Architectural Design

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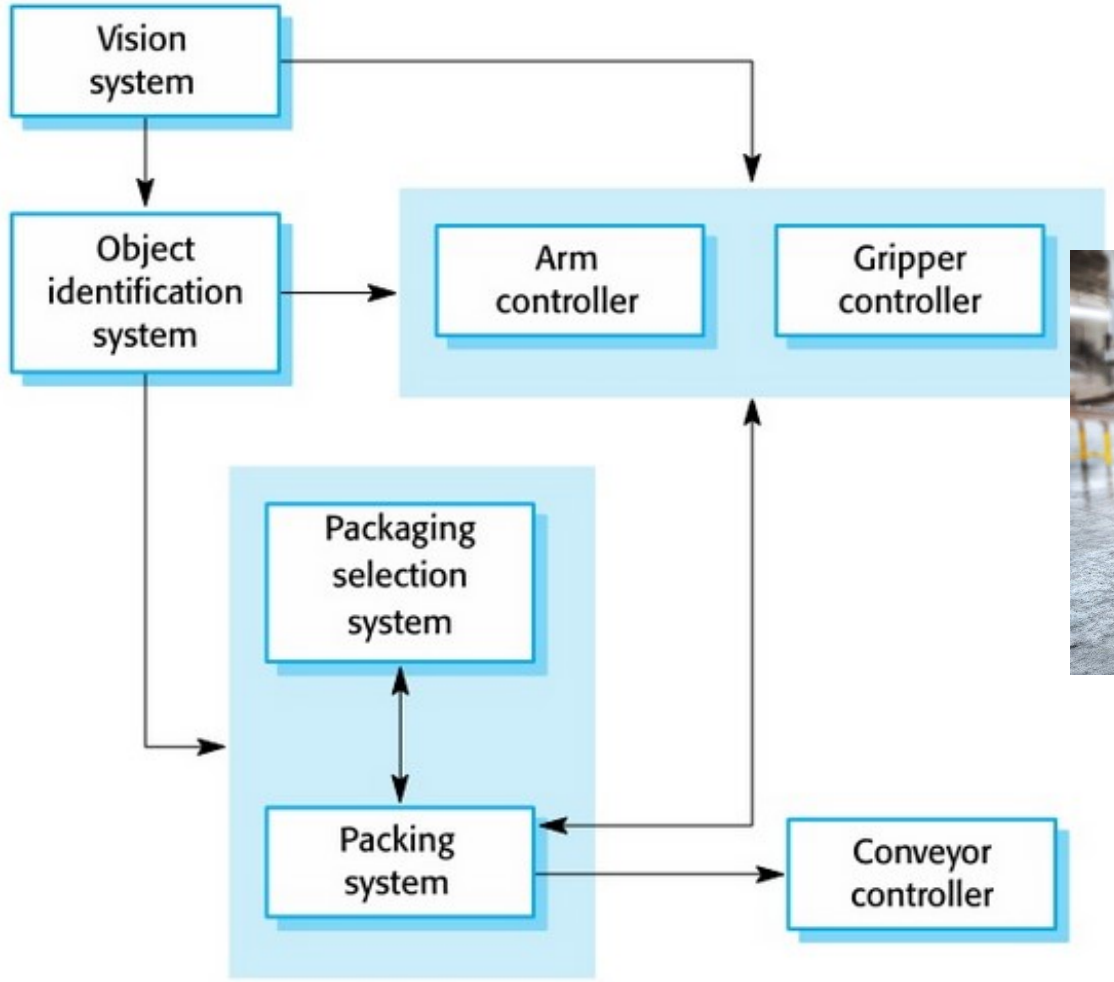
Architectural design

- **Architectural design** is concerned with understanding **how** a software system should be organized **and** designing the overall structure of that system
- Architectural design is **the critical link** between design and requirements engineering, as it identifies the main structural components in a system and the relationships between them
- **The output** of the architectural design process is **an architectural model** that describes how the system is organized as a set of communicating components

Agility & architecture

- It is generally accepted that **an early stage** of agile processes is to design an overall systems architecture
- Refactoring the system architecture is usually expensive because it affects so many components in the system

The architecture of a packing robot control system



Architectural abstraction

- **Architecture in the small** is concerned with the architecture of individual programs
  - At this level, we are concerned with the way that an individual program is decomposed into **components**
- **Architecture in the large** is concerned with the architecture of complex enterprise system that include other systems, programs, and program components
  - These enterprise systems are distributed over different computers, which may be owned and managed by different companies

Advantages of explicit architecture

- For stakeholder communication
  - Architecture may be used as **a focus of discussion** by system stakeholders
- For system analysis
  - Analysis of whether the system can meet its non-functional requirements
- For large-scale **reuse**
  - The architecture may be reusable across a range of systems
  - Product-line architectures may be developed

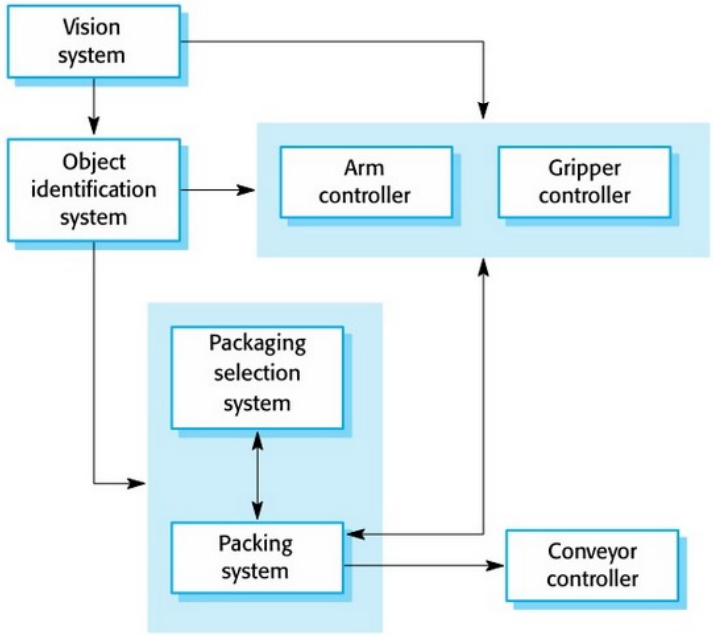
Architectural representations

- Simple informal **block diagrams** showing entities and relationships are the most frequently used method for documenting software architectures
- But these have been criticized because of the lack of semantics, do not show the types of relationships between entities nor the visible properties of entities in the architecture

Box and line diagrams

- Very abstract – they don't show the nature of component relationships

  nor the externally visible properties of the sub-systems



Use of architectural models

- As a way of facilitating discussion about the system design
  - **useful** for communication with system stakeholders and project planning because it is **not** cluttered with detail
  - Stakeholders can relate to it and understand an abstract view of the system
  - They can discuss **the system as a whole** without being confused by detail
- As a way of documenting an architecture that has been designed
  - The aim here is to produce **a complete system model** that shows the different components in a system, their interfaces and their connections

Architectural design decisions

- Architectural design is a creative process so the process **differs** depending on the type of system being developed
- However, a number of common decisions span all design processes and these decisions affect the non-functional characteristics of the system

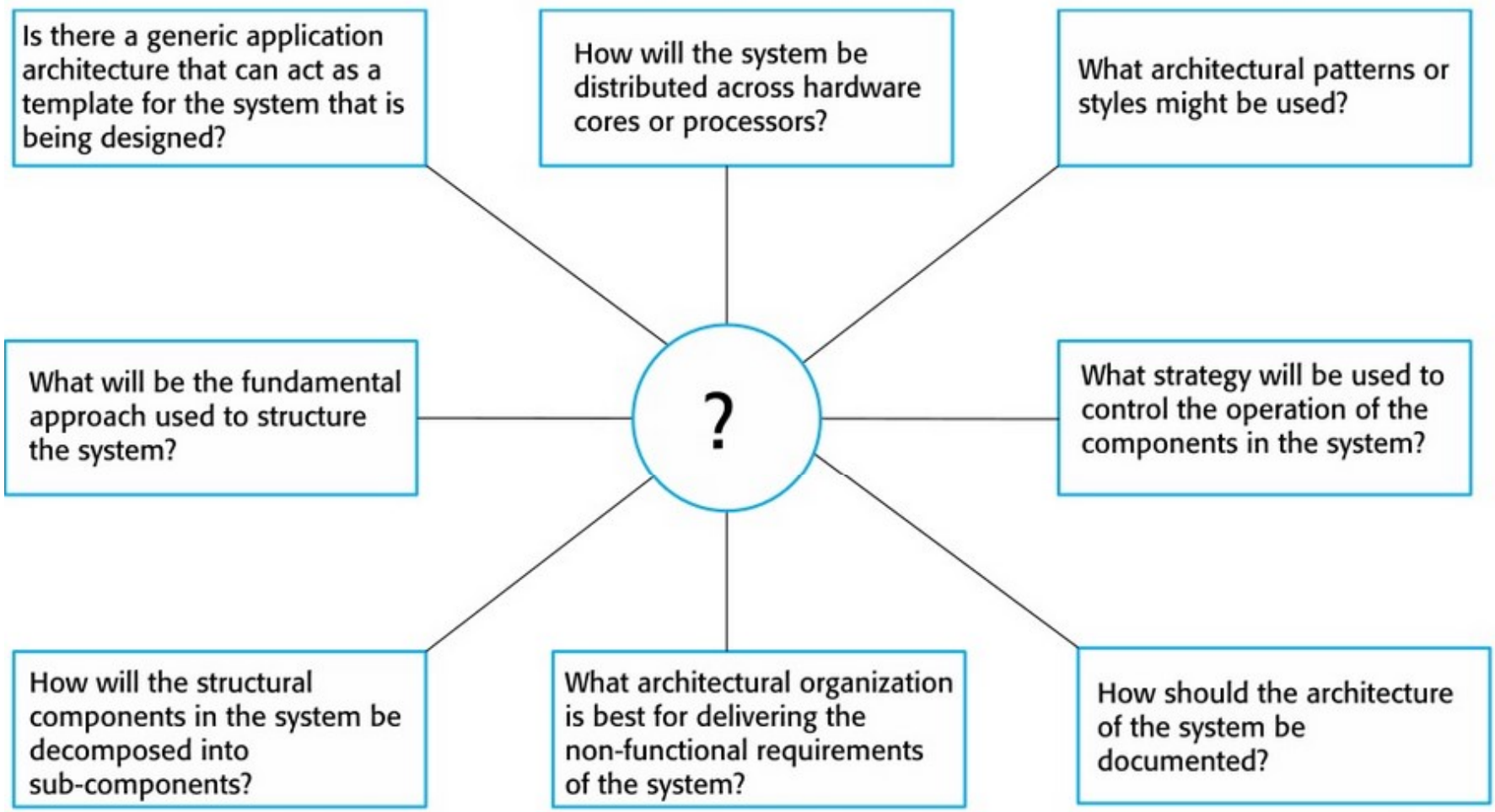
Color
Red
Blue

Size
Small
Medium
Large
Extra Large

vs.
w.r.t
performance

Color	Size
Red	Small
Blue	Small
Red	Medium
Blue	Medium
Red	Large
Blue	Large
Red	Extra Large
Blue	Extra Large

Architectural design decisions



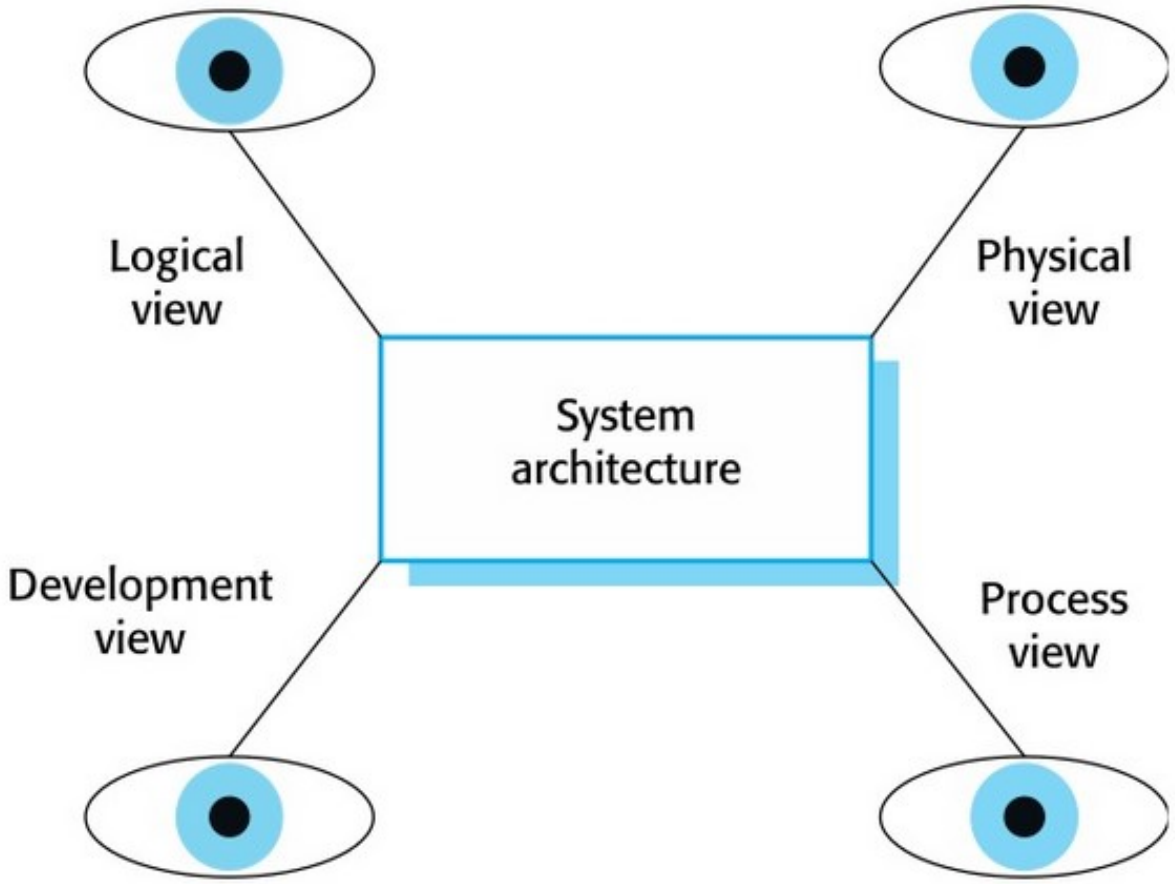
Architecture and system characteristics

- Performance
  - Localize critical operations and minimize communications
  - Use large rather than fine-grain components
- Security
  - Use a layered architecture with critical assets in the inner layers
- Safety
  - Localize safety-critical features in a small number of sub systems
- Availability
  - include redundant components and mechanisms for fault tolerance
- Maintainability
  - use fine-grain, replaceable components

Architectural views

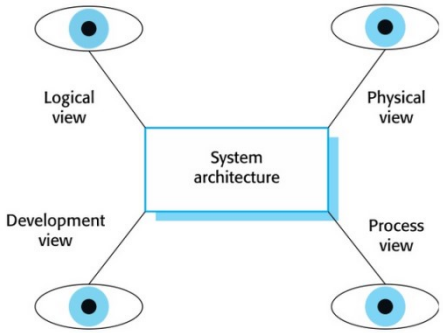
- **What** views or perspectives are **useful** when designing and documenting a system's architecture?
- **What** notations should be used for describing architectural models?
- **Each architectural model** only shows **one view** or **perspective** of the system
  - it might show **how** a system is decomposed into modules,
  - **how** the run-time processes interact or the different ways in which system components are distributed across a network
  - For both **design** and **documentation**, you usually need to present multiple views of the software architecture

Architectural views



4+1 view model of software architecture

- **A logical view**, which shows the key abstraction in the system as objects or object classes
- **A process view**, which shows how, at run-time, the system is composed of interacting processes
- **A development view**, which shows **how** the software is decomposed for development
- **A physical view,** which shows the system hardware and how software components are distributed across the processors in the system
- Related **use cases** or **scenarios** (+1)



Architectural patterns

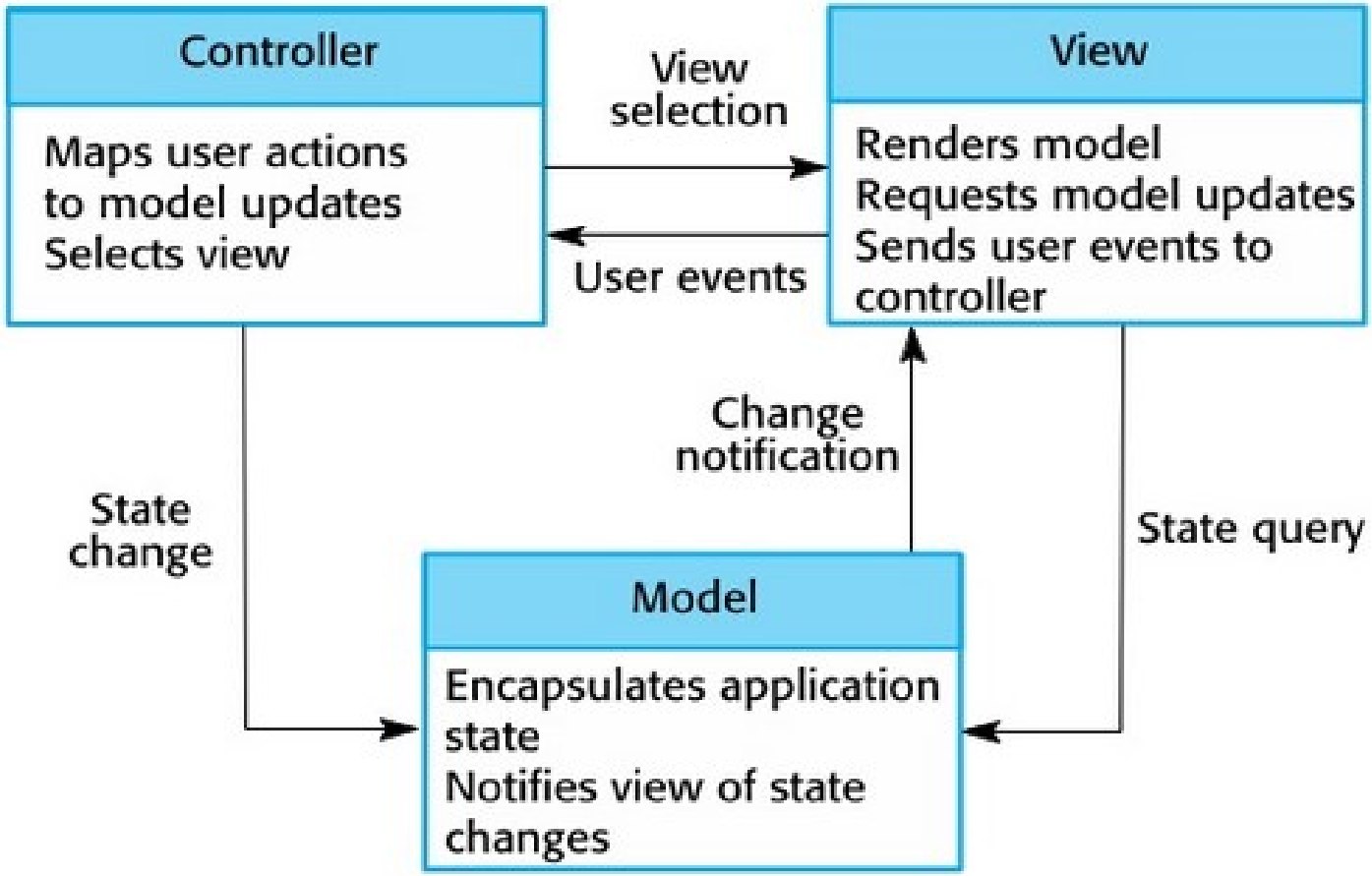
- **Patterns** are a means of representing, sharing, and reusing knowledge
- **An architectural pattern** is a stylized description of good design practice, which has been tried and tested in different environments
- **Patterns** should include information about when they are and when they are not useful
- **Patterns** may be represented using tabular and graphical descriptions

the Model-View-Controller(MVC) pattern

Name	MVC
Description	Separate presentation and interaction from the system data. The system is structured into 3 logical components that interact with each other. • The Model component manages the system data and associated operations on that data. • The View component defines and manages how the data is presented to the user. • The Controller component manages user interaction (e.g., key presses, mouse click, etc.) and passes these interactions to the View and the Model
Example	*Next slide* shows the architecture of a web-based application system organized using the MVC pattern
When used	when there are multiple ways to view and interact with data. Also used when the future requirements for interaction and presentation of data are unknown
Advantages	Allows the data to change independently of its representation and vice verse. Supports presentation of the same data in different ways with changes made in one representation shown in all of them
Disadvantages	can involve additional code and code complexity

The organization of the MVC

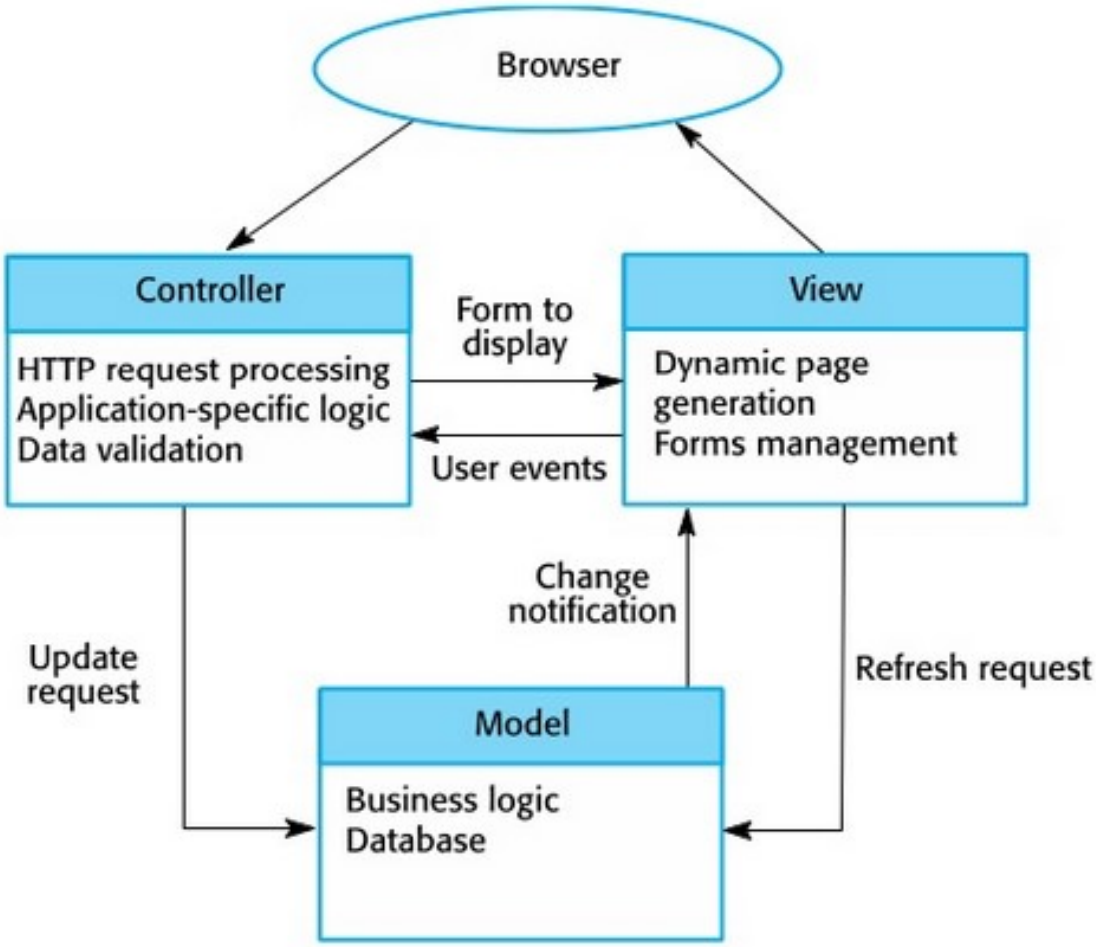
manages *user interaction* and **passes** *these interactions to the View and the Model*



manages how the data is presented to the user

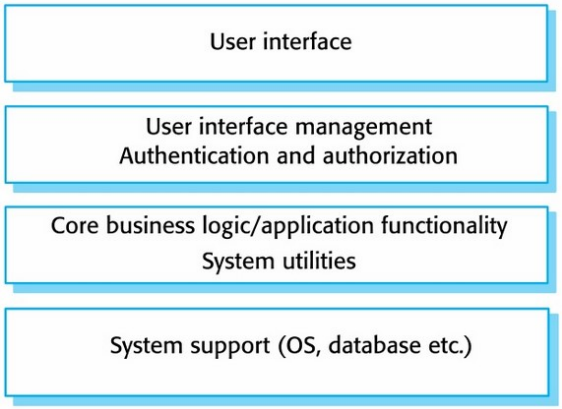
manages the **system data** and **associated operations** on that data.

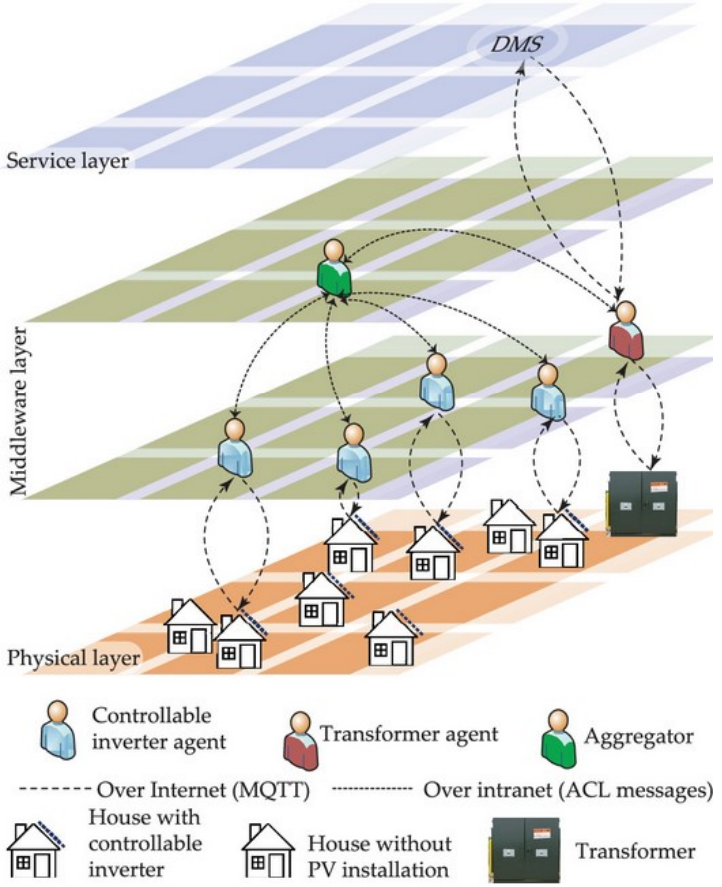
Web application architecture using the MVC pattern



Layered architecture

- Organizes the system into **a set of layers,** 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

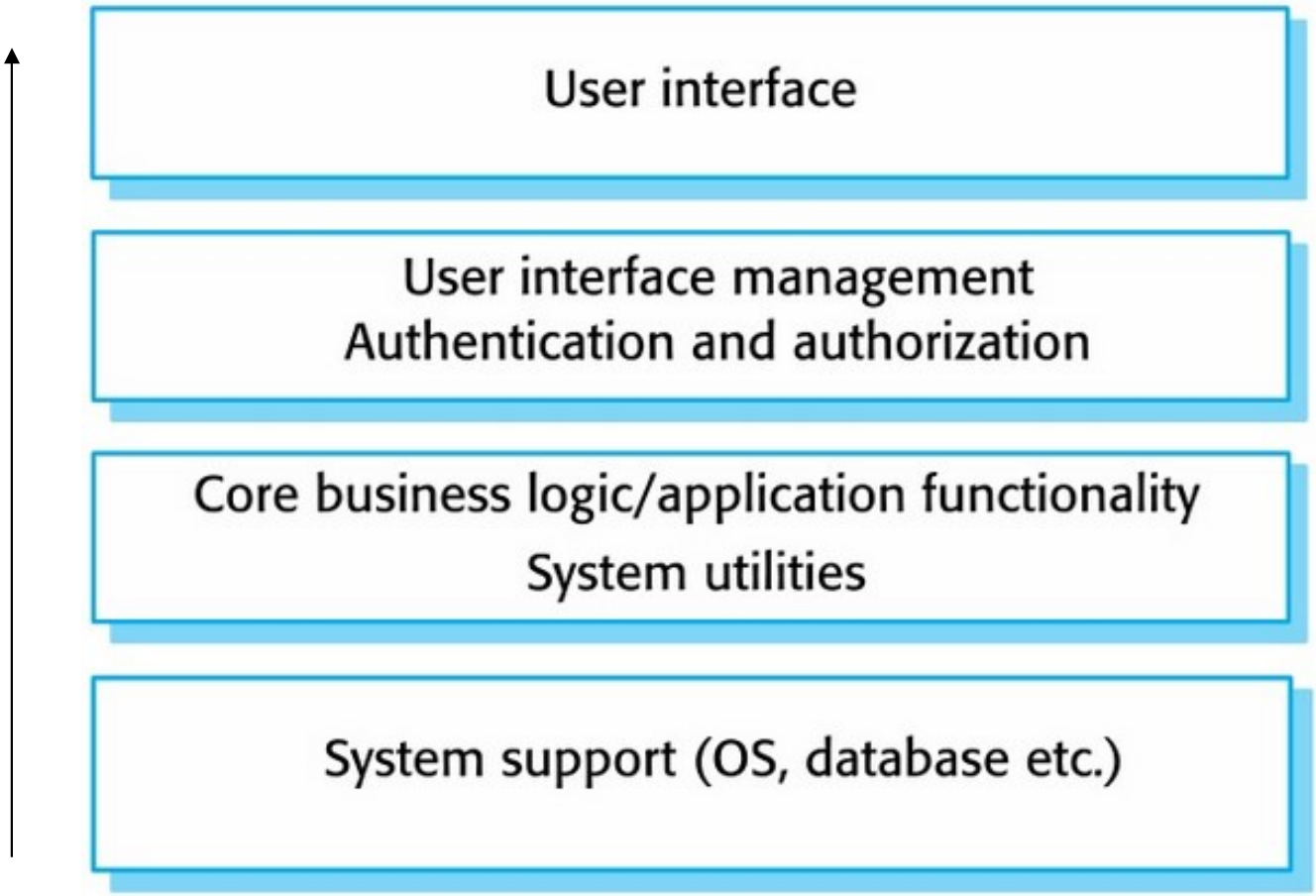




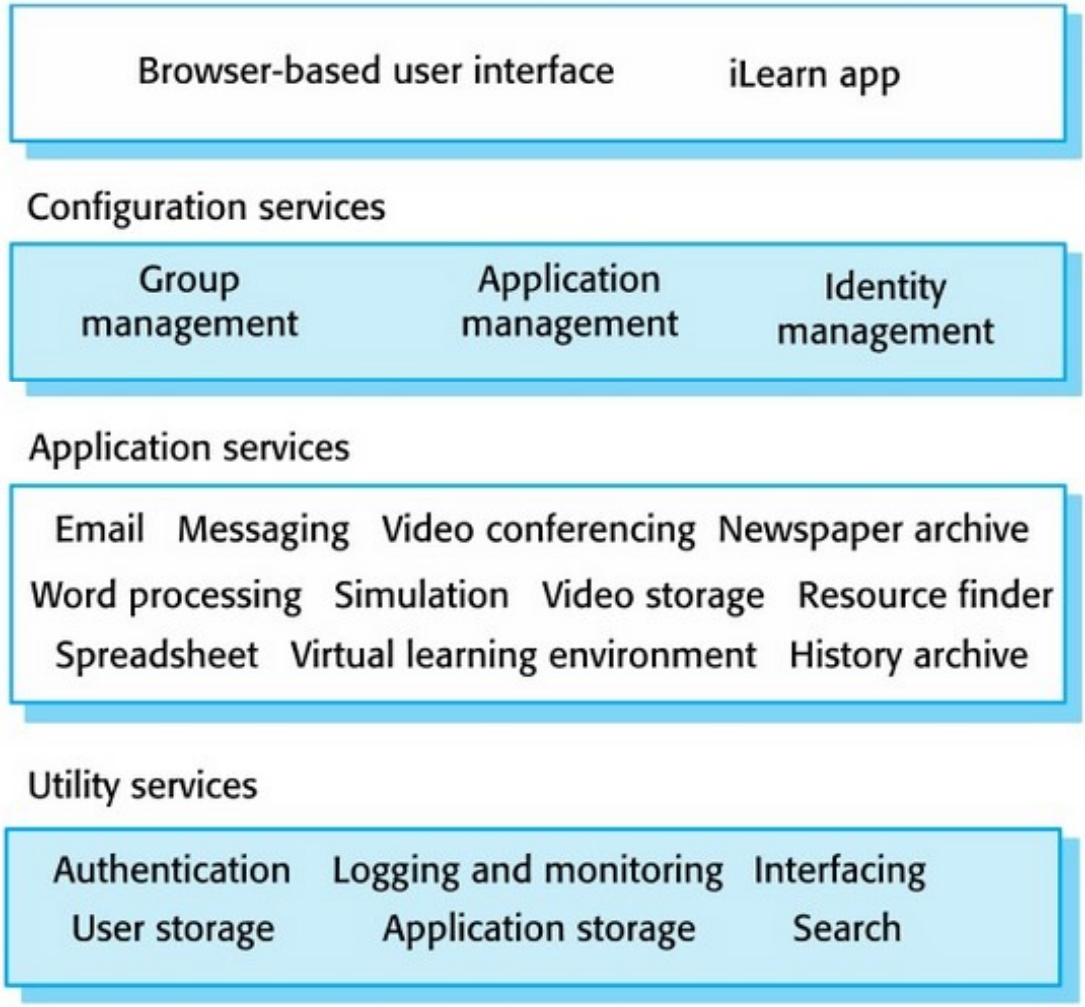
The layered architecture pattern

Name	Layered architecture
Description	• Organizes the system into layers with related functionality associated with each layer. • A layer provides services to the layer **above it** so the lowest-level layers represent core services that are likely to be used throughout the system .
When used	• when building new facilities on top of existing systems; • when the development is spread across several teams with each team responsibility for a layer of functionality; • when there is a requirement for multi-level security
Advantages	Allows replacement of the entire layer so long as the interface is maintained. Redundant facilities (e.g., authentication) can be provided in each layer to increase the dependability of the system
Disadvantages	In practice, providing a clean separation between layers is often difficult and a high-level layer may have to interact directly with lower-level layers rather than through the layer immediately below it. Performance can be a problem because of multiple levels of interpretation of a service request as it is processed at each layer

A generic layer architecture

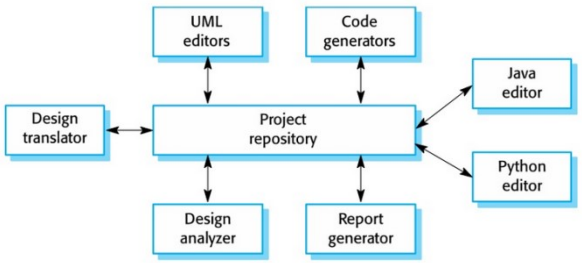


The architecture of the iLearn system



Repository architecture

- Sub-systems **must exchange** data
- This may be done in 2 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 as this is an efficient data sharing mechanism

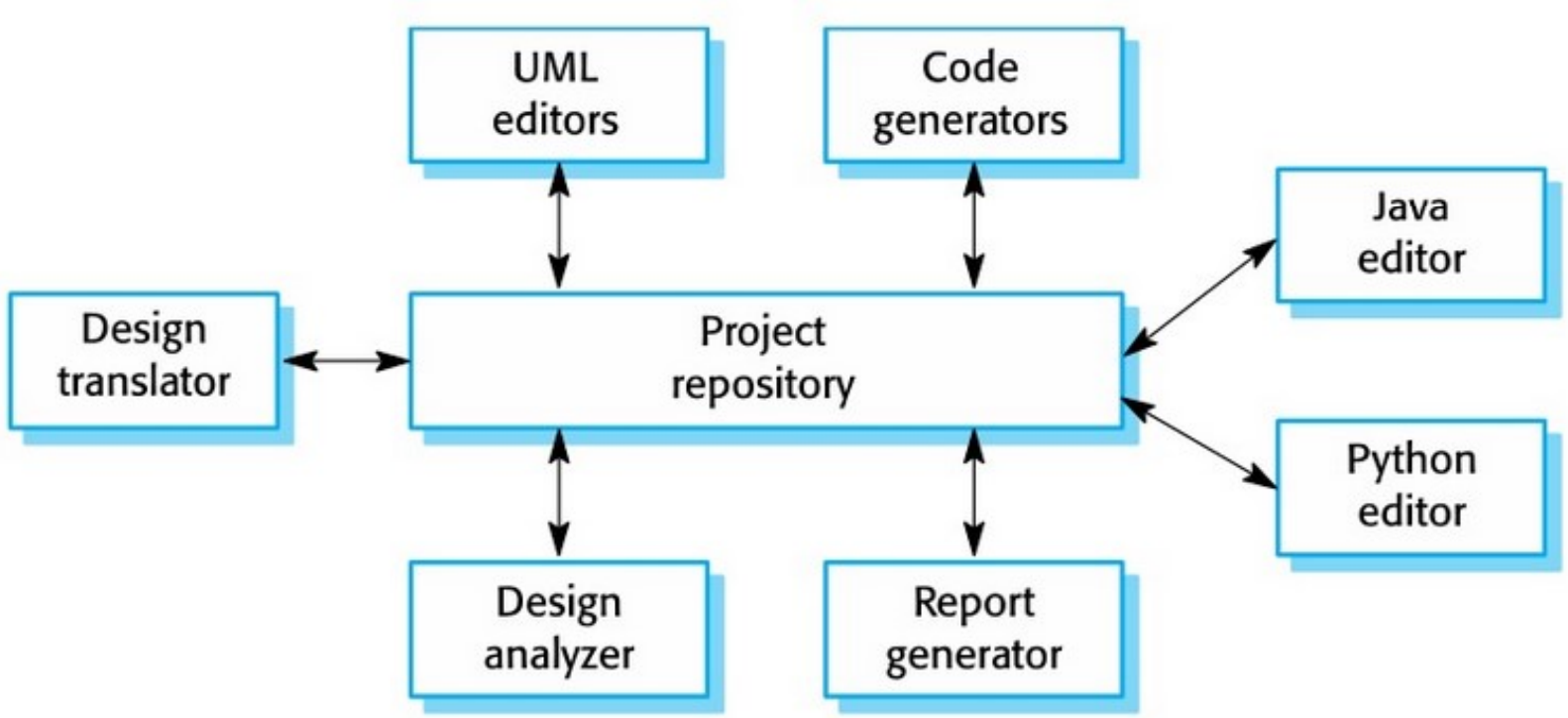


The repository pattern

Name	repository
Description	• **All data** in a system is managed in a central repository that is accessible to all system components. • Components do not interact directly, only through the repository
When used	when you have a system in which large volumes of information generated has to be stored for a long time. You may also use it in a data-driven systems where the inclusion of data in the repository triggers an action or tool
Advantages	Components can be independent – they do not need to know the existence of other components. Changes made by one component can be propagated to all components. All data can be managed consistently (e.g., backup done at the same time) as it is all in one place
Disadvantages	Failures happen in the repository, so problems → affect the whole system. May be inefficient in organizing all communication through the repository. Distributing the repository across several computers may be difficult

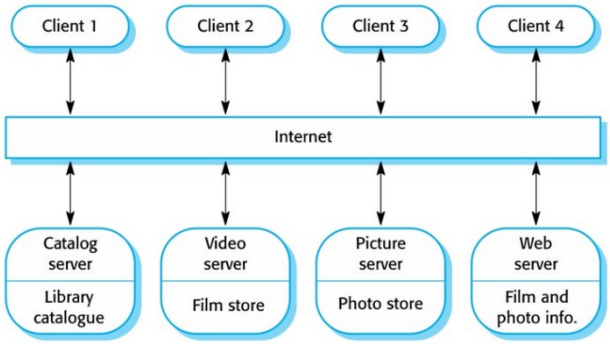
A repository architecture for an IDE

an example of an IDE where the components use a repository of system design information. Each software tool generates information which is then available for use by other tools



Client-server architecture

- **Distributed system model** which shows **how** data and processing is distributed across a range of components
  - Can be implemented on a single computer
- **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

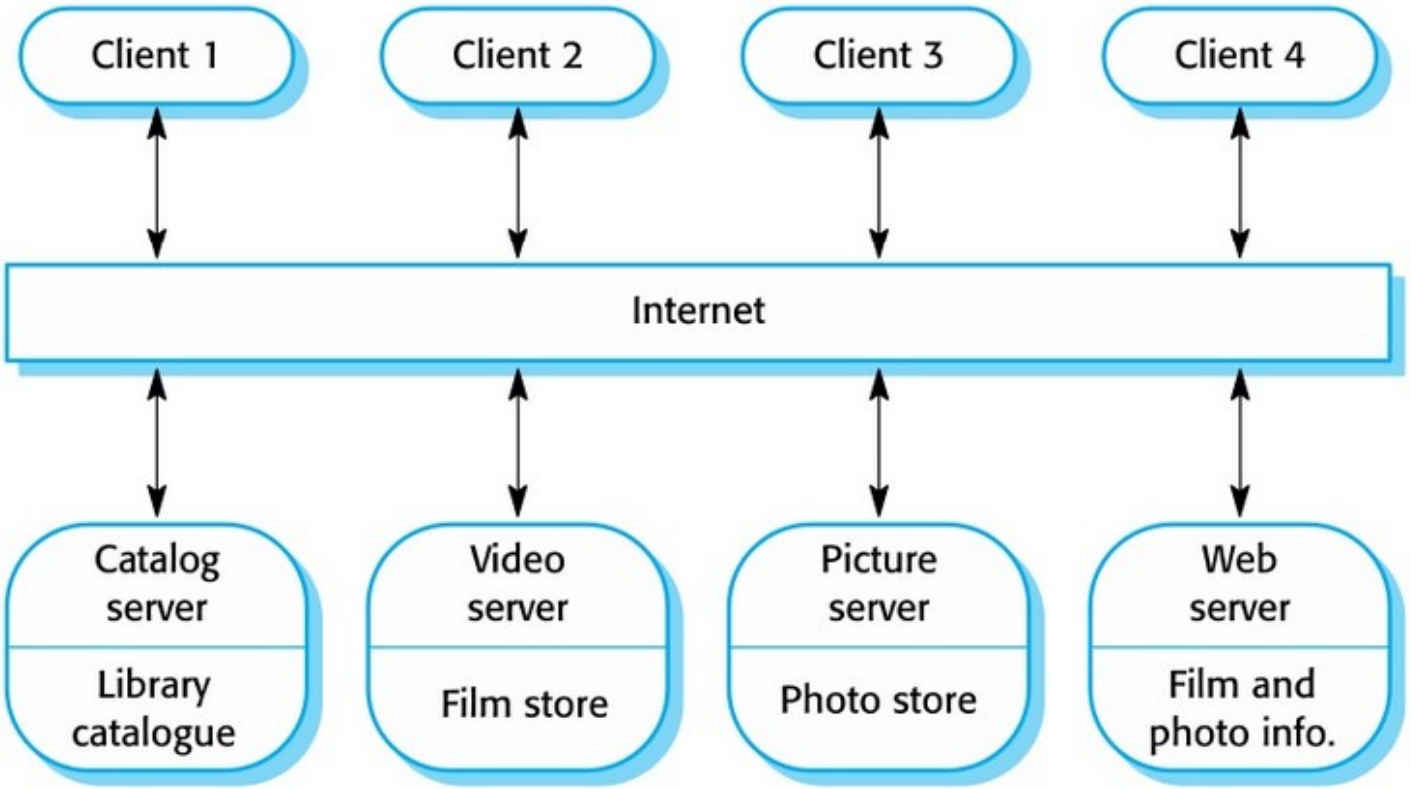


The client-server pattern

Name	Client-server
Description	• In a client-server architecture, the functionality of the system is organized into **services,** with each service delivered from a separate server. • Clients are users of these services and access servers to make use of them
Example	Fig.
When used	when data in a shared database has to be accessed from a range of locations. Because servers can be replicated, may also be used when the load on a system is variable
Advantages	The principle advantage of this model is that servers can be distributed across a network. General functionality (e.g., a printing service) can be available to all clients and does not need to be implemented by all services
Disadvantages	Performance may be unpredictable because it depends on the network as well as the system. May be management problems if servers are owned by different organizations

A client-server architecture for a film library

an example of a film and video/DVD library organized as a client-server system



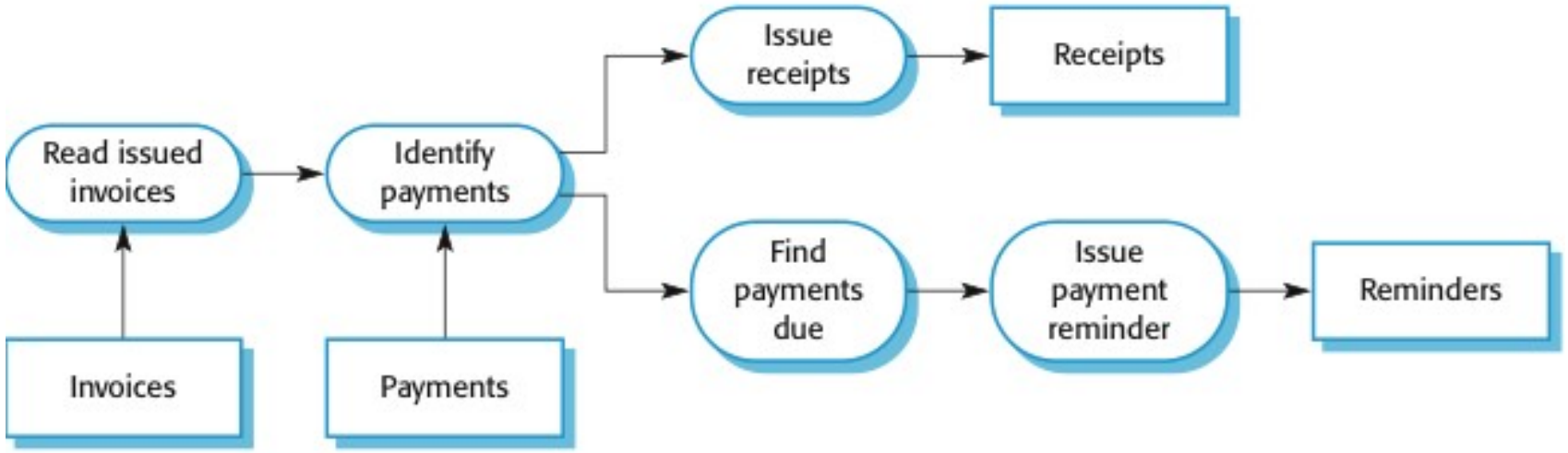
Pipe & filter architecture

- **Functional transformations** process their inputs to proceduce outputs
- May be referred to as a pipe and filter model
- 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

The pipe and filter pattern

Name	Pipe & filter
Description	The processing of the data in a system is organized so that each processing component (filter) is discrete and carries out one type of data transformation. The data flows (as in a pipe) from one component to another for processing
Example	Fig.
When used	Common used in data processing applications (both batch- and transaction-based) when inputs are processed in separate stages to generate related outputs
Advantages	Workflow style matches the structure of many business processes. Evolution by adding transformations is straightforward. Can be implemented as either a sequential or concurrent system
Disadvantages	The format for data transfer has to be agreed upon between communicating transformations. Each transformation must parse its input & unparse its output to the agreed form. This increases system overhead and may mean that it is impossible to reuse functional transformations that use incompatible data structures

An example of the pipe & filter architecture used in a payment system



Application architectures

- Application systems are designed to meet an organization need
- As **businesses** have much **in common**, their application system also tend to have a common architecture that reflects the application requirements
- **A generic application architecture** is an architecture of a type of software system that may be configured and adapted to create a system that meets specific requirements

Use of application architectures

- As a starting point for architectural design
- As a design checklist
- As a way of organizing the work of the development team
- As a means of assessing components for reuse
- As a vocabulary for talking about application types

Examples of application types

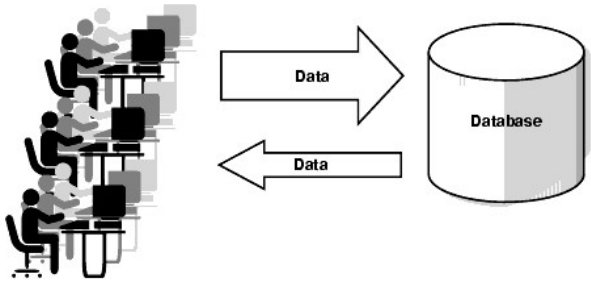
- Data processing applications
  - Data driven applications that process data in batches **without** explicit user intervention during the processing
- **Transaction processing applications**
  - Data-centered applications that process user requests and update information in a system database
- Event processing systems
  - Applications where system actions depend on interpreting events from the system's environment
- **Language processing systems**
  - Applications where the users' intentions are specified in a formal language that is processed and interpreted by the system

Application type examples

- Two very widely used **generic application architectures** are **transaction processing systems** and **language processing systems**
- Transaction processing systems
  - E-commerce systems
  - Reservation systems
- Language processing systems
  - Compilers
  - Command interpreters

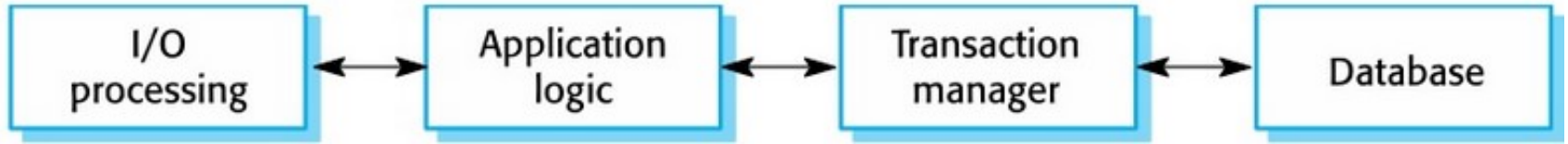
Transaction processing systems

- Process user requests for information from a database or requests to update the database

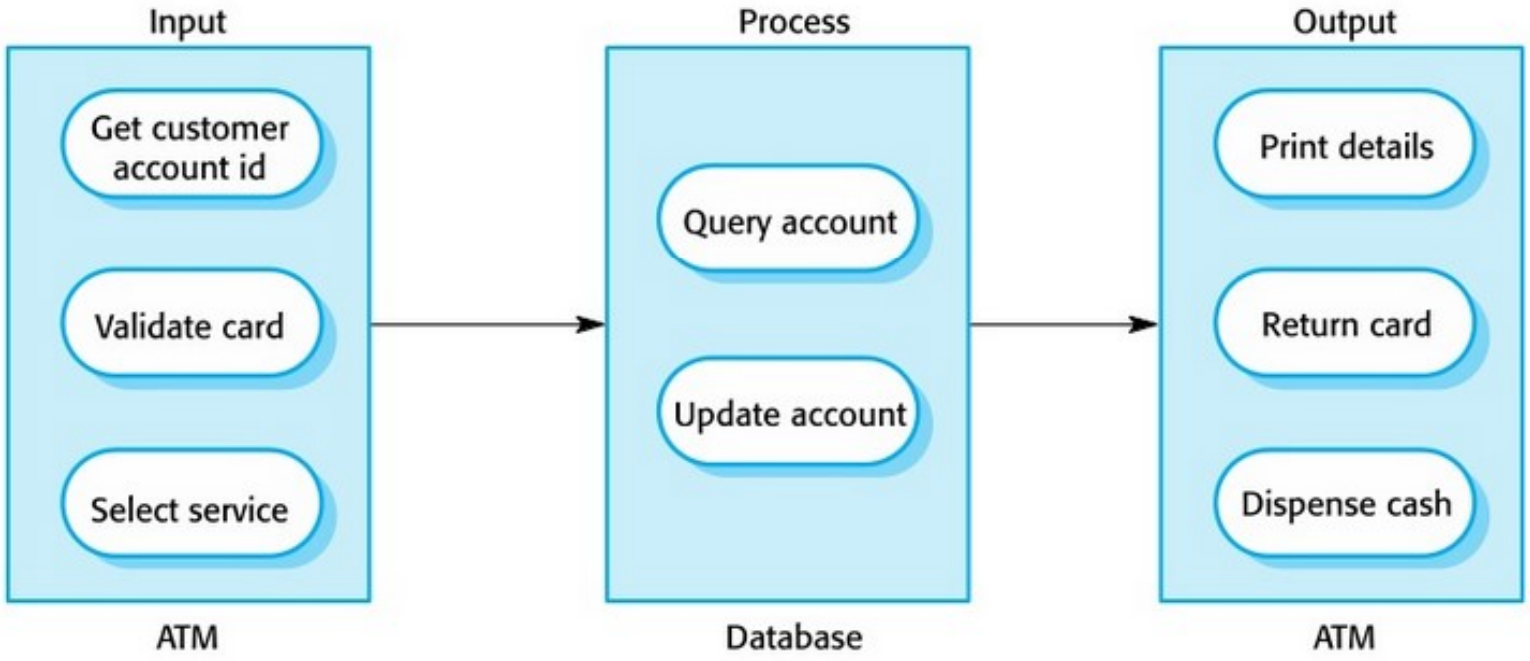


- From a user perspective**, a transaction** is
  - Any coherent sequence of operations that satisfies a goal
  - E.g., Find the times of flights from London to Paris

- The structure of transaction processing applications

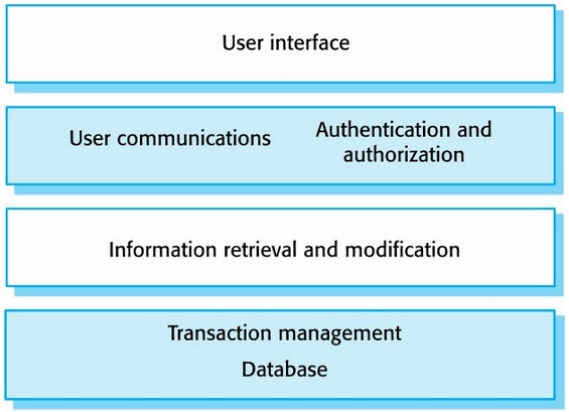


The software architecture of an ATM system

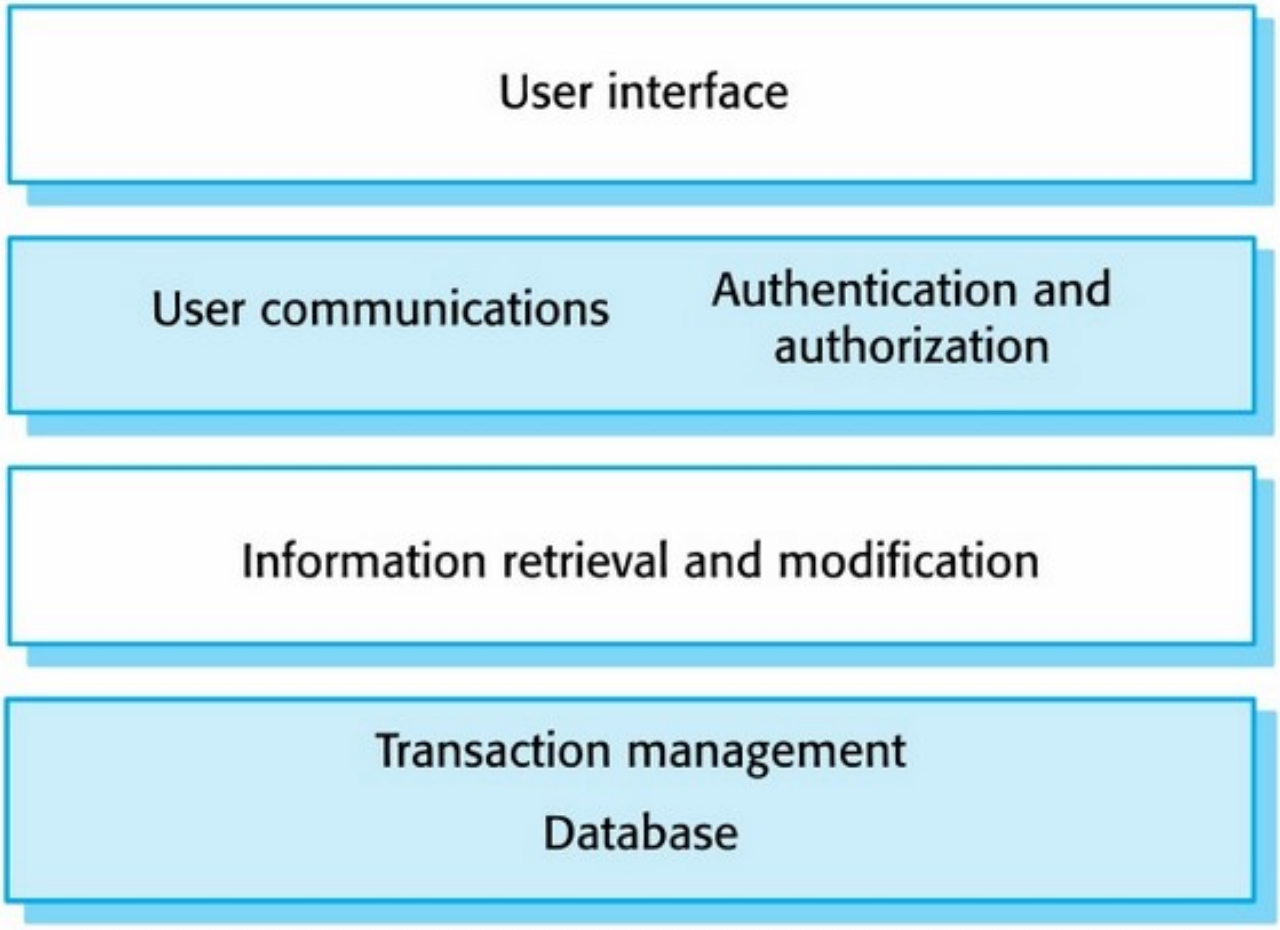


Information systems architecture

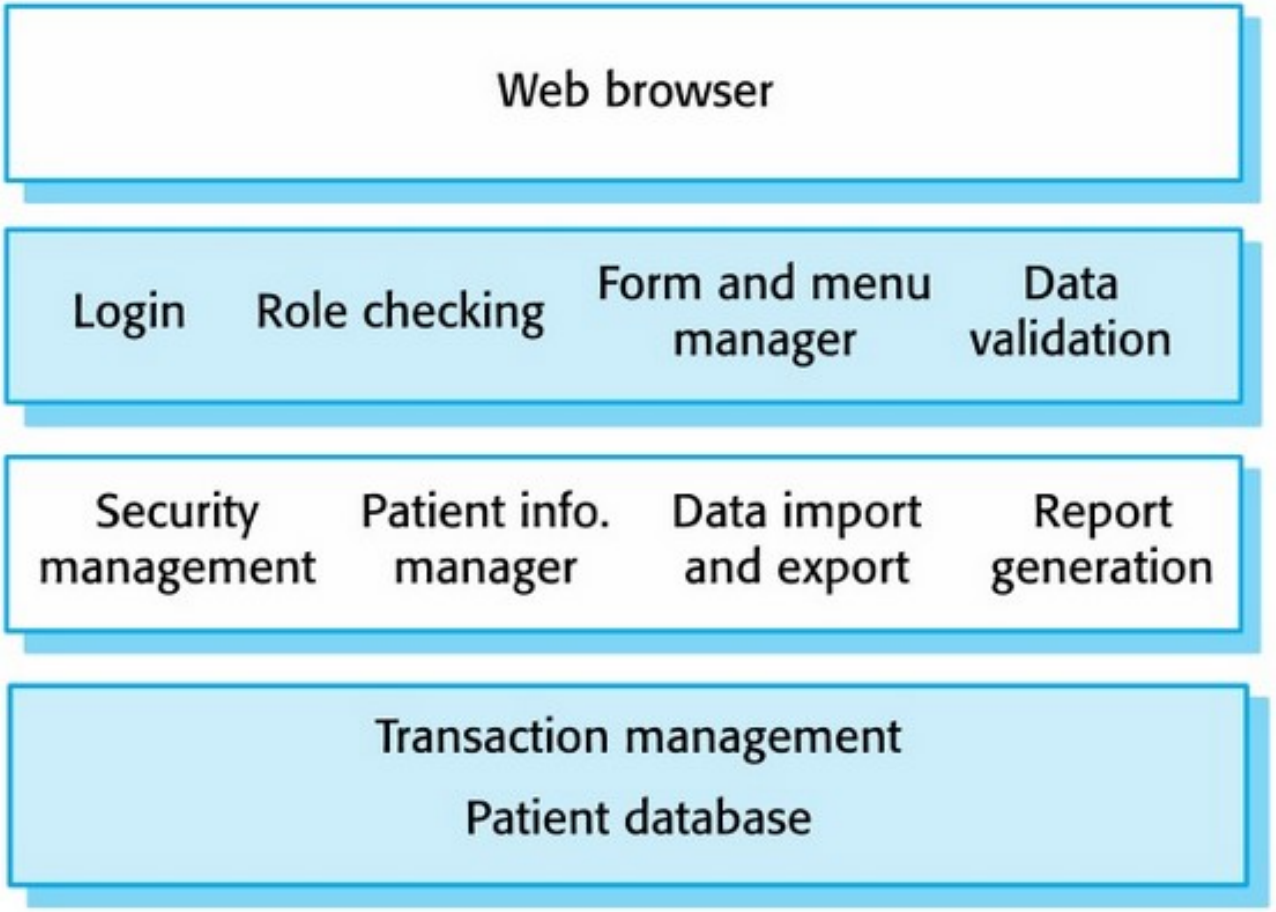
- Information systems have a generic architecture that can be organized as a layered architecture
- These are transaction-based systems as interaction with these systems generally involves database transactions
- Layers include
  - The user interface
  - User communications
  - Information retrieval
  - System databases



Layered information system architecture



The architecture of the Mentcare system

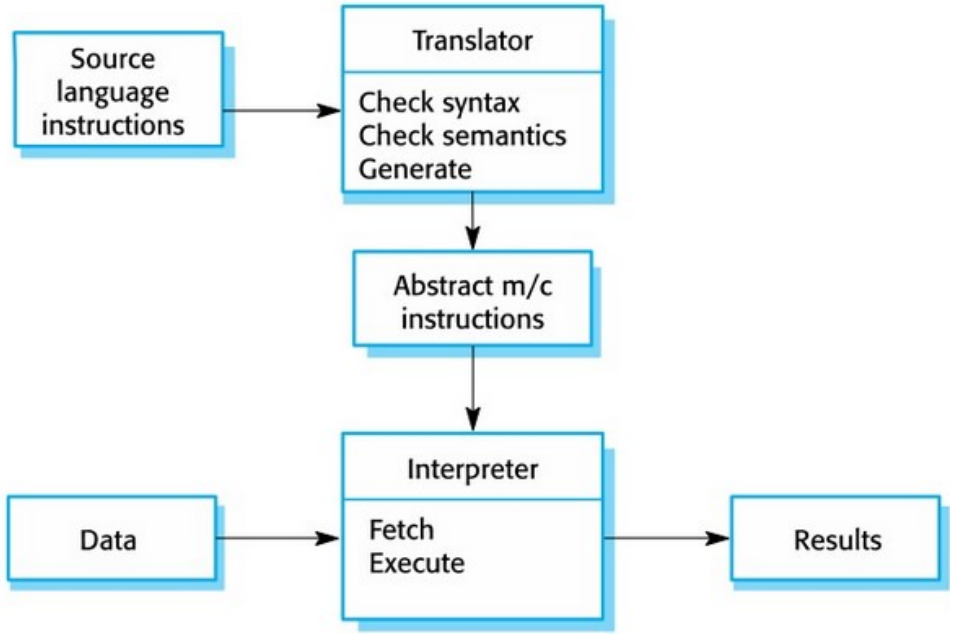


Web-based information systems

- Information and resource management systems are now usually web-based systems where the user interfaces are implemented using a web browser
- E.g., e-commerce systems are Internet-based resource management systems that accept electronic orders for goods or services and then arrange delivery of these goods or services to the customer
- In an e-commerce system, the application-specific layer includes additional functionality supporting a 'shopping cart' in which users can place a number of items in separate transactions, then pay for them all together in a single transaction

Language processing systems

- Accept a natural or artificial language as input and generate some other representation of that language
- May include **an interpreter** to act on the instructions in the language that is being processed
- The architecture of LP system



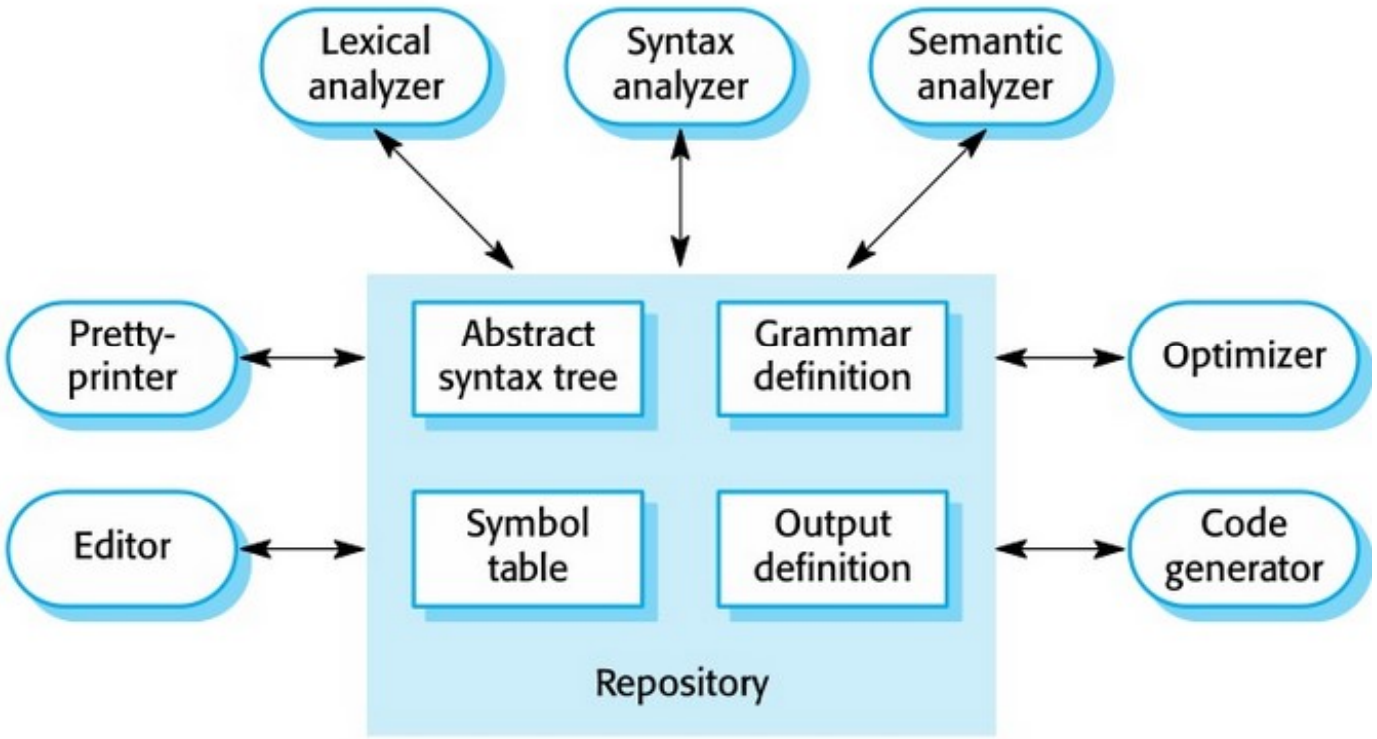
Compiler components

- **A lexical analyzer**, which takes input language token and converts them to an internal form
- **A symbol table**, which holds information about the names of entities (variables, class names, object names, etc.) used in the text that is being translated
- **A syntax analyzer**, which checks the syntax of the language being translated
- **A syntax tree**, which is an internal structure representing the program being compiled

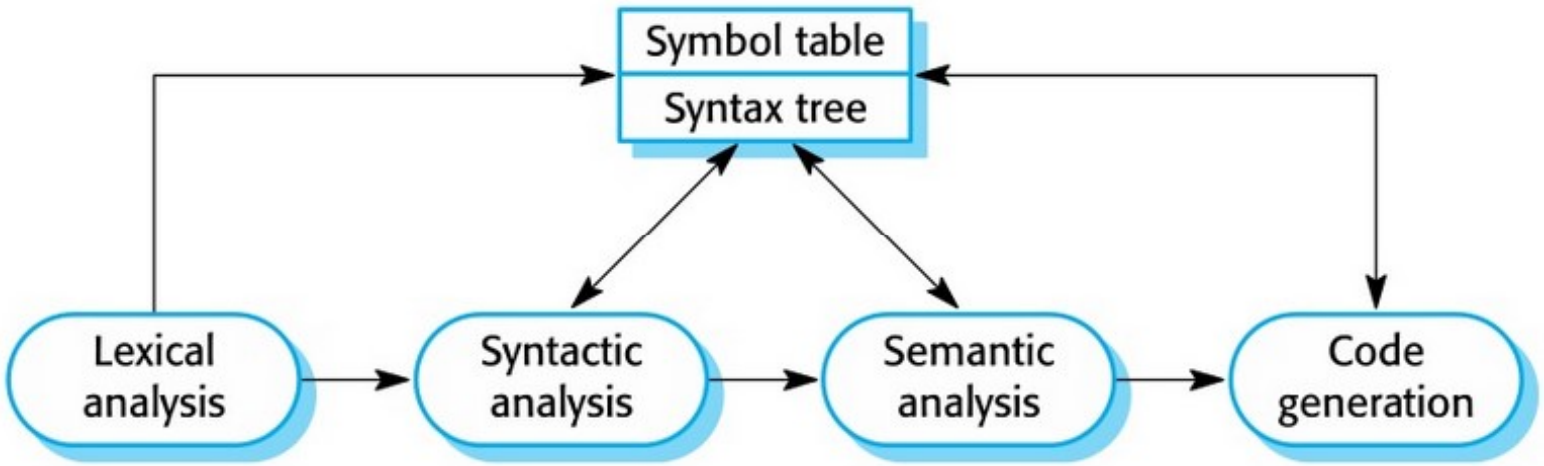
Compiler components

- **A semantic analyzer** that uses information from the syntax tree and the symbol table to check the semantic correctness for the input language text
- **A code generator** that ‘walks’ the syntax tree and generates abstract machine code

A repository architecture for a language processing system



A pipe and filter compiler architecture



Key points

- A software architecture is a description of how a software system is organized
- Architectural design decision include decisions on the type of application, the distribution of the system, the architectural styles to be used
- Architectures may be documented from several different perspectives or views such as a conceptual view, a logical view, a process view, and a development view
- Architectural patterns are a means of reusing knowledge about generic system architectures
  - They describe the architecture, explain when it may be used an describe its advantages and disadvantages

Key points

- Models of application systems architectures help us understand and compare applications, validate application system design and assess large-scale components for reuse
- Transaction processing systems are interactive systems that allow information in a database to be remotely accessed and modified by a number of users
- language processing systems are used to translate texts from one language into another and to try out the instructions specified in the input language
  - They include a translator and an abstract machine that executes the generated language