

MCA Part-II
Paper-XI: Software Engineering
Topic: Software Design

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Introduction

Software design encompasses the set of principles, concepts, and practices that lead to the development of a high-quality system or product. Design principles establish an overriding philosophy that guides you in the design work you must perform. Design concepts must be understood before the mechanics of design practice are applied, and design practice itself leads to the creation of various representations of the software that serve as a guide for the construction activity that follows. Design is pivotal to successful software engineering. Software design is the first step in SDLC (Software Design Life Cycle), which moves the concentration from problem domain to solution domain. It tries to specify how to fulfill the requirements mentioned in SRS.

Software Design Levels

Software design yields three levels of results:

- **Architectural Design** - The architectural design is the highest abstract version of the system. It identifies the software as a system with many components interacting with each other. At this level, the designers get the idea of proposed solution domain.
- **High-level Design**- The high-level design breaks the 'single entity-multiple component' concept of architectural design into less-abstracted view of sub-systems and modules and depicts their interaction with each other. High-level

design focuses on how the system along with all of its components can be implemented in forms of modules. It recognizes modular structure of each sub-system and their relation and interaction among each other.

- **Detailed Design-** Detailed design deals with the implementation part of what is seen as a system and its sub-systems in the previous two designs. It is more detailed towards modules and their implementations. It defines logical structure of each module and their interfaces to communicate with other modules.

Modularization

Modularization is a technique to divide a software system into multiple discrete and independent modules, which are expected to be capable of carrying out task(s) independently. These modules may work as basic constructs for the entire software. Designers tend to design modules such that they can be executed and/or compiled separately and independently.

Modular design unintentionally follows the rules of 'divide and conquer' problem-solving strategy this is because there are many other benefits attached with the modular design of a software.

Advantage of modularization:

- Smaller components are easier to maintain
- Program can be divided based on functional aspects
- Desired level of abstraction can be brought in the program
- Components with high cohesion can be re-used again
- Concurrent execution can be made possible
- Desired from security aspect

Concurrency

Back in time, all software are meant to be executed sequentially. By sequential execution we mean that the coded instruction will be executed one after another implying only one portion of program being activated at any given time. Say, a software has multiple modules, then only one of all the modules can be found active at any time of execution.

In software design, concurrency is implemented by splitting the software into multiple independent units of execution, like modules and executing them in parallel. In other

words, concurrency provides capability to the software to execute more than one part of code in parallel to each other.

It is necessary for the programmers and designers to recognize those modules, which can be made parallel execution.

Example

The spell check feature in word processor is a module of software, which runs along side the word processor itself.

Coupling and Cohesion

When a software program is modularized, its tasks are divided into several modules based on some characteristics. As we know, modules are set of instructions put together in order to achieve some tasks. They are though, considered as single entity but may refer to each other to work together. There are measures by which the quality of a design of modules and their interaction among them can be measured. These measures are called coupling and cohesion.

Cohesion

Cohesion is a measure that defines the degree of intra-dependability within elements of a module. The greater the cohesion, the better is the program design.

There are seven types of cohesion, namely –

- **Co-incident cohesion** - It is unplanned and random cohesion, which might be the result of breaking the program into smaller modules for the sake of modularization. Because it is unplanned, it may serve confusion to the programmers and is generally not-accepted.
- **Logical cohesion** - When logically categorized elements are put together into a module, it is called logical cohesion.
- **Temporal Cohesion** - When elements of module are organized such that they are processed at a similar point in time, it is called temporal cohesion.
- **Procedural cohesion** - When elements of module are grouped together, which are executed sequentially in order to perform a task, it is called procedural cohesion.

- **Communicational cohesion** - When elements of module are grouped together, which are executed sequentially and work on same data (information), it is called communicational cohesion.
- **Sequential cohesion** - When elements of module are grouped because the output of one element serves as input to another and so on, it is called sequential cohesion.
- **Functional cohesion** - It is considered to be the highest degree of cohesion, and it is highly expected. Elements of module in functional cohesion are grouped because they all contribute to a single well-defined function. It can also be reused.

Coupling

Coupling is a measure that defines the level of inter-dependability among modules of a program. It tells at what level the modules interfere and interact with each other. The lower the coupling, the better the program.

There are five levels of coupling, namely -

- **Content coupling** - When a module can directly access or modify or refer to the content of another module, it is called content level coupling.
- **Common coupling**- When multiple modules have read and write access to some global data, it is called common or global coupling.
- **Control coupling**- Two modules are called control-coupled if one of them decides the function of the other module or changes its flow of execution.
- **Stamp coupling**- When multiple modules share common data structure and work on different part of it, it is called stamp coupling.
- **Data coupling**- Data coupling is when two modules interact with each other by means of passing data (as parameter). If a module passes data structure as parameter, then the receiving module should use all its components.

Software Analysis and Design Tools

Software analysis and design includes all activities, which help the transformation of requirement specification into implementation. Requirement specifications specify all functional and non-functional expectations from the software. These requirement specifications come in the shape of human readable and understandable documents, to which a computer has nothing to do.

Software analysis and design is the intermediate stage, which helps human-readable requirements to be transformed into actual code.

Let us see few analysis and design tools used by software designers:

Data Flow Diagram

Data flow diagram is graphical representation of flow of data in an information system. It is capable of depicting incoming data flow, outgoing data flow and stored data. The DFD does not mention anything about how data flows through the system.

There is a prominent difference between DFD and Flowchart. The flowchart depicts flow of control in program modules. DFDs depict flow of data in the system at various levels. DFD does not contain any control or branch elements.

Types of DFD

Data Flow Diagrams are either Logical or Physical.

- **Logical DFD** - This type of DFD concentrates on the system process, and flow of data in the system. For example in a Banking software system, how data is moved between different entities.
- **Physical DFD** - This type of DFD shows how the data flow is actually implemented in the system. It is more specific and close to the implementation.

DFD Components

DFD can represent Source, destination, storage and flow of data using the following set of components -

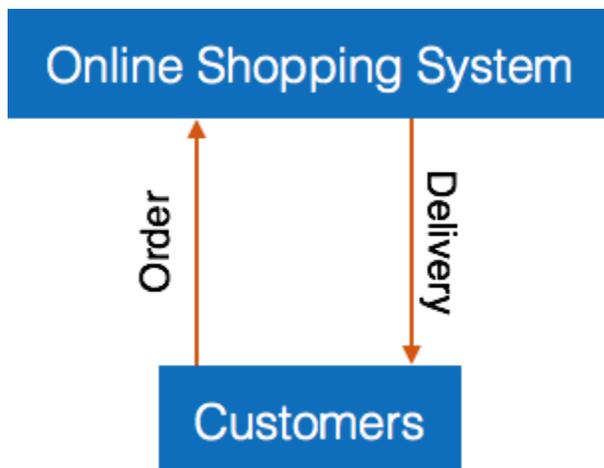


- **Entities** - Entities are source and destination of information data. Entities are represented by a rectangles with their respective names.
- **Process** - Activities and action taken on the data are represented by Circle or Round-edged rectangles.

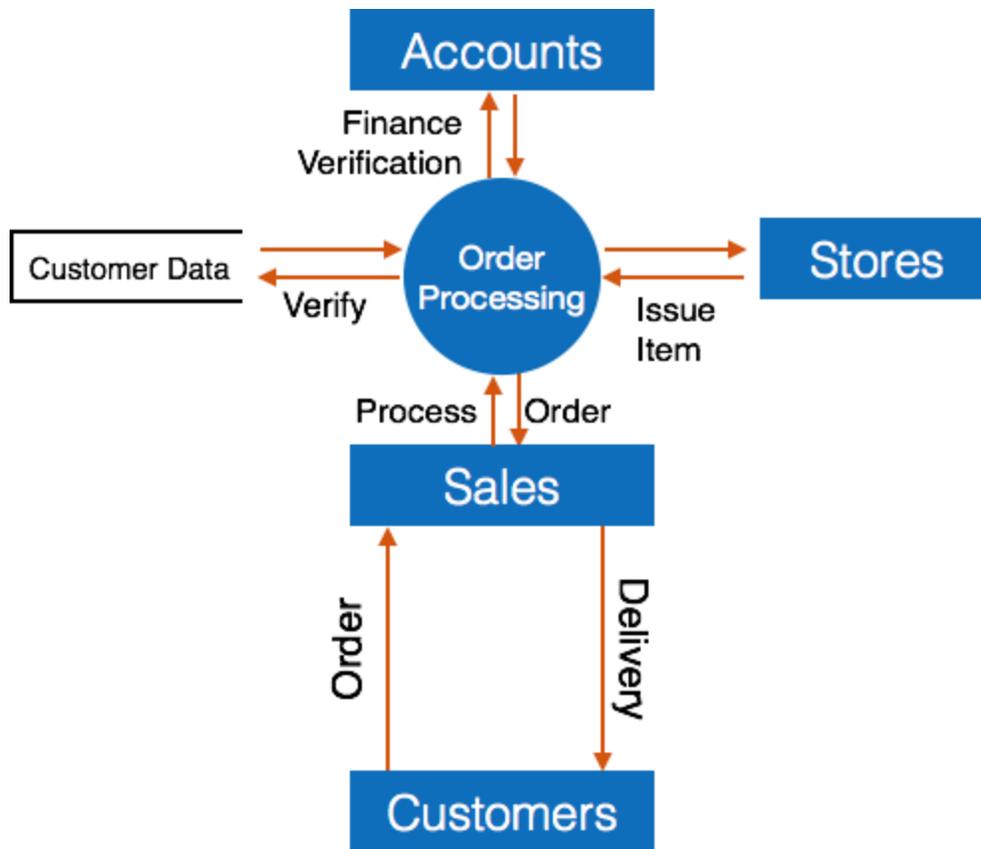
- **Data Storage** - There are two variants of data storage - it can either be represented as a rectangle with absence of both smaller sides or as an open-sided rectangle with only one side missing.
- **Data Flow** - Movement of data is shown by pointed arrows. Data movement is shown from the base of arrow as its source towards head of the arrow as destination.

Levels of DFD

- **Level 0** - Highest abstraction level DFD is known as Level 0 DFD, which depicts the entire information system as one diagram concealing all the underlying details. Level 0 DFDs are also known as context level DFDs.



- **Level 1** - The Level 0 DFD is broken down into more specific, Level 1 DFD. Level 1 DFD depicts basic modules in the system and flow of data among various modules. Level 1 DFD also mentions basic processes and sources of information.



- **Level 2** - At this level, DFD shows how data flows inside the modules mentioned in Level 1.

Higher level DFDs can be transformed into more specific lower level DFDs with deeper level of understanding unless the desired level of specification is achieved.

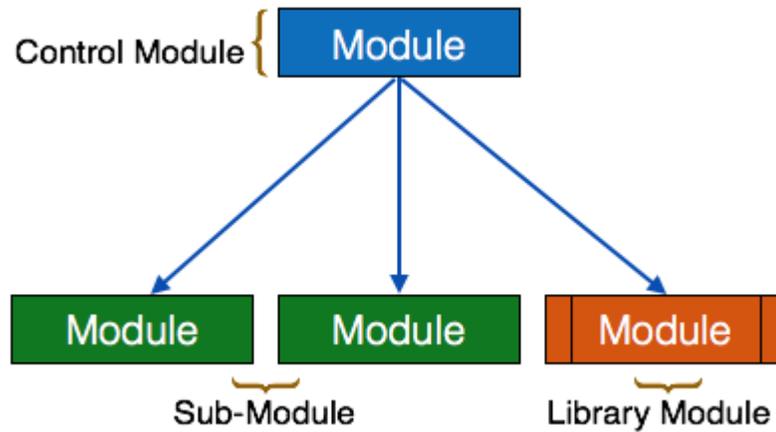
Structure Charts

Structure chart is a chart derived from Data Flow Diagram. It represents the system in more detail than DFD. It breaks down the entire system into lowest functional modules, describes functions and sub-functions of each module of the system to a greater detail than DFD.

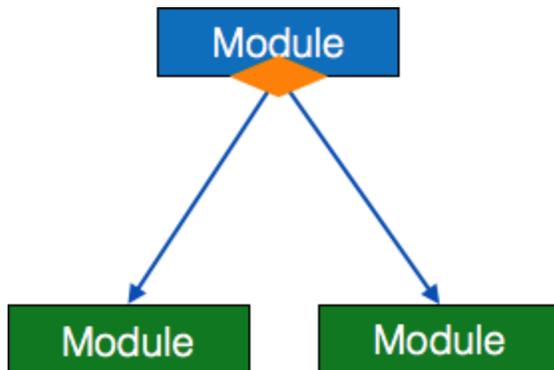
Structure chart represents hierarchical structure of modules. At each layer a specific task is performed.

Here are the symbols used in construction of structure charts -

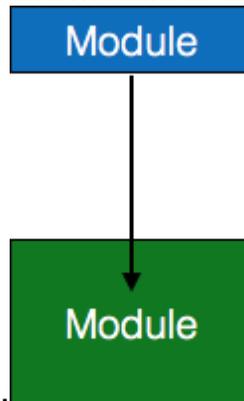
- **Module** - It represents process or subroutine or task. A control module branches to more than one sub-module. Library Modules are re-usable and invocable from



- any module.
- **Condition** - It is represented by small diamond at the base of module. It depicts that control module can select any of sub-routine based on some condition.

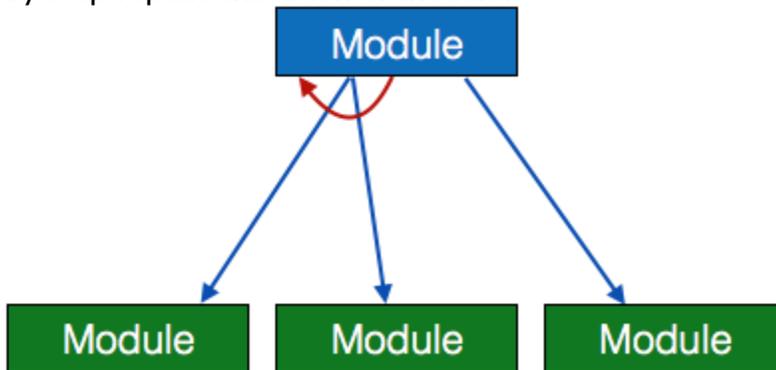


- **Jump** - An arrow is shown pointing inside the module to depict that the control

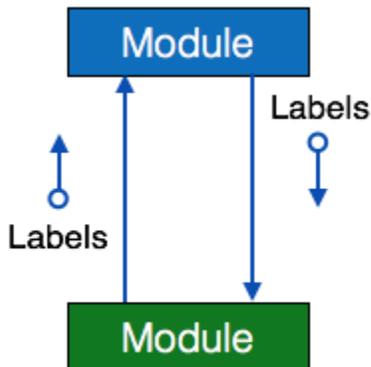


will jump in the middle of the sub-module.

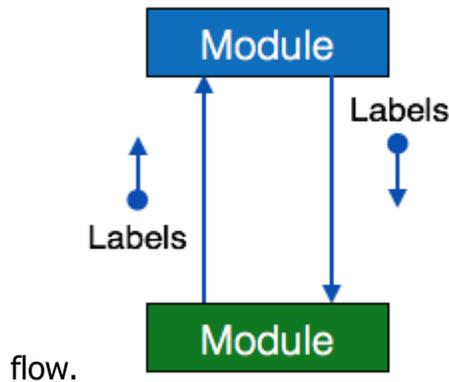
- **Loop** - A curved arrow represents loop in the module. All sub-modules covered by loop repeat execution of module.



- **Data flow** - A directed arrow with empty circle at the end represents data flow.



- **Control flow** - A directed arrow with filled circle at the end represents control

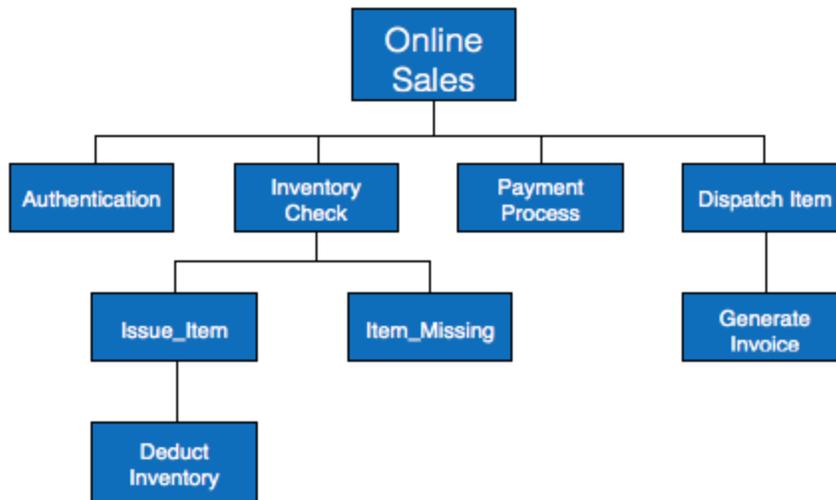


HIPO Diagram

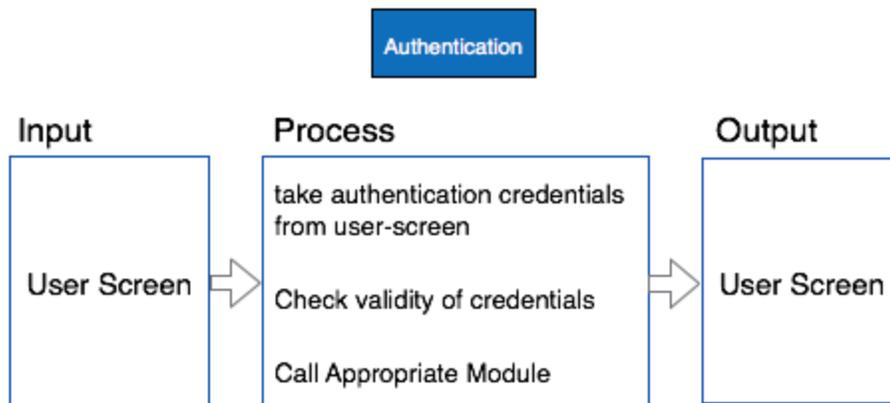
The HIPO (Hierarchy plus Input-Process-Output) technique was developed by IBM's System Development Division (SDD) in the late 1970s. It offers diagrammatic and textual representations for the documentation of systems, programs and processes. The HIPO technique is made up of two main components.

- (i) **Visual Table of Contents (VTOC):** The VTOC is represented as a chart showing how functions of a system or modules of a program are decomposed in a tree format. It offers a top-down analysis of a program, system or process. HIPO diagram represents the hierarchy of modules in the software system. Analyst uses HIPO diagram in order to obtain high-level view of system functions. It decomposes functions into sub-functions in a hierarchical manner. It depicts the functions performed by system.
- (ii) **Input-Process-Output (IPO) :** IPO depicts the flow of control and data in a module.

HIPO diagrams are good for documentation purpose. Their graphical representation makes it easier for designers and managers to get the pictorial idea of the system structure.



In contrast to IPO (Input Process Output) diagram, which depicts the flow of control and data in a module, VTOC does not provide any information about data flow or control flow.



Both parts of HIPO diagram, Hierarchical presentation and IPO Chart are used for structure design of software program as well as documentation of the same.

Entity-Relationship Diagram(ERD)

ER Model is represented by means of an ER diagram. Any object, for example, entities, attributes of an entity, relationship sets, and attributes of relationship sets, can be represented with the help of an ER diagram.

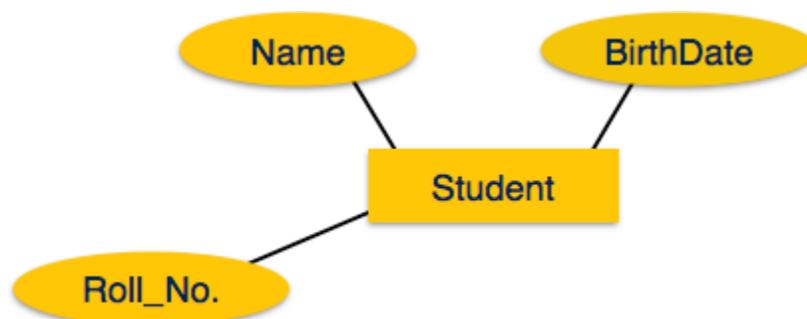
Entity

Entities are represented by means of rectangles. Rectangles are named with the entity set they represent.

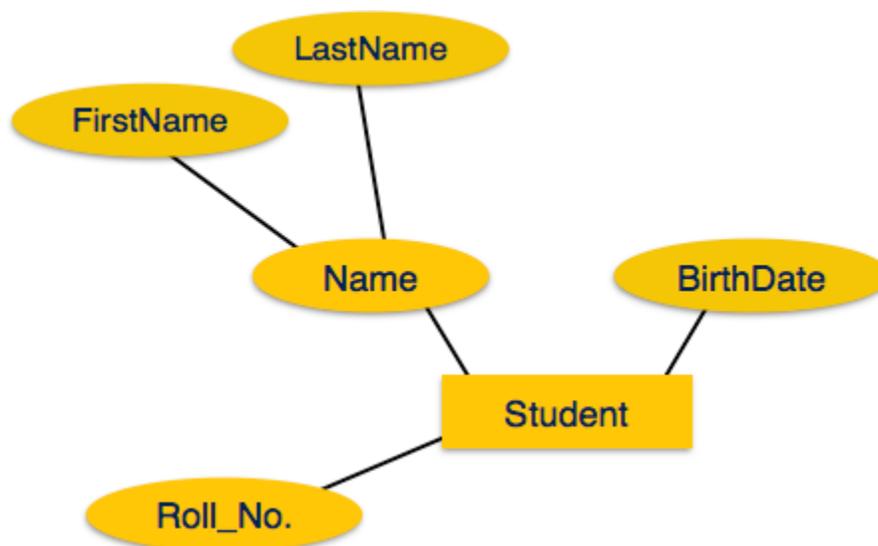


Attributes

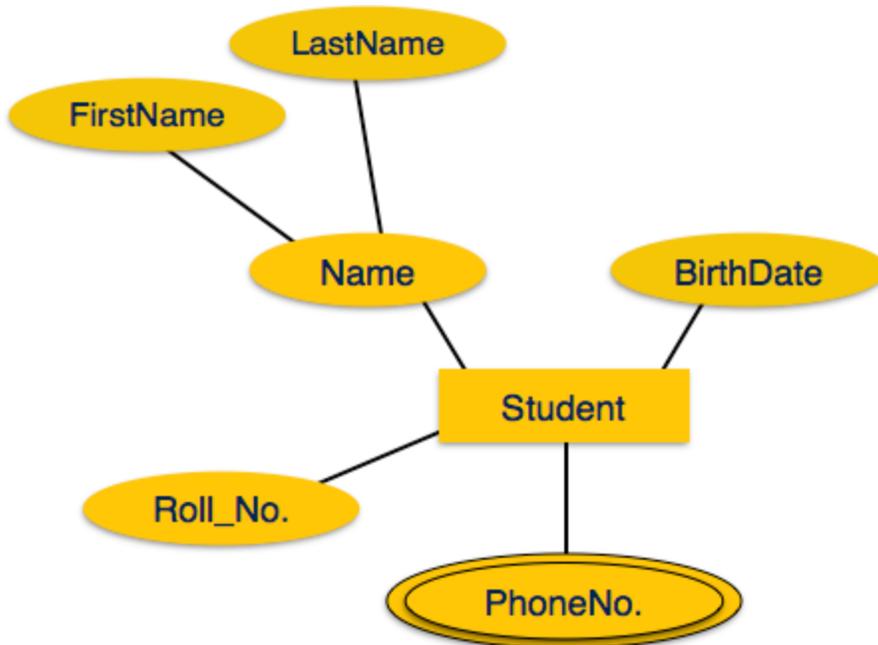
Attributes are the properties of entities. Attributes are represented by means of ellipses. Every ellipse represents one attribute and is directly connected to its entity (rectangle).



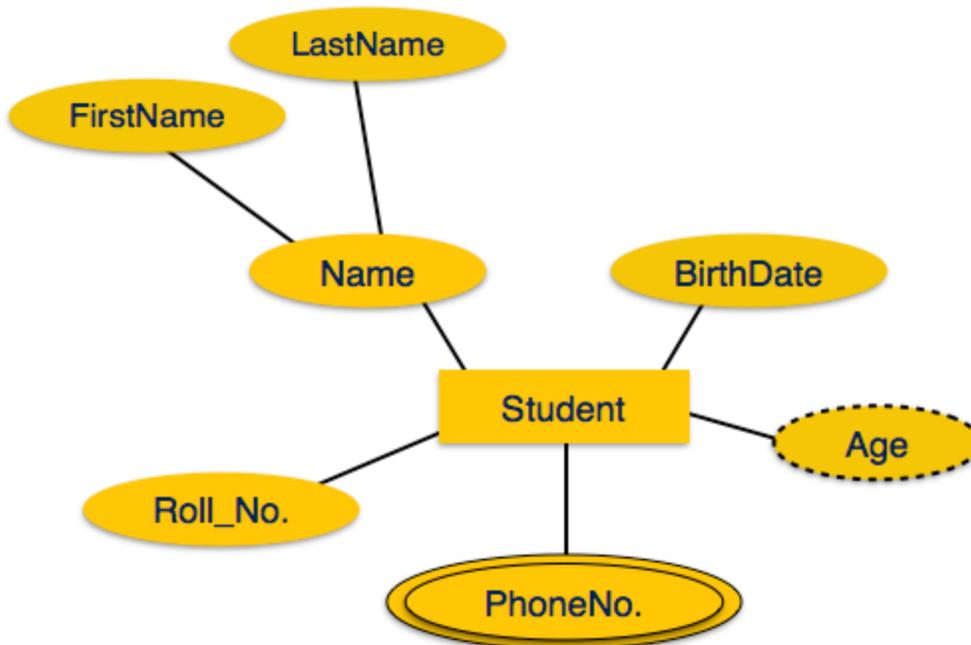
If the attributes are **composite**, they are further divided in a tree like structure. Every node is then connected to its attribute. That is, composite attributes are represented by ellipses that are connected with an ellipse.



Multivalued attributes are depicted by double ellipses.



Derived attributes are depicted by dashed ellipse.



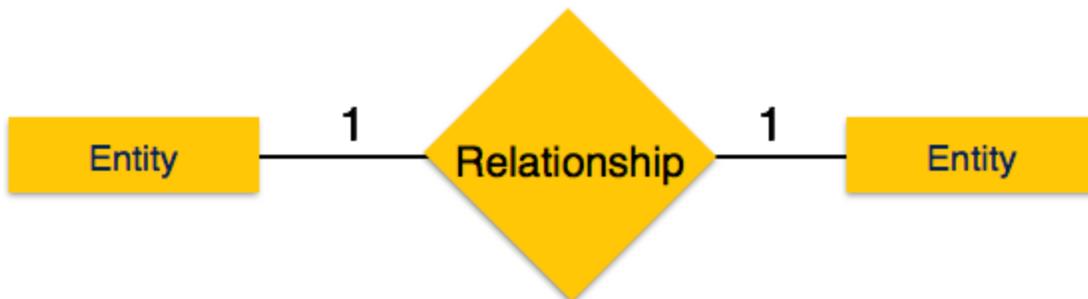
Relationship

Relationships are represented by diamond-shaped box. Name of the relationship is written inside the diamond-box. All the entities (rectangles) participating in a relationship, are connected to it by a line.

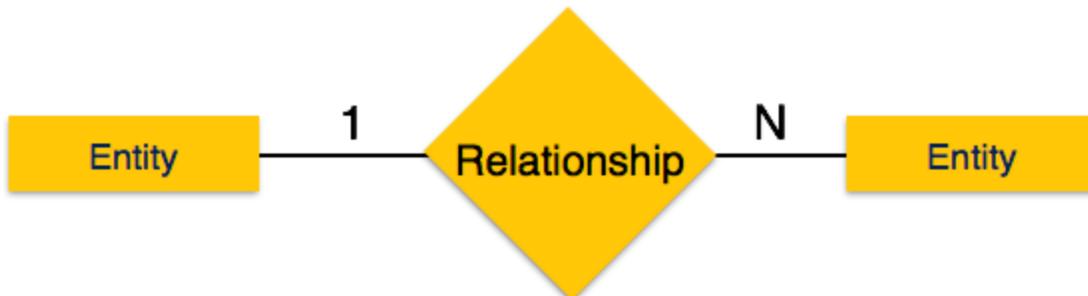
Binary Relationship and Cardinality

A relationship where two entities are participating is called a **binary relationship**. Cardinality is the number of instance of an entity from a relation that can be associated with the relation.

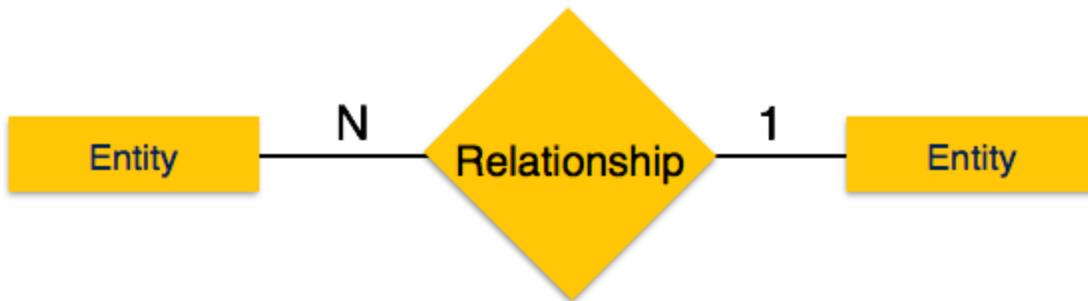
- **One-to-one** – When only one instance of an entity is associated with the relationship, it is marked as '1:1'. The following image reflects that only one instance of each entity should be associated with the relationship. It depicts one-to-one relationship.



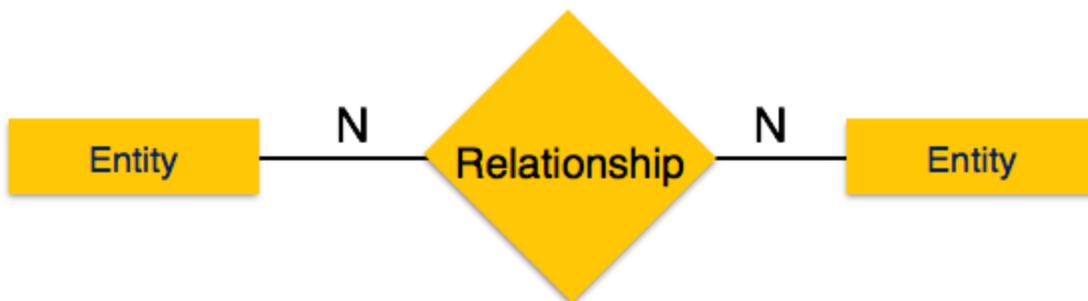
- **One-to-many** – When more than one instance of an entity is associated with a relationship, it is marked as '1:N'. The following image reflects that only one instance of entity on the left and more than one instance of an entity on the right can be associated with the relationship. It depicts one-to-many relationship.



- **Many-to-one** – When more than one instance of entity is associated with the relationship, it is marked as 'N:1'. The following image reflects that more than one instance of an entity on the left and only one instance of an entity on the right can be associated with the relationship. It depicts many-to-one relationship.

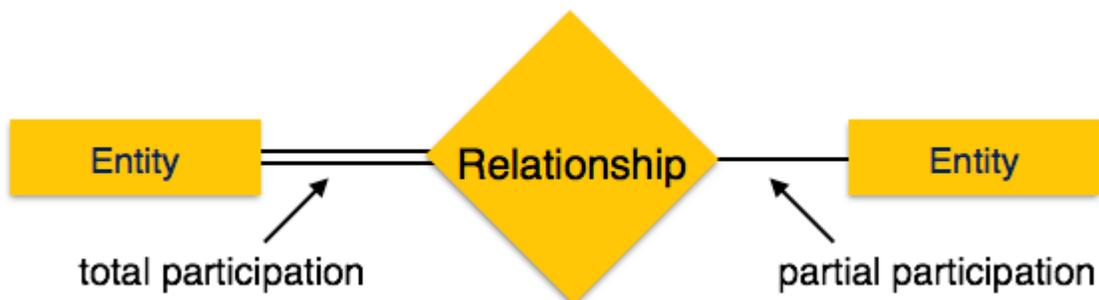


- **Many-to-many** – The following image reflects that more than one instance of an entity on the left and more than one instance of an entity on the right can be associated with the relationship. It depicts many-to-many relationship.



Participation Constraints

- **Total Participation** – Each entity is involved in the relationship. Total participation is represented by double lines.
- **Partial participation** – Not all entities are involved in the relationship. Partial participation is represented by single lines.



Structured English

Most programmers are unaware of the large picture of software so they only rely on what their managers tell them to do. It is the responsibility of higher software management to provide accurate information to the programmers to develop accurate yet fast code.

Other forms of methods, which use graphs or diagrams, may be sometimes interpreted differently by different people.

Hence, analysts and designers of the software come up with tools such as Structured English. It is nothing but the description of what is required to code and how to code it. Structured English helps the programmer to write error-free code.

Other form of methods, which use graphs or diagrams, may be sometimes interpreted differently by different people. Here, both Structured English and Pseudo-Code try to mitigate that understanding gap.

Structured English is the It uses plain English words in structured programming paradigm. It is not the ultimate code but a kind of description what is required to code and how to code it. The following are some tokens of structured programming.

**IF-THEN-ELSE,
DO-WHILE-UNTIL**

Analyst uses the same variable and data name, which are stored in Data Dictionary, making it much simpler to write and understand the code.

Example

We take the same example of Customer Authentication in the online shopping environment. This procedure to authenticate customer can be written in Structured English as:

```
Enter Customer_Name  
SEEK Customer_Name in Customer_Name_DB file  
IF Customer_Name found THEN  
    Call procedure USER_PASSWORD_AUTHENTICATE()  
ELSE  
    PRINT error message
```

Call procedure NEW_CUSTOMER_REQUEST()

ENDIF

The code written in Structured English is more like day-to-day spoken English. It can not be implemented directly as a code of software. Structured English is independent of programming language.

Pseudo-Code

Pseudo code is written more close to programming language. It may be considered as augmented programming language, full of comments and descriptions.

Pseudo code avoids variable declaration but they are written using some actual programming language's constructs, like C, Fortran, Pascal etc.

Pseudo code contains more programming details than Structured English. It provides a method to perform the task, as if a computer is executing the code.

Example

Program to print Fibonacci up to n numbers.

void function Fibonacci

Get value of n;

Set value of a to 1;

Set value of b to 1;

Initialize I to 0

for (i=0; i< n; i++)

{

if a greater than b

{

Increase b by a;

Print b;

}

else if b greater than a

{

```
    increase a by b;
    print a;
}
}
```

Decision Tables

A Decision table represents conditions and the respective actions to be taken to address them, in a structured tabular format.

It is a powerful tool to debug and prevent errors. It helps group similar information into a single table and then by combining tables it delivers easy and convenient decision-making.

Creating Decision Table

To create the decision table, the developer must follow basic four steps:

- Identify all possible conditions to be addressed
- Determine actions for all identified conditions
- Create Maximum possible rules
- Define action for each rule

Decision Tables should be verified by end-users and can lately be simplified by eliminating duplicate rules and actions.

Example

Let us take a simple example of day-to-day problem with our Internet connectivity. We begin by identifying all problems that can arise while starting the internet and their respective possible solutions.

We list all possible problems under column conditions and the prospective actions under column Actions.

	Conditions/Actions	Rules							
Conditions	Shows Connected	N	N	N	N	Y	Y	Y	Y

	Ping is Working	N	N	Y	Y	N	N	Y	Y
	Opens Website	Y	N	Y	N	Y	N	Y	N
Actions	Check network cable	X							
	Check internet router	X				X	X	X	
	Restart Web Browser							X	
	Contact Service provider		X	X	X	X	X	X	
	Do no action								

Table : Decision Table – In-house Internet Troubleshooting

Data Dictionary

Data dictionary is the centralized collection of information about data. It stores meaning and origin of data, its relationship with other data, data format for usage etc. Data dictionary has rigorous definitions of all names in order to facilitate user and software designers.

Data dictionary is often referenced as meta-data (data about data) repository. It is created along with DFD (Data Flow Diagram) model of software program and is expected to be updated whenever DFD is changed or updated.

Requirement of Data Dictionary

The data is referenced via data dictionary while designing and implementing software. Data dictionary removes any chances of ambiguity. It helps keeping work of programmers and designers synchronized while using same object reference everywhere in the program.

Data dictionary provides a way of documentation for the complete database system in one place. Validation of DFD is carried out using data dictionary.

Contents

Data dictionary should contain information about the following

- Data Flow
- Data Structure
- Data Elements
- Data Stores
- Data Processing

Data Flow is described by means of DFDs as studied earlier and represented in algebraic form as described.

=	Composed of
{ }	Repetition
()	Optional
+	And
[/]	Or

Example

Address = House No + (Street / Area) + City + State

Course ID = Course Number + Course Name + Course Level + Course Grades

Data Elements

Data elements consist of Name and descriptions of Data and Control Items, Internal or External data stores etc. with the following details:

- Primary Name
- Secondary Name (Alias)
- Use-case (How and where to use)
- Content Description (Notation etc.)
- Supplementary Information (preset values, constraints etc.)

Data Store

It stores the information from where the data enters into the system and exists out of the system. The Data Store may include -

- **Files**
 - Internal to software.
 - External to software but on the same machine.
 - External to software and system, located on different machine.
- **Tables**
 - Naming convention
 - Indexing property

Data Processing

There are two types of Data Processing:

- **Logical:** As user sees it
- **Physical:** As software sees it
- .

Software Design Approaches

Here are two generic approaches for software designing:

Top Down Design

We know that a system is composed of more than one sub-systems and it contains a number of components. Further, these sub-systems and components may have their own set of sub-system and components and creates hierarchical structure in the system.

Top-down design takes the whole software system as one entity and then decomposes it to achieve more than one sub-system or component based on some characteristics. Each sub-system or component is then treated as a system and decomposed further. This process keeps on running until the lowest level of system in the top-down hierarchy is achieved.

Top-down design starts with a generalized model of system and keeps on defining the more specific part of it. When all components are composed the whole system comes into existence.

Top-down design is more suitable when the software solution needs to be designed from scratch and specific details are unknown.

Bottom-up Design

The bottom up design model starts with most specific and basic components. It proceeds with composing higher level of components by using basic or lower level components. It keeps creating higher level components until the desired system is not evolved as one single component. With each higher level, the amount of abstraction is increased.

Bottom-up strategy is more suitable when a system needs to be created from some existing system, where the basic primitives can be used in the newer system.

Both, top-down and bottom-up approaches are not practical individually. Instead, a good combination of both is used.