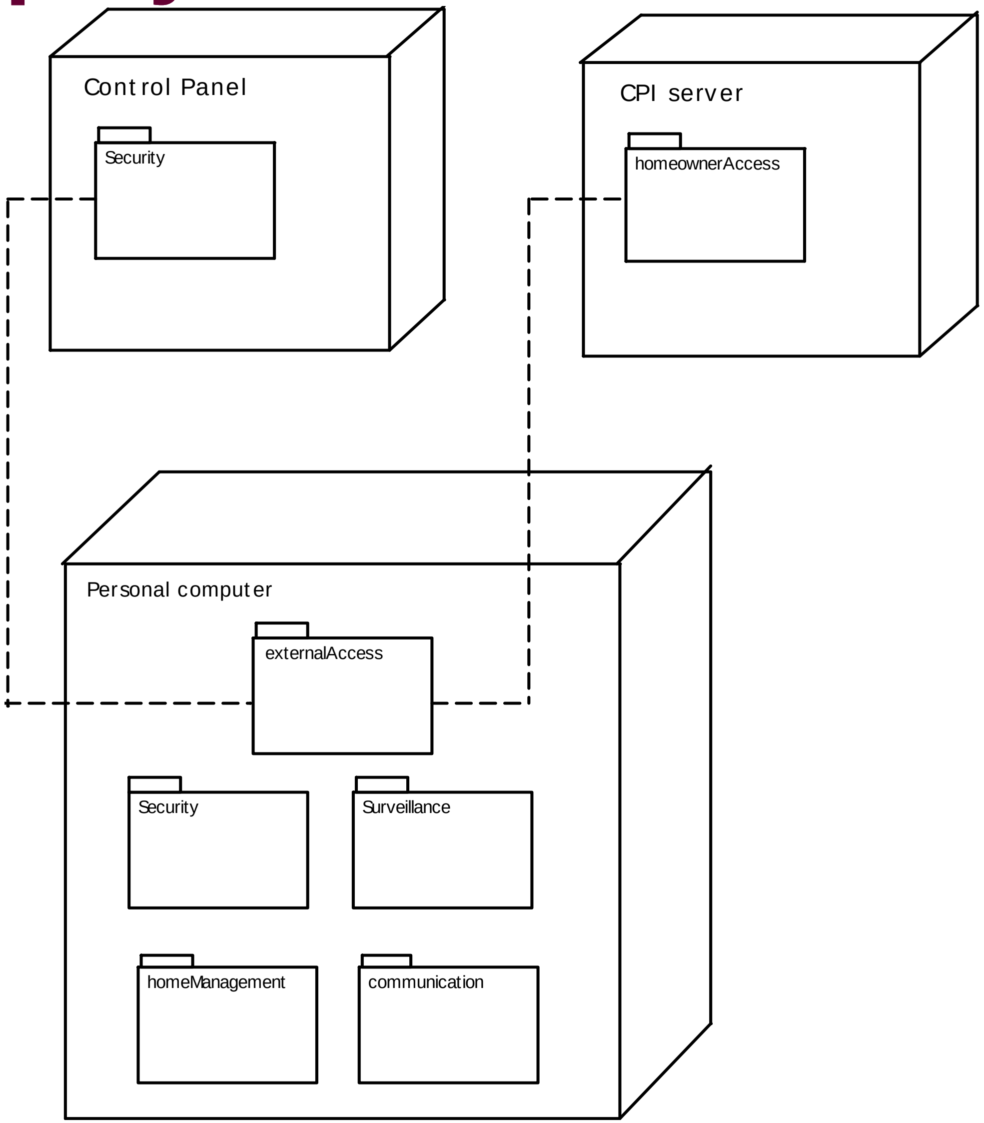
Interface Elements



Component Elements



Deployment Elements



Design Principles

- The design process should not suffer from 'tunnel vision.'
- The design should be ***traceable*** to the analysis model.
- 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 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]

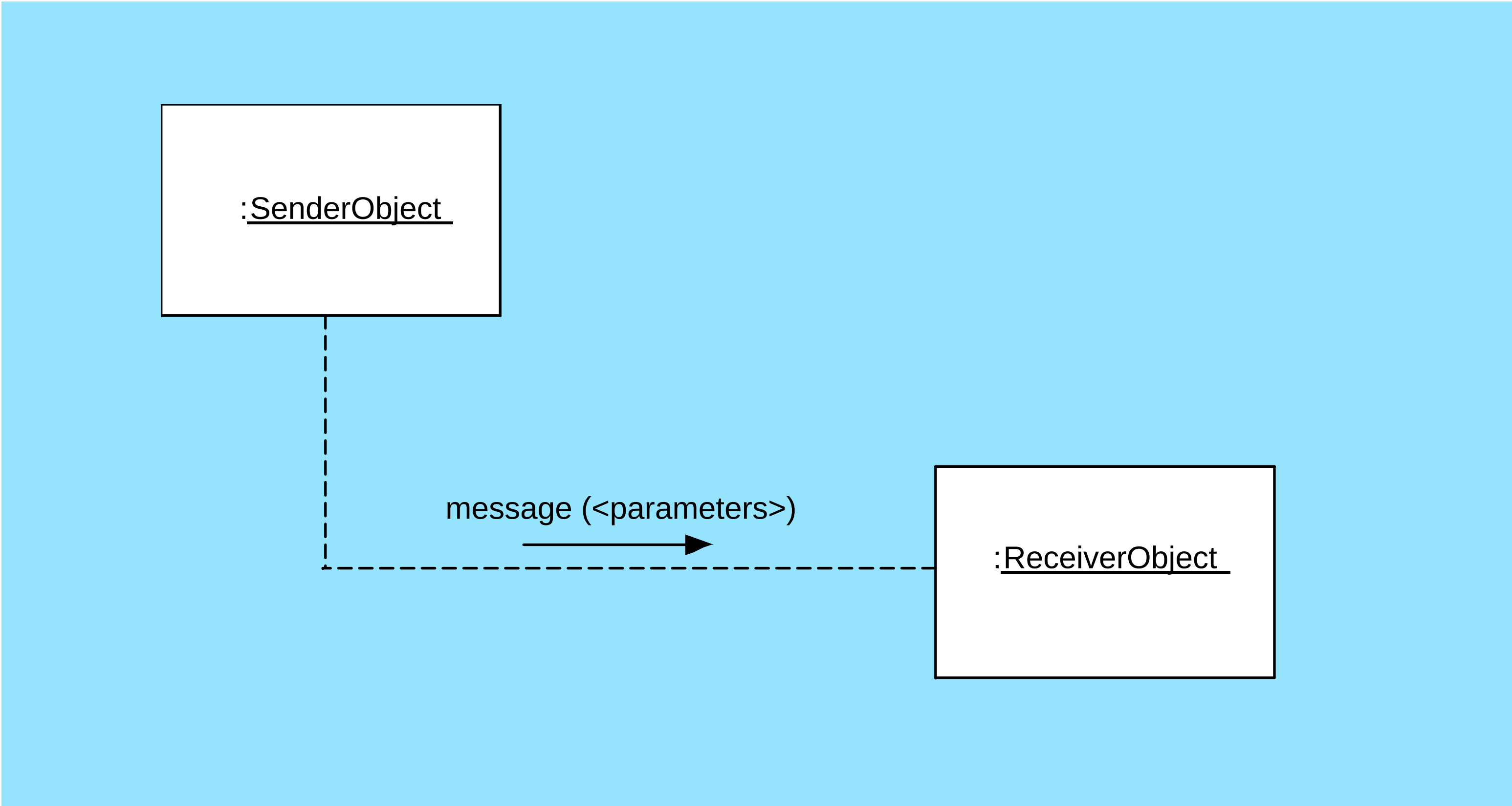
OO Design Concepts

- 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

Inheritance

- Design options:
  - The class can be designed and built from scratch. That is, inheritance is not used.
  - The class hierarchy can be searched to determine if a class higher in the hierarchy (a superclass)contains most of the required attributes and operations. The new class inherits from the superclass and additions may then be added, as required.
  - The class hierarchy can be restructured so that the required attributes and operations can be inherited by the new class.
  - Characteristics of an existing class can be overridden and different versions of attributes or operations are implemented for the new class.

Messages



Polymorphism

Conventional approach …

```
case of graphtype:
        if graphtype = linegraph then DrawLineGraph (data);
        if graphtype = piechart then DrawPieChart (data);
        if graphtype = histogram then DrawHisto (data);
        if graphtype = kiviat then DrawKiviat (data);
end case;
```

All of the graphs become subclasses of a general class called graph. Using a concept called overloading [TAY90], each subclass defines an operation called *draw*. An object can send a *draw* message to any one of the objects instantiated from any one of the subclasses. The object receiving the message will invoke its own *draw* operation to create the appropriate graph.

graphtype draw

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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.

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