# Lecture 4 – System Architecture and Design

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# Objectives

- To introduce architectural design and to discuss its importance
- To explain why multiple models are required to document a software architecture
- To describe types of architectural model that may be used
- To discuss how domain-specific reference models may be used as a basis for product-lines and to compare software architectures

# Software Architecture

- The design process for identifying the sub-systems making up a system and the framework for sub-system control and communication is *architectural design*
- The output of this design process is a description of the *software architecture*

# Architectural Design

- An early stage of the system design process
- Represents the link between specification and design processes
- Often carried out in parallel with some specification activities
- It involves identifying major system components and their communications

# Advantages of Explicit Architecture

- Stakeholder communication
  - Architecture may be used as a focus of discussion by system stakeholders
- System analysis
  - Means that analysis of whether the system can meet its non-functional requirements is possible
- Large-scale reuse
  - The architecture may be reusable across a range of systems

# Architectural Design Process

- System structuring
  - The system is decomposed into several principal sub-systems and communications between these sub-systems are identified
- Control modelling
  - A model of the control relationships between the different parts of the system is established
- Modular decomposition
  - The identified sub-systems are decomposed into modules

# Sub-systems and Modules

- A sub-system is a system in its own right whose operation is independent of the services provided by other sub-systems.
- A module is a system component that provides services to other components but would not normally be considered as a separate system

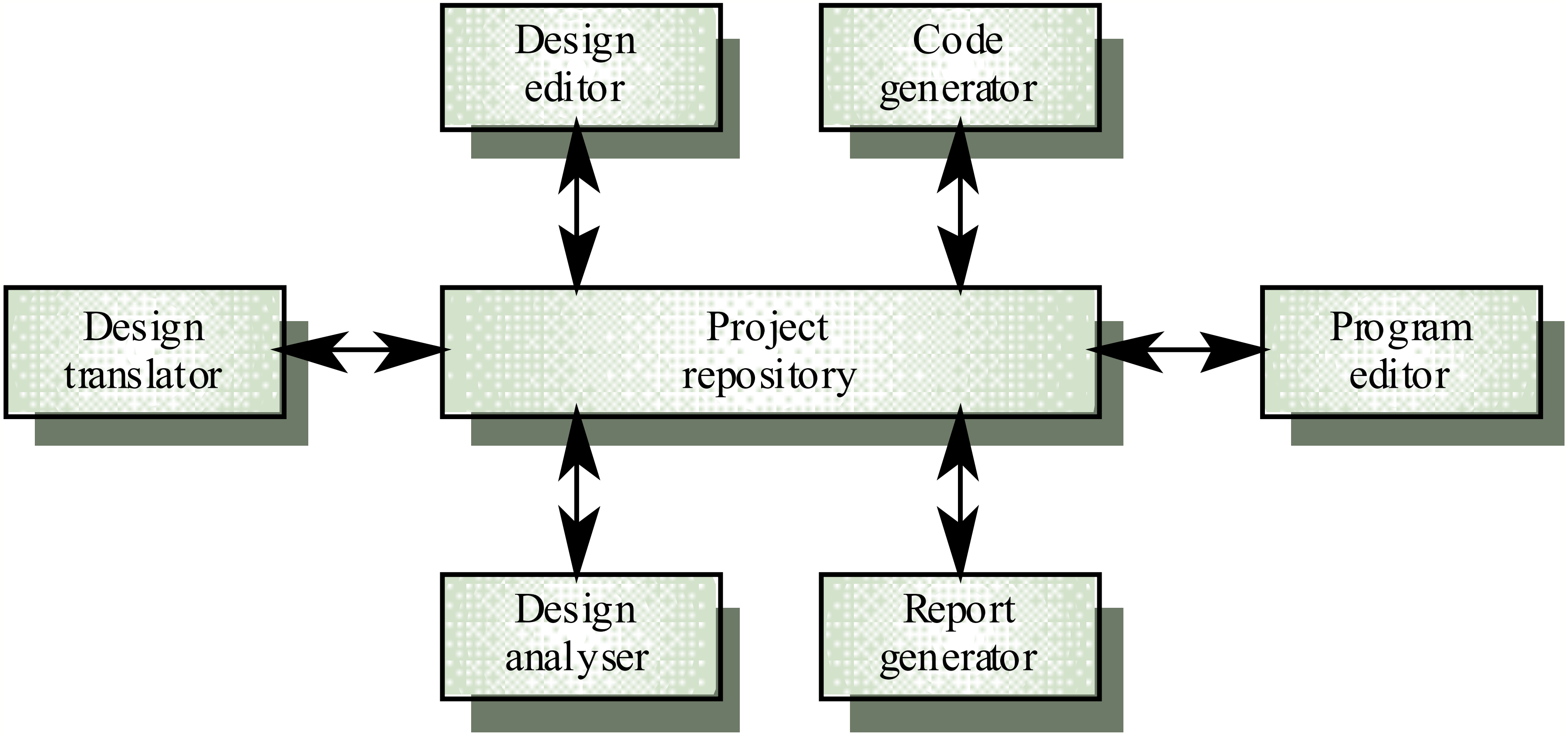
# Architecture Attributes

- Performance
  - Localise operations to minimise sub-system communication
- Security
  - Use a layered architecture with critical assets in inner layers
- Safety
  - Isolate safety-critical components
- Availability
  - Include redundant components in the architecture
- Maintainability
  - Use fine-grain, self-contained components

# The Repository Model

- Sub-systems must exchange data. This may be done in two ways:
  - Shared data is held in a central database or repository and may be accessed by all sub-systems
  - Each sub-system maintains its own database and passes data explicitly to other sub-systems
- When large amounts of data are to be shared, the repository model of sharing is most commonly used

# CASE Toolset Architecture



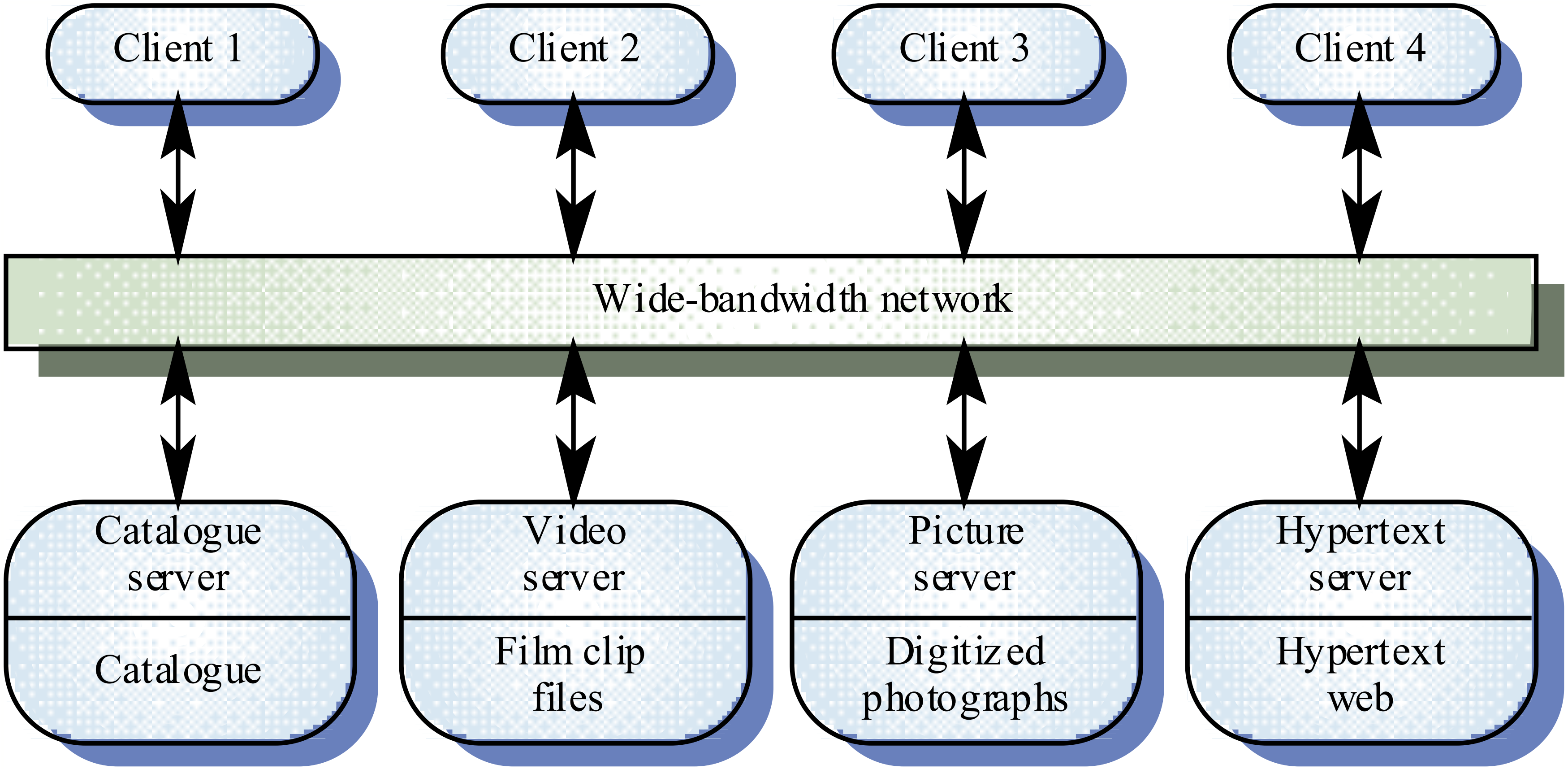
# Repository Model Characteristics

- Advantages
  - Efficient way to share large amounts of data
  - Sub-systems need not be concerned with how data is produced Centralised management e.g. backup, security, etc.
  - Sharing model is published as the repository schema
- Disadvantages
  - Sub-systems must agree on a repository data model. Inevitably a compromise
  - Data evolution is difficult and expensive
  - No scope for specific management policies
  - Difficult to distribute efficiently

# Client-server Architecture

- Distributed system model which shows how data and processing is distributed across a range of components
- Set of stand-alone servers which provide specific services such as printing, data management, etc.
- Set of clients which call on these services
- Network which allows clients to access servers

# Film and Picture Library



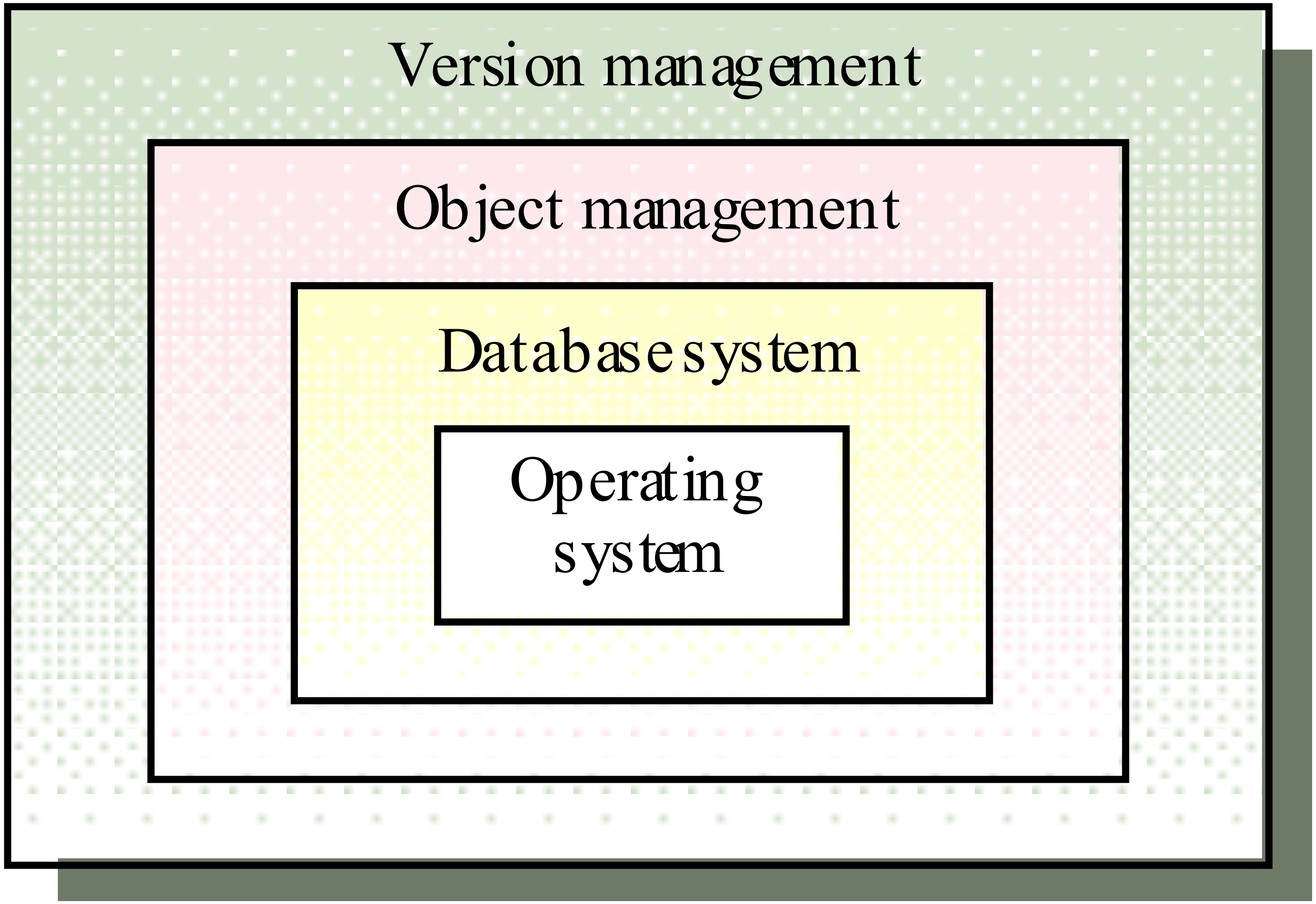
# Client-server Characteristics

- Advantages
  - Distribution of data is straightforward
  - Makes effective use of networked systems. May require cheaper hardware
  - Easy to add new servers or upgrade existing servers
- Disadvantages
  - No shared data model so sub-systems use different data organisation. data interchange may be inefficient
  - Redundant management in each server
  - No central register of names and services - it may be hard to find out what servers and services are available

# Abstract Machine Model

- Used to model the interfacing of sub-systems
- Organises the system into a set of layers (or abstract machines) each of which provide a set of services
- Supports the incremental development of sub-systems in different layers. When a layer interface changes, only the adjacent layer is affected
- However, often difficult to structure systems in this way

# Version Management System



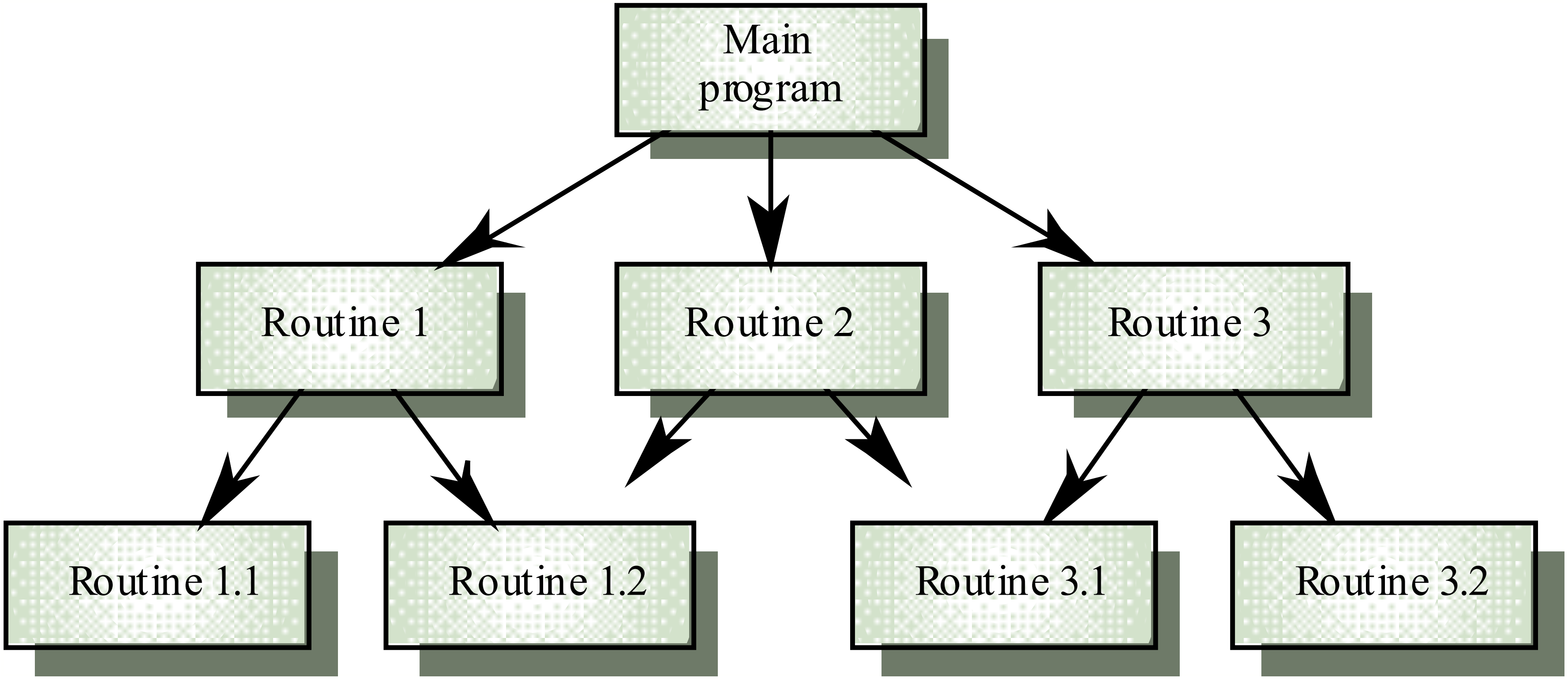
# Control Models

- Are concerned with the control flow between sub-systems. Distinct from the system decomposition model
- Centralised control
  - One sub-system has overall responsibility for control and starts and stops other sub-systems
- Event-based control
  - Each sub-system can respond to externally generated events from other sub-systems or the system's environment

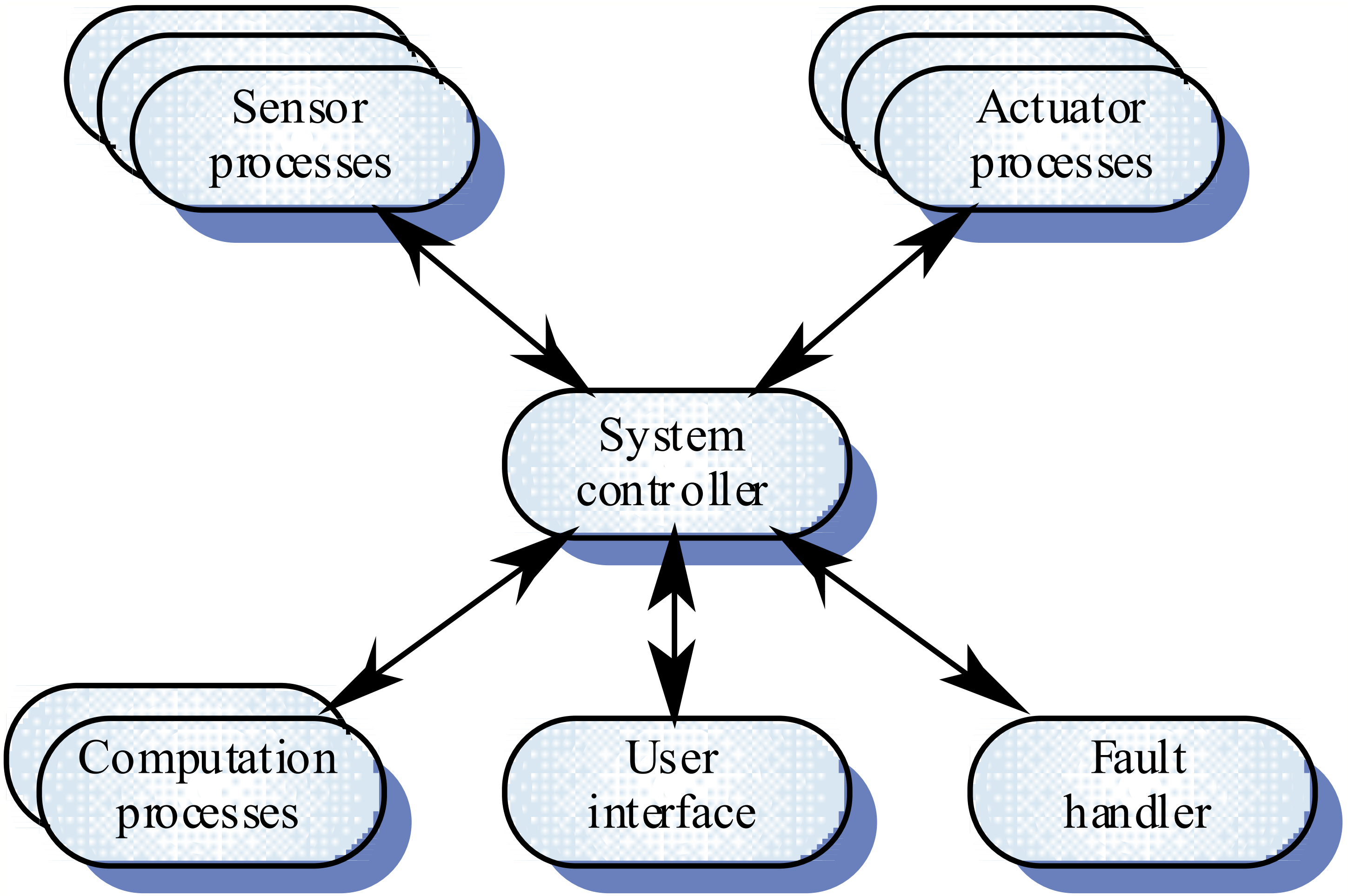
# Centralised Control

- A control sub-system takes responsibility for managing the execution of other sub-systems
- Call-return model
  - Top-down subroutine model where control starts at the top of a subroutine hierarchy and moves downwards. Applicable to sequential systems
- Manager model
  - Applicable to concurrent systems. One system component controls the stopping, starting and coordination of other system processes. Can be implemented in sequential systems as a case statement

# Call-return Model



# Real-time System Control



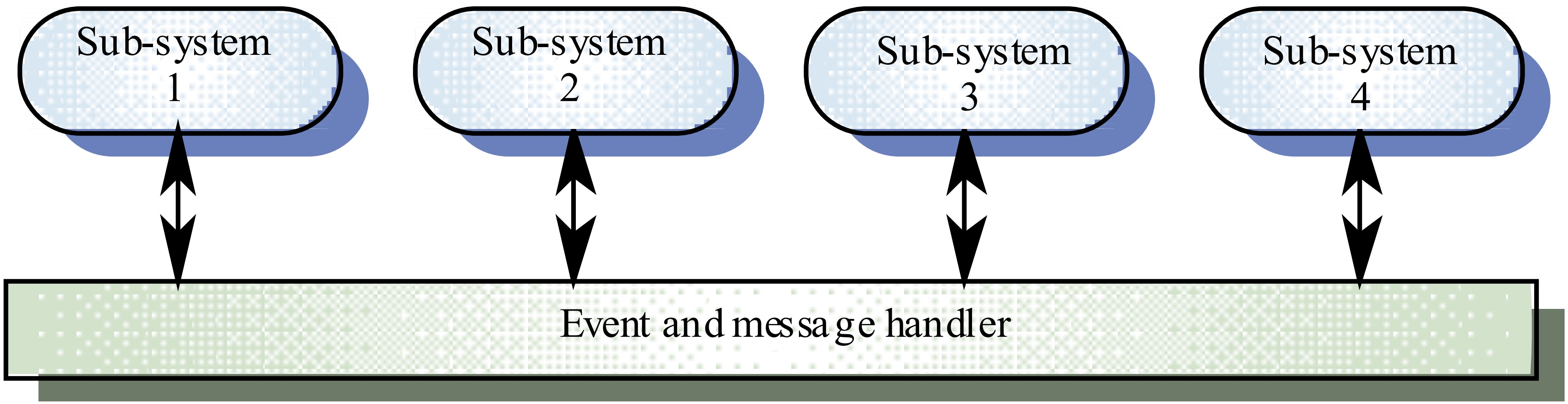
# Event-driven Systems

- Driven by externally generated events where the timing of the event is out with the control of the sub-systems which process the event
- Two principal event-driven models
  - Broadcast models. An event is broadcast to all sub-systems. Any sub-system which can handle the event may do so
  - Interrupt-driven models. Used in real-time systems where interrupts are detected by an interrupt handler and passed to some other component for processing
- Other event driven models include spreadsheets and production systems

# Broadcast Model

- Effective in integrating sub-systems on different computers in a network
- Sub-systems register an interest in specific events. When these occur, control is transferred to the sub-system which can handle the event
- Control policy is not embedded in the event and message handler. Sub-systems decide on events of interest to them
- However, sub-systems don’t know if or when an event will be handled

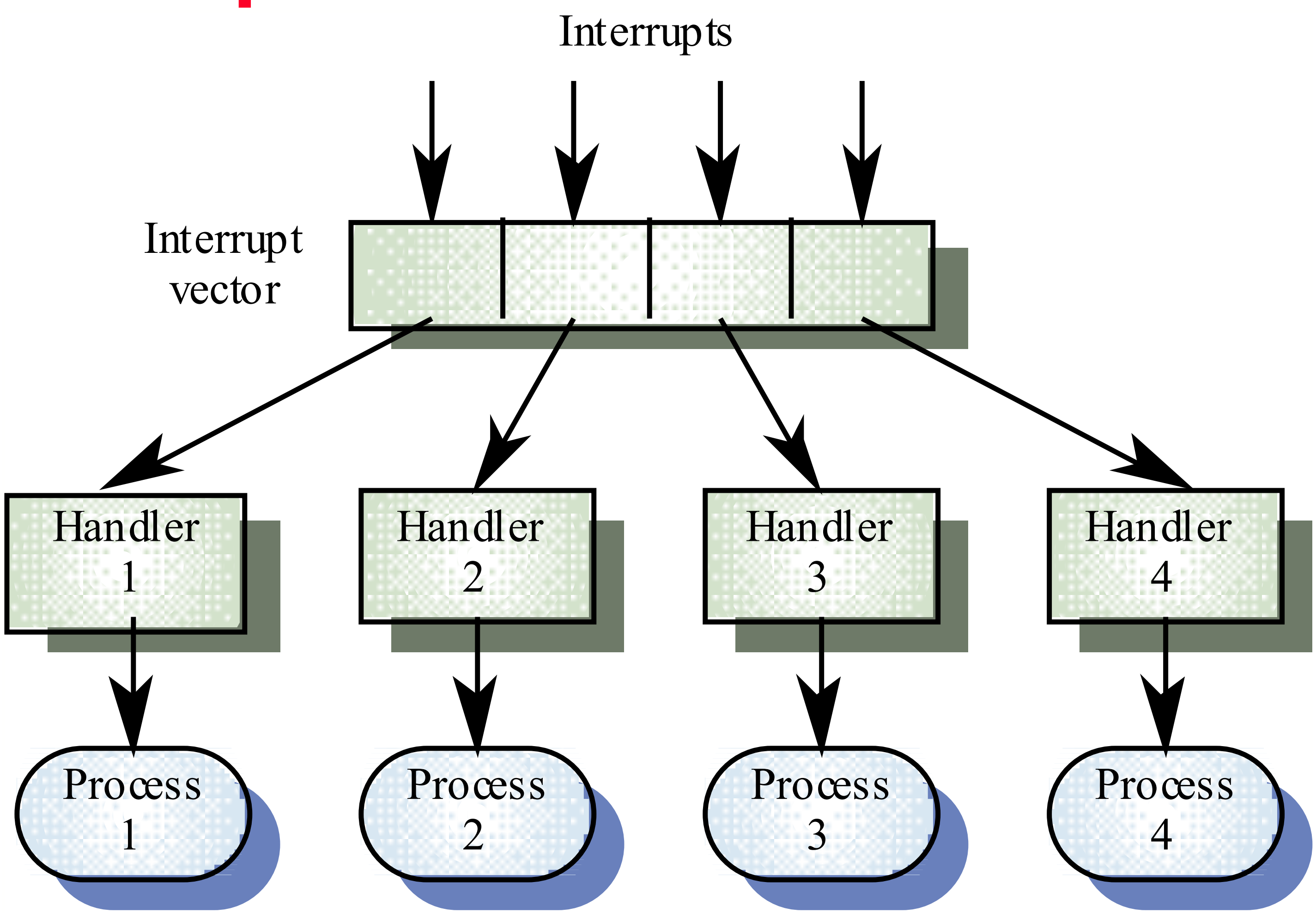
# Selective Broadcasting



# Interrupt-driven Systems

- Used in real-time systems where fast response to an event is essential
- There are known interrupt types with a handler defined for each type
- Each type is associated with a memory location and a hardware switch causes transfer to its handler
- Allows fast response but complex to program and difficult to validate

# Interrupt-driven Control



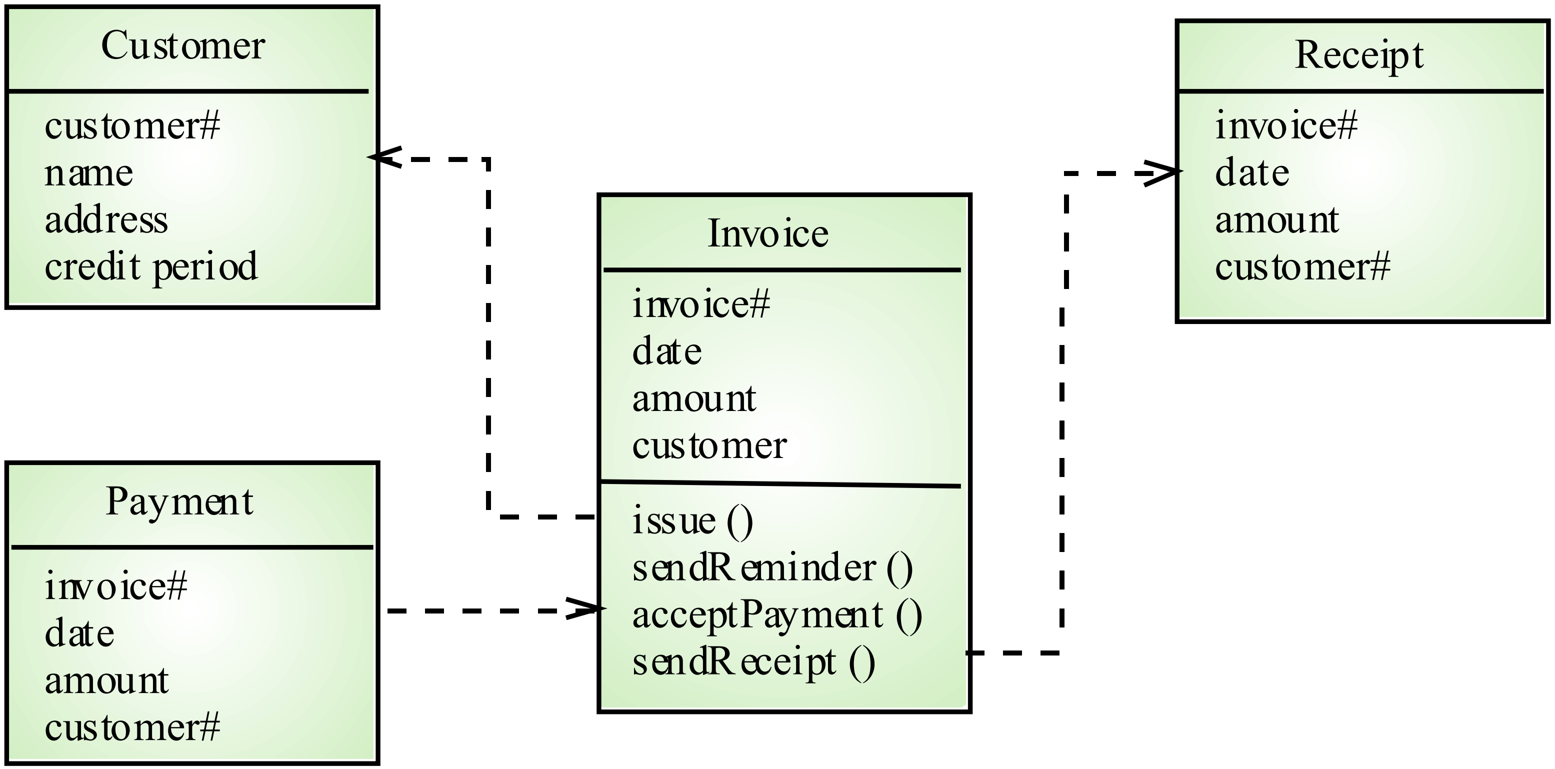
# Modular Decomposition

- Another structural level where sub-systems are decomposed into modules
- Two modular decomposition models covered
  - An object model where the system is decomposed into interacting objects
  - A data-flow model where the system is decomposed into functional modules which transform inputs to outputs. Also known as the pipeline model
- If possible, decisions about concurrency should be delayed until modules are implemented

# Object Models

- Structure the system into a set of loosely coupled objects with well-defined interfaces
- Object-oriented decomposition is concerned with identifying object classes, their attributes and operations
- When implemented, objects are created from these classes and some control model used to coordinate object operations

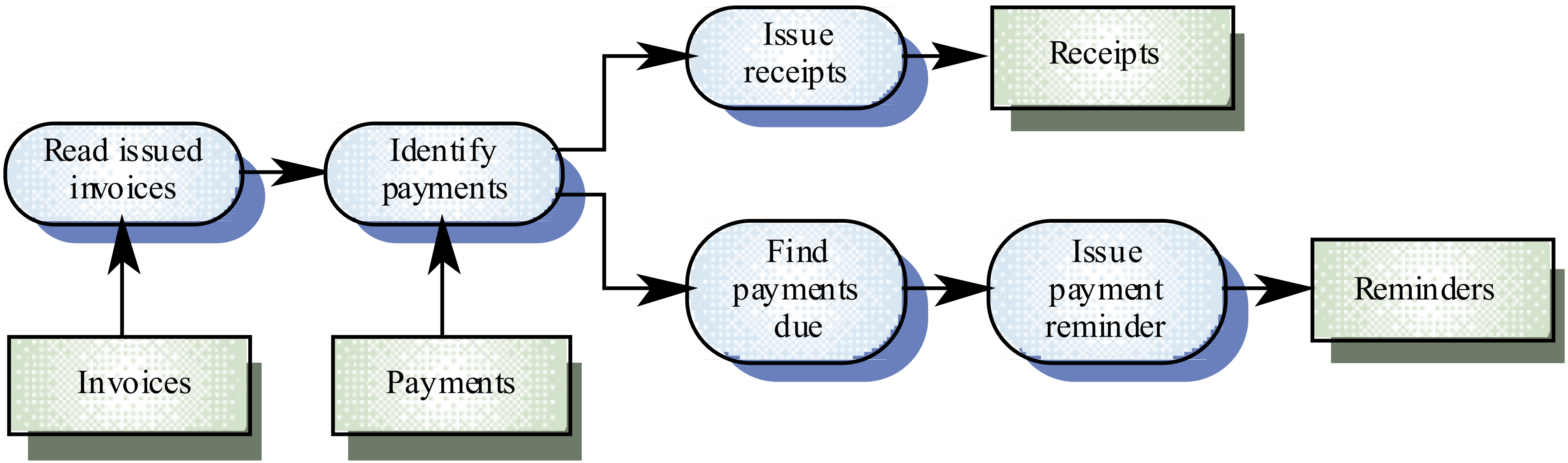
# Invoice Processing System



# Data-flow Models

- Functional transformations process their inputs to produce outputs
- May be referred to as a pipe and filter model (as in UNIX shell)
- Variants of this approach are very common. When transformations are sequential, this is a batch sequential model which is extensively used in data processing systems
- Not really suitable for interactive systems

# Invoice Processing System



# Key Points

- The software architect is responsible for deriving a structural system model, a control model and a sub-system decomposition model
- Large systems rarely conform to a single architectural model
- System decomposition models include repository models, client-server models and abstract machine models
- Control models include centralised control and event-driven models

# Key Points

- Modular decomposition models include data-flow and object models
- Domain specific architectural models are abstractions over an application domain. They may be constructed by abstracting from existing systems or may be idealised reference models