Architectural Design

Establishing the overall structure
of a software system

Objectives

- To introduce architectural design and its role in the software process
- To describe a number of different types of architectural model
- To show how the architecture of a system may be modeled in different ways
- To discuss how domain-specific reference models may be used to compare software architectures

Topics covered

- System structuring
- Control models
- Modular decomposition
- Domain-specific architectures

Architectural parallels

- Architects are the technical interface between the customer and the contractor building the system
- A bad architectural design for a building cannot be rescued by good construction; the same is true for software
- There are specialist types of building and software architects
- There are schools or styles of building and software architecture

Architectural design process

- System structuring
  - The system is decomposed into several principal sub-systems and communications between these sub-systems are identified
- Control modeling
  - 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

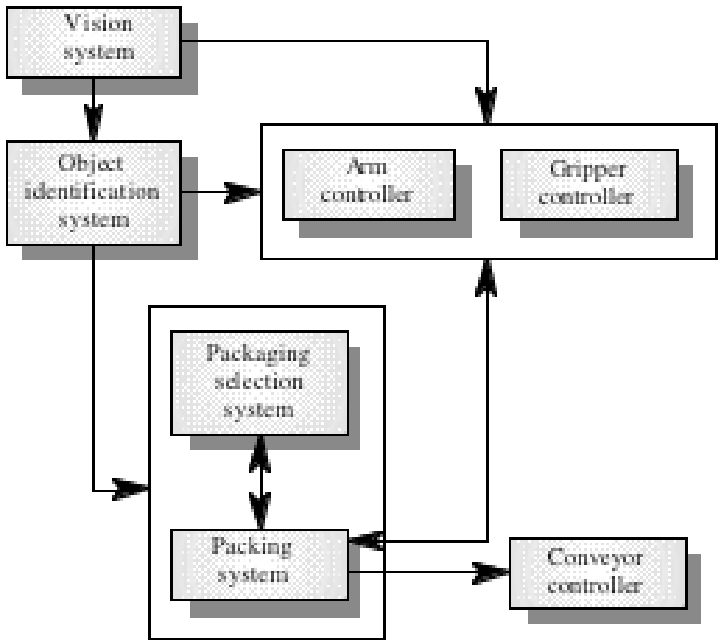
Architectural models

- Structure, control and modular decomposition may be based on a particular model or architectural style
- However, most systems are heterogeneous in that different parts of the system are based on different models and, in some cases, the system may follow a composite model
- The architectural model used affects the performance, robustness, distributability and maintainability of the system

System structuring

- Concerned with decomposing the system into interacting sub-systems
- The architectural design is normally expressed as a block diagram presenting an overview of the system structure
- More specific models showing how sub-systems share data, are distributed and interface with each other may also be developed

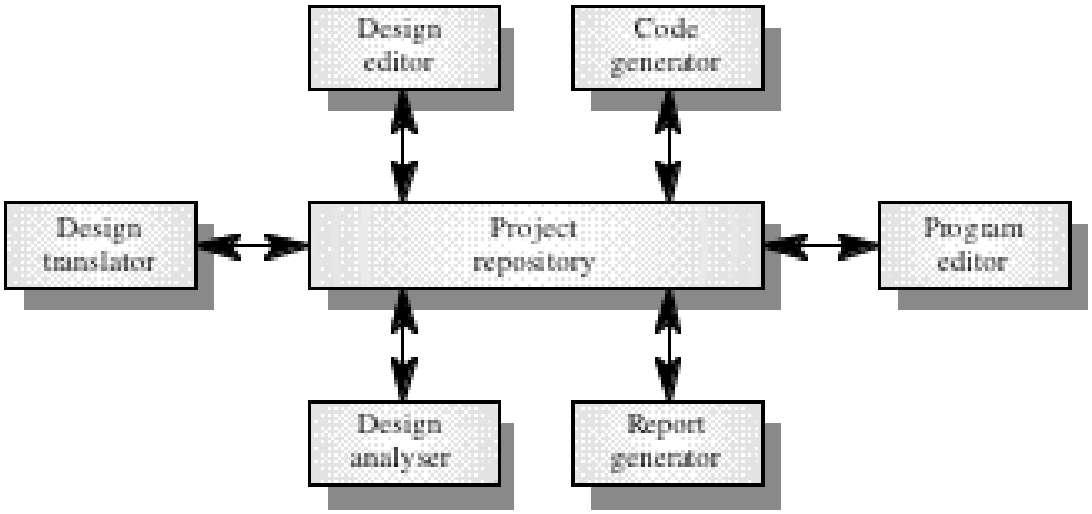
Packing robot control system



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



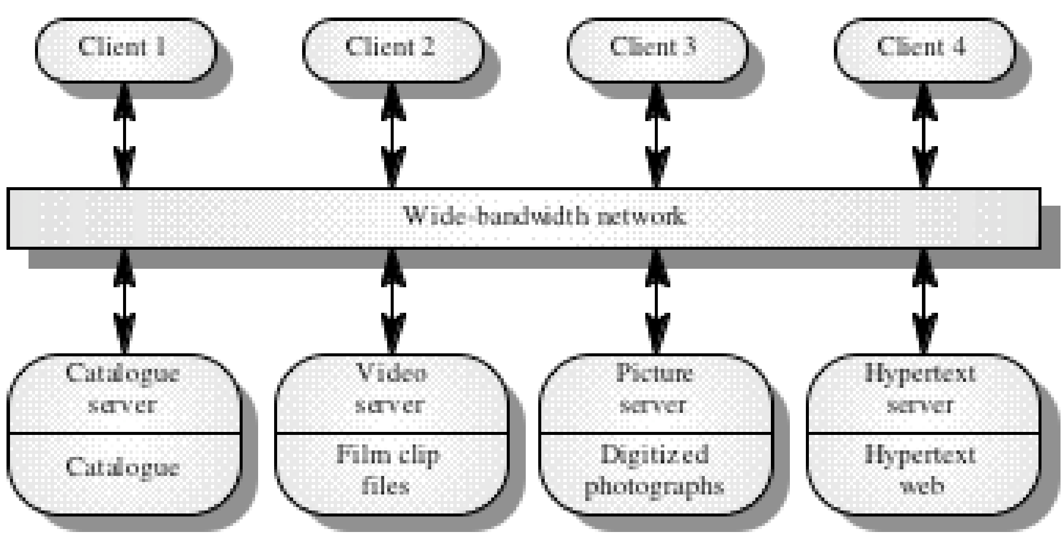
Repository model characteristics

- Advantages
  - Efficient way to share large amounts of data
  - Sub-systems need not be concerned with how data is produced
  - Centralized 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



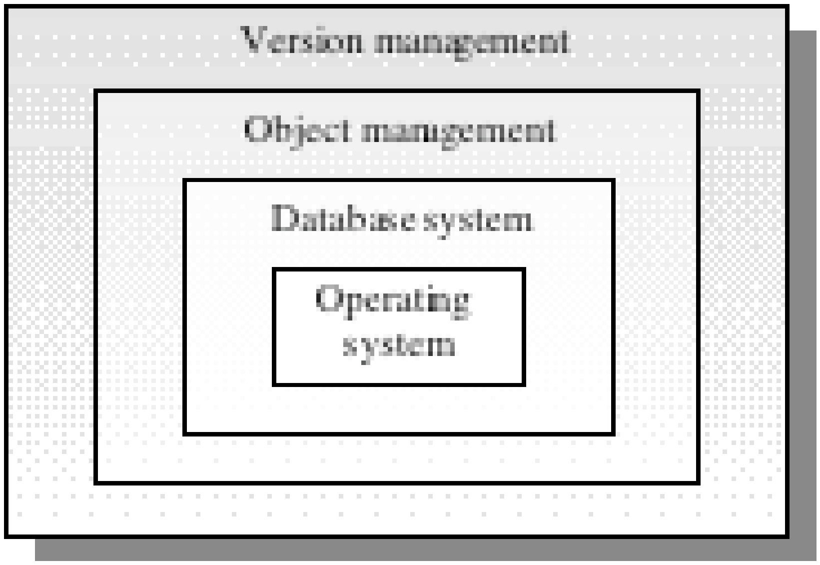
Client-server characteristics

- 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 organization. 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
- Organizes 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



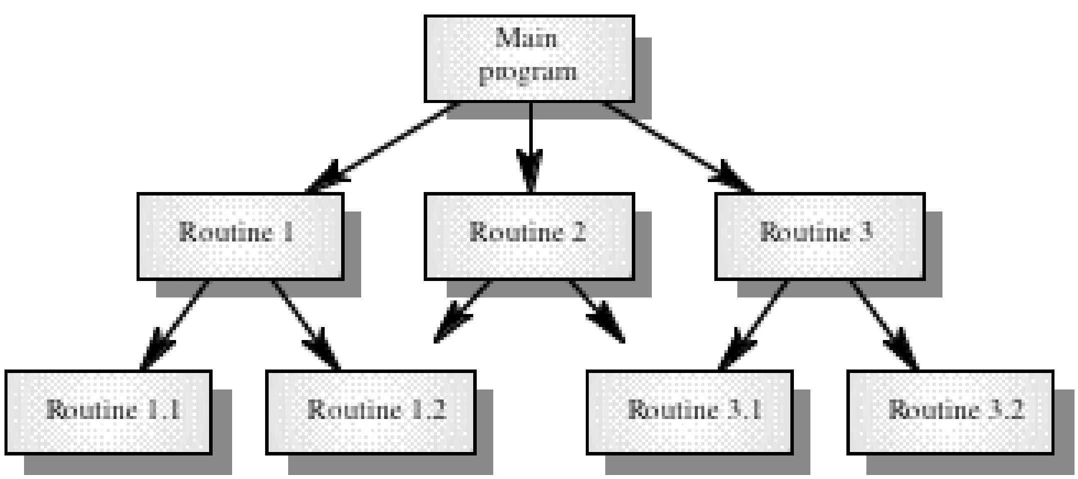
Control models

- Are concerned with the control flow between sub-systems. Distinct from the system decomposition model
- Centralized 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

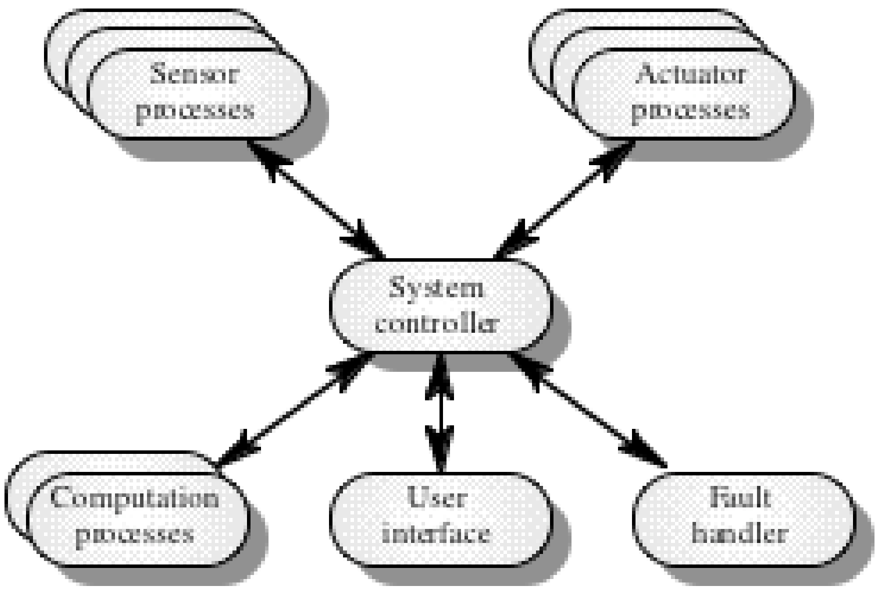
Centralized control

- 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



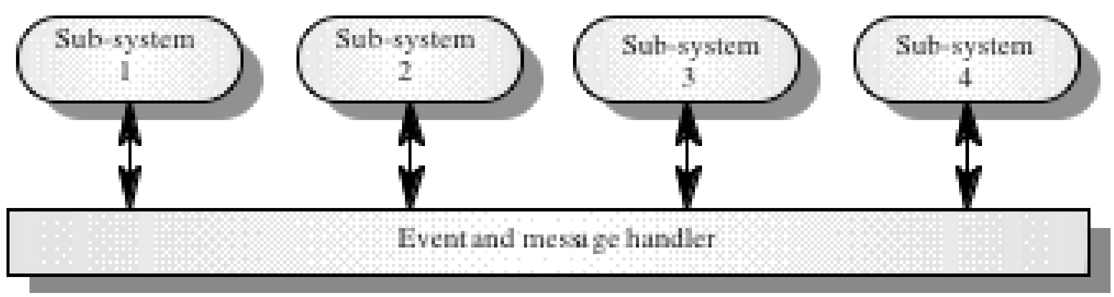
Event-driven systems

- Driven by externally generated events where the timing of the event is outside 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

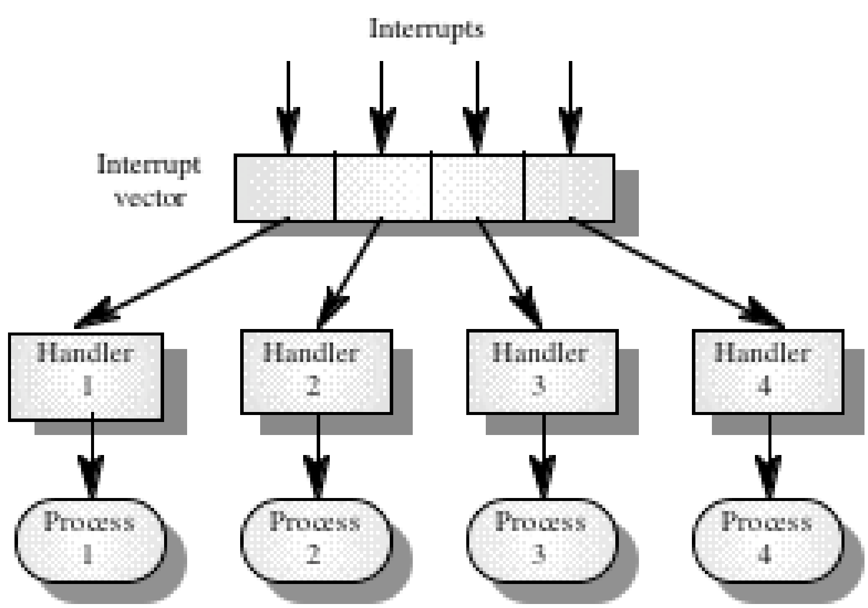
Selective broadcasting



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



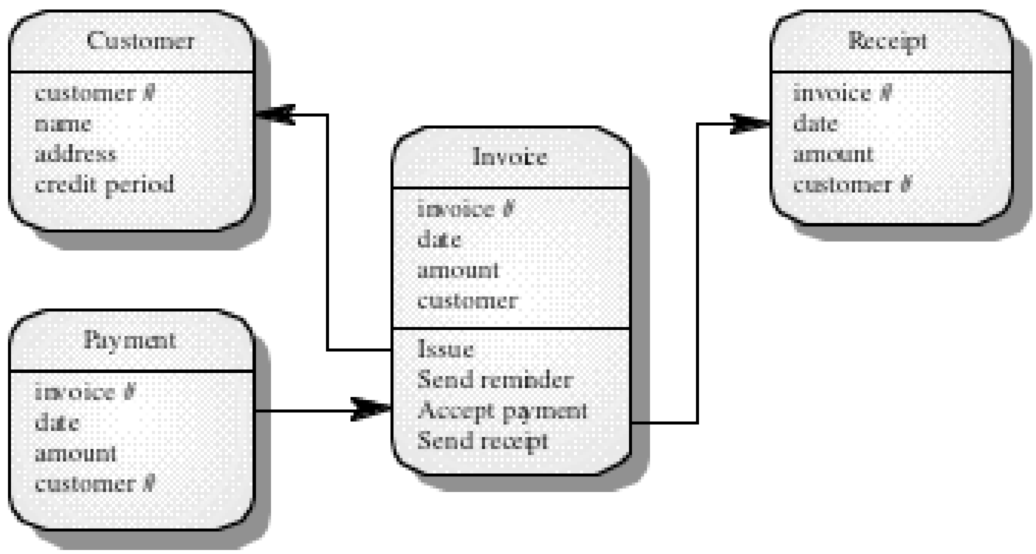
Modular decomposition

- 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

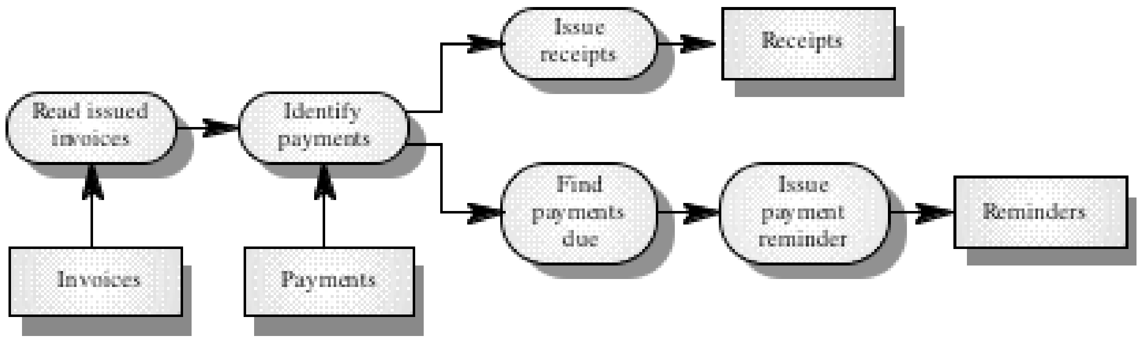
Invoice processing system



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



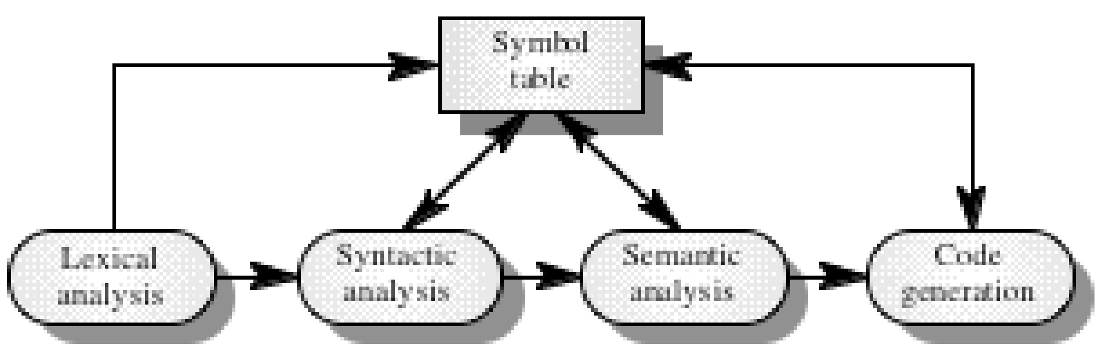
Domain-specific architectures

- Architectural models which are specific to some application domain
- Two types of domain-specific model
  – Generic models which are abstractions from a number of real systems and which encapsulate the principal characteristics of these systems
  – Reference models which are more abstract, idealized model. Provide a means of information about that class of system and of comparing different architectures
- Generic models are usually bottom-up models; Reference models are top-down models

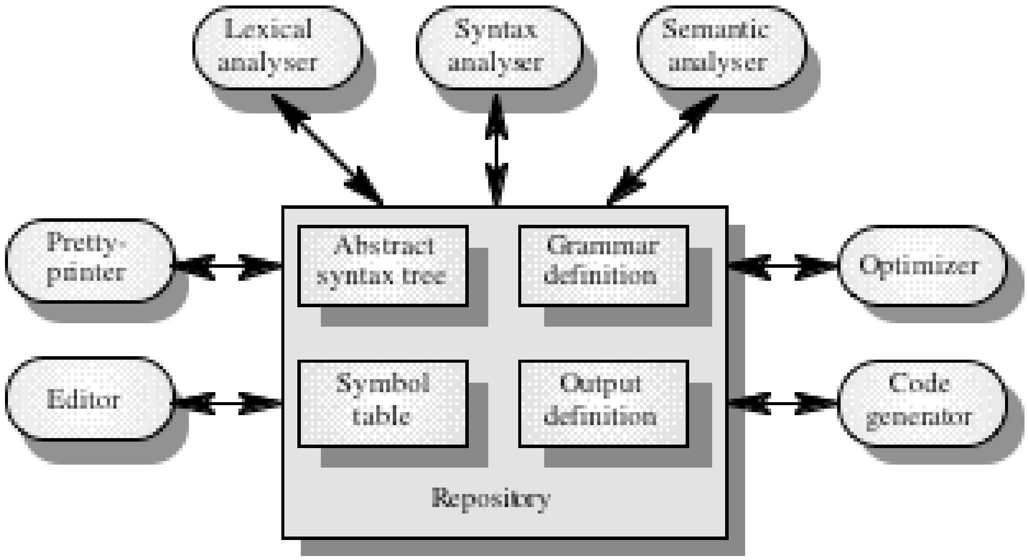
Generic models

- Compiler model is a well-known example although other models exist in more specialized application domains
  - Lexical analyzer
  - Symbol table
  - Syntax analyzer
  - Syntax tree
  - Semantic analyzer
  - Code generator
- Generic compiler model may be organized according to different architectural models

Compiler model



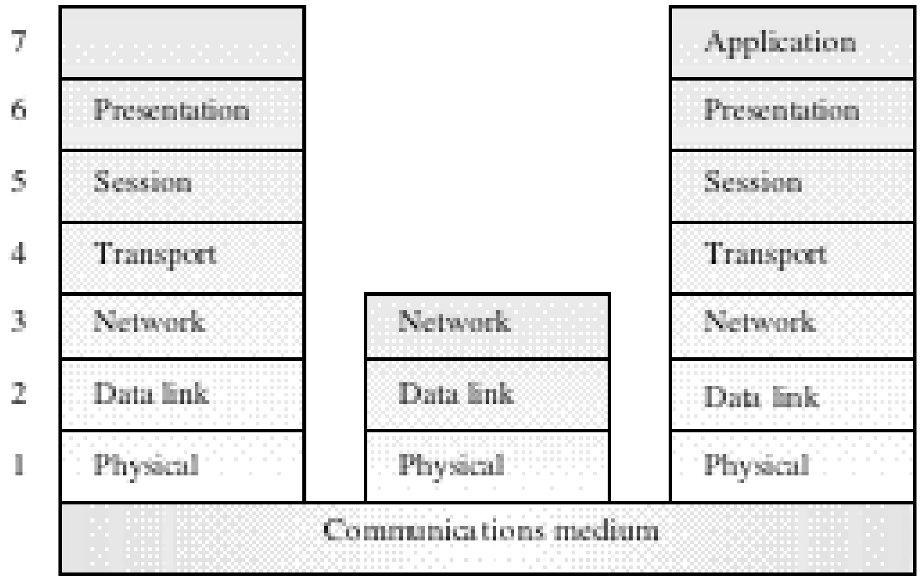
Language processing system



Reference architectures

- Reference models are derived from a study of the application domain rather than from existing systems
- May be used as a basis for system implementation or to compare different systems. It acts as a standard against which systems can be evaluated
- OSI model is a layered model for communication systems

OSI reference model



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 centralized 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 idealized reference models