UNIT II
REQUIREMENTS ANALYSIS AND SPECIFICATION

Software Requirements: Functional and Non-Functional, User requirements, System requirements, Software Requirements Document – Requirement Engineering Process: Feasibility Studies, Requirements elicitation and analysis, requirements validation, requirements management -Classical analysis: Structured system Analysis, Petri Nets- Data Dictionary.

2.1 SOFTWARE REQUIREMENTS

- The process of establishing the services that the customer requires from a system and the constraints under which it operates and is developed
- Requirements may be functional or non-functional
  - Functional requirements describe system services or functions
  - Non-functional requirements is a constraint on the system or on the development process.

Types of requirements

- User requirements
- Statements in natural language (NL) plus diagrams of the services the system provides and its operational constraints. Written for customers
- System requirements
- A structured document setting out detailed descriptions of the system services. Written as a contract between client and contractor
- Software specification
- A detailed software description which can serve as a basis for a design or implementation. Written for developers

2.1.1 FUNCTIONAL AND NON-FUNCTIONAL COMPONENTS:

a) Functional requirements:

- Functionality or services that the system is expected to provide.
- Functional requirements may also explicitly state what the system shouldn‘t do.
- Functional requirements specification should be:
  - Complete: All services required by the user should be defined
  - Consistent: should not have contradictory definition (also avoid ambiguity don‘t leave room for different interpretations)

b) Examples:

- The LIBSYS system
- A library system that provides a single interface to a number of databases of articles in different libraries.
- Users can search for, download and print these articles for personal study.

c) The user shall be able to search either all of the initial set of databases or select a subset from it.

d) The system shall provide appropriate viewers for the user to read documents in the document store.

e) Every order shall be allocated a unique identifier (ORDER_ID) which the user shall be able to copy to the account's permanent storage area.

f) Non-Functional requirements:

- Requirements that are not directly concerned with the specific functions delivered by the system
- Typically relate to the system as a whole rather than the individual system features
- Often could be deciding factor on the survival of the system (e.g. reliability, cost, response time)

g) Non-Functional requirements classifications:

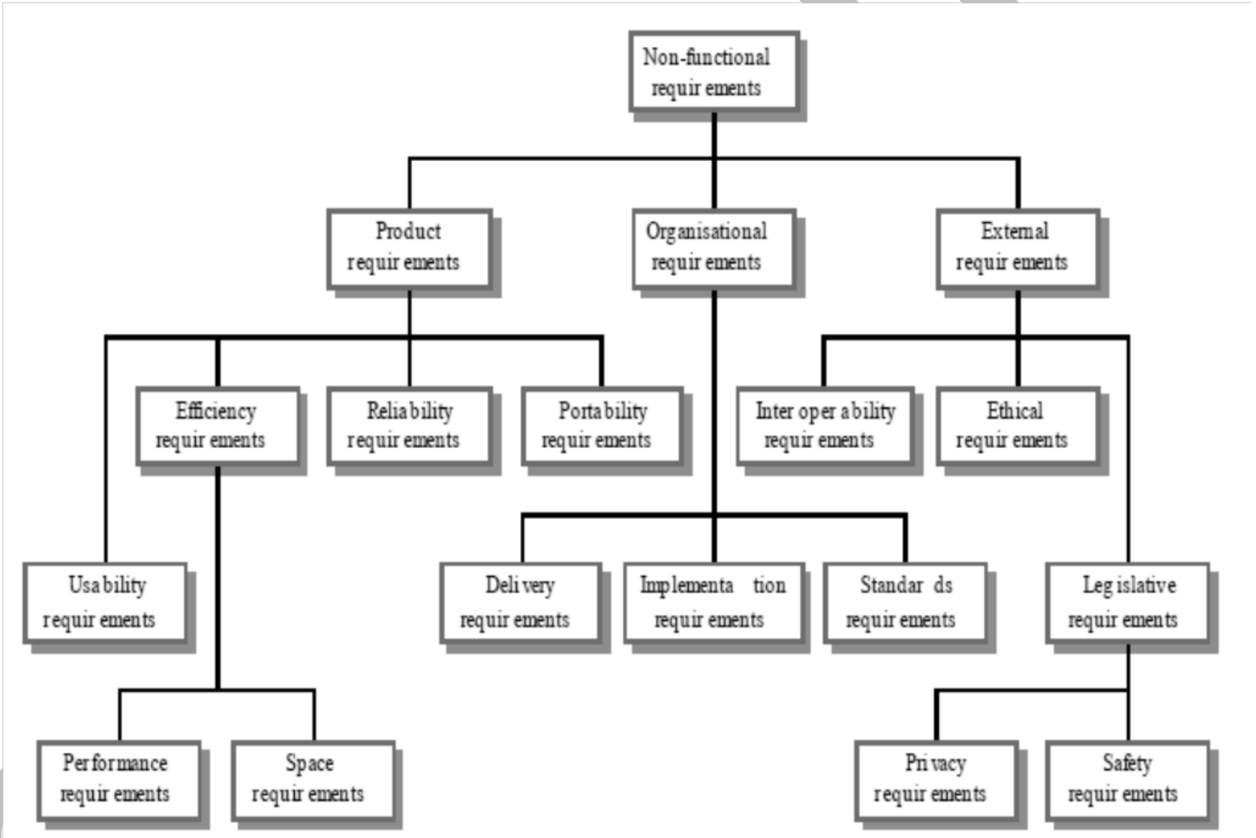


Figure 2.1 Non Functional Requirement Classification

We can see from this diagram that the non-functional requirements may come from required characteristics of the software (product requirements), the organization developing the software (organizational requirements) or from external sources.

The types of non-functional requirements are:

h) Product requirements

- Specify the desired characteristics that a system or subsystem must possess.
- Most NFRs are concerned with specifying constraints on the behavior of the executing system.

- o Performance
- o Capacity
- Others are more difficult to quantify and, consequently, are often stated informally
- o Usability

i) Organisational requirements

- Process requirements are constraints placed upon the development process of the system
- Process requirements include:
- o Performance
- o Capacity
- Others are more difficult to quantify and, consequently, are often stated informally
- o Usability

j) Organisational requirements

- Process requirements are constraints placed upon the development process of the system
- Process requirements include:

- o Requirements on development standards and methods which must be followed
- o CASE tools which should be used
- o The management reports which must be provided

k) Examples of process requirements

- The development process to be used must be explicitly defined and must be conformant with ISO 9000 standards
- The system must be developed using the XYZ suite of CASE tools
- Management reports setting out the effort expended on each identified system component must be produced every two weeks
- A disaster recovery plan for the system development must be specified

i) External requirements

- May be placed on both the product and the process
- Derived from the environment in which the system is developed
- External requirements are based on:
- o Application domain information
- Organizational considerations.
- The need for the system to work with other systems
- Health and safety or data protection regulations
- Or even basic natural laws such as the laws of physics.

j) Examples of external requirements

- Medical data system: The organization's data protection officer must certify that all data is maintained according to data protection legislation before the system is put into operation.
- Train protection system: The time required to bring the train to a complete halt is computed using the following function:
- The deceleration of the train shall be taken as:

2.1.2 USER REQUIREMENT:

- The **user requirement(s) document** (URD) or **user requirement(s) specification** is a document usually used in software engineering that specifies the requirements the user expects
- from software to be constructed in a software project.
- Once the required information is completely gathered it is documented in a URD, which is meant to spell out exactly what the software must do and becomes part of the contractual agreement.
- A customer cannot demand features not in the URD, whilst the developer cannot claim the product is ready if it does not meet an item of the URD.
- The URD can be used as a guide to planning cost, timetables, milestones, testing, etc. The explicit nature of the URD allows customers to show it to various stakeholders to make sure all necessary features are described.
- Formulating a URD requires negotiation to determine what is technically and economically feasible.
- Preparing a URD is one of those skills that lies between a science and an art, requiring both software technical skills and interpersonal skills.
- Often a URD includes priority ranking for each requirement. A typical system might be as follows:

- ✓ M Mandatory requirement. This feature must be built into the final system.
- ✓ D Desirable requirement. This feature should be built into the final system unless the cost is too high.
- ✓ Optional requirement.
- ✓ E Possible future enhancement.

2.1.3 SYSTEM REQUIREMENTS

Purpose of SRS

- Official statement of what is required by the system developer.
- It should include user requirements and specification of system requirements
- It should describe what the system should do.

Ways of writing an SRS:

1. Natural Language
2. Structured Natural Language
3. Design Description Language
4. Graphical Notations
5. Mathematical specification

Guidelines for Writing SRS:

1. Use standard formats
2. Use “shall” for mandatory requirements and “should” for desirable requirements.
3. Use text highlighting to identify key parts of requirements.
4. Include rationale of why a requirements is necessary

- To be used efficiently, all computer software needs certain hardware components or other software resources to be present on a computer.

- Most software defines two sets of system requirements: minimum and recommended.
- With increasing demand for higher processing power and resources in newer versions of software, system requirements tend to increase over time. Industry analysts suggest that this trend plays a bigger part in driving upgrades to existing computer systems than technological advancements.
- A second meaning of the term of System requirements is a generalization of this first definition, giving the requirements to be met in the design of a system or sub-system.
- Typically an organization starts with a set of Business requirements and then derives the System requirements from there.

2.2 SOFTWARE REQUIREMENT DOCUMENT

Should provide for communication among team members

- Should act as an information repository to be used by maintenance engineers
- Should provide enough information to management to allow them to perform all program management related activities
- Should describe to users how to operate and administer the system
- specify external system behavior
- Specify implementation constraints
- Easy to change
- Serve as reference tool for maintenance
- Record forethought about the life cycle of the system i.e. predict changes
- Characterize responses to unexpected events.

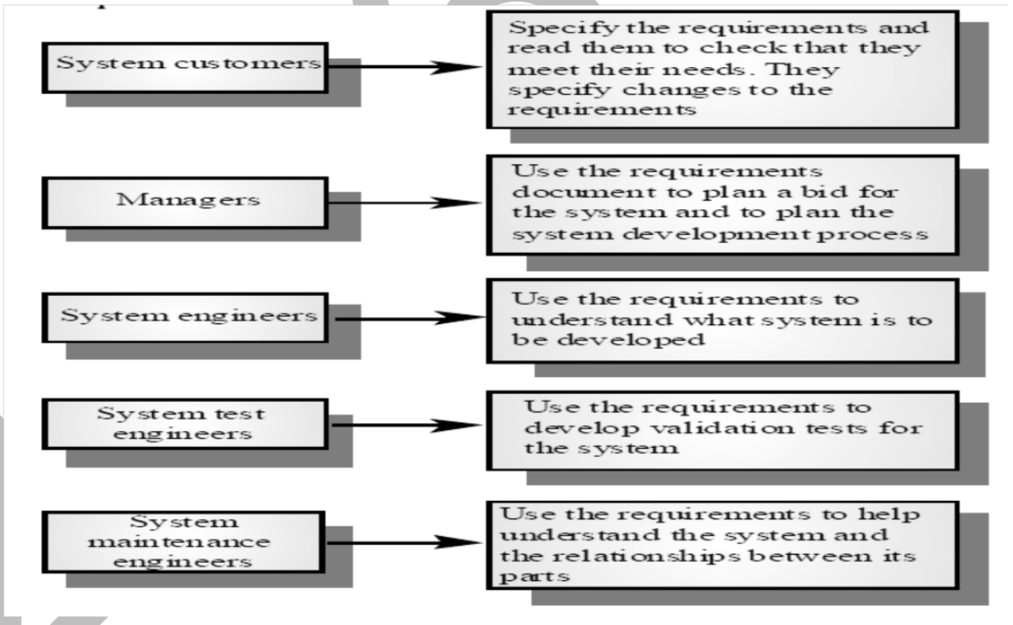

System customers
Specify the requirements and read them to check that they meet their needs. They specify changes to the requirements
Managers
Use the requirements document to plan a bid for the system and to plan the system development process
System engineers
Use the requirements to understand what system is to be developed
System test engineers
Use the requirements to develop validation tests for the system
System maintenance engineers
Use the requirements to help understand the system and the relationships between its parts

Figure 2.2 Users of a requirements document

IEEE suggests the following structure for requirements document

1. Introduction

1.1 Purpose of the requirements document

1.2 Scope of the product

1.3 Definitions, acronyms and abbreviations

1.4 Overview of the remainder of the document

2. General description

2.1 Product perspective

2.2 Product functions

2.3 User characteristics

2.4 General constraints

2.5 Assumptions and dependencies

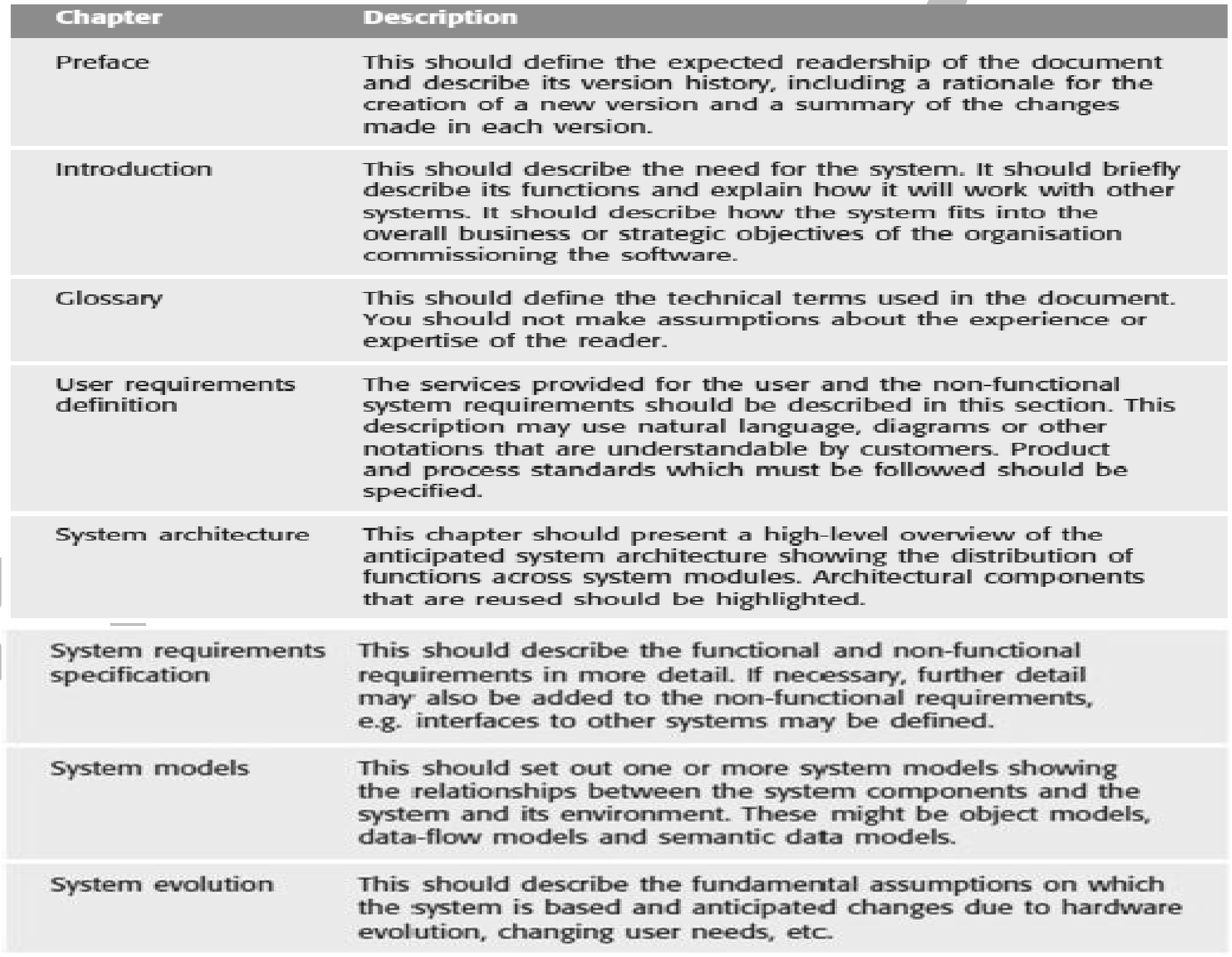
3. **Specific requirements** cover functional, non-functional and interface requirements.

i) This is obviously the most substantial part of the document but because of the wide variability in organizational practice, it is not appropriate to define standard structure for this section.

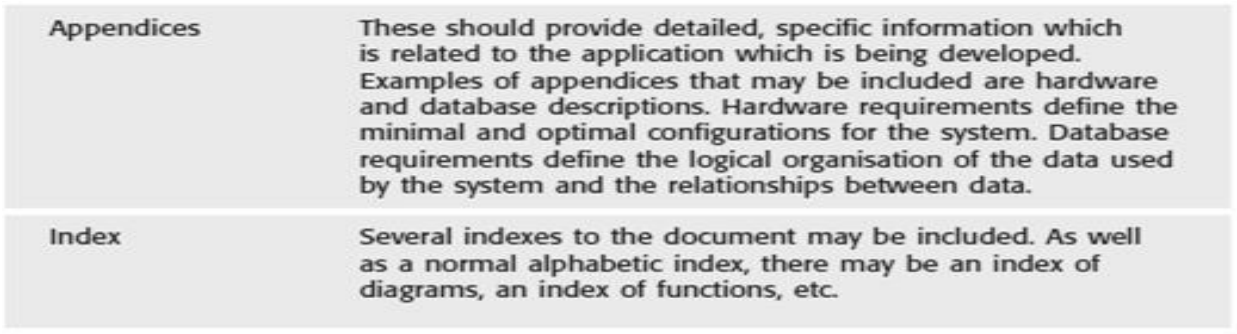
ii) The requirements may document external interfaces, describe system functionality and performance, specify logical database requirements, design constraints, emergent system properties and quality characteristics.

4. Appendices

5. Index



Chapter	Description
Preface	This should define the expected readership of the document and describe its version history, including a rationale for the creation of a new version and a summary of the changes made in each version.
Introduction	This should describe the need for the system. It should briefly describe its functions and explain how it will work with other systems. It should describe how the system fits into the overall business or strategic objectives of the organisation commissioning the software.
Glossary	This should define the technical terms used in the document. You should not make assumptions about the experience or expertise of the reader.
User requirements definition	The services provided for the user and the non-functional system requirements should be described in this section. This description may use natural language, diagrams or other notations that are understandable by customers. Product and process standards which must be followed should be specified.
System architecture	This chapter should present a high-level overview of the anticipated system architecture showing the distribution of functions across system modules. Architectural components that are reused should be highlighted.
System requirements specification	This should describe the functional and non-functional requirements in more detail. If necessary, further detail may also be added to the non-functional requirements, e.g. interfaces to other systems may be defined.
System models	This should set out one or more system models showing the relationships between the system components and the system and its environment. These might be object models, data-flow models and semantic data models.
System evolution	This should describe the fundamental assumptions on which the system is based and anticipated changes due to hardware evolution, changing user needs, etc.



Appendices	These should provide detailed, specific information which is related to the application which is being developed. Examples of appendices that may be included are hardware and database descriptions. Hardware requirements define the minimal and optimal configurations for the system. Database requirements define the logical organisation of the data used by the system and the relationships between data.
Index	Several indexes to the document may be included. As well as a normal alphabetic index, there may be an index of diagrams, an index of functions, etc.

2.3 REQUIREMENT ENGINEERING PROCESS

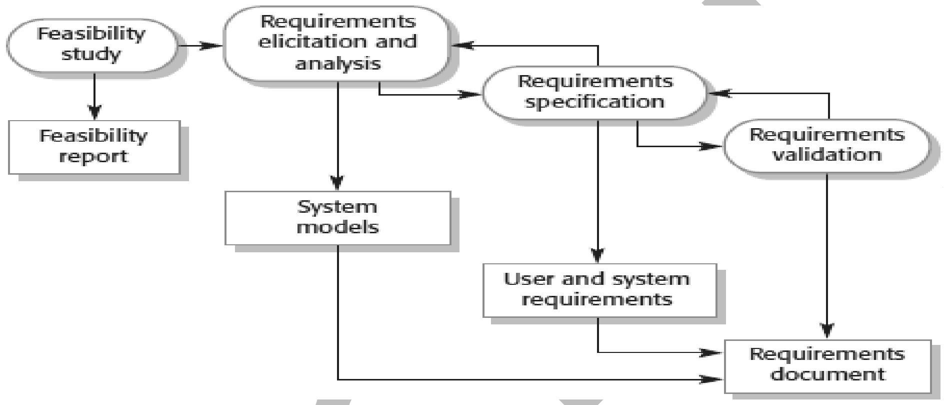


Figure 2.3:The requirements engineering process

- The requirements engineering process includes a feasibility study, requirements elicitation and analysis, requirements specification and requirements management

2.3.1 Feasibility Studies

- A feasibility study decides whether or not the proposed system is worthwhile
- A short focused study that checks
  - If the system contributes to organizational objectives
  - If the system can be engineered using current technology and within budget
  - If the system can be integrated with other systems that are used
- Based on information assessment (what is required), information collection and report writing
- Questions for people in the organization
  - What if the system wasn‘t implemented?
  - What are current process problems?
  - How will the proposed system help?
  - What will be the integration problems?
  - Is new technology needed? What skills?
  - What facilities must be supported by the proposed system?

2.3.2 Requirement Elicitation and analysis

- Sometimes called requirements elicitation or requirements discovery
- Involves technical staff working with customers to find out about
  - The application domain

- May involve end-users, managers, engineers involved in maintenance, domain experts, trade unions, etc.
    - These are called stakeholders

a) Problems of requirements analysis

- Stakeholders don‘t know what they really want
- Stakeholders express requirements in their own terms
- Different stakeholders may have conflicting requirements
- Organizational and political factors may influence the system requirements
- The requirements change during the analysis process
    - New stakeholders may emerge and the business environment change.

b) System models

- Different models may be produced during the requirements analysis activity
- Requirements analysis may involve three structuring activities which result in these different models
    - Partitioning – Identifies the structural (part-of) relationships between entities
    - Abstraction – Identifies generalities among entities
    - Projection – Identifies different ways of looking at a problem

c) Scenarios

- Scenarios are descriptions of how a system is used in practice
- They are helpful in requirements elicitation as people can relate to these more readily than abstract statement of what they require from a system
- Scenarios are particularly useful for adding detail to an outline requirements description

d) Ethnography

- A social scientists spends a considerable time observing and analyzing how people actually work
- People do not have to explain or articulate their work
- Social and organizational factors of importance may be observed
- Ethnographic studies have shown that work is usually richer and more complex than suggested by simple system models.

2.3.3 Requirements validation

- Concerned with demonstrating that the requirements define the system that the customer really wants.
- Requirements error costs are high so validation is very important.
    - Fixing a requirements error after delivery may cost up to 100 times the cost of fixing an implementation error.
- Requirements checking
    - Validity
    - Consistency
    - Completeness
    - Realism

Requirements validation techniques

- Reviews
  - • Systematic manual analysis of the requirements
- Prototyping
  - • Using an executable model of the system to check requirements.
- Test-case generation
  - • Developing tests for requirements to check testability
- Automated consistency analysis
  - • Checking the consistency of a structured requirements description

2.3.4 Requirements management

- Requirements management is the process of managing changing requirements during the requirements engineering process and system development
- Requirements are inevitably incomplete and inconsistent
  - ➢ New requirements emerge during the process as business needs change and a better understanding of the system is developed
  - ➢ Different viewpoints have different requirements and these are often contradictory.

2.3.4.1 Enduring and volatile requirements:

Enduring requirements:

- These are the stable requirements that are derived from the core activity of the organization. These requirements are dependent upon the application domain of the software.
- For example: For banking system, transfer of money from one account to another is the enduring requirement.

Volatile requirements:

- For certain requirements if there is a possibility that those requirements may get changed during the development stage or after the system becomes operational, then such requirements are called volatile requirements.

2.3.4.2 Requirement Management Planning

Traceability is concerned with relationship between requirements their sources and the system design. Using traceability the requirement finding becomes easy.
Various types of traceability are

1. Source traceability
2. Requirements traceability
3. Design traceability

Steps involved in planning requirement process

- **Requirement identification** : Requirements are individually identified
- **Change Management Process** : Process plan followed when analysing a requirement
- **Traceability Policies** : The amount of information about requirement
- **Case Tool Support** : The tool support which is required to manage

- Rapid, iterative development of the prototype is essential so that costs are controlled and system stakeholders can experiment with the prototype early in the software process.

A software prototype can be used in a software development process in several ways:

1. In the requirements engineering process, a prototype can help with the elicitationand validation of system requirements.
2. In the system design process, a prototype can be used to explore particular softwaresolutions and to support user interface design.
3. In the testing process, a prototype can be used to run back-to-back tests withthe system that will be delivered to the customer.

- System prototypes allow users to see how well the system supports their work.
- They may get new ideas for requirements and find areas of strength and weakness in the software. They may then propose new system requirements. Furthermore, as the prototype is developed, it may reveal errors and omissions in the requirements that have been proposed.
- A system prototype may be used while the system is being designed to carry out design experiments to check the feasibility of a proposed design.

For example,

- ✓ A database design may be prototyped and tested to check that it allows for the most efficient data access for the most common user queries.
- ✓ Prototyping is also an essential part of the user interface design process.
- ✓ Because of the dynamic nature of user interfaces, textual descriptions and diagrams are not good enough for expressing the user interface requirements.

- When a system prototype is available, we can reduce the effort involved in result checking by running back-to-back tests figure Back-to back testing. The same test cases are submitted to the prototype and to the system under test. If both systems give the same result, the test case has probably not detected a fault. If the results differ, it may mean that there is a system fault and the reasons for the difference should be investigated.
- Finally, as well as supporting software process activities, prototypes can be used to reduce the time required to develop user documentation and to train users with the system.

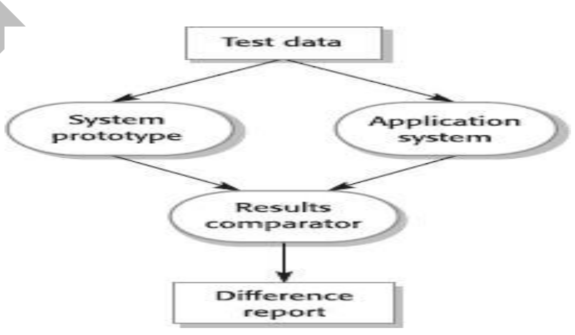


Figure 2.4: Back-to back testing

- **Prototyping in the Software Process**

a)System prototyping

- Prototyping is the rapid development of a system
- Now, the boundary between prototyping and normal system development is blurred and many systems are developed using an evolutionary approach

b)Uses of system prototypes

- The principal use is to help customers and developers understand the requirements for the system
  - o Requirements elicitation. Users can experiment with a prototype to see how the system supports their work
  - o Requirements validation. The prototype can reveal errors and omissions in the requirements
- Prototyping can be considered as a risk reduction activity which reduces requirements risks.

c)Prototyping benefits

- Misunderstandings between software users and developers are exposed
- Missing services may be detected and confusing services may be identified
- A working system is available early in the process
- The prototype may serve as a basis for deriving a system specification
- The system can support user training and system testing

d) Prototyping in the software process

- **Evolutionary prototyping**
  An approach to system development where an initial prototype is produced and refined through a number of stages to the final system

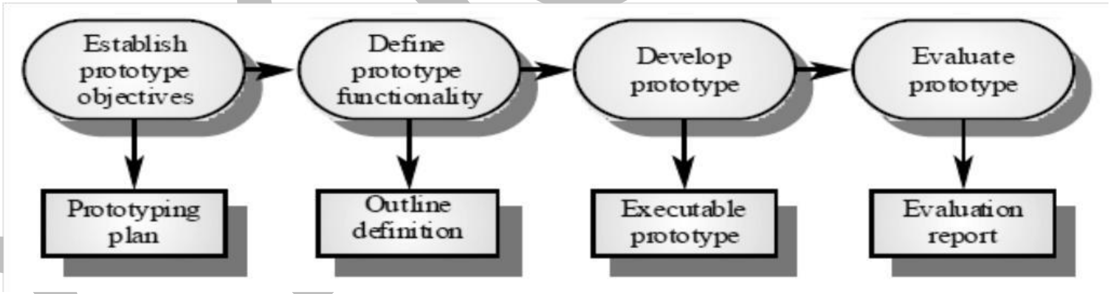


Figure2.5 Prototyping Process

- **Throw-away prototyping**
  A prototype which is usually a practical implementation of the system is produced to help discover requirements problems and then discarded. The system is then developed using some other development process

2.3.5 Data Model

- Used to describe the logical structure of data processed by the system
- Entity-relation-attribute model sets out the entities in the system, the relationships between these

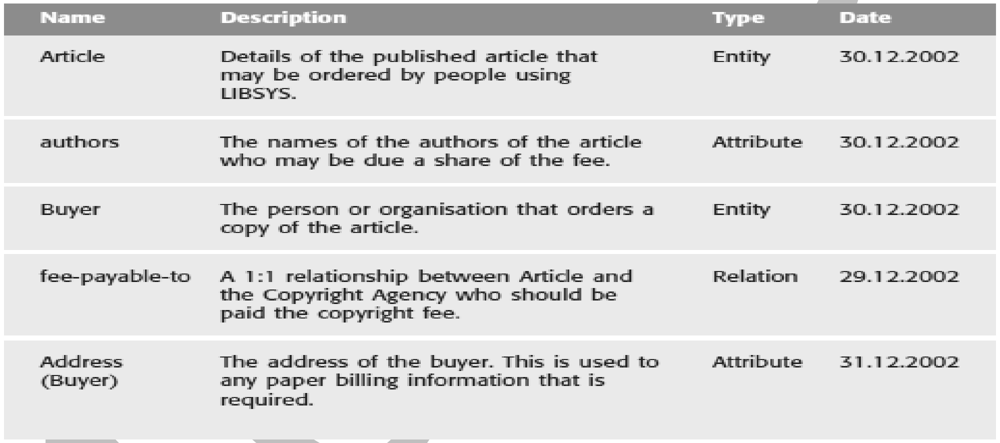
i) The UML does not include a specific notation for this database modelling, as it assumes an object-oriented development process and models data using objects and their relationships. However, you can use the UML to represent a semantic data model. You can think of entities in an ERA model as simplified object classes (they have no operations), attributes as class attributes and named associations between the classes as relations.

ii) Like all graphical models, data models lack detail, and you should maintain more detailed descriptions of the entities, relationships and attributes that are included in the model. You may collect these more detailed descriptions in a repository or data dictionary.

The advantages of using a data dictionary are:

1. **It is a mechanism for name management.** Many people may have to invent names for entities and relationships when developing a large system model. These names should be used consistently and should not clash. The data dictionary software can check for name uniqueness where necessary and warn requirements analysts of name duplications.
2. **It serves as a store of organisational information.**

As the system is developed, information that can link analysis, design, implementation and evolution is added to the data dictionary, so that all information about an entity is in one place.



Name	Description	Type	Date
Article	Details of the published article that may be ordered by people using LIBSYS.	Entity	30.12.2002
authors	The names of the authors of the article who may be due a share of the fee.	Attribute	30.12.2002
Buyer	The person or organisation that orders a copy of the article.	Entity	30.12.2002
fee-payable-to	A 1:1 relationship between Article and the Copyright Agency who should be paid the copyright fee.	Relation	29.12.2002
Address (Buyer)	The address of the buyer. This is used to any paper billing information that is required.	Attribute	31.12.2002

Figure 2.6: Examples of data dictionary entries

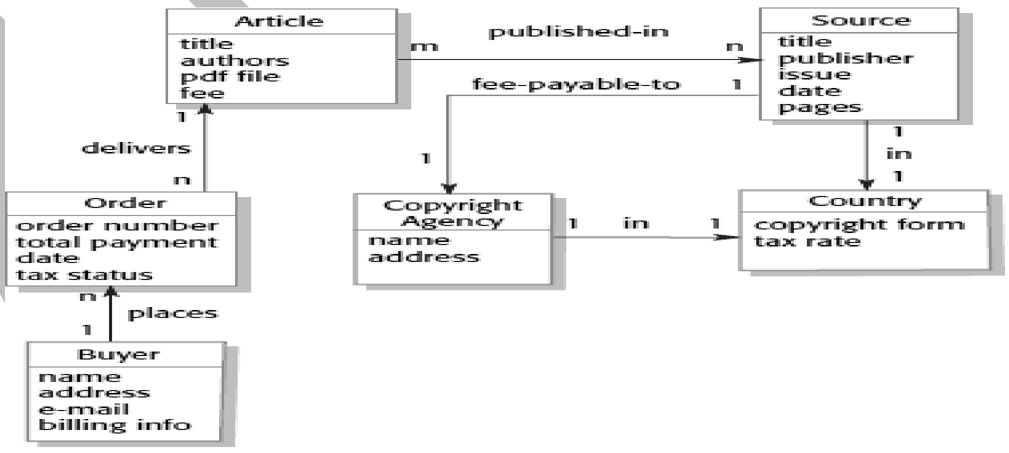


Figure 2.7:Semantic data model for the LIBSYS system

The data dictionary entries shown in Figure 2.8(Examples of data dictionary entries**)** define the names in the semantic data model for LIBSYS.

2.3.6 Functional Model

- Information is transformed as it flows through a computer-based system.
- The system accepts input in a variety of forms; applies hardware, software, and human elements to transform it; and produces output in a variety of forms.

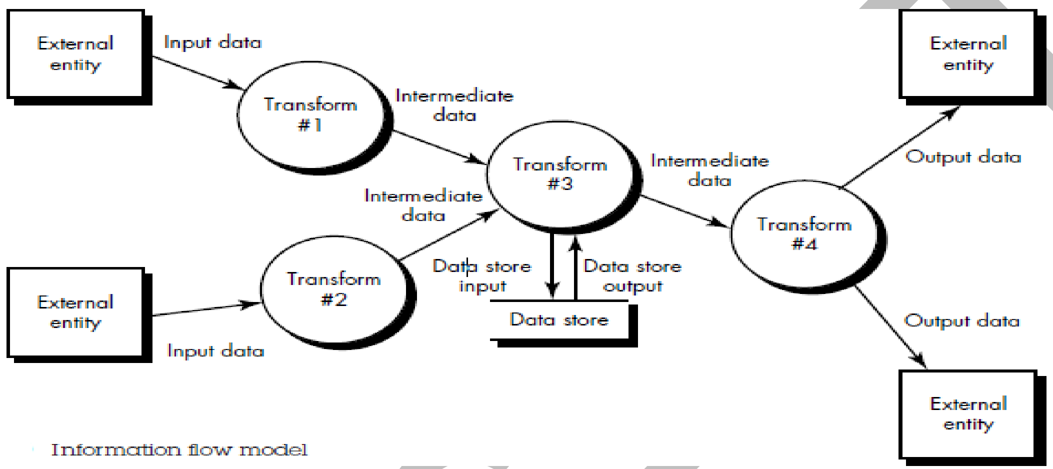


Figure 2.8 Information flow model

- Input may be a control signal transmitted by a transducer, a series of numbers typed by a human operator, a packet of information transmitted on a network link, or a voluminous data file retrieved from secondary storage.
- The transform(s) may comprise a single logical comparison, a complex numerical algorithm, or a rule-inference approach of an expert system.
- Output may light a single LED or produce a 200-page report.
- In effect, we can create a flow model for any computer-based system, regardless of size and complexity.
- Structured analysis began as an information flow modeling technique. A computer-based system is represented as an information transform as shown in Figure 2.8 above.
- A rectangle is used to represent an external entity; that is, a system element (e.g., hardware, a person, and another program) or another system that produces information for transformation by the software or receives information produced by the software.
- A circle (sometimes **called a bubble**) represents a process or transform that is applied to data (or control) and changes it in some way.
- An arrow represents one or more data items (**data objects).** All arrows on a data flow diagram should be labeled.
- The double line represents a data store—stored information that is used by the software.
- It is important to note that no explicit indication of the sequence of processing or conditional logic is supplied by the diagram.
- Procedure or sequence may be implicit in the diagram.

2.3.7 Data Flow Diagrams

- A data flow diagram is a graphical representation that depicts information flow and the transforms that are applied as data move from input to output.
- The basic form of a data flow diagram, also known as a data flow graph or a bubble chart, is illustrated in Figure 2.8.
- The data flow diagram may be used to represent a system or software at any level of abstraction.
- In fact, DFDs may be partitioned into levels that represent increasing information flow and functional detail.
- Therefore, the DFD provides a mechanism for functional modeling as well as information flow modeling.
- A level 0 DFD, also called a fundamental system model or a context model, represents the entire software element as a single bubble with input and output data indicated by incoming and outgoing arrows, respectively.
- Additional processes (bubbles) and information flow paths are represented as the level 0 DFD is partitioned to reveal more detail.
- For example, a level 1 DFD might contain five or six bubbles with interconnecting arrows.
- As we noted earlier, each of the bubbles may be refined or layered to depict more detail.
- Figure 2.9below illustrates this concept. A fundamental model for system F indicates the primary input is A and ultimate output is B.

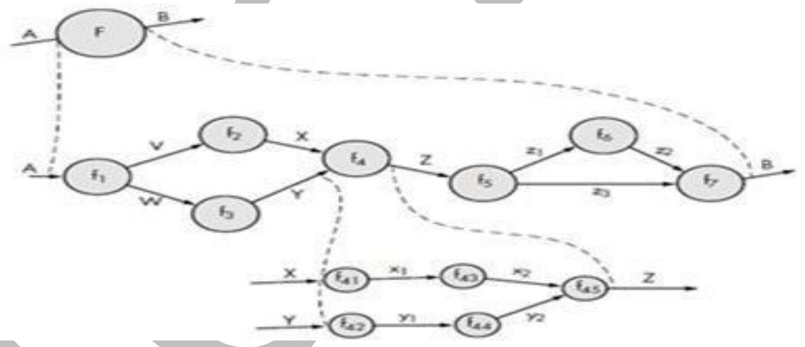


Figure 2.9 Information flow model

- We refine the F model into transformsf1 to f7.
- Note that information flow continuity must be maintained; that is, input and output to each refinement must remain the same.
- This concept, sometimes called balancing, is essential for the development of consistent models.
- Further refinementoff4 depicts detail in the form of transforms f41 to f45. Again, the input (X, Y) and output (Z) remain unchanged.
- DFD graphical notation must be augmented with descriptive text.
- A process specification (PSPEC) can be used to specify the processing details implied by a bubble within a DFD.
- The process specification describes the input to a function, the algorithm that is applied to transform the input, and the output that is produced.

- In addition, the PSPEC indicates restrictions and limitations imposed on the process (function), performance characteristics that are relevant to the process, and design constraintsthat may influence the way in which the process will be implemented.

a) Extensions for Real-Time Systems

- A real-time system must interact with the real world in a time frame dictated by the real world.
- Aircraft avionics, manufacturing process control, consumer products, andindustrial instrumentation are but a few of hundreds of real-time software applications.
- To accommodate the analysis of real-time software, a number of extensions to the basic Notation for structured analysis have been defined.
- These extensions, developed by Ward and Mellor and Hatley and Pirbhai and illustrated.

b) Ward and Mellor Extensions

Ward and Mellor extend basic structured analysis notation to accommodate the following demands imposed by a real-time system:

• Information flow is gathered or produced on a time-continuous basis.
• Control information is passed throughout the system and associated controlprocessing.
• Multiple instances of the same transformation are sometimes encountered in multitasking situations.
• Systems have states and a mechanism causes transition between states.

In a significant percentage of real-time applications, the system must monitor timecontinuousinformation generated by some real-world process.

- For example, a real time test monitoring system for gas turbine engines might be required to monitor turbine speed, combustor temperature, and a variety of pressure probes on a continuous basis.
- One extension to basic structured analysis notation, shown in Figure 2.10 above, provides a mechanism for representing time-continuous data flow.
- The double headed arrow is used to represent time-continuous flow while a single headed arrow is used to indicate discrete data flow.
- In the figure 2.10, **monitored temperature** is measured continuously while a single value for **temperature set point** is also provided.
- The process shown in the figure 2.10produces a time-continuous output, **corrected value.**

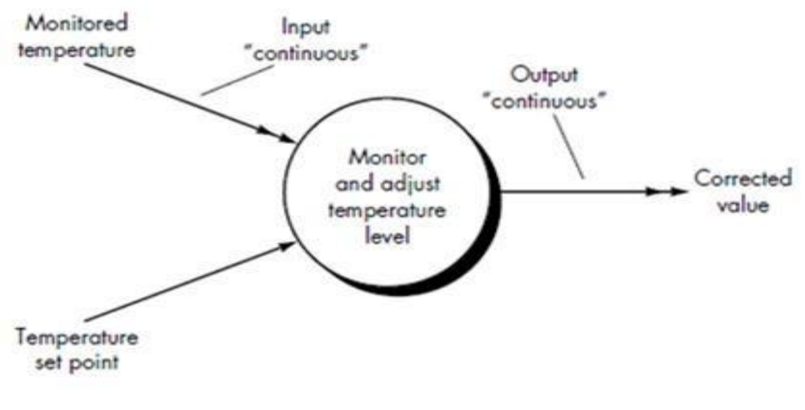


Figure 2.10 Time-continuous Flow

- A process that handles only control flows, called a control process, is similarly represented using a dashed bubble.
- **Control flow** can be input directly to a conventional process or into a control process.
- Figure 2.12 illustrates control flow and processing as it would be represented using Ward and Mellor notation.
- The figure 2.12 illustrates a top-level view of a data and control flow for a manufacturing cell.
- As components to be assembled by a robot are placed on fixtures, a status bit is set within a **parts status buffer** (a control store) that indicates the presence or absence of each component.

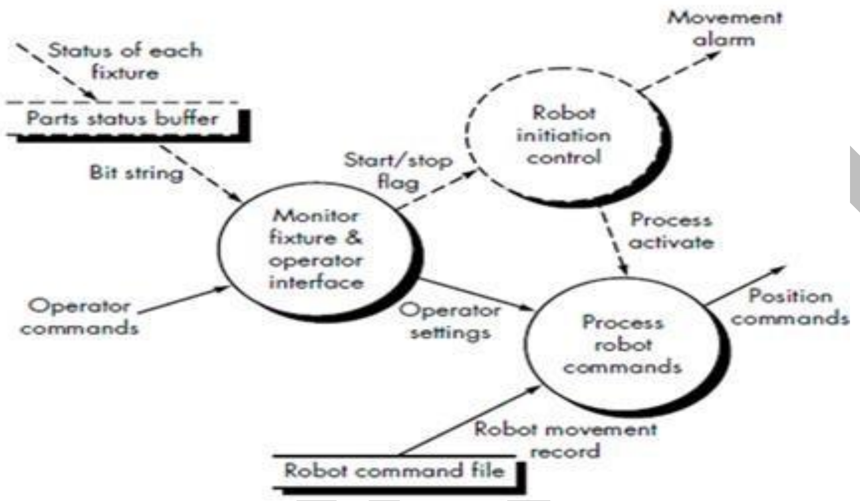


Figure 2.11 Data and Control Flows

- Event information contained within the **parts status buffer** is passed as a bit string to a process, monitor fixture and operator interface.
- The process will read **operator commands** only when the control information, bit string, indicates that all fixtures contain components.
- An event flag, **start/stop flag,** is sent to robot initiation control, a control process that enables further command processing.
- Other data flows occur as a consequence of the **process activate** event that is sent to process robot commands.

c) Hatley and Pirbhai Extensions

- The Hatley and Pirbhai focus less on the creation of additional graphical symbols and more on the representation and specification of the control-oriented aspects of the software.
- The dashed arrow is once again used to represent control or event flow.
- Unlike Ward and Mellor, Hatley and Pirbhai suggest that dashed and solid notation be represented separately.
- Therefore, a control flow diagram is defined.
- The CFD contains the same processes as the DFD, but shows control flow, rather than data flow.
- Instead of representing control processes directly within the flow model, a notational reference (a solid bar) to a control specification (CSPEC) is used.

- In essence, the solid bar can be viewed as a "Window" into an "executive" (the CSPEC) that controls the processes (functions) represented in the DFD based on the event that is passed through the window.
- A process specification is used to describe the inner workings of a process represented in a flow diagram.
- Data flow diagrams are used to represent data and the processes that manipulate it.
- Control flow diagrams show how events flow among processes and illustrate those external events that cause various processes to be activated.
- The interrelationship between the process and control models is shown schematically in Figure 2.12.
- The process model is "connected" to the control model through data conditions.
- The control model is "connected" to the process model through process activation information contained in the CSPEC.
- A data condition occurs whenever data input to a process result in control output.
- This situation is illustrated in Figure 2.12, part of a flow model for an automated monitoring and control system for pressure vessels in an oil refinery.
- The process check and convert pressure implements the algorithm described in the PSPEC pseudo code shown.
- When the **absolute tank pressure** is greater than an allow able maximum, an **above pressure** event is generated.
- Note that when Hatley and Pirbhai notation is used, the data flow is shown as part of a DFD, while the control flow is noted separately as part of a control flow diagram.
- As we noted earlier, the vertical solid bar into which the **above pressure** event flows is a pointer to the CSPEC.
- Therefore, to determine what happens when this event occurs, we must check the CSPEC.
- The control specification (CSPEC) contains a number of important modeling tools.
- A process activation table is used to indicate which processes are activated by a given event.
- For example, a process activation table (PAT)for Figure 2.12might indicate that the **above pressure** event would cause a process reduce tank pressure (not shown) to be invoked.

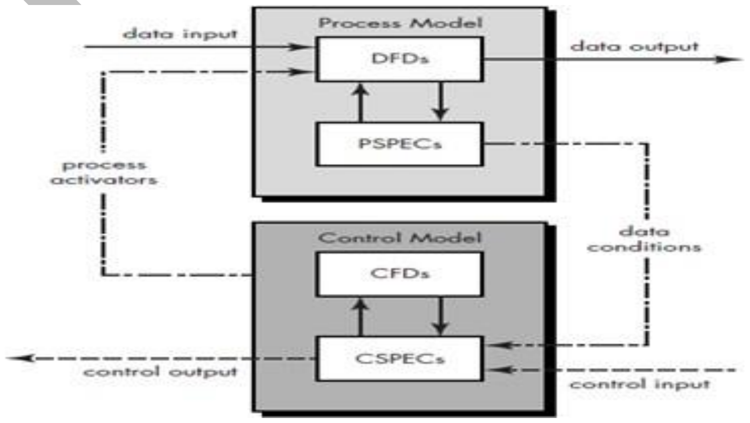
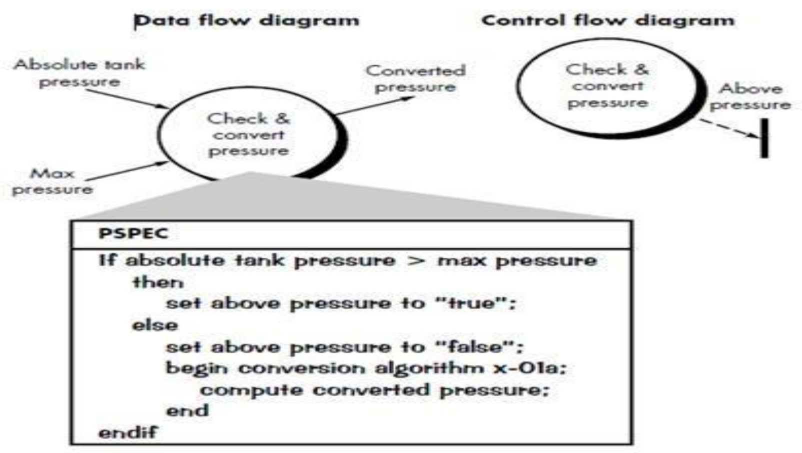


Figure 2.12 Relationship between data and control models

- The STD is a behavioral model that relies on the definition of a set of system states and is described as following section.



```
PSPEC
If absolute tank pressure > max pressure
   then
      set above pressure to "true";
   else
      set above pressure to "false";
      begin conversion algorithm x-01a;
         compute converted pressure;
      end
endif
```

Figure 2.13 Data conditions

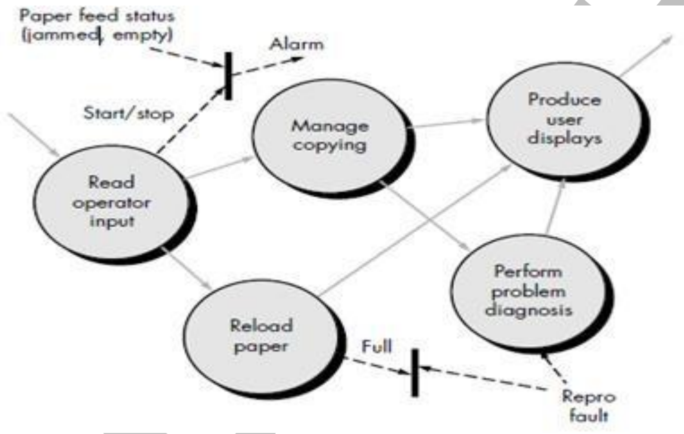


Figure 2.14 Level 1 CFD for photocopier software

2.3.8 Behavioral Model

- Behavioural models are used to describe the overall behaviour of the system.
- Two types of behavioural model here: data-flow models, which model the data processing in the system, and state machine models, which model how the system reacts to events.
- These models may be used separately or together, depending on the type of system that is being developed.

a) Data-flow models

- Most business systems are primarily driven by data. They are controlled by the data inputs to the system with relatively little external event processing. A dataflow model may be all that is needed to represent the behaviour of these systems.
- Data-flow models are an intuitive way of showing how data is processed by a system.
- The notation used in these models represents functional processing (rounded rectangles), data

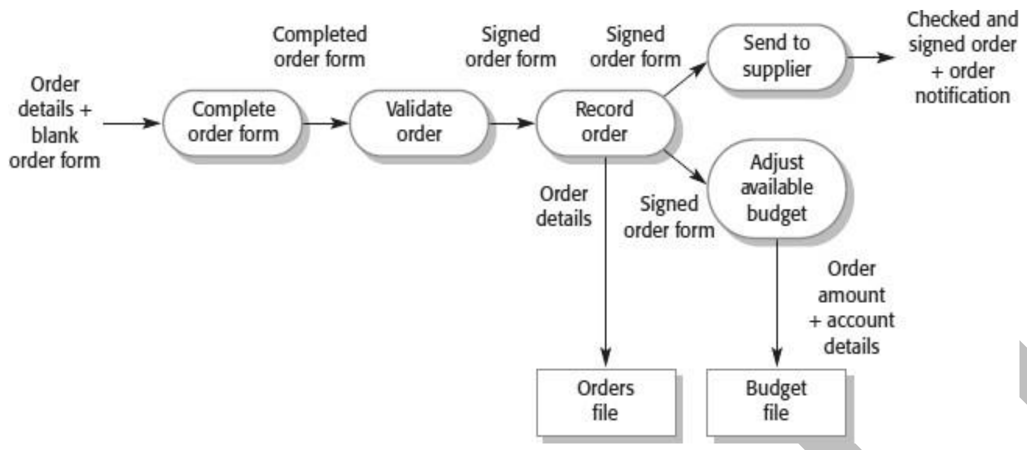


Figure2.15: Data-flow diagram of order processing

- Data-flow models are used to show how data flows through a sequence of processing steps.
- For example, a processing step could be to filter duplicate records in a customer database.
- The data is transformed at each step before moving on to the next stage.
- These processing steps or transformations represent software processes or functions when data-flow diagrams are used to document a software design.
- A data-flow model, which shows the steps involved in processing an order for goods (such as computer equipment) in an organisation, is illustrated in the above figure 2.14
- This particular model describes the data processing in the Place equipment order activity in the overall process model shown in below Figure 2.15 (Process model of equipment procurement.) illustrates a process model for the process of procuring equipment in an organisation.
- This involves specifying the equipment required, finding and choosing suppliers, ordering the equipment, taking delivery of the equipment and testing it after delivery.
- When specifying computer support for this process, you have to decide which of these activities will actually be supported. The other activities are outside the boundary of the system.

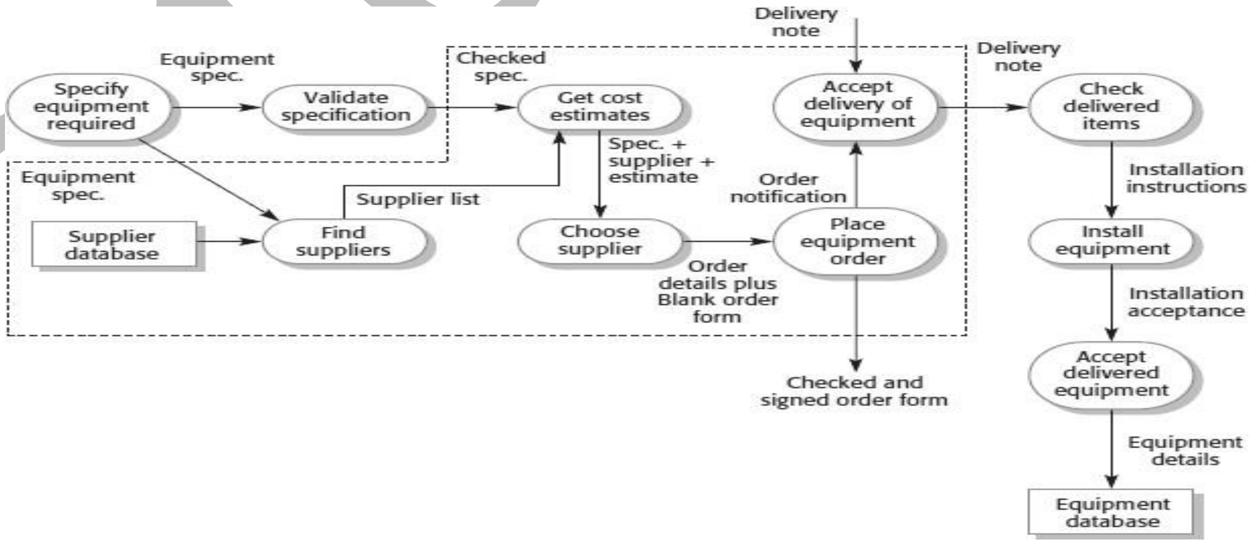


Figure2.16: Process model of equipment procurement

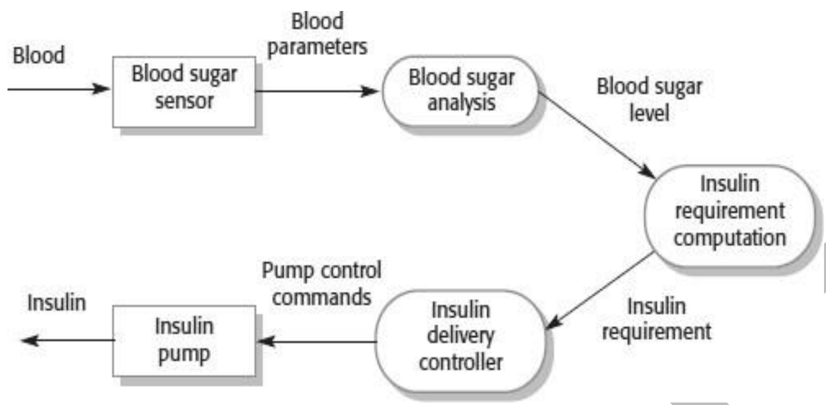


Figure 2.17: Data-flow diagram of an insulin pump

2.3.9 State machine models

- They show the system‘s responses to stimuli so are often used for modeling real-time systems
- State machine models show system states as nodes and events as arcs between these nodes.
- When an event occurs, the system moves from one state to another
- State charts are an integral part of the UML
- ➢ It does not show the flow of data within the system.
- ➢ This typeof model is often used for modelling real-time systems.
- ➢ For example, the real-time alarm system responds to stimuli from movement sensors, door opening sensors, and so on.
- ➢ A state machine model of a system assumes that, at any time, the system is in one of a number of possible states.
- ➢ When a stimulus is received, this may trigger a transition to a different state.
- ➢ For example, a system controlling a valve may move from a state ‘Valve open’ to a state ‘Valve closed’ when an operator command (the stimulus) is received.
- ➢ This approach to system modelling is illustrated in Figure 2.18(State machine model of a simple microwave oven)
- ➢ This diagram shows a state machine model of a simple microwave oven equipped with buttons to set the power and the timer and to start the system.

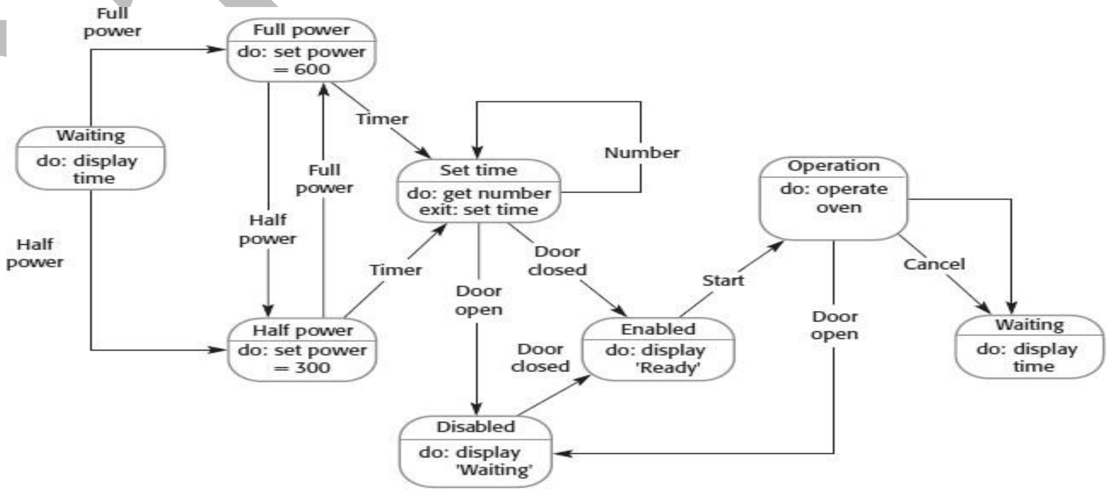


Figure2.18: State machine model of a simple microwave oven

- The sequence of actions in using the microwave is:
- Select the power level (either half-power or full-power).
- Input the cooking time.
- Press Start, and the food is cooked for the given time.
- For safety reasons, the oven should not operate when the door is open and, on completion of cooking, a buzzer is sounded.
- The oven has a very simple alphanumeric display that is used to display various alerts and warning messages.
- The rounded rectangles in model represent system states.
- They include a brief description(following 'do') ofthe actions taken in that state.
- The labelled arrows represent stimuli that force a transition from one state to another.
- Therefore, from Figure that the system responds initially to either the full-power or the half- power button.
- Users can change their mind after selecting one of these and press the other button.
- The time is set and, if the door is closed, the Start button is enabled. Pushing this button starts the oven operation and cooking takes place for the specified time.
- The problem with the state machine approach is that the number of possible states increases rapidly.
- For large system models, therefore, some structuring of these state models is necessary.
- One way to do this is by using the notion of a super state that encapsulates a number of separate states.
- This super state looks like a single state on a high-level model but is then expanded in more detail on a separate diagram.
- To illustrate this concept, consider the Operation state in Figure 2.18(State machine model of a simple microwave oven). This is a superstatethat can be expanded, as illustrated in Figure 2.19 (Microwave oven operation).
- The Operation state includes a number of sub-states.
- It shows that operation starts with a status check, and that if any problems are discovered, an alarm is indicated and operation is disabled.
- Cooking involves running the microwave generator for the specified time; on completion, a buzzer is sounded.

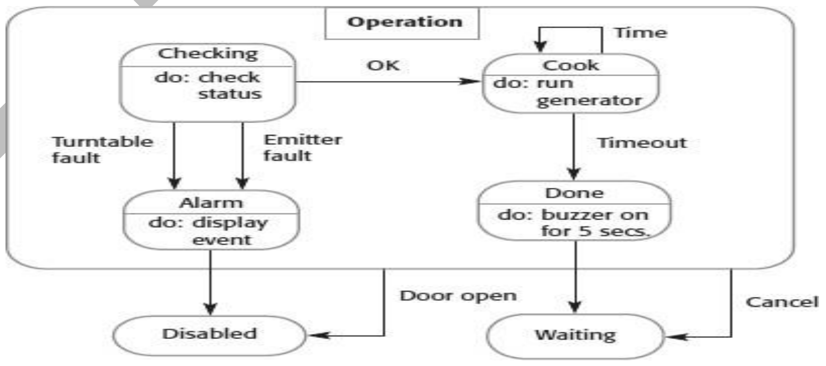


Figure 2.19: Microwave oven operation

2.4 STRUCTURED ANALYSIS

2.4.1 Creating an Entity/Relationship Diagram

The entity/relationship diagram enables a software engineer to fully specify the data objects that are input and output from a system, the attributes that define the properties of these objects, and their relationships.

The following approach is taken:

1. During requirements elicitation, customers are asked to list the "things" thatthe application orbusiness process addresses. These "things" evolve into a list of input and output data objects as well as external entities that produce or consume information.

2.Taking the objects one at a time, the analyst and customer define whether or not a connection (unnamed at this stage) exists between the data object and other objects.

3.Wherever a connection exists, the analyst and the customer create one or more object/relationship pairs.

4. For each object/relationship pair, cardinality and modality are explored.

5. Steps 2 through 4 are continued iteratively until all object/relationships have been defined. It is common to discover omissions as this process continues. New objects and relationships will invariably be added as the number of iterations grows.

6. The attributes of each entity are defined.

7. An entity relationship diagram is formalized and reviewed.

8. Steps 1 through 7 are repeated until data modelling is complete.

For Safe Home the following (partial) list of "things" are relevant to the problem:

• homeowner

• control panel

• sensors

• security system

For example, referring to Figure 2.20 (Establishing connections), a direct connection exists between **homeowner** and **control panel, security system,** and **monitoring service.**

A single connection exists between **sensor** and **security system**, and so forth.

For example, the connection between **sensor** and **security system** is determined to have the following object/relationship pairs:

1. **security system** monitors **sensor**
2. **security system** enables/disables **sensor**
3. **security system** tests **sensor**
4. **security system** programs **sensor**

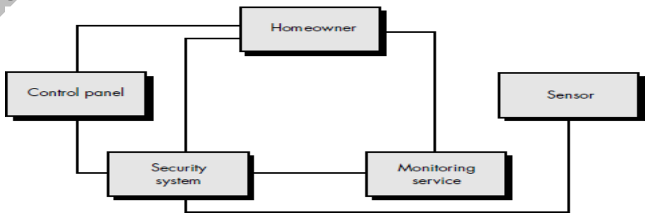


Figure 2.20: Establishing connections

- Each of these object/relationship pairs is analysed to determine cardinality and modality.
- For example, considering the object/relationship pair **security system** monitors **sensor,** the cardinality between **security system** and **sensor** is one to many.
- The modality is one occurrence of **security system** (mandatory) and at least one occurrence of**sensor** (mandatory).
- Connecting line between **security system** and **sensor** would be modified as shown in below Figure 2.21. Similar analysis would be applied to all other data objects.

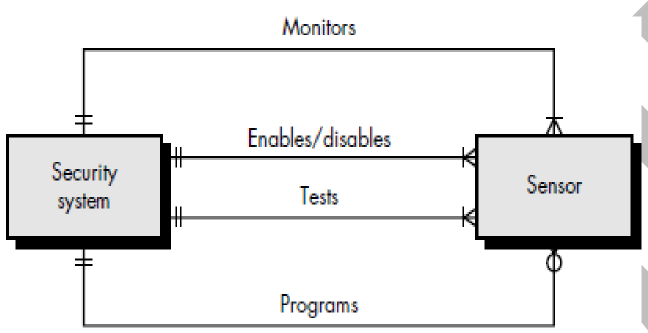


Figure 2.21: Developing relationships and cardinality/ modality

2.4.2 Creating a Data Flow Model

- The data flow diagram enables the software engineer to develop models of the information domain and functional domain at the same time. the DFD is refined into greater levels of detail, so decomposition of the system, takes place.
- A few simple guidelines can aid immeasurably during derivation of a data flow diagram:

(1) The level 0 data flow diagram should depict the software/system as a single bubble;

(2) Primary input and output should be carefully noted;

(3) Refinement should begin by isolating candidate processes, data objects, and stores to berepresented at the next level;

(4) All arrows and bubbles should be labelled with meaningful names;

(5) Information flow continuity must be maintained from level to level, and

(6) One bubble at a time should be refined. There is a natural tendency to overcomplicate the data flow diagram.

- Again considering the SafeHomeproduct, a level 0 DFD for the system is shown in Figure2.23Context-level DFD for Safe Home. The primary external entities (boxes) produce information for use by the system and consume information generated by the system.
- The labelled arrows represent data objects or data object type hierarchies.
- The level 0 DFD is now expanded into a level 1 model.
- All verbs areSafeHomeprocesses; that is, they may ultimately be represented as bubbles in a sub-sequent DFD. All nouns are either external entities (boxes), data or control objects (arrows), or

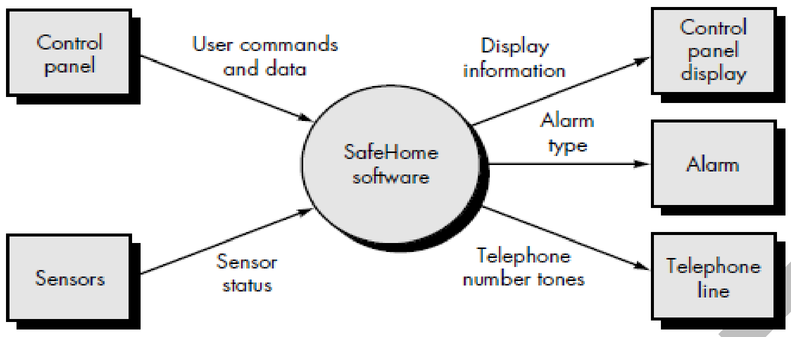


Figure 2.22 Context-level DFD for Safe Home

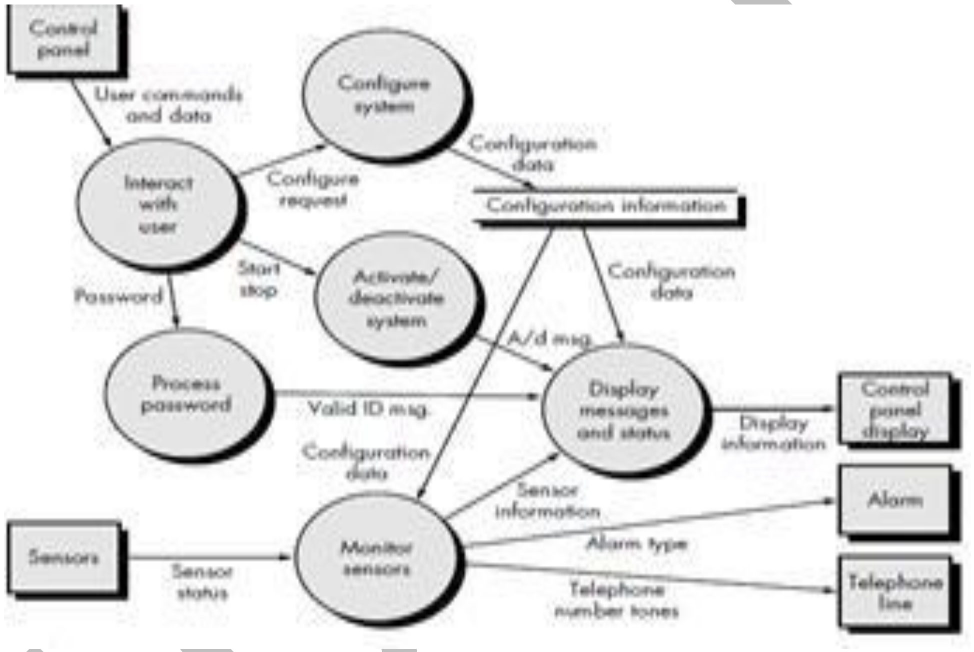


Figure 2.23 level 1 DFD

- Using this information, a level 1 DFD is shown in Figure 2.22 (The context level process) has been expanded into six processes derived from an examination of the grammatical parse.
- Similarly, the information flow between processes at level 1 has been derived from the parse.
- The processes represented at DFD level 1 can be further refined into lower levels.
- Note once again that information flow continuity has been maintained between levels.
- The refinement of DFDs continues until each bubble performs a simple function.
- That is, until the process represented by the bubble performs a function that would beeasily implemented as a program component (refine DFDs until each bubble is "single-minded.")

2.4.3 Creating a Control Flow Model

- A data flow model is “stripped" of all data flow arrows. Events and control items (dashed arrows) are then added to the diagram and a "window" (a vertical bar) into the control specification is shown. But how are events selected?
- We have already noted that an event or control item is implemented as a Booleavalue or a din list of conditions (empty, jammed, full). To select potential candidate events, the following guidelines

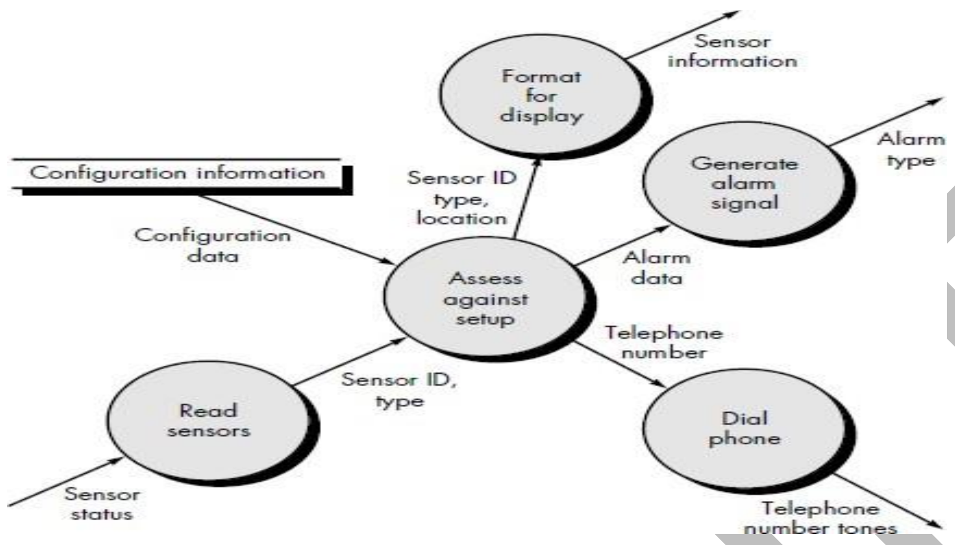


Figure 2.24 Level 2 DFD that refines the monitor sensors process

• List all sensors that are "read" by the software.
• List all interrupt conditions.
• List all "switches" that are actuated by an operator.
• List all data conditions.
• Recalling the noun/verb parse that was applied to the processing narrative,review all "control items" as possible CSPEC inputs/outputs.
• Describe the behaviour of a system by identifying its states; identify how each state is reached; and define the transitions between states.
• Focus on possible omissions—a very common error in specifying control; Forexample, ask: "Is there any other way I can get to this state or exit from it?"

- A level 1 CFD for SafeHomesoftware is illustrated.
- Among the events and control items noted are **sensor event** ,**blink flag** and **start/stop switch.**
- When the event flows into the CSPEC window from the outside world, it implies that the CSPEC will activate one or more of the processes shown in the CFD.
- When a control item emanates from a process and flows into the CSPEC window, control and activation of some other process or an outside entity is implied.

2.4.4 The Control Specification

- The control specification (CSPEC) represents the behaviour of the system in two different ways.
- The CSPEC contains a state transition diagram that is a sequential specification of behaviour. It can also contain a program activation table—a combinatorial specification of behaviour.
- The labelled transition arrows indicate how the system responds to events as it traverses the four states defined at this level
- For example, in the figure STD indicates that the only transition from the reading user input state occurs when the **start/stop switch** is encountered and a transition to the monitoring system status state occurs.
- This is an error in specification and would, we hope, be uncovered during review and corrected.

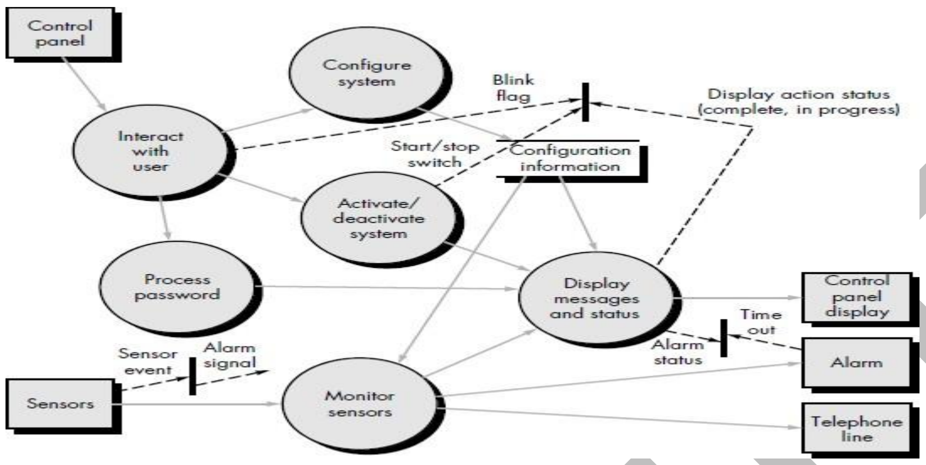


Figure 2.25 Level 1 CFD for Safe Home

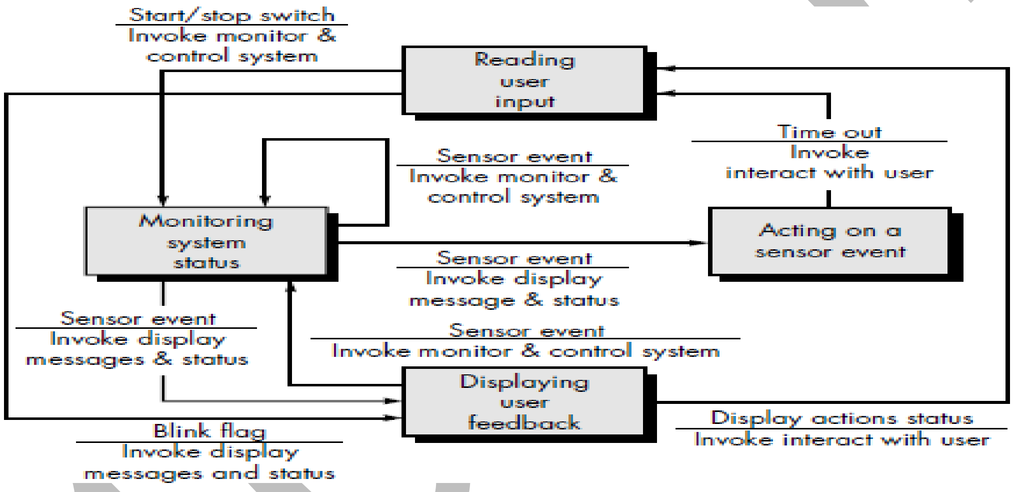
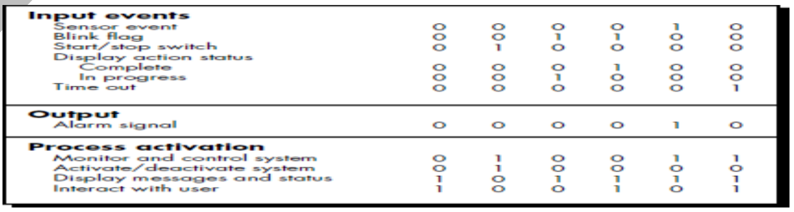

Start/stop switch
Invoke monitor & control system
Reading user input
Time out
Invoke interact with user
Sensor event
Invoke monitor & control system
Monitoring system status
Acting on a sensor event
Sensor event
Invoke display message & status
Sensor event
Invoke display messages & status
Sensor event
Invoke monitor & control system
Displaying user feedback
Display actions status
Invoke interact with user
Blink flag
Invoke display messages and status

Figure 2.26 State transition diagram for Safe Home

- A somewhat different mode of behavioral representation is the process activation table.
- The PAT represents information contained in the STD in the context of processes, not states.
- That is, the table indicates which processes (bubbles) in the flow model will be invoked when an event occurs.



Input events						
Sensor event	0	0	0	0	1	0
Blink flag	0	0	1	1	0	0
Start/stop switch	0	1	0	0	0	0
Display action status						
Complete	0	0	0	1	0	0
In progress	0	0	1	0	0	0
Time out	0	0	0	0	0	1
Output						
Alarm signal	0	0	0	0	1	0
Process activation						
Monitor and control system	0	1	0	0	1	1
Activate/deactivate system	0	1	0	0	0	0
Display messages and status	1	0	1	1	1	1
Interact with user	1	0	0	1	0	1

Figure 2.27 Process activation table for Safe Home

2.4.5 The Process Specification

- The process specification (PSPEC) is used to describe all flow model processes that appear at the final level of refinement.
- The content of the process specification can include narrative text, a program design language (PDL) description of the process algorithm, mathematical equations, tables, diagrams, or charts.
- To illustrate the use of the PSPEC, consider the process password transform represented in the flow model for Safe Home. The PSPEC for this function might take the form:

a) PSPEC: process password

- The process password transform performs all password validation for the SafeHomesystem.
- Process password receives a four-digit password from the interact with user function.
- The password is first compared to the master password stored within the system.
- If the master password matches, <valid id message = true> is passed to the message and status display function.
- If the master password does not match, the four digits are compared to a table of secondary passwords (these may be assigned to house guests and/or workers who require entry to the home when the owner is not present).
- If the password matches an entry within the table, <valid id message = true> is passed to the message and status display function.
- If there is no match, <valid id message = false> is passed to the message and status display function.

2.5 CLASSICAL ANALYSIS:

2.5.1 Structured System Analysis

● Structures system analysis — A nine-step technique to analyse client’s needs

● Step-wise refinement is used in many of steps

Step 1: Draw the Data Flow Diagram (DFD)

- A pictorial representation of all aspects of the logical data flow
- Logical data flow — What happens
- Physical data flow — How it happens
- Any non-trivial product contains many elements
- DFD is developed by stepwise refinement
- For large products a hierarchy of DFDs instead of one DFD
- Constructed by identifying data flows: Within requirements document or rapid prototype
- Four basic symbols

Source or destination of data (double-square box)
Data flow (arrow)
Process (rounded rectangle)
Data store (open-ended rectangle)

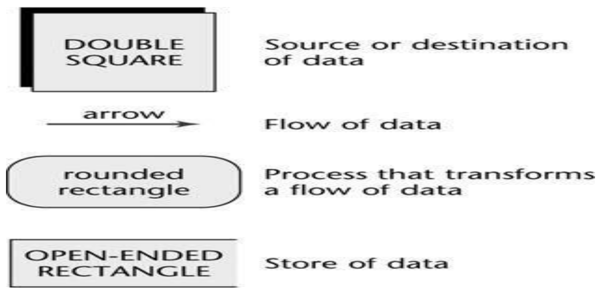


Figure 2.28 Basic symbols

Step 2: Decide what sections to computerize and how (batchor online)

- Depending on client’s needs and budget limitations
- Cost-benefit analysis is applied

Step 3: Determine details of data flows

- Decide what data items must go into various data flows.
- Stepwise refinement of each flow.
- For larger products, a data dictionary is generated.

Step 4: Define logic of processes

- Determine what happens within each process.
- Use of decision trees to consider all cases.

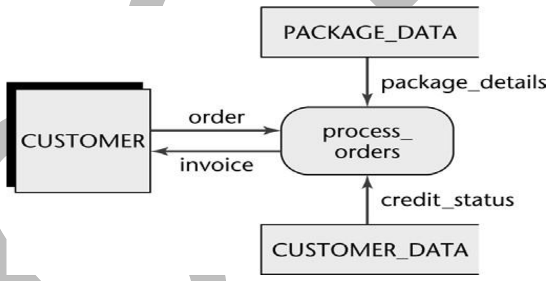


Figure 2.29 Data flow

Step 5: Define data stores

- Exact contents of each store and its representation (format)

Step 6: Define physical resources

- File names, organization (sequential, indexed, etc.), storage medium, and records
- If a database management system (DBMS) used: Relevant information for each table

Step 7: Determine input-output specifications

- Input forms and screens
- Printed outputs

Step 8: Determine sizing

- Computing numerical data to determine hardware requirements
- Volume of input (daily or hourly)
- Frequency of each printed report and its deadline
- Size and number of records of each type to pass between CPUand mass storage

Step 9: Determine hardware requirements

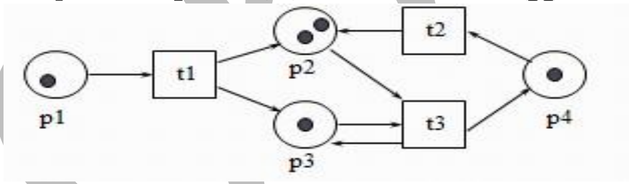
- Use of sizing information to determine mass storage requirements
- Mass storage for backup
- Determine if client's current hardware system is adequate
- After approval by client: Specification document is handed to design team, and software process continues

2.6 PETRI NETS

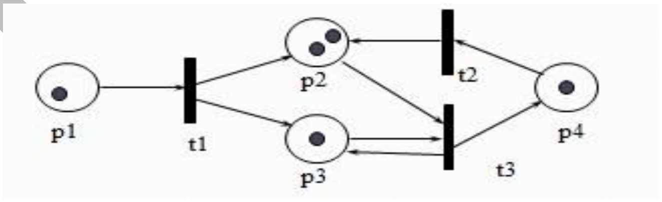
● Petri nets — Formal technique for describing concurrent interrelated activities
● Invented by Carl Adam Petri, 1962
● Consists of four parts
(1) A set of places
(2) A set of transitions
(3) An input function
(4) An output function
● Originally of interest to automata theorists
● Found wide applicability in computer science

- Performance evaluation
- Operating systems
- Software engineering

The Classical Petri Net Model:
A Petri net is a network composed of **places(O) and transitions(∏)**



Connections are directed and between a place and a transition, or a transition and a place(e.g. Between "p1 and t1" or "t1 and p2" above)Tokens(.) are the dynamic objects.Another (**equivalent**) notation is to use a solid bar for the transitions:



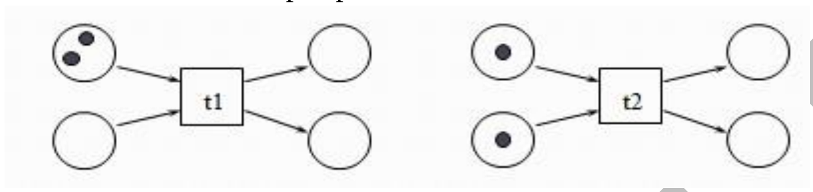
We may use either notation since they are equivalent, sometimes one makes the diagram easier to read than the other.

The **state** of a Petri net is determined by the distribution of tokens over the places (we could represent the above **state** as (1,2,1,1) for (p1,p2,p3,p4))

- Transition t1 has three **input places** (p1, p2 and p3) and two **output places** (p3 and p4).
- Place p3 is both an input and an output place of t1.

Enabling Condition:

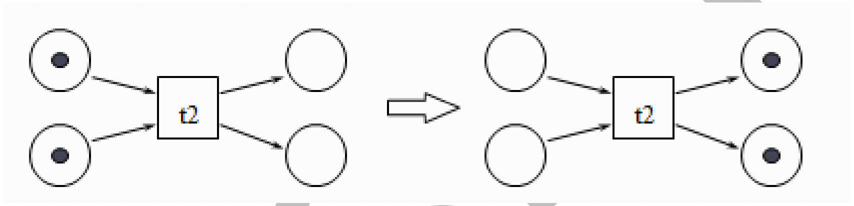
- Transitions are the **active** components and places and tokens are **passive** components.
- A transition is **enabled** if each of the input places contains tokens.



Transition t1 is not enabled, transition t2 is enabled.

Firing:

- An enabled transition may fire.
- Firing corresponds to consuming tokens from the input places and producing tokens for the output places.



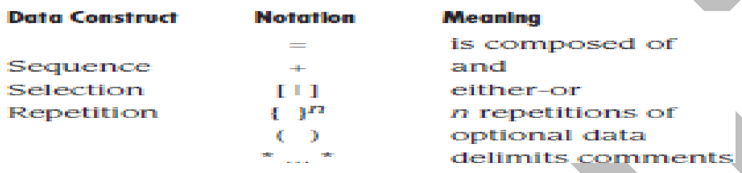
Firing is atomic (only one transition fires at a time, even if more than one is enabled**)**

2.7 THE DATA DICTIONARY

- Data dictionary provide an organized approach for representing the characteristics of each data object and control item.
- The data dictionary has been proposed as a quasi-formal grammar for describing the content of objects defined during structured analysis.
- This important modelling notation has been defined in the following manner :
  The data dictionary is an organized listing of all data elements that are pertinent to the system, with precise, rigorous definitions so that both user and system analyst will have a common understanding of inputs, outputs, components of stores and [even] intermediate calculations.
- Today, the data dictionary is always implemented as part of a CASE "structured analysis and design tool."
- Although the format of dictionaries varies from tool to tool, most contain the following information:

Name	Description
Name	The primary name of the data or control item, the data store or an external entity.
Alias	other names used for the first entry
Where-used/how-used	a listing of the processes that use the data or control item and how itis used (e.g., input to the process, output from the process process, as a store, as an external entity.

- When a dictionary entry is created, the CASE tool scans DFDs and CFDs to determine which processes use the data or control information and how it is used.
- For large projects, it is often quite difficult to determine the impact of a change.
- Many a software engineer has asked, "Where is this data object used? What else will have to change if we modify it? What will the overall impact of the change be?" Because the data dictionary can be treated as a database, the analyst can ask "where used/how used" questions, and get answers to these queries.
- The notation used to develop a content description is noted in the following table:

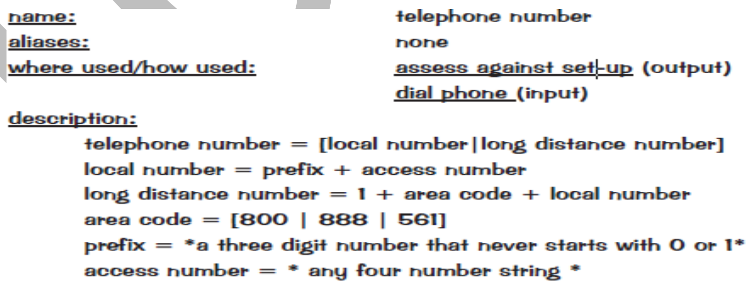


Data Construct	Notation	Meaning
	=	is composed of
Sequence	+	and
Selection	[|]	either-or
Repetition	$\{\ \}^n$	*n* repetitions of
	( )	optional data
	* ... *	delimits comments

- The notation enables a software engineer to represent composite data in one of the three fundamental ways that it can be constructed:

  1. As a sequence of data items.
  2. As a selection from among a set of data items.
  3. As a repeated grouping of data items. Each data item entry that is representedas part of a sequence, selection, or repetition may itself be another compositedata item that needs further refinement within the dictionary.

- The use of the data dictionary:
- The data dictionary provides us with a precise definition of **telephone number** for the DFD in question.
- It indicates where and how this data item is used and any supplementary information that is relevant to it.



<u>name:</u>	telephone number
<u>aliases:</u>	none
<u>where used/how used:</u>	<u>assess against set-up</u> (output)
	<u>dial phone</u> (input)

<u>description:</u>

```
        telephone number = [local number|long distance number]
        local number = prefix + access number
        long distance number = 1 + area code + local number
        area code = [800 | 888 | 561]
        prefix = *a three digit number that never starts with 0 or 1*
        access number = * any four number string *
```

- The data dictionary entry begins as follows:
- The content description is expanded until all composite data items have been represented as elementary items or until all composite
- Items are represented in terms that would be well-known and unambiguous to all readers.
- It is also important to note that a specification of elementary data often restricts a system.
- For example, the definition of area code indicates that only three area codes (two toll-free and one in South Florida) are valid for this system.
- The data dictionary defines information items unambiguously.

Advantages:

1. Data dictionary support name management and avoid duplication.
2. It is a store of organisational knowledge linking analysis,design and implementation.

Important questions:

Difference between Functional and Non-functional Requirements

Functional Requirements	**Non-functional Requirements**
The functional requirements specify the features of the software system	The non-functional requirements specify the properties of the software system.
Functional Requirements describe what the product must do.	Non-functional Requirements describe how he product should perform
The functional requirements specify the actions with which the work is concerned.	The non-functional requirements specify the experience of the user while using the system.
Example: For a library management system allowing user to read the article online is a functional requirement.	Example: For a library management system, for a user who wishes to read the article online must be authenticated first.

Difference between Functional and Behavioural models:

Functional model	**Behavioural model**
The functional model depicts all the essential functionalities of the system	The behavioral model represents how system behaves
The functional model is represented by data flow and control flow diagrams	The behavioral model is represented by state chart diagram
The DFDS can be represented by levels	The state diagram has some number of states and transitions
The functional diagram gives detailed scenario of system which has to be developed.	The behavioral model gives the abstract representation of the system.

Difference between Data flow diagram and state transition diagram

Data flow diagram	**State Transition Diagram**
Data flow diagram is graphical representation for representing the information flow and the transforms that are applied as data move from input to output	State transition diagram is a graphical representation for representing the behavior of a system by depicting its states and the events that cause the system, to change state
The data flow diagram is a collection of process data store, flow of data	The State transition diagram is a collection of states and events.
The data flow diagrams are used to represent the system at any level of abstractions and the increasing levels are used to expose more and more functionalities in the system.	The state transition diagrams are typically drawn at single level .They intended to expose the overall behavior of the system.