CMPE 331
Software and Software Engineering

Dr. İlknur Dönmez

(Source: Pressman, R. *Software Engineering: A Practitioner’s Approach*. McGraw-Hill, 2005
& Sommerville, I. (2004). Software Engineering. International computer science series. *ed:Addison Wesley*)

Architectural Design -Topics covered

- Architectural design decisions
- Architectural views
- Architectural patterns
- Application architectures

Architectural design

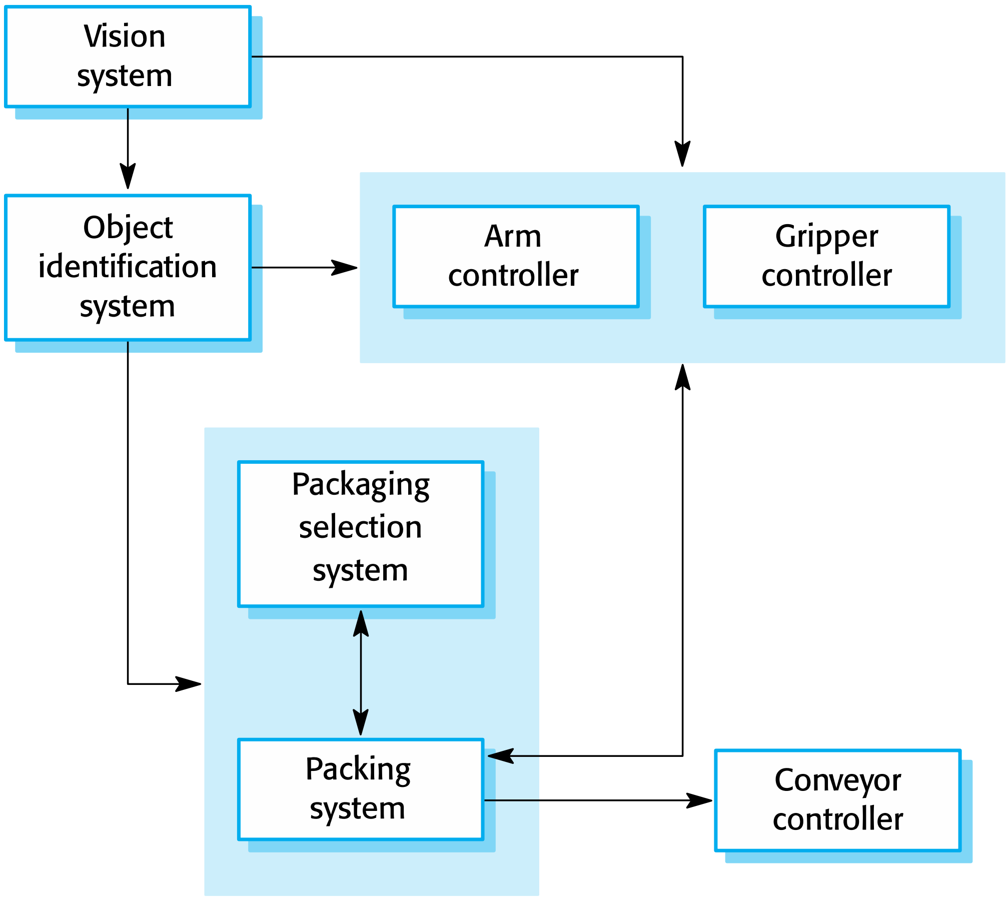
- Architectural design is concerned with understanding how a software system should be organized and
- it is concerned with designing the overall structure of that system.
- Architectural design is the critical link between design and requirements engineering,
- it identifies the main structural components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

Agility and 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 an individual program is decomposed into components.
- Architecture in the large is concerned with the architecture of complex enterprise systems.
  - They 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

- Stakeholder communication
  - Architecture may be used as a focus of discussion by system stakeholders.
- System analysis
  - 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
  - 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 they 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 do not show the nature of component relationships nor the externally visible properties of the sub-systems.
- However, useful for communication with stakeholders and for project planning.

Use of architectural models

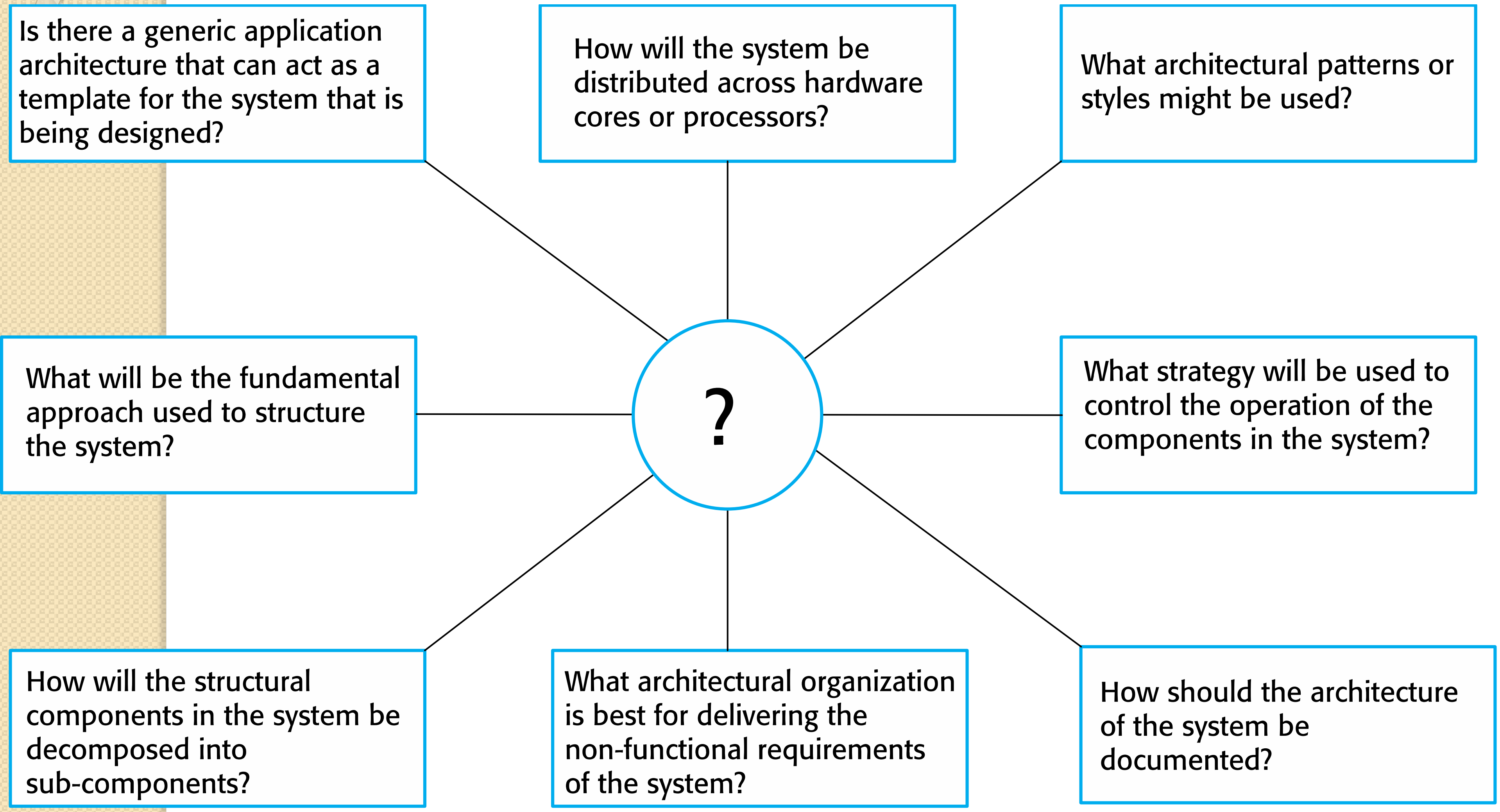
- As a way of facilitating discussion about the system design
  - A high-level architectural view of a system is useful for communication with system stakeholders and project planning because it is not cluttered with detail. They can then discuss the system as a whole without being confused by detail.
- 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 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.

Architectural design decisions



Is there a generic application architecture that can act as a template for the system that is being designed?

How will the system be distributed across hardware cores or processors?

What architectural patterns or styles might be used?

What will be the fundamental approach used to structure the system?

?

What strategy will be used to control the operation of the components in the system?

How will the structural components in the system be decomposed into sub-components?

What architectural organization is best for delivering the non-functional requirements of the system?

How should the architecture of the system be documented?

Architecture reuse

- Systems in the same domain often have similar architectures that reflect domain concepts.

- The architecture of a system may be designed around one of more architectural patterns or 'styles'.

Architecture and system characteristics

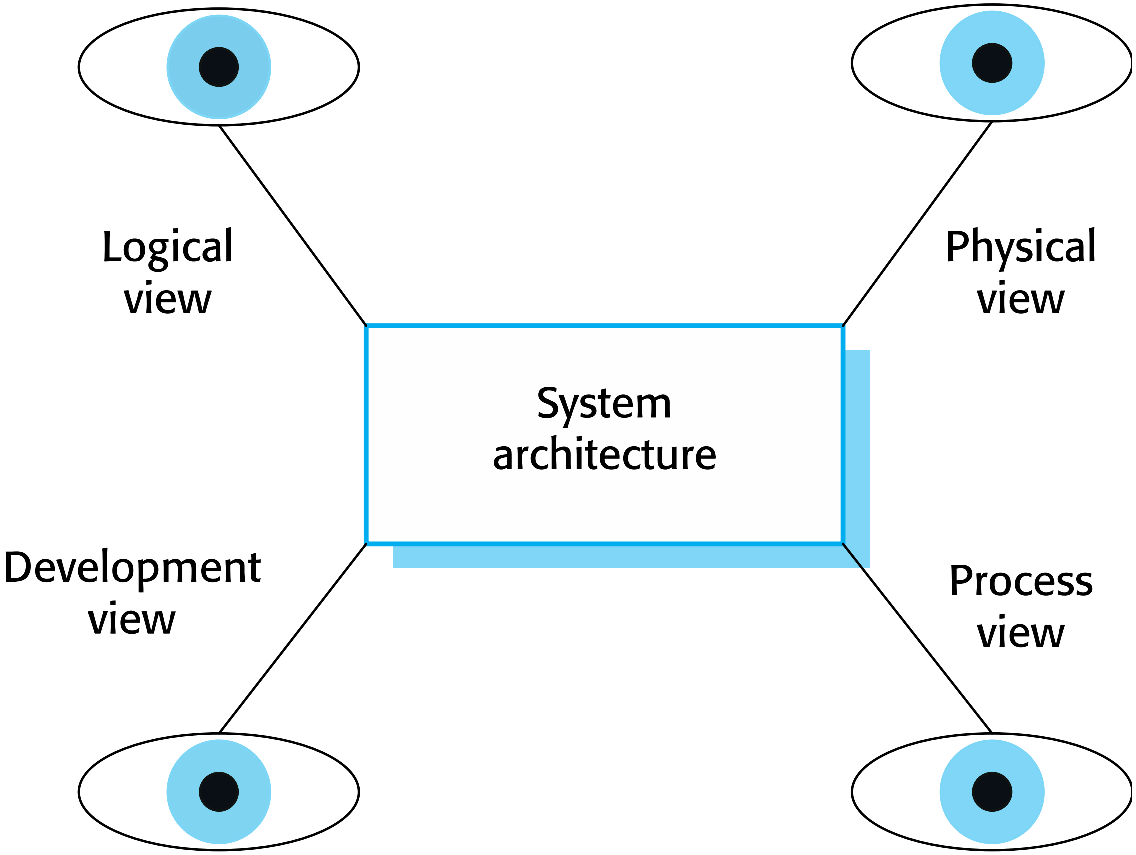
- Performance :
  - Localize critical operations and minimize communications. Use large rather than fine-grain components.
- Security
  - Use a layered architecture with critical ones in the inner layers.
- Safety
  - Localize safety-critical features in a small number of sub-systems.
- Availability
  - Include redundant components and mechanisms for fault tolerance of availability (more capacity, more cables etc).
- Maintainability
  - Use fine-grain, replaceable components.

Architectural views

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.

Architectural views



4 + 1 view model of software architecture

- A logical view, which shows the key abstractions 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 view using use cases or scenarios (+1)

Representing architectural views

- Some people argue that the Unified Modeling Language (UML) is an appropriate notation for describing and documenting system architectures
- But UML does not include abstractions appropriate for high-level system description.
- Architectural description languages (ADLs) have been developed but are not widely used

Architectural patterns

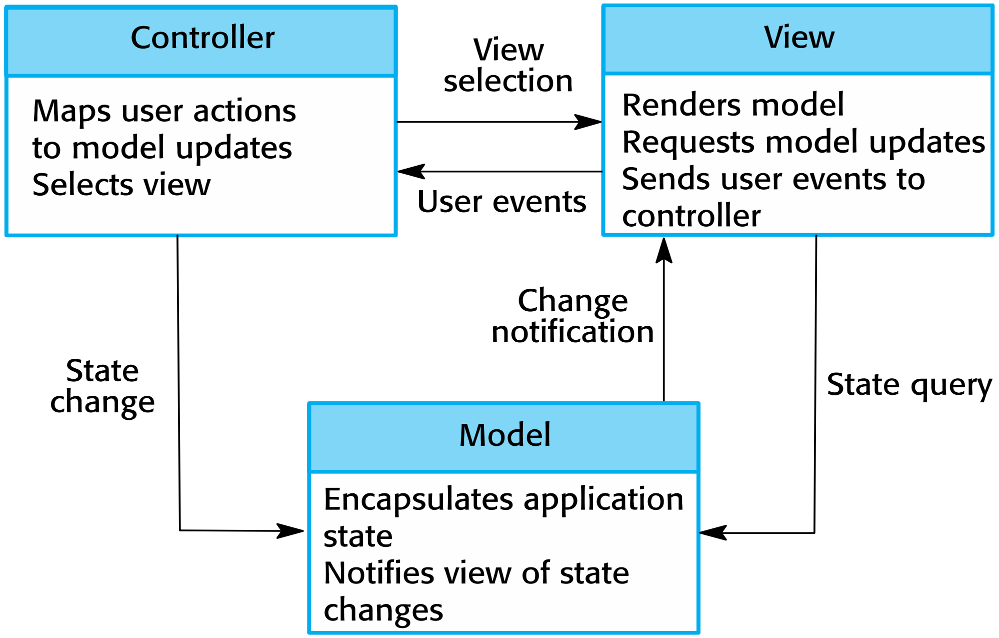
Architectural patterns

- 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 the are not useful.
- Patterns may be represented using tabular and graphical descriptions.

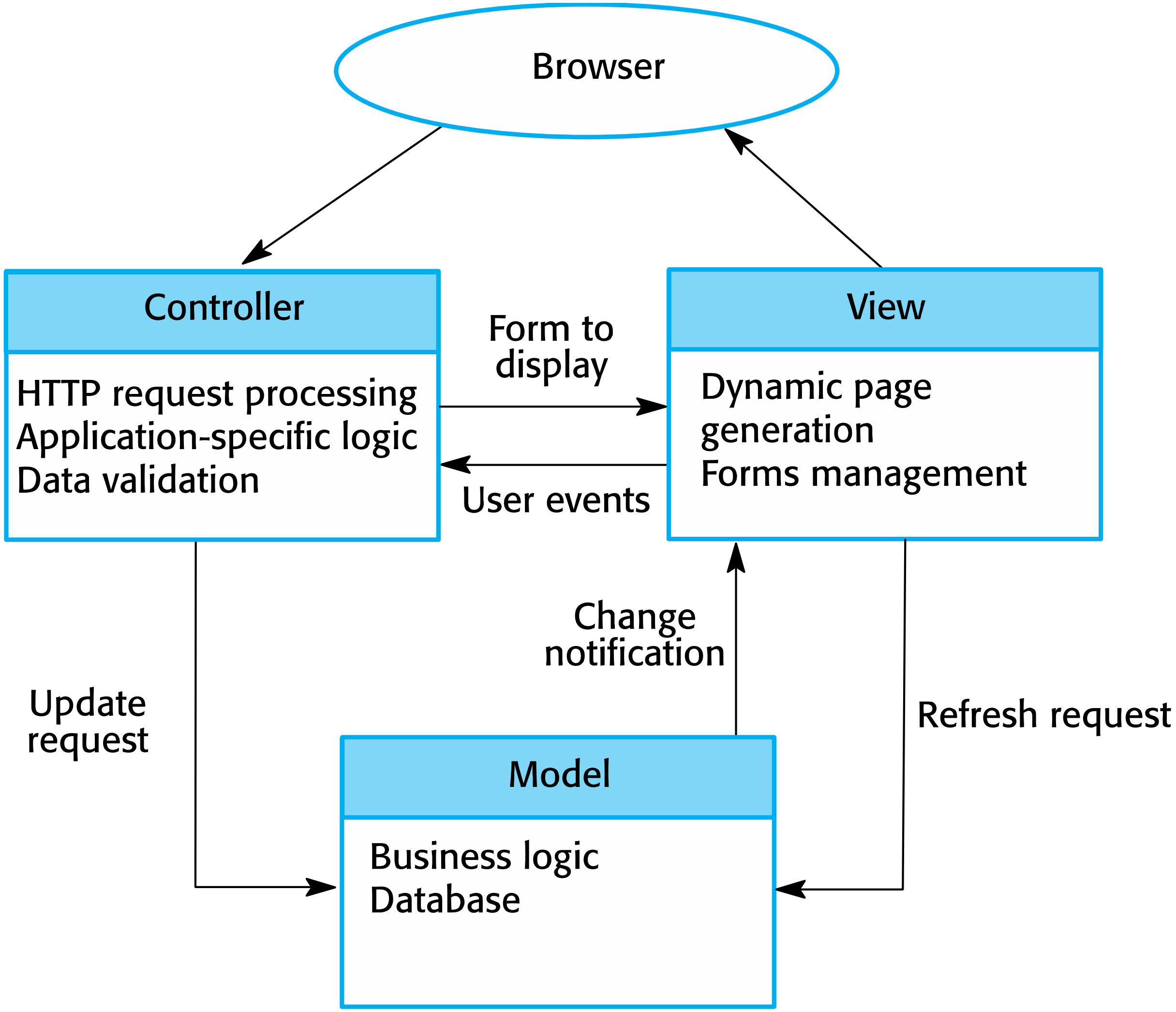
The Model-View-Controller (MVC) pattern

Name	MVC (Model-View-Controller)
Description	The MVC pattern is a UI presentation pattern that focuses on separating the UI (View) from its business layer (Model). The pattern separates responsibilities across three components: the view is responsible for rending UI elements, the controller is responsible for responding to UI actions, and the model is responsible for business behaviors and state management.
When used	Used when there are multiple ways to view and interact with data. (Same function with different UI's or same UI with different functions) Also used when the future requirements for interaction and presentation of data are unknown.
Disadvantages	Can involve additional code and code complexity when the data model and interactions are simple.
Advantages	Allows the data to change independently of its representation and vice versa. Supports presentation of the same data in different ways.

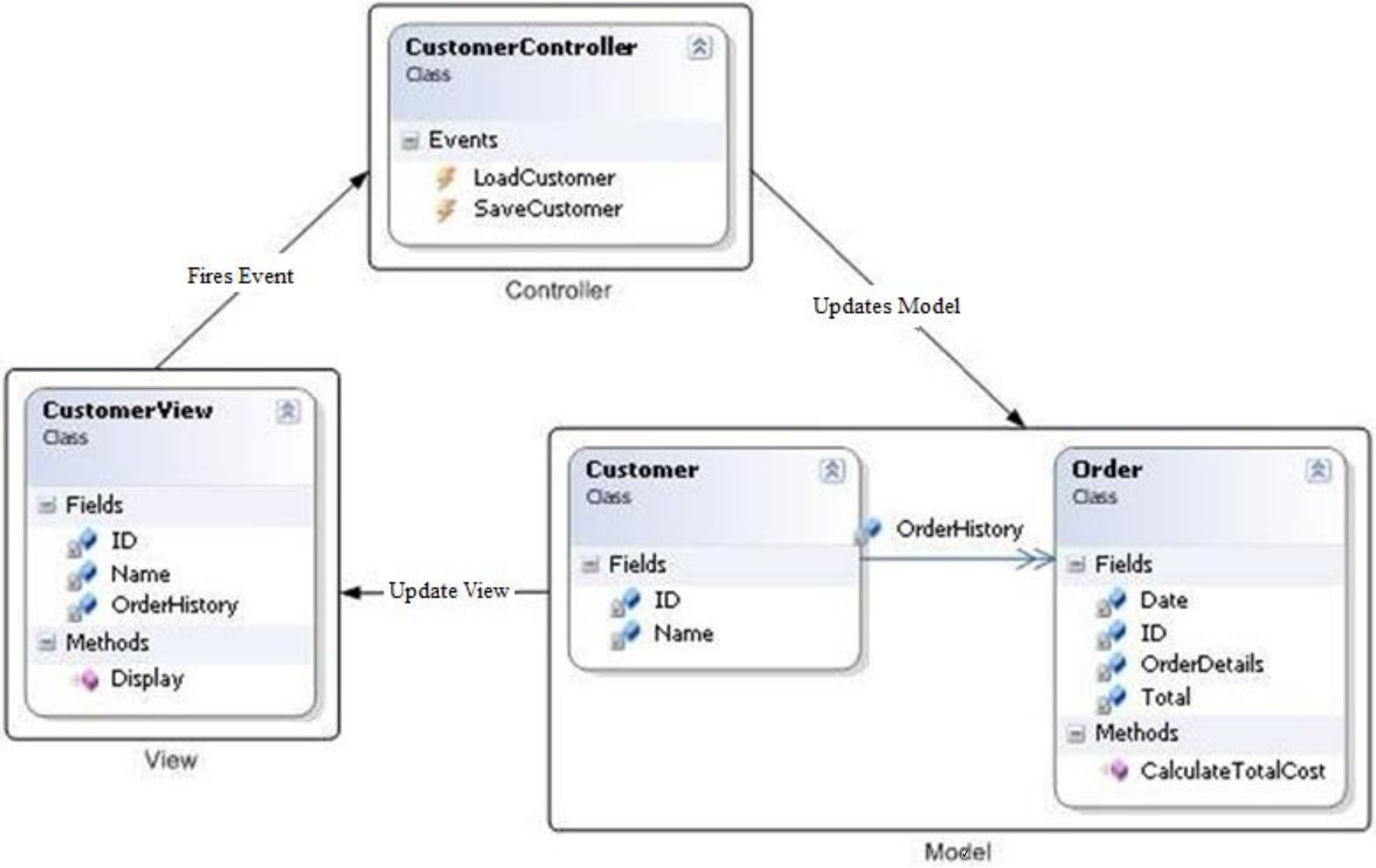
The organization of the Model-View-Controller



Web application architecture using the MVC pattern



UI application architecture using the MVC pattern



Layered architecture

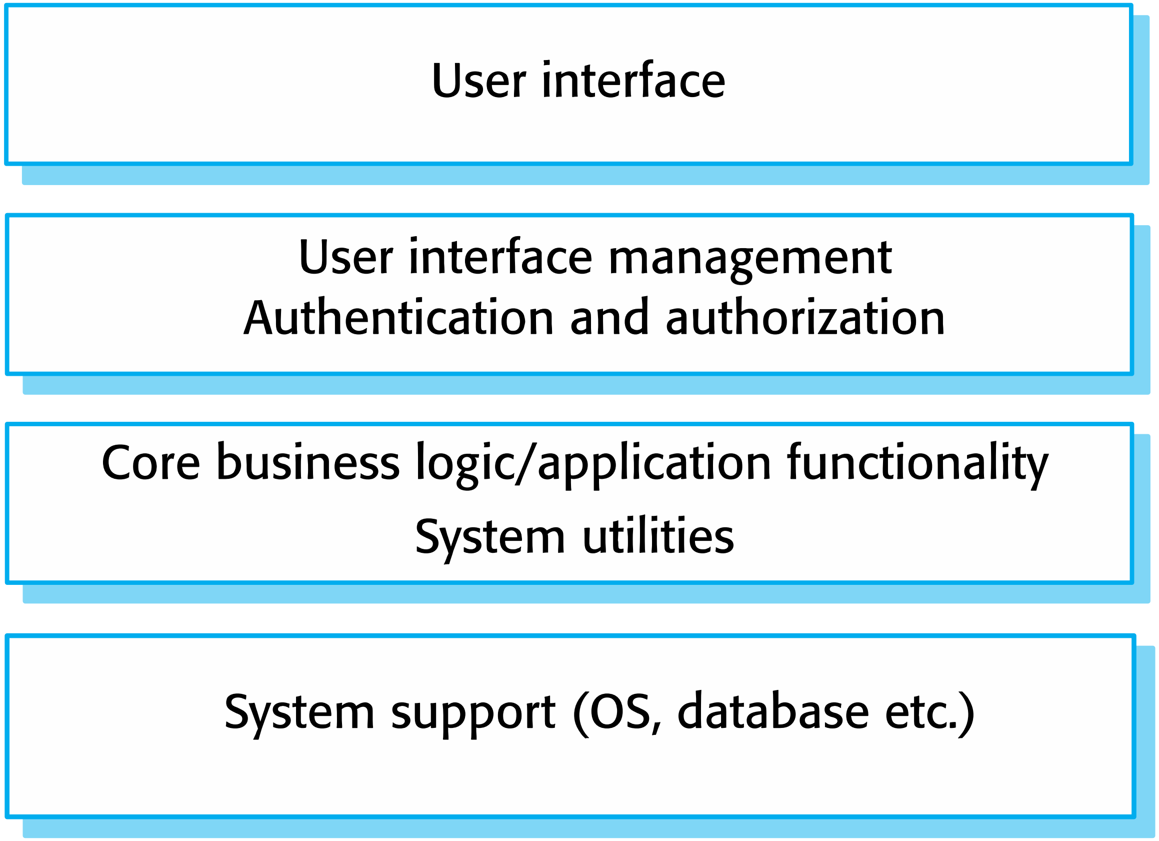
- Used to model the interfacing of sub-systems.
- Organises the system into a set of layers (or abstract machines) each of which provide a set of services.

- Supports the incremental development of sub-systems in different layers. When a layer interface changes, only the adjacent layer is affected.

The Layered architecture pattern

Name	**Layered architecture**
Description	Organizes the system into layers with related functionality. 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.
Disadvantages	• Providing a clean separation between layers is often difficult. • A high-level layer may need 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.
Advantages	Allows replacement of entire layers 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. (Security in each level)

A generic layered architecture



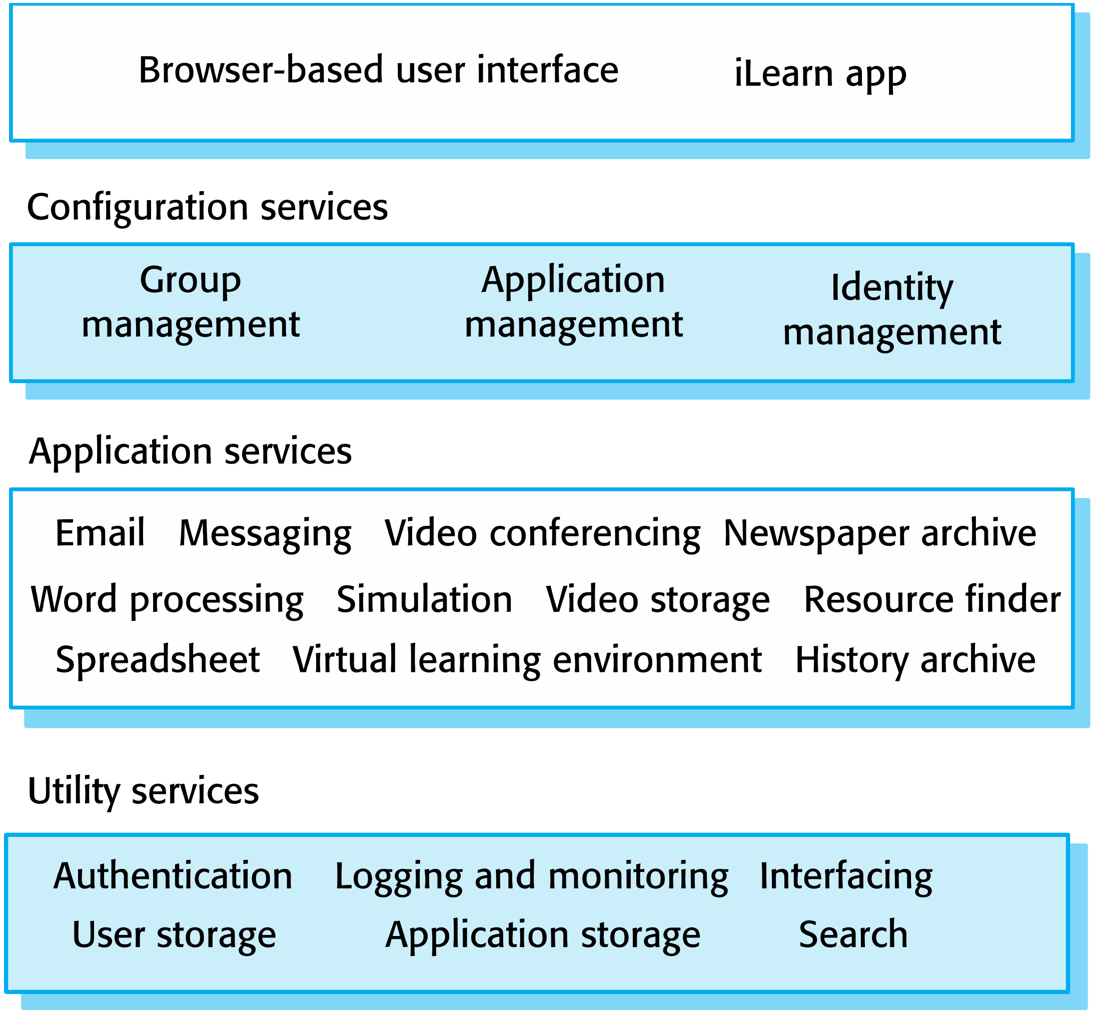
User interface

User interface management
Authentication and authorization

Core business logic/application functionality
System utilities

System support (OS, database etc.)

The architecture of the iLearn system



Browser-based user interface iLearn app

Configuration services

Group management Application management Identity management

Application services

Email Messaging Video conferencing Newspaper archive

Word processing Simulation Video storage Resource finder

Spreadsheet Virtual learning environment History archive

Utility services

Authentication Logging and monitoring Interfacing

User storage Application storage Search

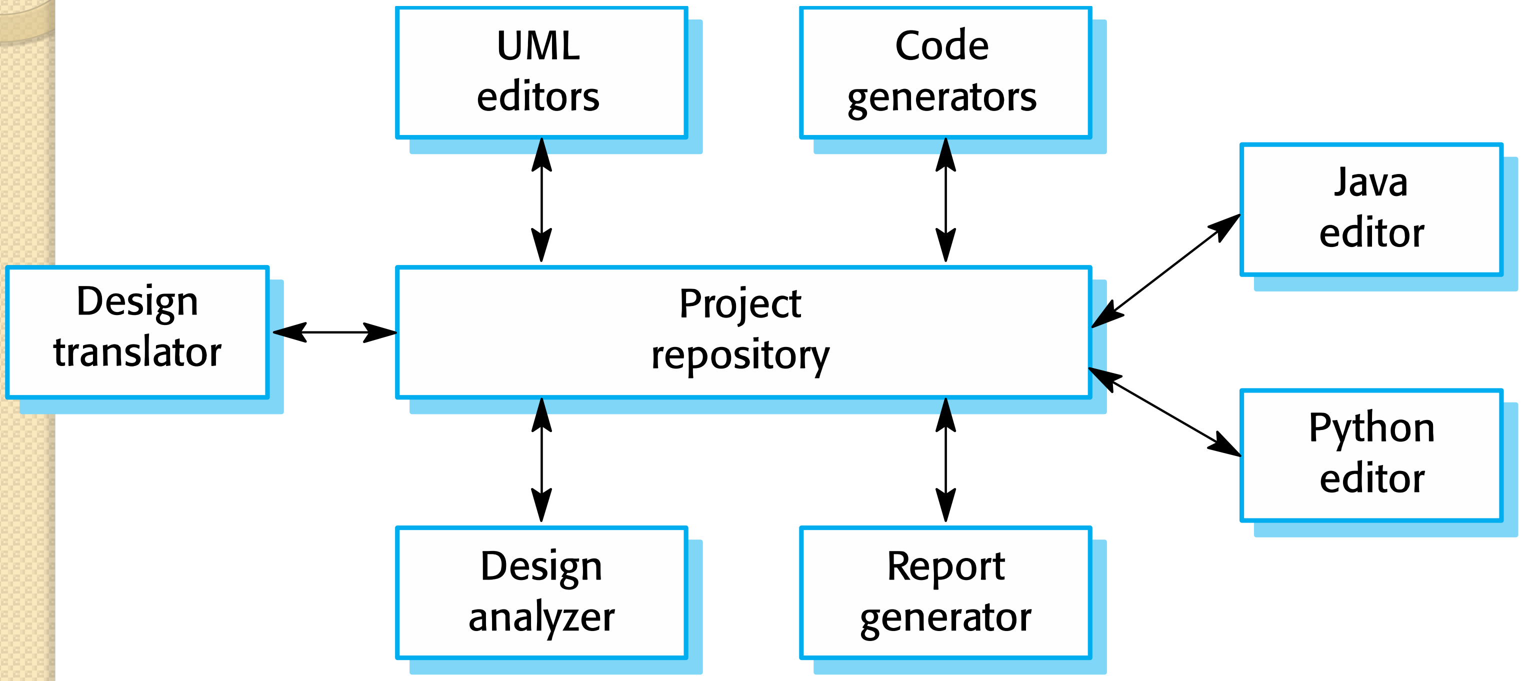
Repository architecture

- Sub-systems must exchange data. This may be done in two ways:
  - Shared data is held in a central database or repository and data 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. 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	You should use this pattern when you have a system in which large volumes of information are generated that has to be stored for a long time. You may also use it in data-driven systems where the recording data in the repository triggers an action or tool.
Advantages	• Components can be independent—they do not need to know of the existence of other components. • Changes made by one component can be propagated to all components (because they use the same repository). • All data can be managed consistently (e.g., backups done at the same time) as it is all in one place.
Disadvantages	The repository is a single point of failure so problems in the repository affect the whole system. May be inefficiencies in organizing all communication through the repository. Distributing the repository across several computers may be difficult.

A repository architecture for an Integrated Development Environment (IDE)



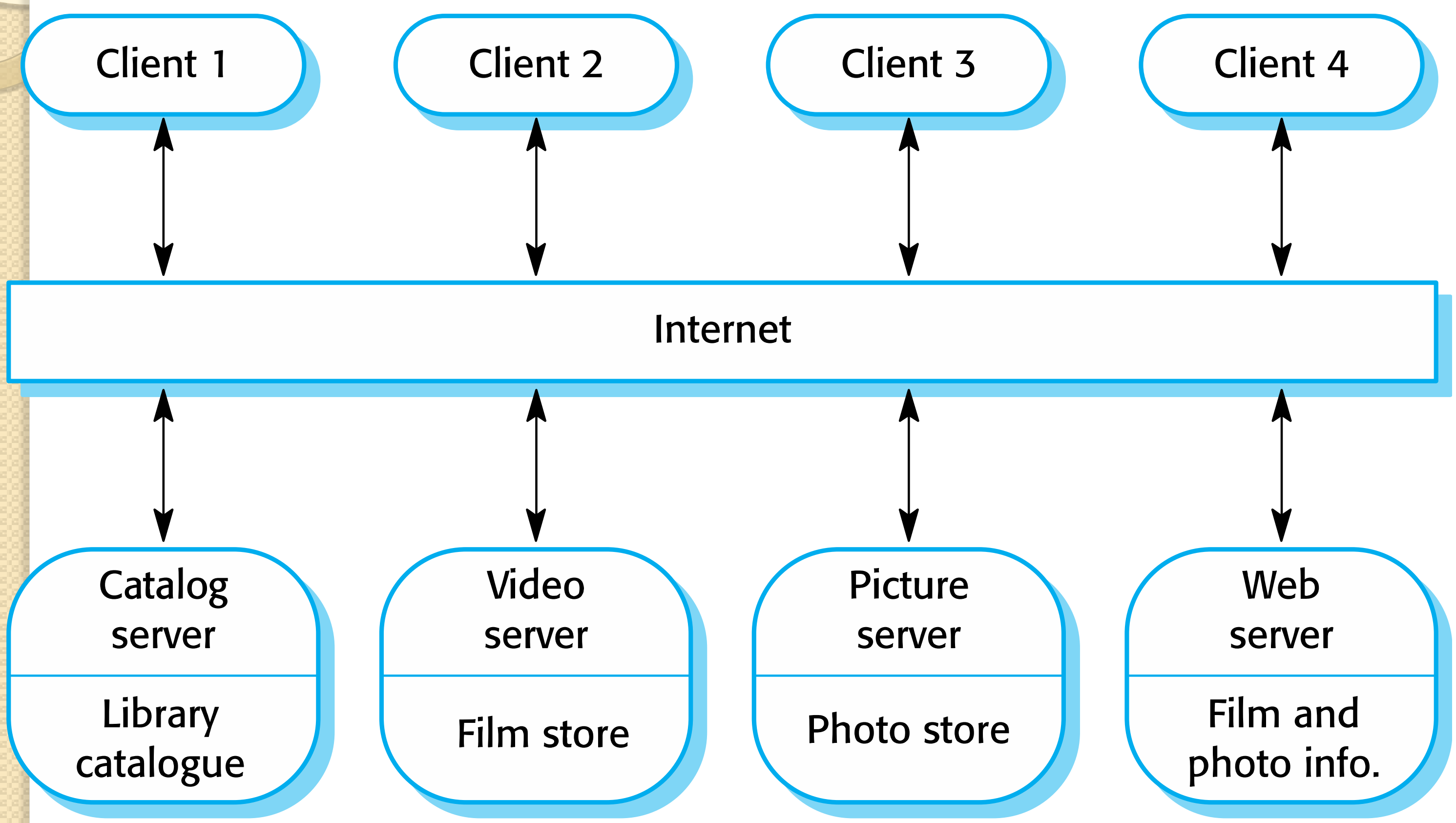
Client-server architecture

- Distributed system model which shows how data and processing is distributed in 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. Each service delivered from a separate server. Clients are users of these services and access servers to make use of them.
When used	Used when data in a shared database has to be accessed from a range of locations. When the load on a system is changeable, it may also be used because servers can be replicated (clients per specific service can be adjusted).
Advantages	The principal 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 this functionality does not need to be implemented by all services.
Disadvantages	Each service is a single point of failure for denial of service attacks or server failure. 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



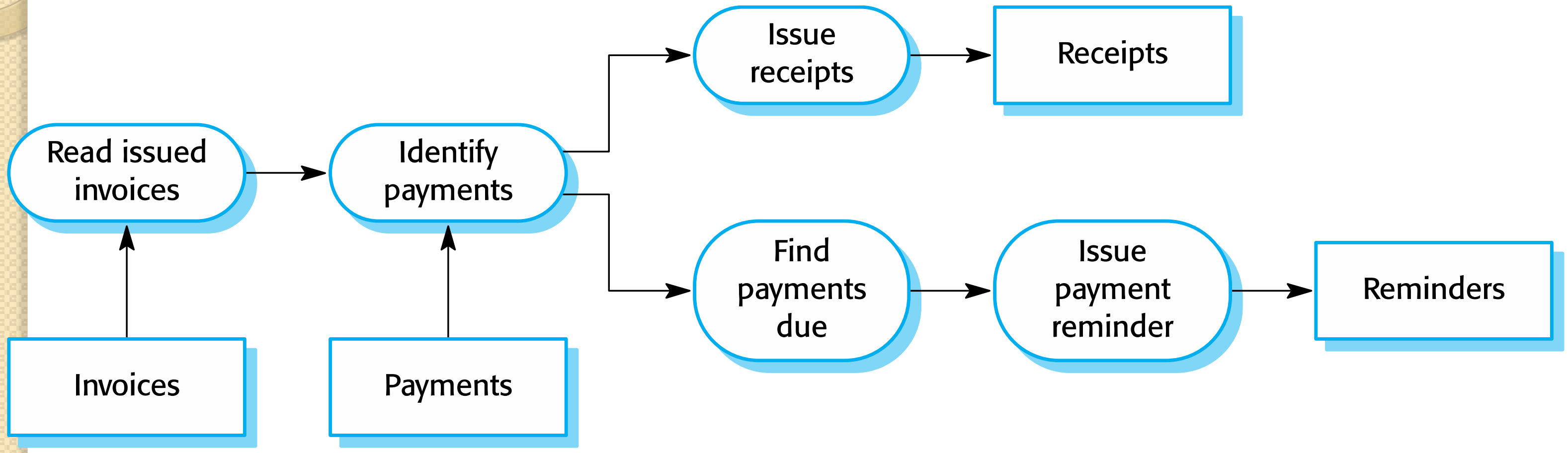
Pipe and filter architecture

- It is functional transformations process. Here inputs are processed 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.

The pipe and filter pattern

Name	Pipe and 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.
When used	Commonly used in data processing applications (both batch- and transaction-based) where inputs are processed in separate stages to generate related outputs.
Advantages	Easy to understand and supports transformation reuse. Workflow style matches the structure of many business processes. 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 and generate its output to the agreed form. This increases system overhead.

An example of the pipe and filter architecture used in a electric invoice payments system



1-For each customer read issued invoice

2-Identify payments for each customer’s invoice

3-a-1 Generate receipts for each customer (Receipt is output)
3-b-1 Find payments due date
3-b-2 Generate payment reminder for customers (Remender emails are output)

Application architectures

Application architectures

- Application systems are designed to meet an organizational need.
- As businesses have much in common, their application systems also tend to have a common architecture that reflects the application requirements.
- A generic application architecture is an architecture for 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 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- centred 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.

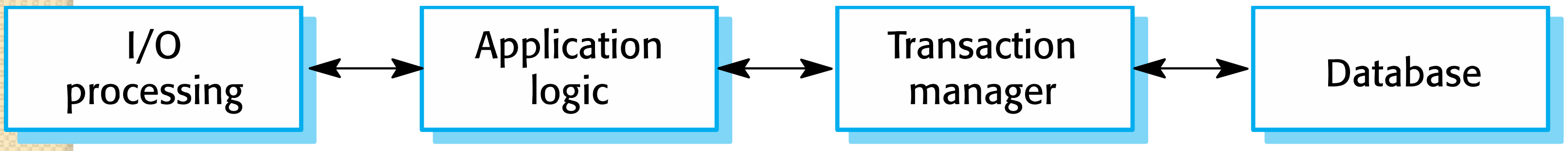
Application type examples

- 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.

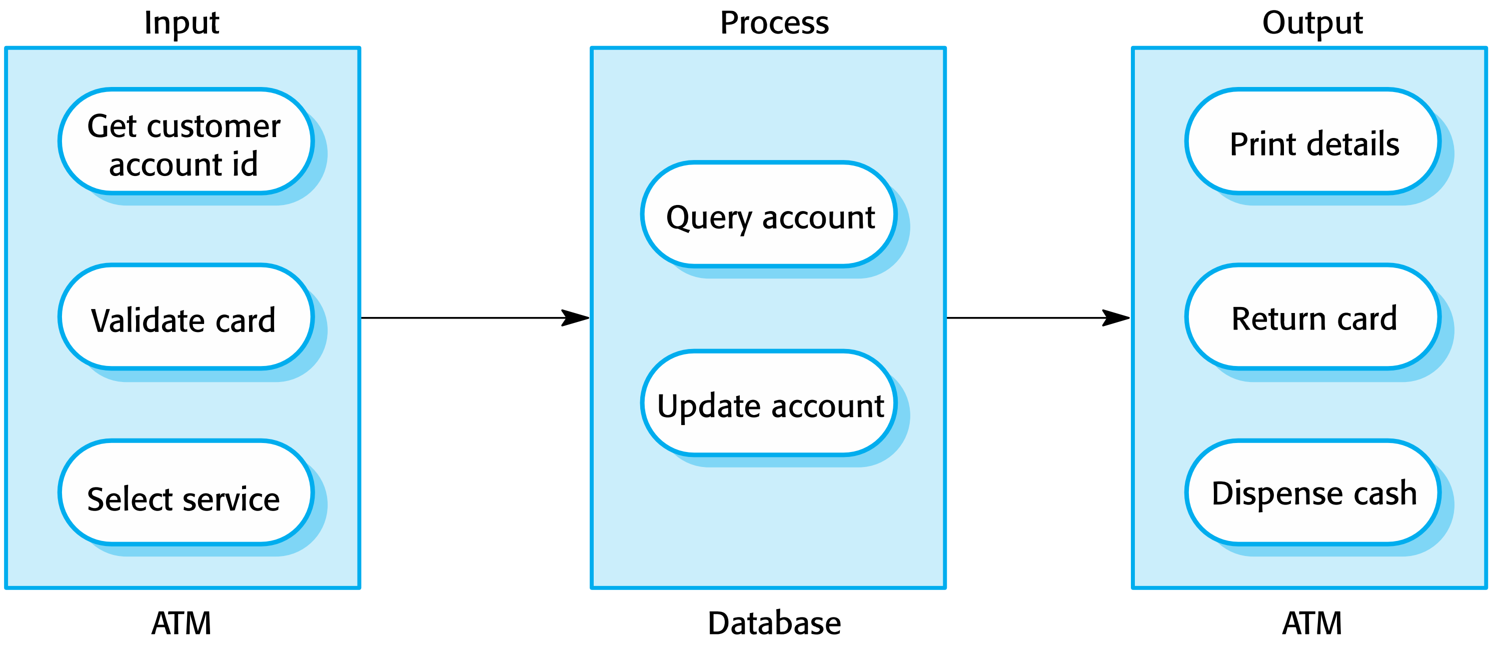
Transaction processing systems

- 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;
  - For example - find the times of flights from London to Paris.
- Users make asynchronous requests for service which are then processed by a transaction manager.

The structure of transaction processing applications



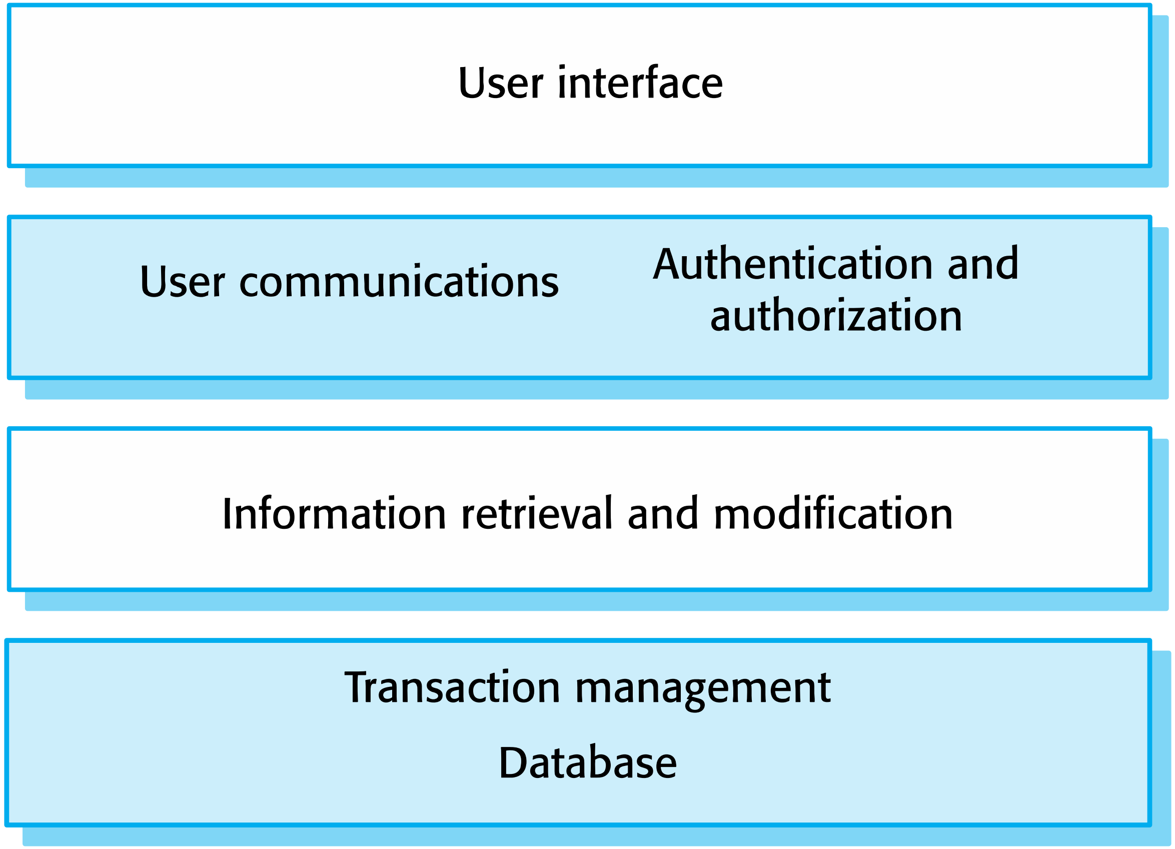
The software architecture of an ATM system



Information systems architecture

- Information systems have a generic architecture that can be organised 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 database

Layered information system architecture



User interface

User communications

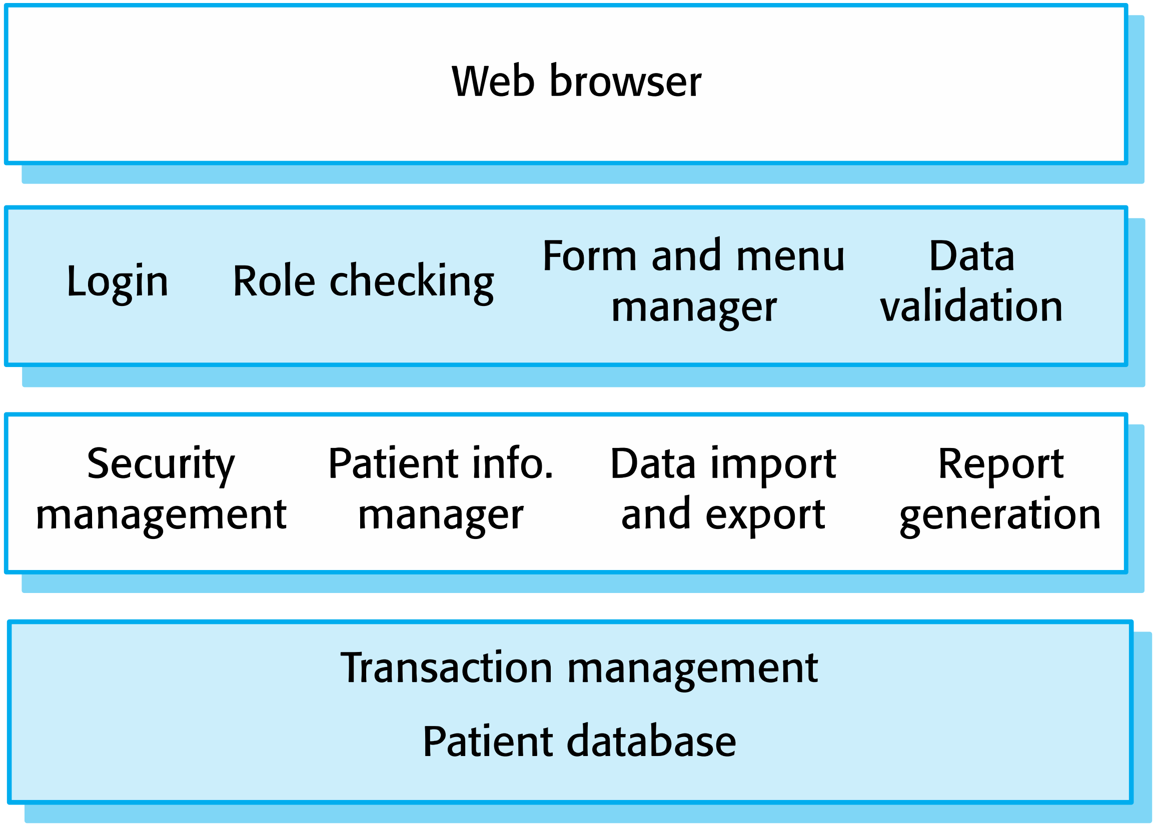
Authentication and authorization

Information retrieval and modification

Transaction management

Database

The architecture of the Mentcare system



Web browser

Login

Role checking

Form and menu manager

Data validation

Security management

Patient info. manager

Data import and export

Report generation

Transaction management

Patient database

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.
- For example, 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.

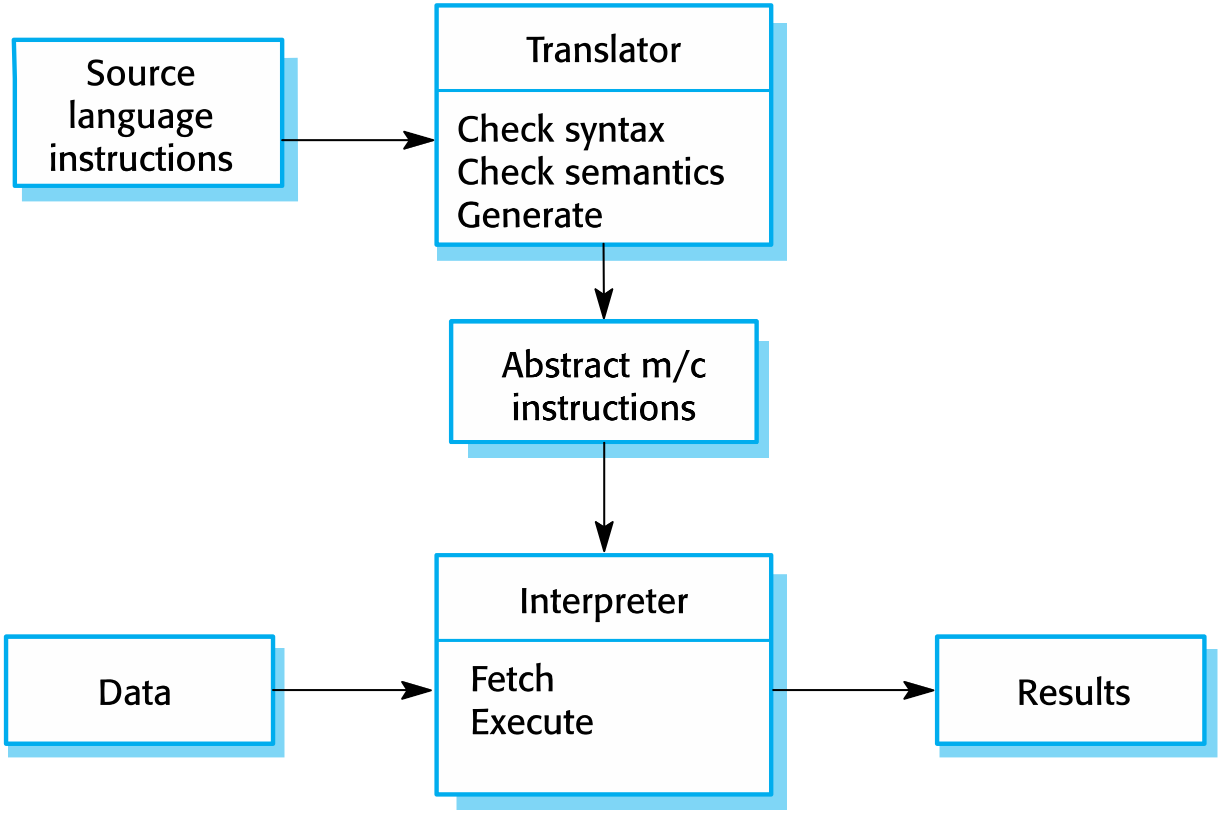
Server implementation

- These systems are often implemented as multi-tier client server/architectures
  - The web server is responsible for all user communications, with the user interface implemented using a web browser;
  - The application server is responsible for implementing application-specific logic as well as information storage and retrieval requests;
  - The database server moves information to and from the database and handles transaction management.

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.
- Used in situations where the easiest way to solve a problem is to describe an algorithm or describe the system data with its format

The architecture of a language processing system



Compiler components

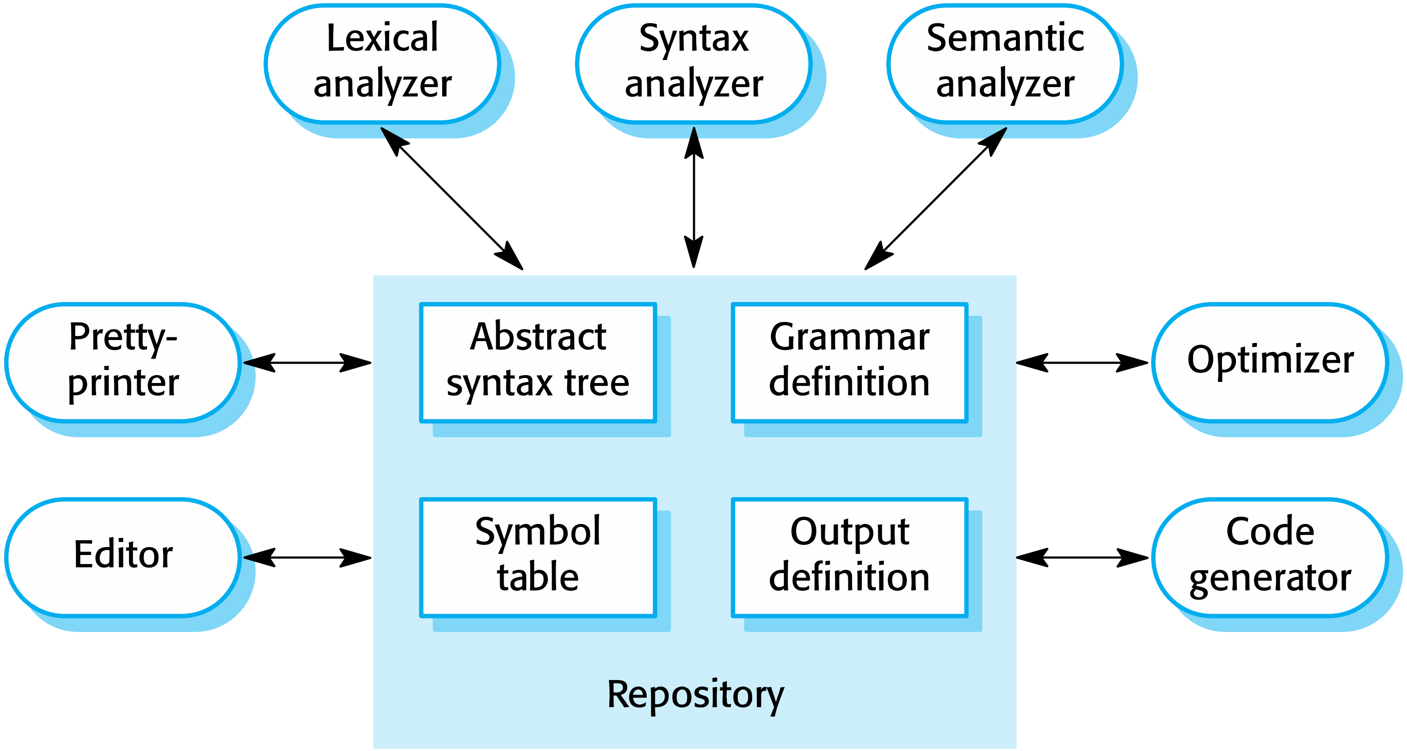
- A lexical analyzer, which takes input language tokens and converts them to an internal form.
- A symbol table, which holds information about the names of entities (variables, class names, object names, etc.) used in the text that is being translated.
- A syntax analyzer, which checks the syntax of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

Compiler components

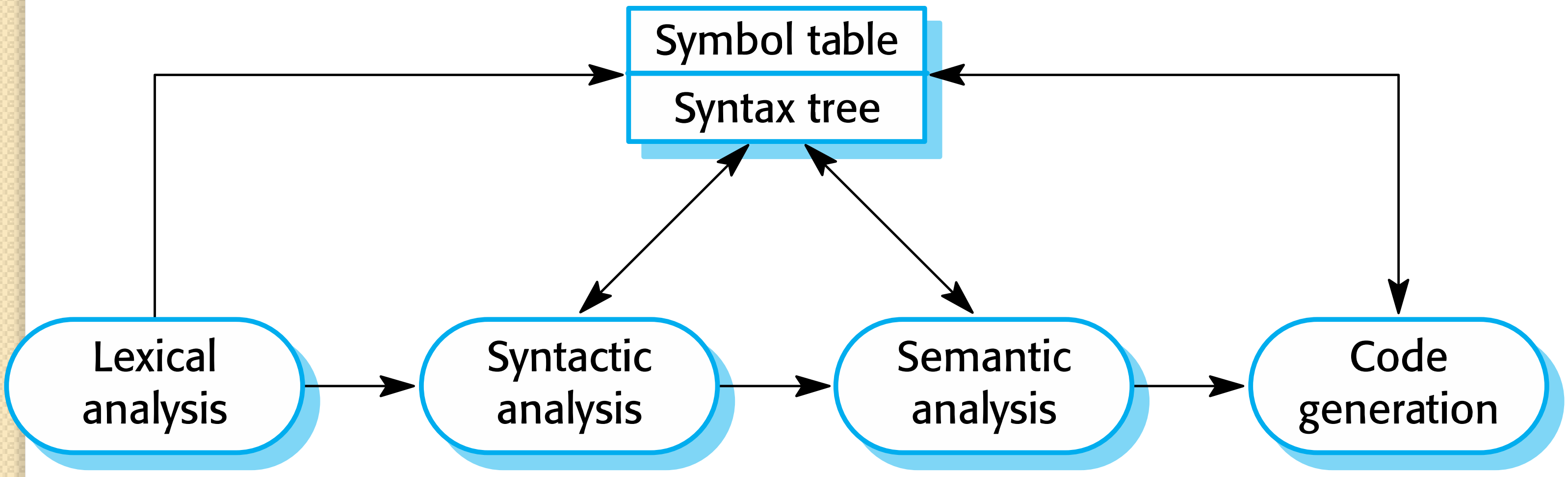
- A semantic analyzer that uses information from the syntax tree and the symbol table to check the semantic correctness of the input language text.

- 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 decisions 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 and describe its advantages and disadvantages.

Key points

- Models of application systems architectures help us understand and compare applications and validate application system designs.
- 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 they are used to carry out the instructions specified in the input language. They include a translator and an abstract machine that executes the generated language.