Introduction to Software Engineering
(CS350)

Lecture 10

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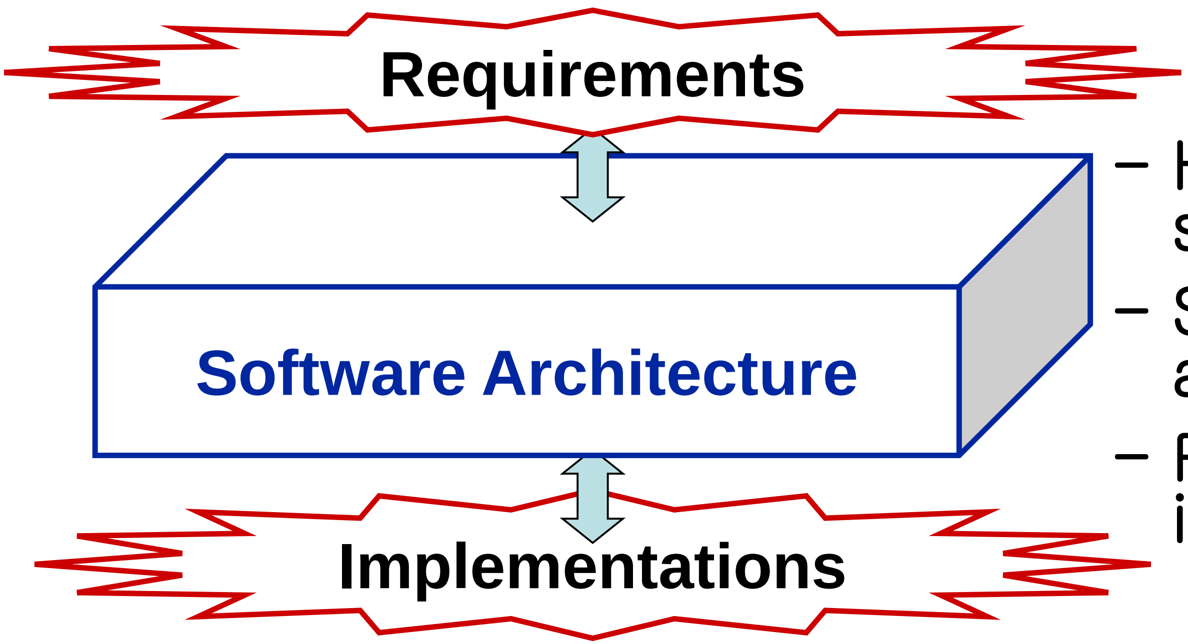
Architectural Design

What is a Software Architecture?

- "the structure or structures of the system, which comprise software components, the externally visible properties of those components, and the relationships among them" [Bas03]
- "A preliminary blueprint from which software is constructed"



- High level of system design
- System-level abstractions
- Reuse design idioms

David Galran, 2007

Why Architecture?

The architecture is not the operational software. Rather, it is a representation that enables a software engineer to:

(1) analyze the effectiveness of the design in meeting its stated requirements,

(2) consider architectural alternatives at a stage when making design changes is still relatively easy, and

(3) reduce the risks associated with the construction of the software.

Why is Architecture Important?

- Representations of software architecture are an enabler for communication between all parties (stakeholders) interested in the development of a computer-based system.
- The architecture highlights early design decisions that will have a profound impact on all software engineering work that follows and, as important, on the ultimate success of the system as an operational entity.
- Architecture “constitutes a relatively small, intellectually graspable mode of how the system is structured and how its components work together” [BAS03].

Architectural Descriptions

- The IEEE Computer Society has proposed IEEE-Std-1471-2000, *Recommended Practice for Architectural Description of Software-Intensive System*, [IEE00], with the following objectives
  - to establish a conceptual framework and vocabulary for use during the design of software architecture,
  - to provide detailed guidelines for representing an architectural description, and
  - to encourage sound architectural design practices.

- The IEEE Standard defines an *architectural description* (AD) as a "a collection of products to document an architecture."
  - The description itself is represented using multiple views, where each *view* is "a representation of a whole system from the perspective of a related set of [stakeholder] concerns."

Architectural Genres

- *Genre* implies a specific category within the overall software domain.

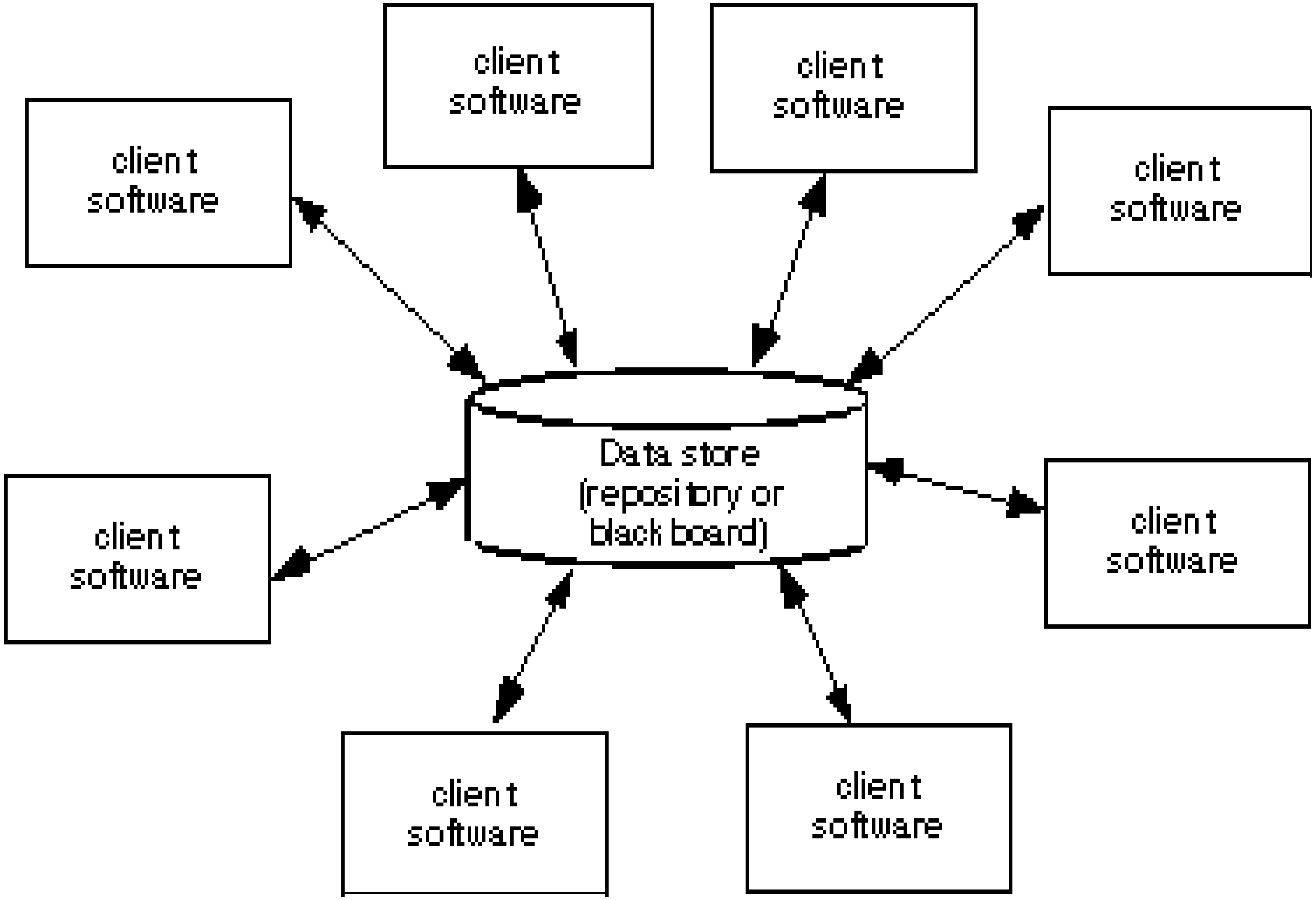
- Within each category, you encounter a number of subcategories.
  - For example, within the genre of *buildings*, you would encounter the following general styles: houses, condos, apartment buildings, office buildings, industrial building, warehouses, and so on.
  - Within each general style, more specific styles might apply. Each style would have a structure that can be described using a set of predictable patterns.

Architectural Styles

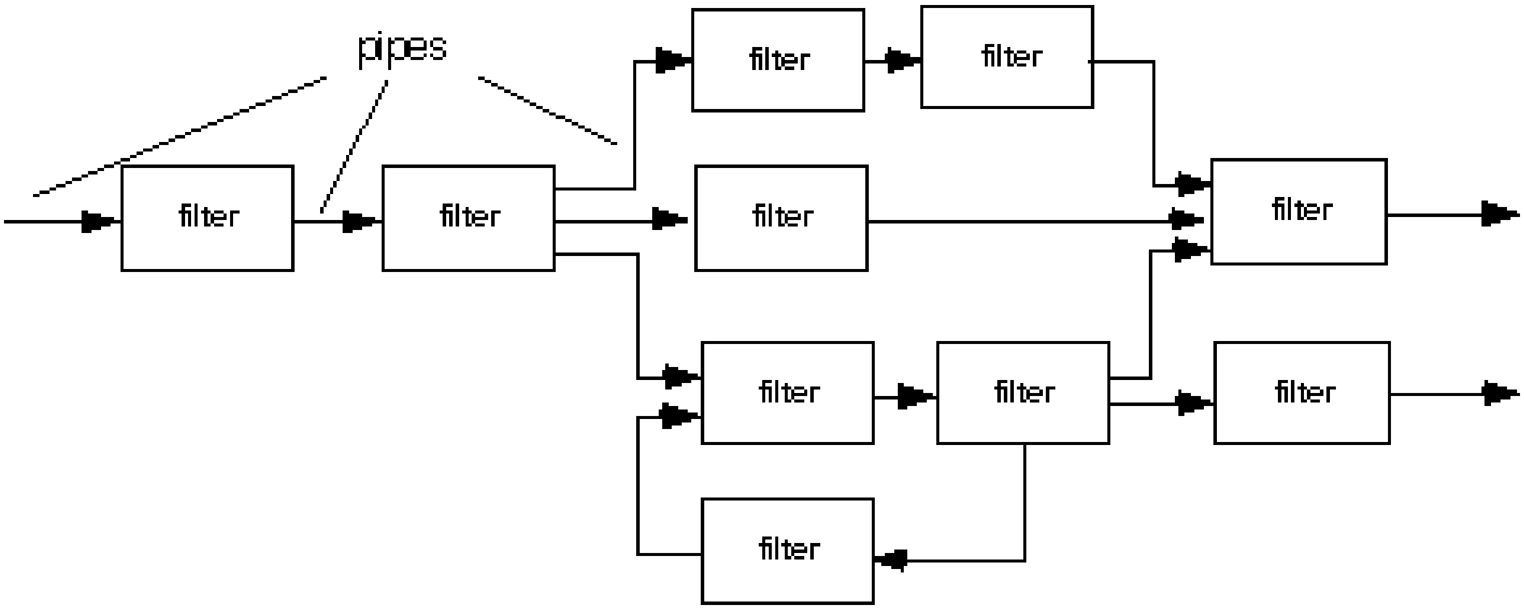
Each style describes a system category that encompasses: (1) **a set of components** (e.g., a database, computational modules) that perform a function required by a system, (2) **a set of connectors** that enable “communication, coordination and cooperation” among components, (3) **constraints** that define how components can be integrated to form the system, and (4) **semantic models** that enable a designer to understand the overall properties of a system by analyzing the known properties of its constituent parts.

- Data-centered architectures
- Data flow architectures
- Call and return architectures
- Object-oriented architectures
- Layered architectures

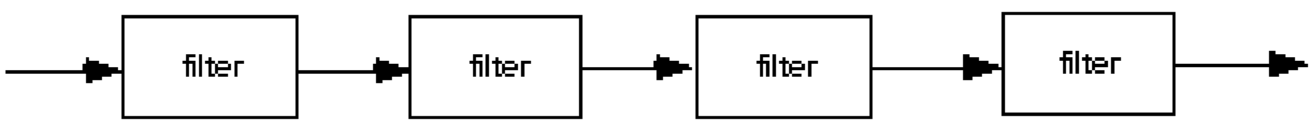
Data-Centered Architecture



Data Flow Architecture

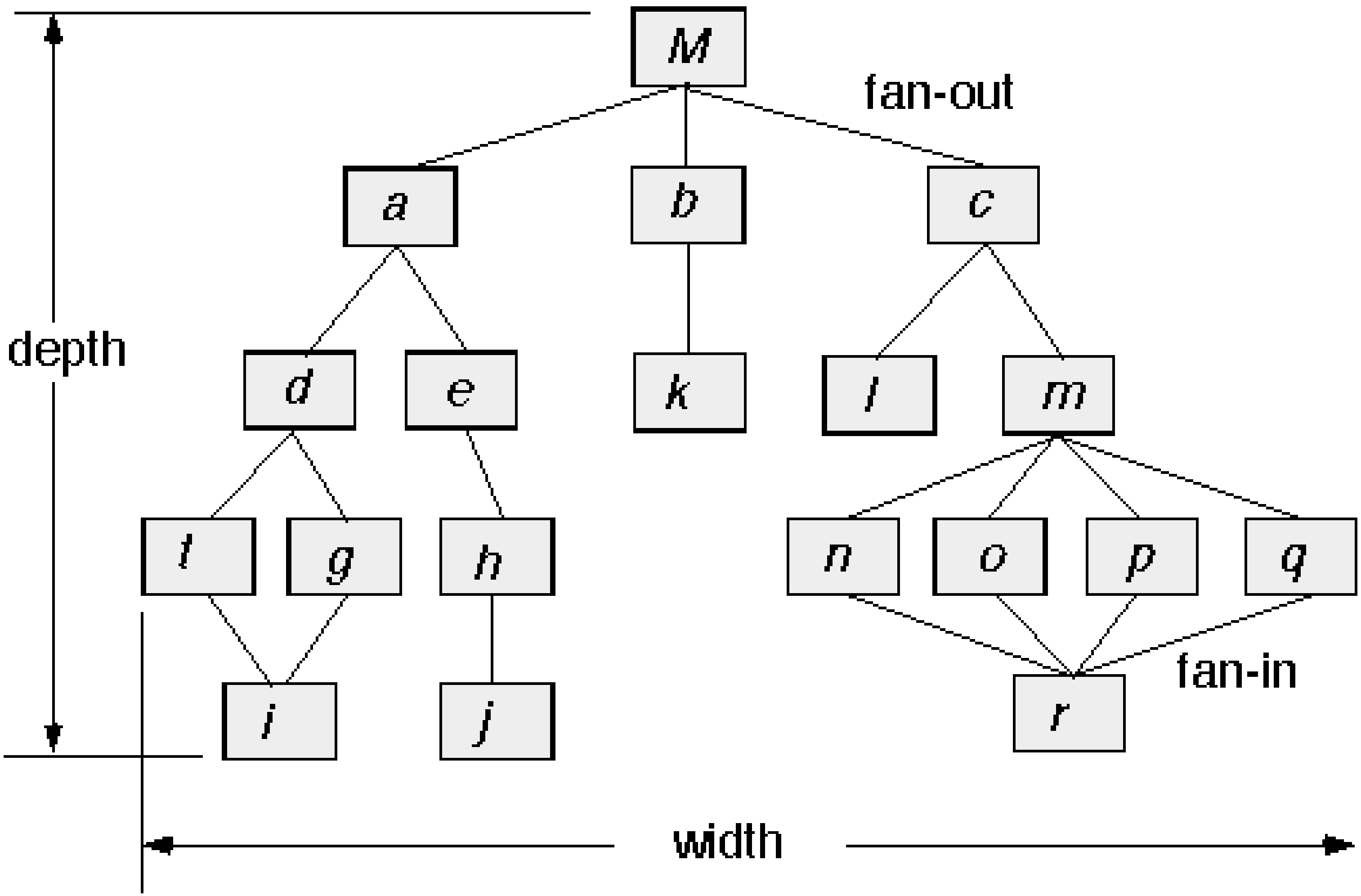


(a) pipes and filters

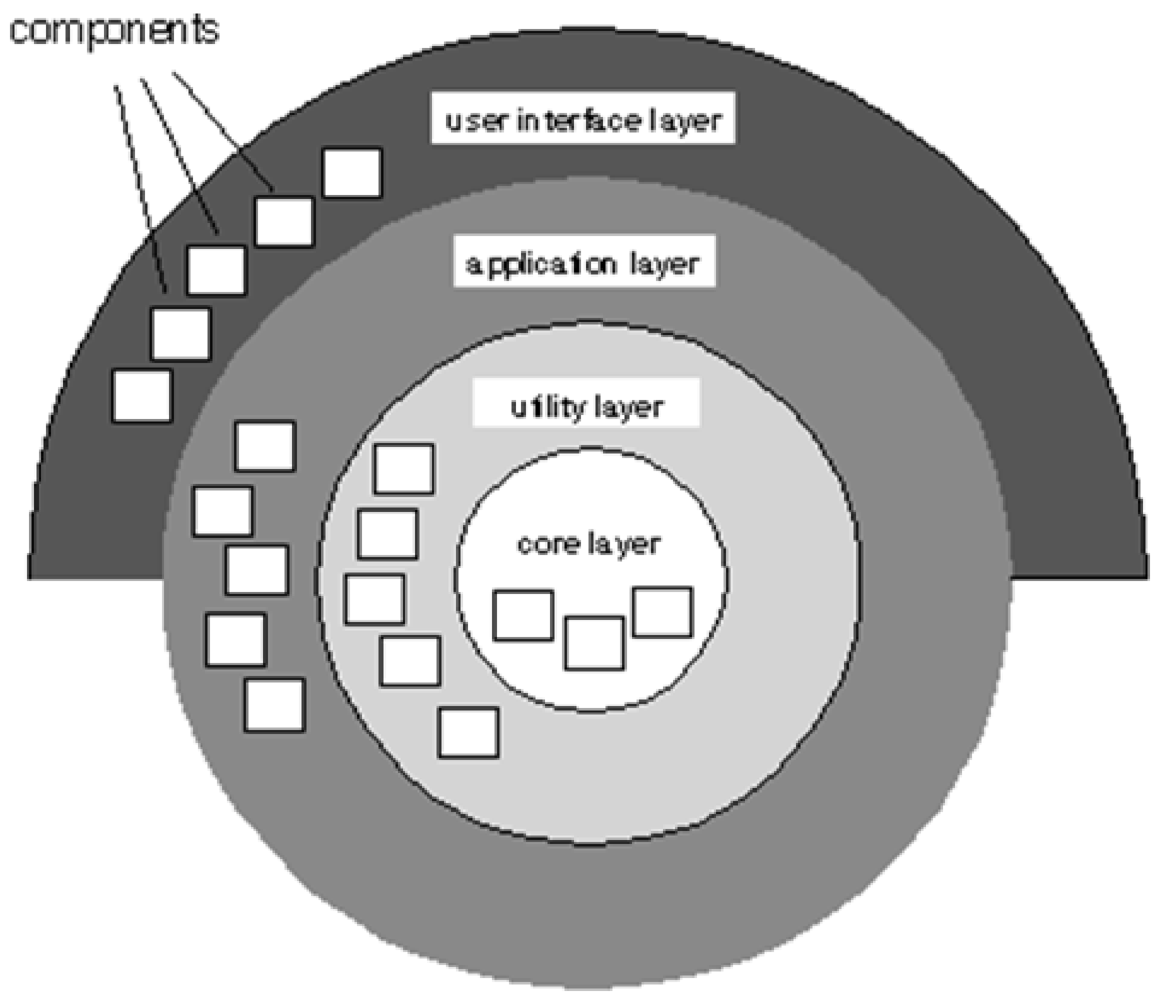


(b) batch sequential

Call and Return Architecture



Layered Architecture



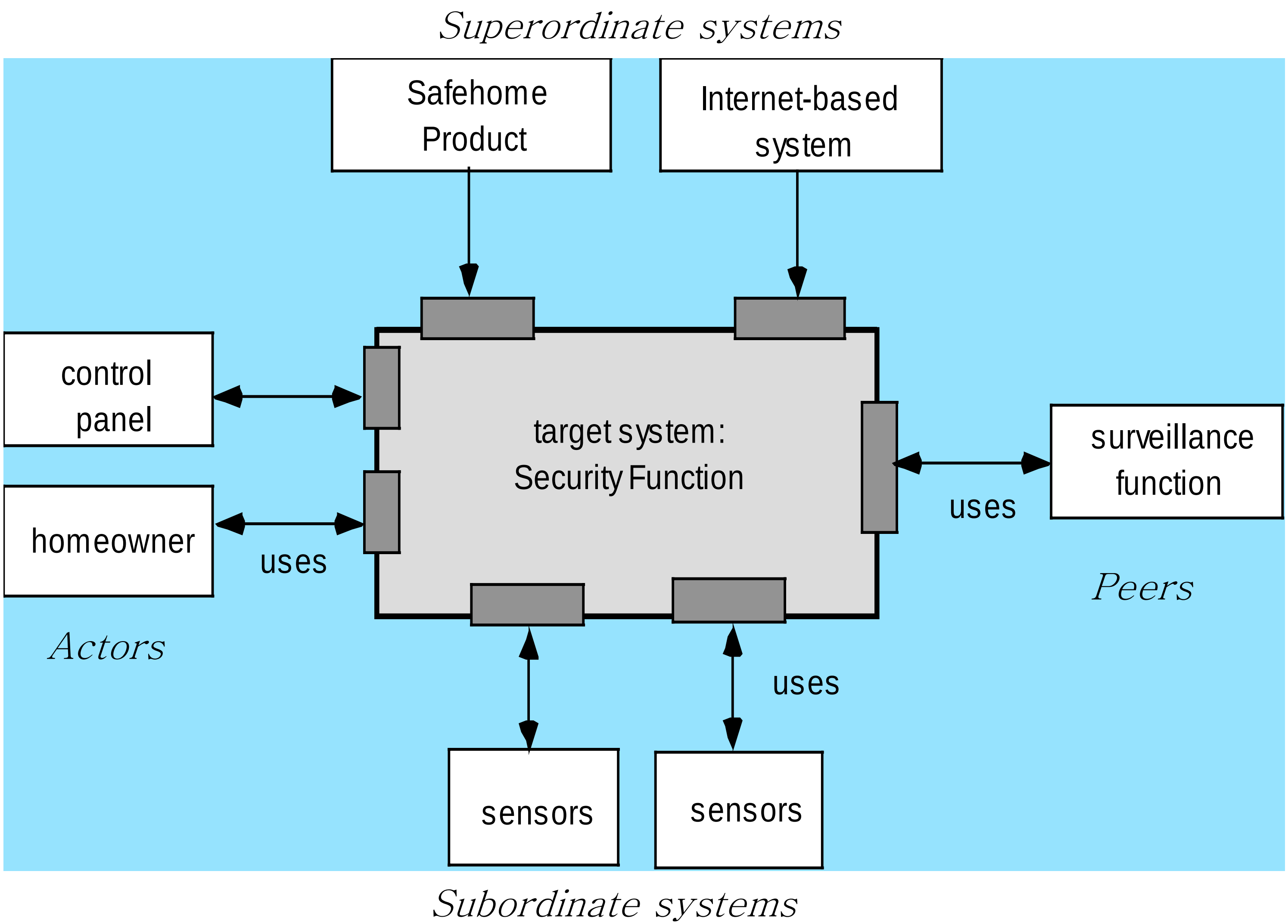
Architectural Patterns

- Concurrency—applications must handle multiple tasks in a manner that simulates parallelism
  - *operating system process management* pattern
  - *task scheduler* pattern
- Persistence—Data persists if it survives past the execution of the process that created it. Two patterns are common:
  - a *database management system* pattern that applies the storage and retrieval capability of a DBMS to the application architecture
  - an *application level persistence* pattern that builds persistence features into the application architecture
- Distribution— the manner in which systems or components within systems communicate with one another in a distributed environment
  - A *broker* acts as a 'middle-man' between the client component and a server component.

Architectural Design

- As architecture begins, the software must be placed into context
  - the design should define the external entities (other systems, devices, people) that the software interacts with and the nature of the interaction
- Once context is modeled, identify a set of architectural archetypes
  - An *archetype* is an abstraction (similar to a class) that represents one element of system behavior
- The designer specifies the structure of the system by defining and refining software components that implement each archetype

Architectural Context



Archetypes

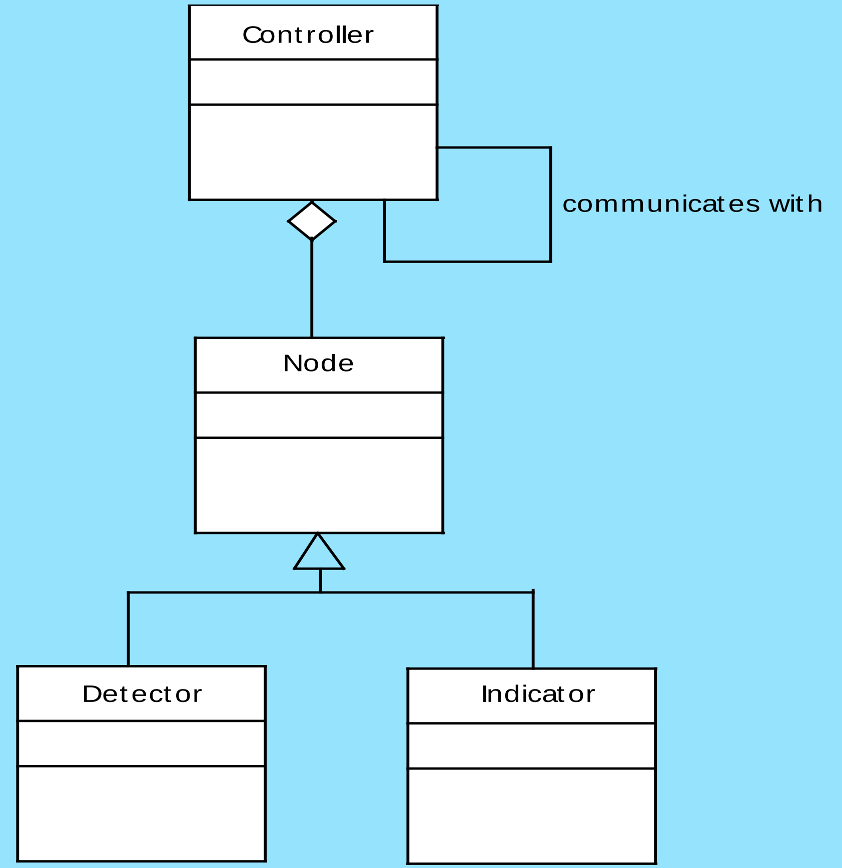
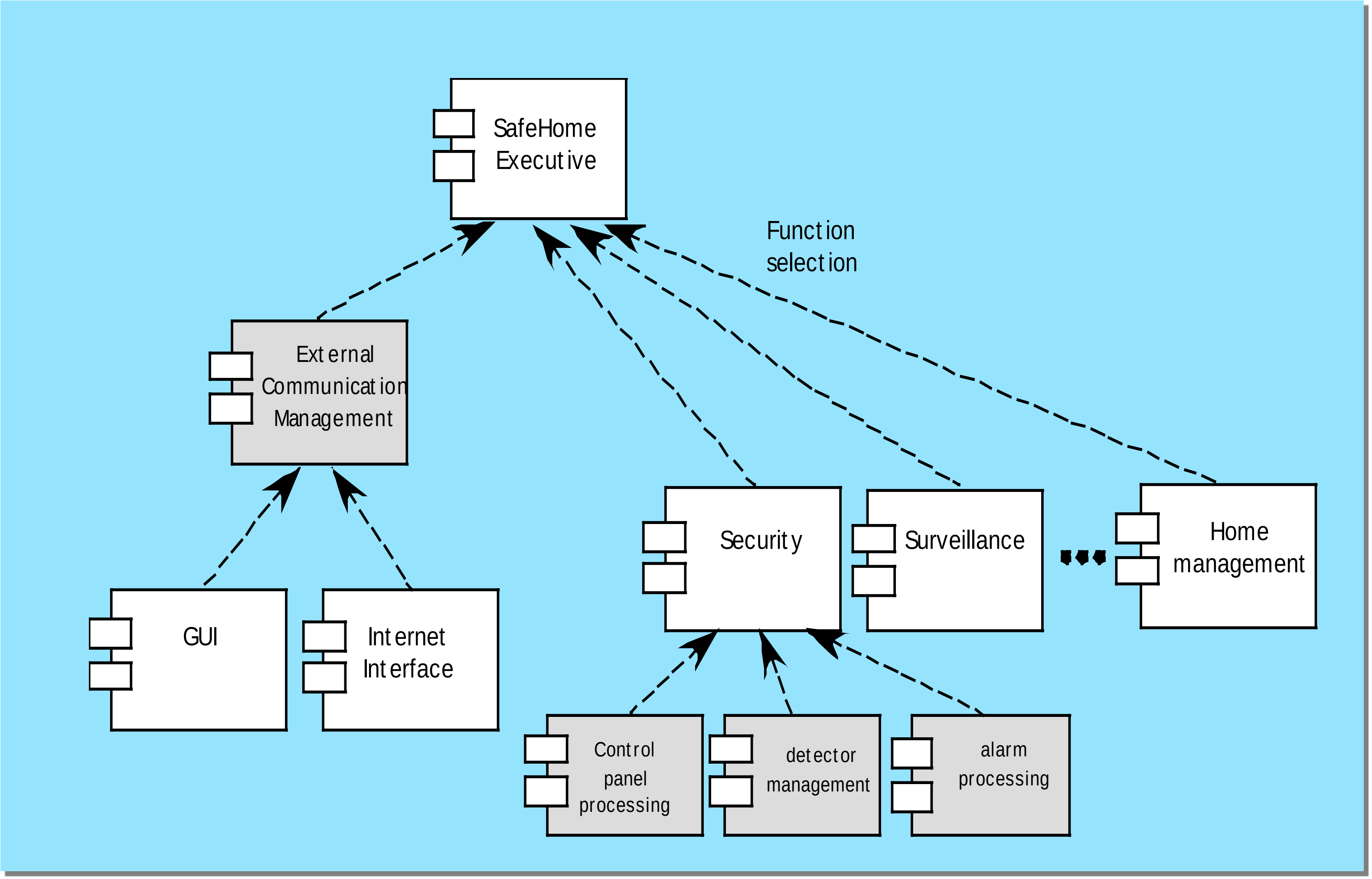
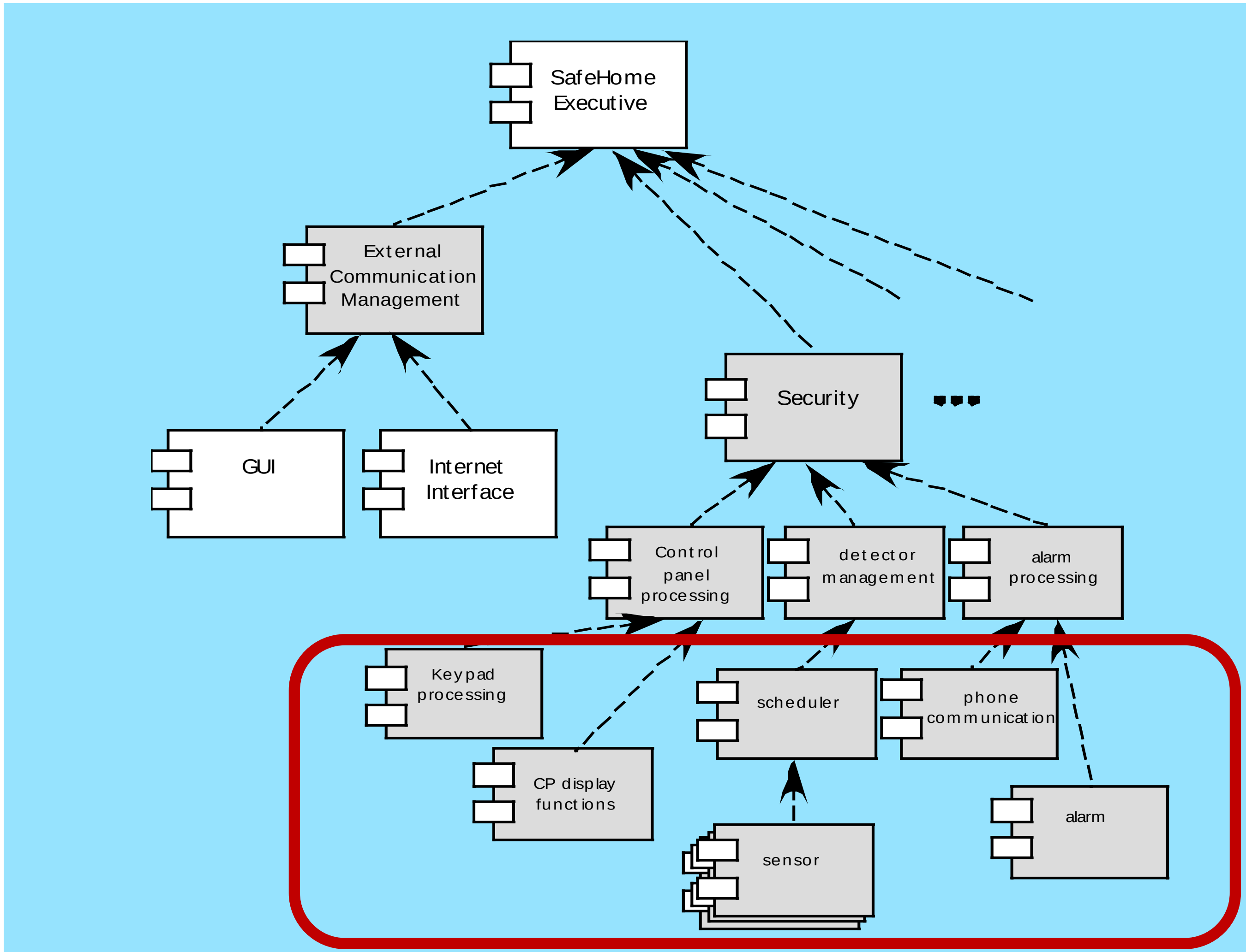


Figure 10.7 UML relationships for SafeHome security function archetypes (adapted from [BOS00])

Component Structure



Refined Component Structure



Analyzing Architectural Design

1. Collect scenarios.
2. Elicit requirements, constraints, and environment description.
3. Describe the architectural styles/patterns that have been chosen to address the scenarios and requirements:
   - Module view
   - Process view
   - Data flow view
4. Evaluate quality attributes by considering each attribute in isolation.
5. Identify the sensitivity of quality attributes to various architectural attributes for a specific architectural style.
6. Critique candidate architectures (developed in step 3) using the sensitivity analysis conducted in step 5.

Architectural Complexity

- the overall complexity of a proposed architecture is assessed by considering the dependencies between components within the architecture [Zha98]
  - *Sharing dependencies* represent dependence relationships among consumers who use the same resource or producers who produce for the same consumers.
  - *Flow dependencies* represent dependence relationships between producers and consumers of resources.
  - *Constrained dependencies* represent constraints on the relative flow of control among a set of activities.

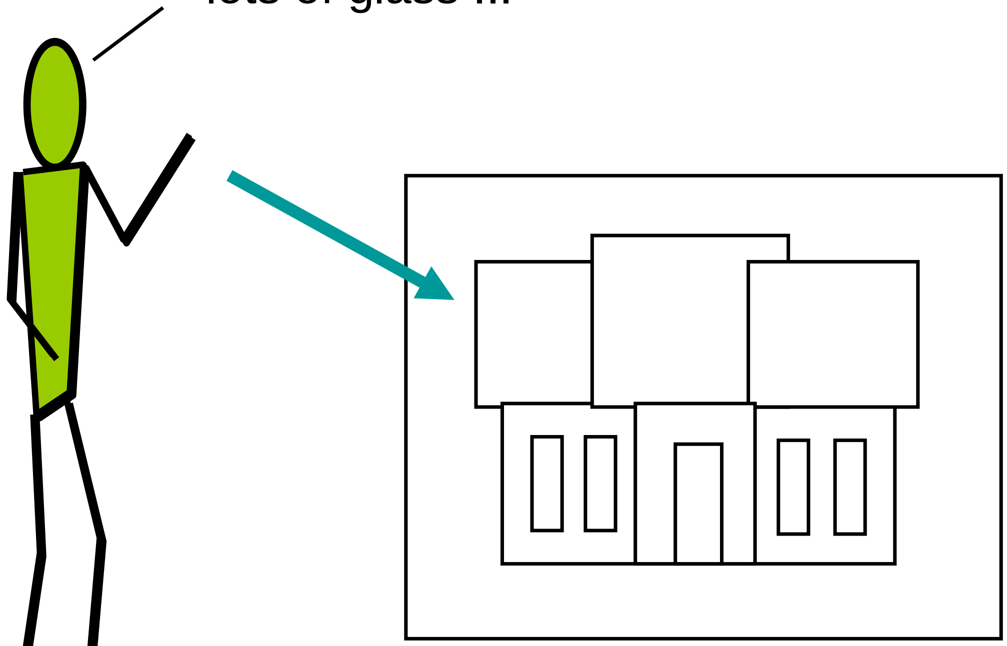
ADL

- *Architectural description language* (ADL) provides a semantics and syntax for describing a software architecture
- Provide the designer with the ability to:
  - decompose architectural components
  - compose individual components into larger architectural blocks and
  - represent interfaces (connection mechanisms) between components.
- Example: AADL (SAE standard), Wright & ACME (Carnegie Mellon), xADL (UCI), Darwin (Imperial College), DAOP-ADL (University of Málaga), etc.
- Common elements: component, connector and configuration

An Architectural Design Method

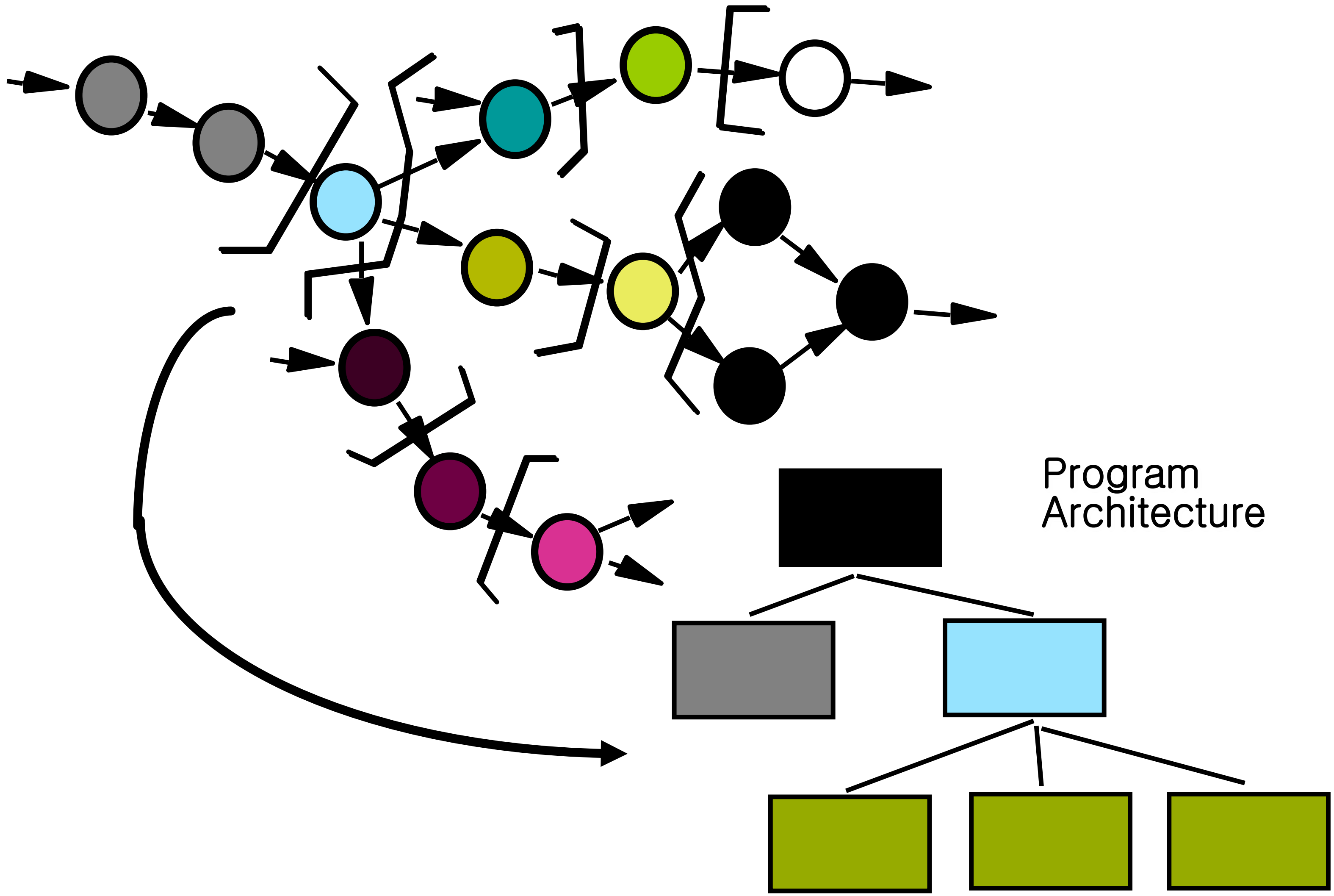
customer requirements

"four bedrooms, three baths,
lots of glass ..."



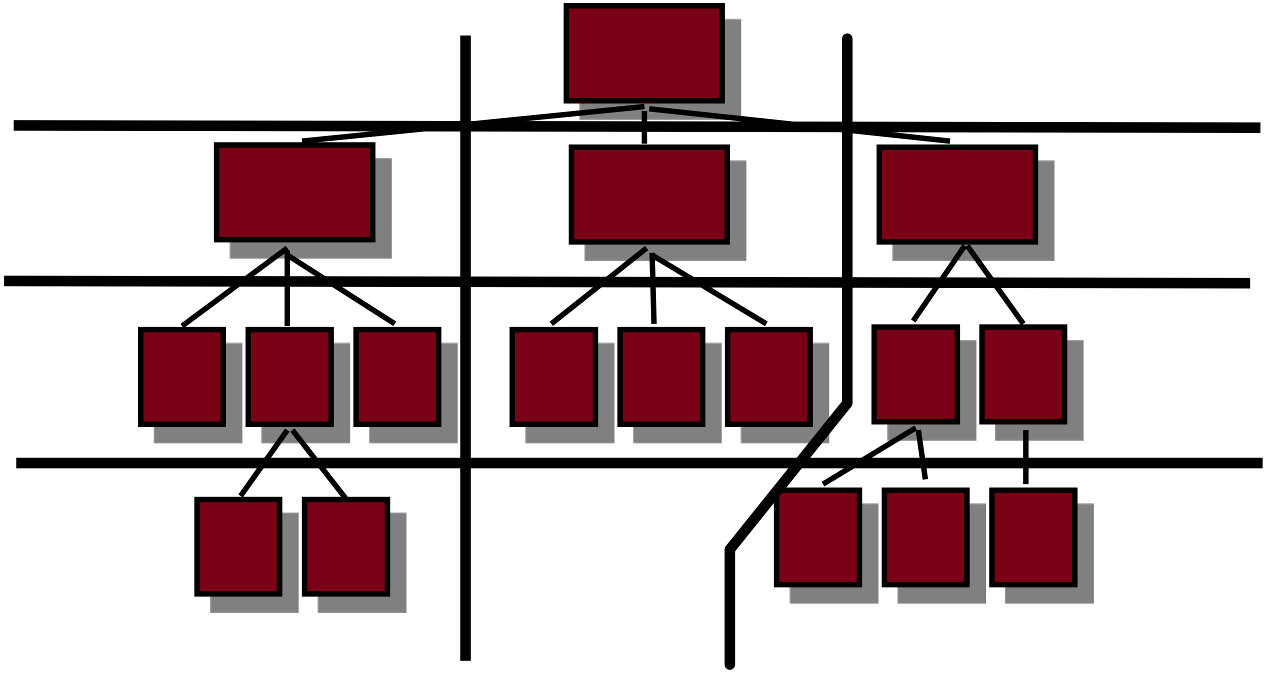
architectural design

Deriving Program Architecture



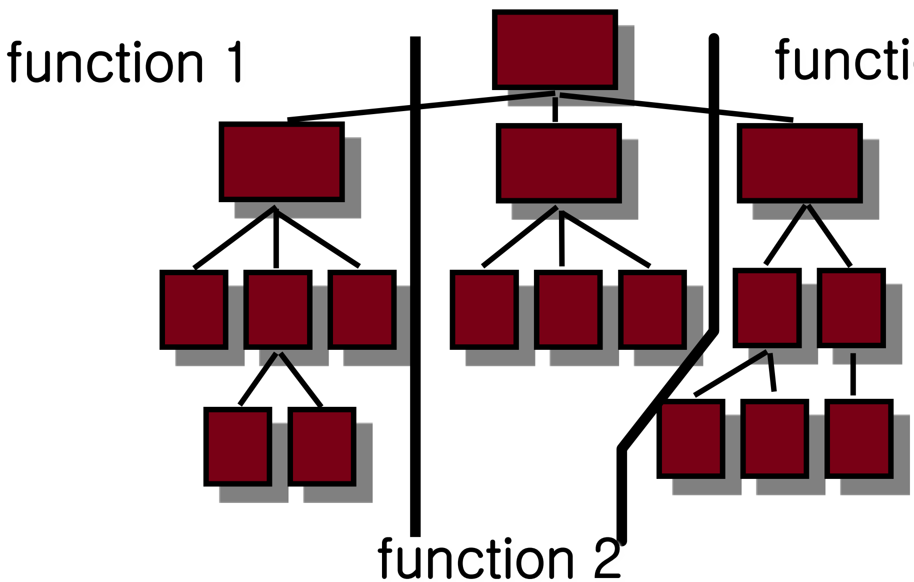
Partitioning the Architecture

- "horizontal" and "vertical" partitioning are required



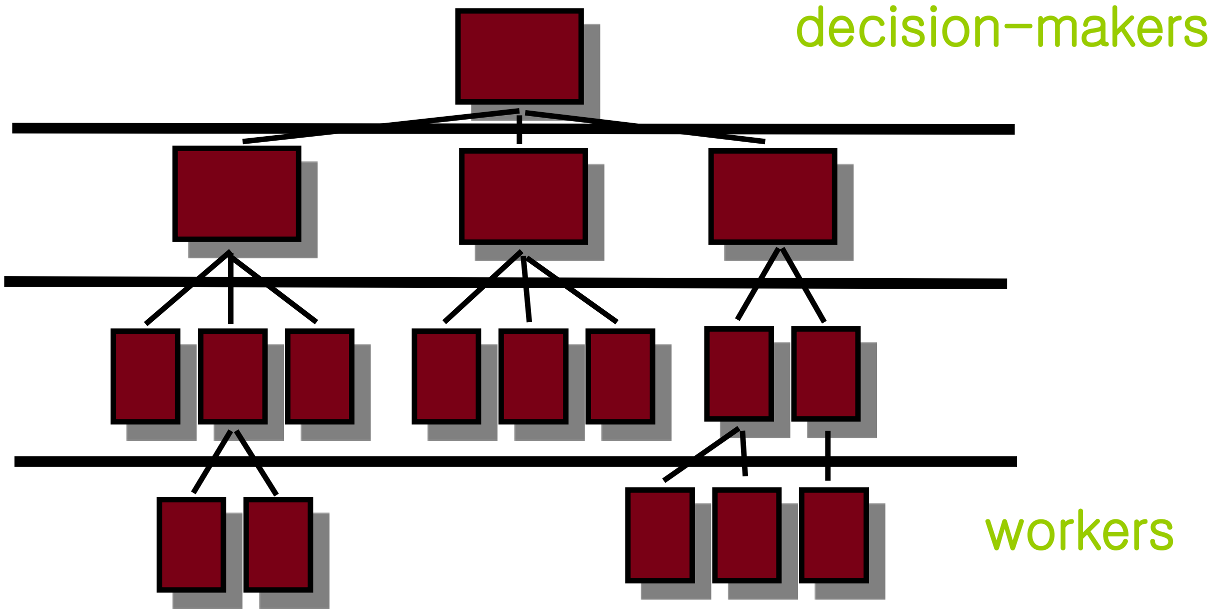
Horizontal Partitioning

- define separate branches of the module hierarchy for each major function
- use control modules to coordinate communication between functions



Vertical Partitioning: Factoring

- design so that decision making and work are stratified
- decision making modules should reside at the top of the architecture



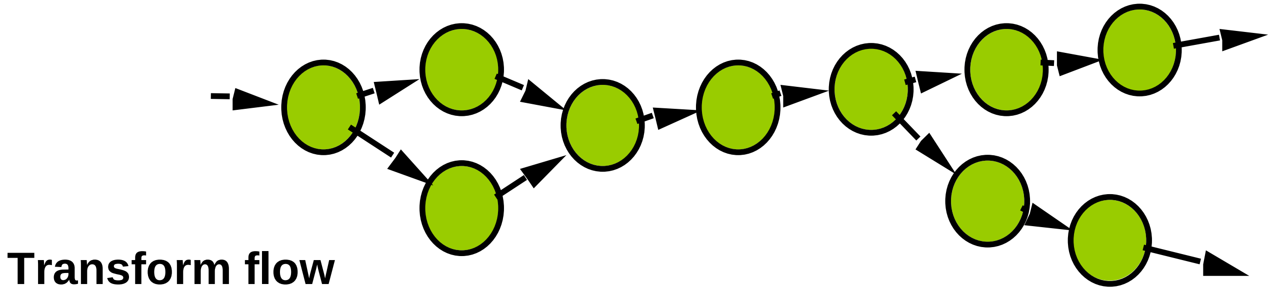
Why Partitioned Architecture?

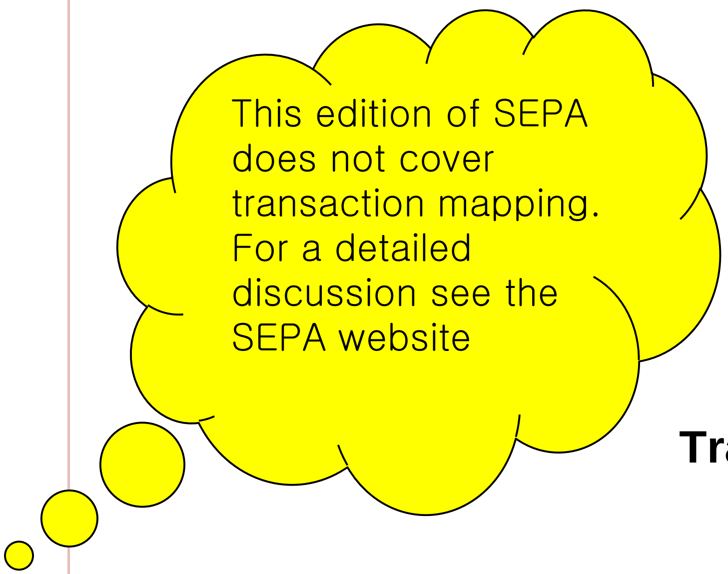
- results in software that is easier to test
- leads to software that is easier to maintain
- results in propagation of fewer side effects
- results in software that is easier to extend

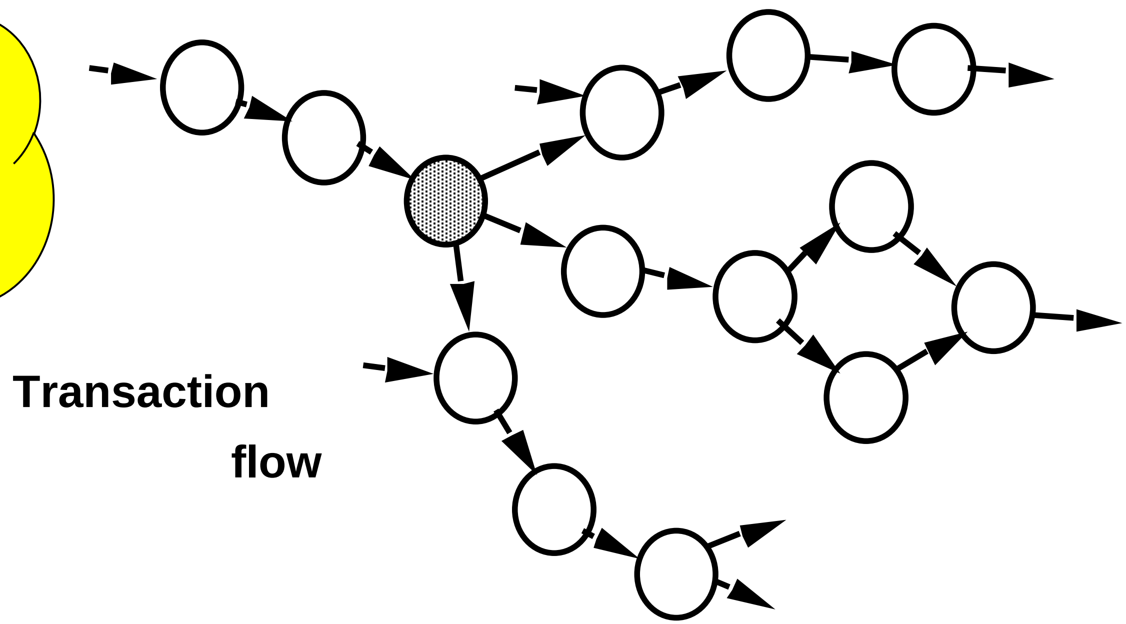
Structured Design

- objective: to derive a program architecture that is partitioned
- approach:
  - a DFD is mapped into a program architecture
  - the PSPEC and STD are used to indicate the content of each module
- notation: structure chart

Flow Characteristics







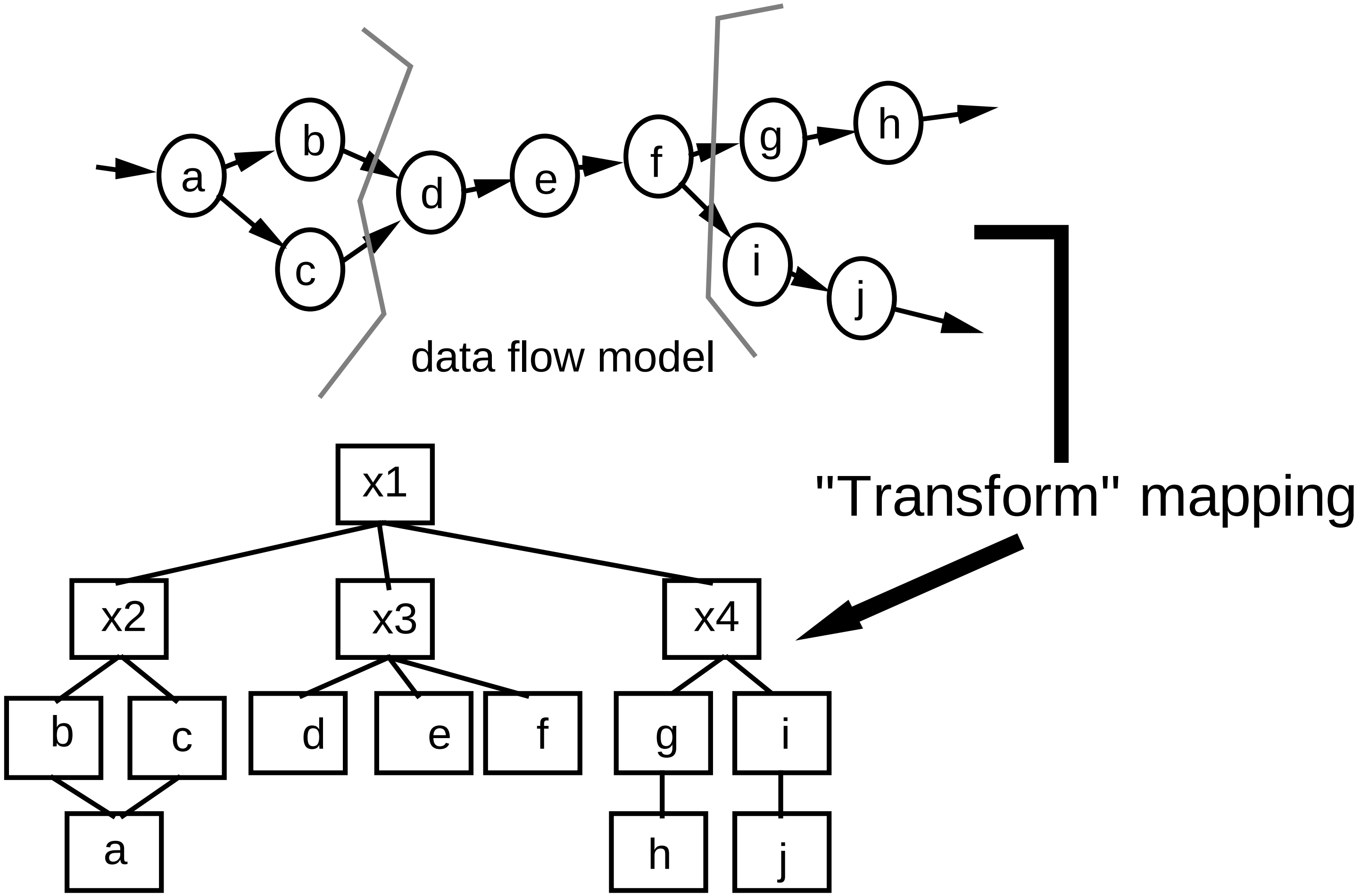
General Mapping Approach

- isolate incoming and outgoing flow boundaries; for transaction flows, isolate the transaction center
- working from the boundary outward, map DFD transforms into corresponding modules
- add control modules as required
- refine the resultant program structure using effective modularity concepts

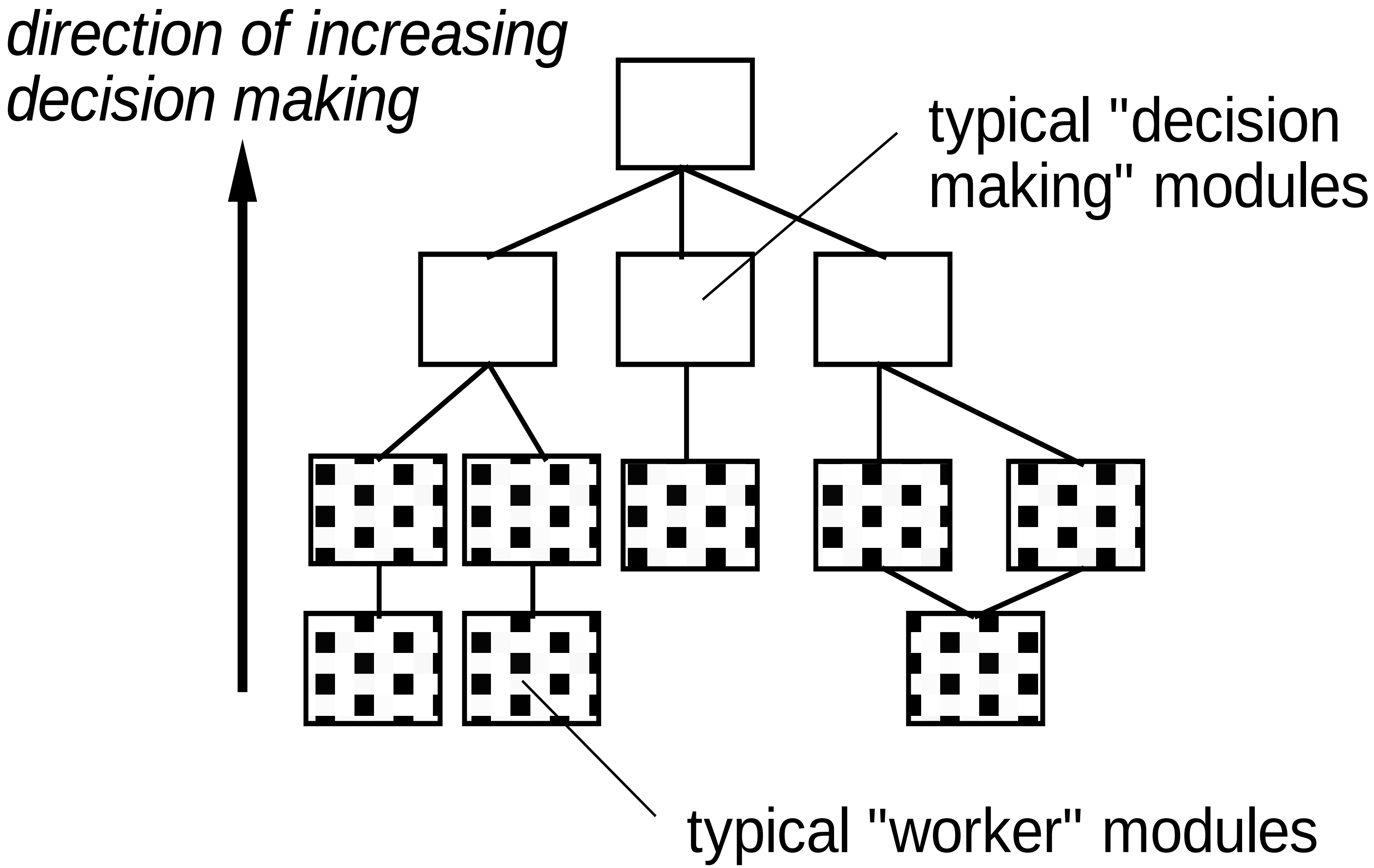
General Mapping Approach

- **Isolate the transform center by specifying incoming and outgoing flow boundaries**
- **Perform "first-level factoring."**
  - The program architecture derived using this mapping results in a top-down distribution of control.
  - *Factoring* leads to a program structure in which top-level components perform decision-making and low-level components perform most input, computation, and output work.
  - Middle-level components perform some control and do moderate amounts of work.
- **Perform "second-level factoring."**

Transform Mapping

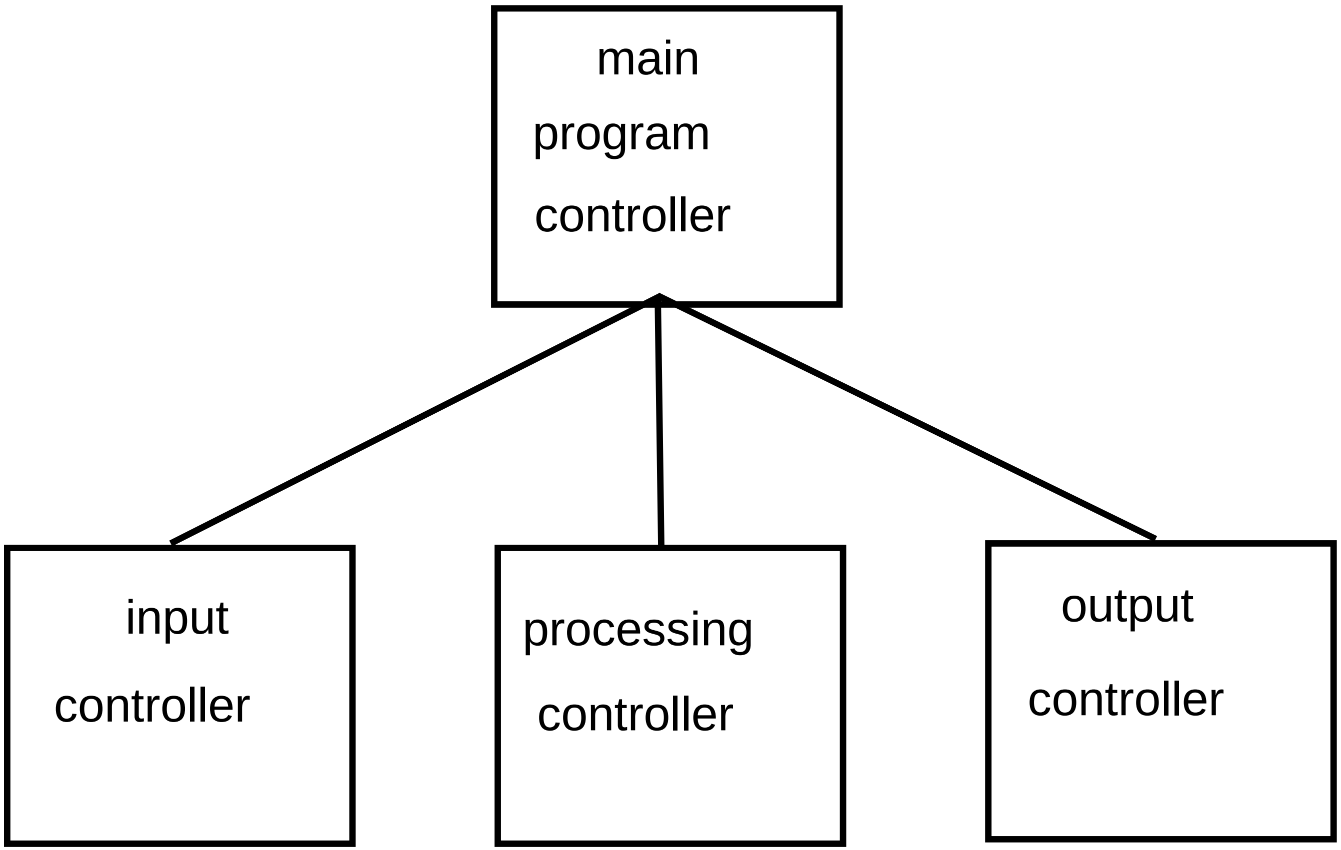


Factoring

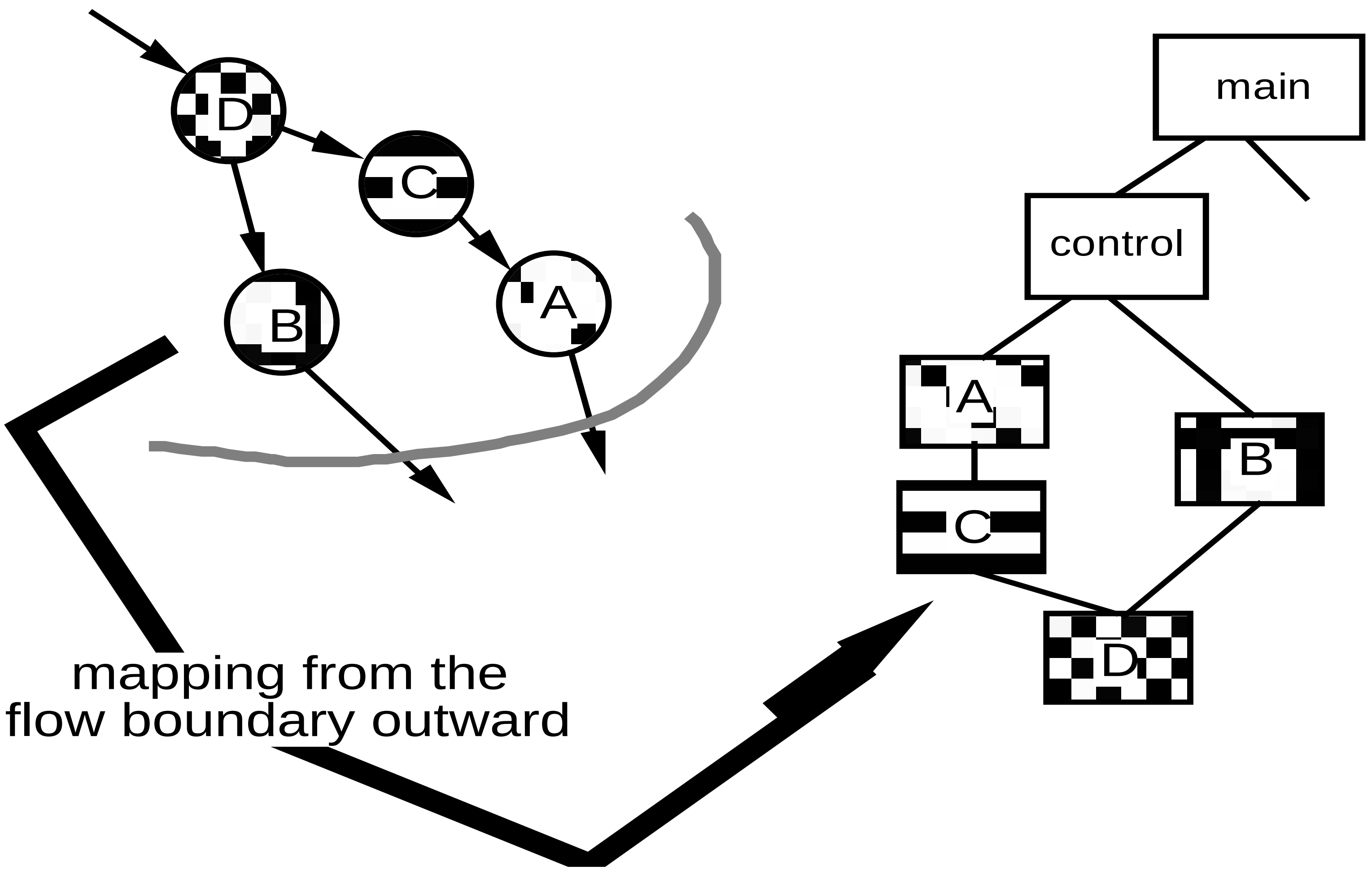


direction of increasing
decision making
typical "decision
making" modules
typical "worker" modules

First Level Factoring



Second Level Mapping



Q & A