MASENO UNIVERSITY

BACHELOR OF SCIENCE IN COMPUTER SCIENCE

YEAR 1 SEMESTER 2

CIR 106: DATABASE SYSTEMS

COURSE NOTES

1.0 OVERVIEW OF DATABASE SYSTEMS

- Data management, which focuses on data collection, storage and retrieval, constitutes a core activity for any organisation.
- To generate relevant information efficiently you need quick access to data (raw facts) from which the required information is produced.
- Efficient data management requires the use of a computer database. A database is a shared, integrated computer structure that houses a collection of: -

  i. End -user data i.e. raw facts of interest to the user.
  ii. Meta -data i.e. raw facts of interest to the user
  iii. Meta data i.e. data about data through which the data is integrated. The Meta data provides a description of the data characteristics and the set of relationships that link the data found within the database. The database resembles a very well organized electronic filing cabinet in which powerful software referred to as DBMS helps manage the cabinet's contents.

1.1 Review Of Traditional Processing And It's Limitations

- Consider a saving bank enterprise that keeps information about all customers and savings accounts in permanent system files at the bank.
- The bank will need a number of applications e.g.

  i. Program to debit or credit an account
  ii. A program to add a new account
  iii. A program to find the balance of an account
  iv. A program to generate monthly statements
  v. Any new program would be added as per the banks requirements

- Such a typical filing /processing system has the limitation of more and more files and application programs being added to the system at any time. Such a scheme has a number of major disadvantages:

  i. **Data redundancy and inconsistency** - Since the files and application programs are created by different programmers over a long period of type, the files are likely to have different formats and the programs may be written in several programming languages. Moreover, the same piece of information may be duplicated in several files. This redundancy leads to higher storage

and access costs. It may also lead to inconsistency i.e. the various copies of the same data may no longer agree.

ii. **Difficulty in accessing** - Suppose that one of the bank officers needs to find out the names of all customers who live within the city's 78-phone code. The officer would ask the data processing department to generate such a list. Such a request may not have been anticipated while designing the system originally and the only options available are:-

- ♦ Extract the data manually
- ♦ Write the necessary application, therefore do not allow the data to be accessed conveniently and efficiently

iii. **Data isolation** - Since data is scattered in various files and files may be in different formats, it may be difficult to write new applications programs to retrieve the appropriate data.

iv. **Concurrent access anomalies** - Interaction of concurrent updates may result in inconsistent data e.g. if 2 customers withdraw funds say 50/= and 100/= from an account at about the same time the result of the concurrent execution may leave the account in an incorrect state.

v. **Security problems** - Not every user of the database system should be able to access all the data. Since application programs are added to the system in an ad-hoc manner, it is difficult to enforce security constraints.

vi. **Integrity** - The data value stored in the database must satisfy certain types of consistency constraints e.g. a balance of a bank account may never fall below a prescribed value e.g. 5,000/=. These constraints are enforced in a system by adding appropriate code in the various application programs. However, when new constraints are added there is need to change the other programs to enforce.

Conclusion.
These difficulties among others have prompted the development of DBMS.

1.2 Evaluation of the DBMS

Unlike the file system with may separate and unrelated files, the Database consists of logically related data store in a single data repository. The problems inherent in file systems make using the database system very desirable and therefore, the database represents a change in the way the end user data are stored accessed and arranged.

1.3 Types Of Database Systems

i. Single User database systems

This is a database system that supports one user at a time such that if user A is using the database, users B & C must wait until user A complete his or her database work.
If a single user database runs on a personal computer it’s called a desktop database.

ii. Multi-user database

This is a database that supports multiple users at the same time for relatively small number e.g. 50 users in a department the database is referred to as a workgroup database. While one, which supports many departments is called an enterprise database.

iii. Centralized Database system
This is a database system that supports a database located at a single site.
iv. Distributed database system

This is a database system that supports a database distributed across several different sites.

v. Transactional DBMS/Production DBMS

This is a database system that supports immediate response transaction e.g. sale of a product.

vi. Decision Support DBMS

It focuses primarily on the production of information required to make a tactical or strategic decision at middle and high management levels.

1.4 Advantages Of The Database Systems

1. **Centralized Control -** Via the DBA it is possible to enforce centralized management and control of data. This means that necessary modifications, which do not affect other application changes, meet the data independence DBMS requirement.

2. **Reduction of redundancies -** Unnecessary duplication of data is avoided effectively reducing total amount of data required, consequently the reduction of storage space. It also eliminates extra processing necessary to trace the required data in a large mass of data. It also eliminates inconsistencies. Any redundancies that exist in the DBMS are controlled and the system ensures that his multiple copies are consistent.

3. **Shared data -** In a DBMS, sharing of data under its control by a number of application programs and user is possible e.g. backups.

4. **Integrity -** Centralized control can also ensure that adequate checks are incorporated to the DBMS provide data integrity. Data integrity means that the data contained in the database is both accurate and consistent e.g. employee age must be between 28-55 years.

5. **Security -** Only authorized people must access confidential data. The DBA ensures that proper access procedures are followed including proper authentication schemes process that the DBMS and additional checks before permitting access to sensitive data. Different levels of security can be implemented for various types of data or operations.

6. **Conflict Resolution -** The DBA is in a position to resolve conflicting requirements of various users and applications. It is by choosing the best file structure and access method to get optimum performance for the response. This could be by classifying applications into critical and less critical applications.

7. **Data Independence** - It involves both logical and physical independence. Logical data independence indicates that the conceptual schemes can be changed without affecting the existing external schemes. Physical data independence indicates that the physical storage structures/devices used for storing the data would be changed without necessitating a change in the conceptual view or any of the external use.

1.5 Disadvantages Of Database Systems

1. Cost - in terms of:

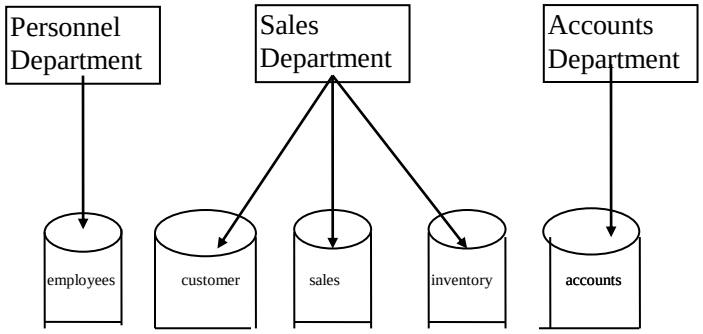
    - The DBMS - software
    - Purchasing or developing S/W
    - H/W
    - Workspace (disks for storage)
    - Migration (movement from tradition separate systems to an integrated one)

2. Centralization Problems

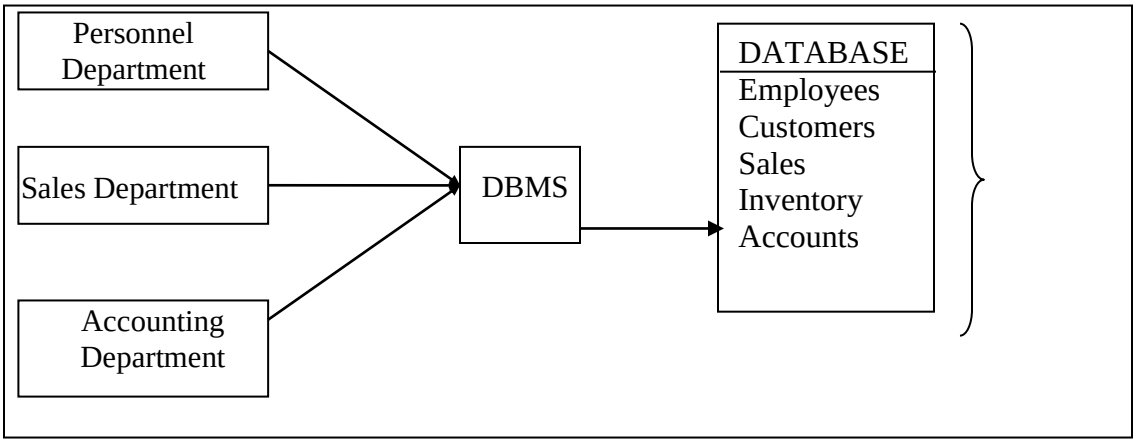
You would require adequate backup incase of failure
You would require increased severity of security breeches and disruption of operation of the organisation because of downtimes and failures.

3. Complexity of Backup and recovery

File System Environment



Database System Environment



Database System Environment

The database eliminates most of the file systems' data inconsistencies, anomalies and structural dependency problems.

The current generation of DBMS software stores not only the data structures in a central location but also stores the relationships between the database components
The DBMS also takes care of defining all the required access paths of the required component.

1.6 The Database System

The term database system refers to an organisation of components that define and regulate the collection storage, management and use of data within a database environment.

The database system is composed of 5 major parts i.e.

a. Hardware
b. Software
c. People
d. Procedures
e. Data

Hardware

This identifies all the systems physical devices e.g. the composition peripherals, storage devices etc.

Software

These are a collection of programs used by the computers within the database system.

i. O.S - manages all hardware components and makes it possible for all other and software to run on the composition.
ii. The DBMS - manages the database within the database system e.g. Oracle, DB2, Ms Access etc.
iii. Applications programs and utilities to access and manipulate data in the DBMS.

People

These are all database systems users:-

Systems administrator - Oversees the database systems general operations.

Database administrator (DBA) - Manages the DBMS use and ensures that the database is functioning properly. His functions include:

i. Scheme definition - The original database scheme is created by writing a set of definitions, which are translated by DDL compiler to a set of tables that are permanently stored in the data dictionary.
ii. Storage structure and Access Methods Definitions - By writing a set of definitions for appropriate storage structures and access methods, which are translated by the data storage and definition language compiler.
iii. Scheme and physical organisation modifications - Modification to either the database schema or description of the physical storage organisation are accompanied by writing a set of definitions which are used by either the DDL compiler or the data storage and definition language compiler to generate modification to appropriate internal systems tables e.g. data dictionary.
iv. Granting authorization to data access - This is so as to regulate which parts of the database users can access.
v. The database manager keeps integrity Constrains in a special system structure whenever an update takes place in the system.

3. **Database designers** - These are the database architects who design the database structure.

4. **Systems Analysts & Programmers (application programmers)** - They design and implement the application programs they design & create the data entry scheme, reports & procedures through which users access and manipulate the databases data.

5. **End users** - These are the people who use the application programs to run the organizations daily operations. They fall in the following classes:

    i. Sophisticated users - These interact with the system without writing programs. They form their requests in a database query language.
    ii. Specialized database applications that do not fit in the traditional data processing framework e.g. CAD Systems, knowledge based & expect systems.
    iii. Application programmers: These interact with the system through the DML & applications.
    iv. Naive – Unsophisticated user who interact with the systems by invoking one of the permanent application programs that have been written previously.

Procedures

- These are instructions and rules that govern the design and use of the database system.
- They enforce standards by which business is conducted within the organisation and with customers.
- They also ensure that there is an organized way to monitor and audit both the data that enter the database and the information that is generated through the use of such data.

Data

This covers the collection for facts stored in the database and since data is the raw material from which information is generated the determination of what data is to be stored into the database and how the data is to be organized is a vital part of the database designer jobs.

2.0 DATABASE ARCHITECTURE AND ENVIRONMENT

2.1 Abstraction and Data Integration

Abstraction is the simplification mechanism to hide superfluous details of a set of objects.
It allows one to concentrate on the properties that are of interest to the application e.g. a car is an abstraction of personal transportation vehicle but does not reveal details about model, year, colour etc.
Vehicle itself is an abstraction that includes the types; car, truck, bus and lorry.

Consider a non- database environment of a number of application programs as shown below:

Application 1 will contain values for the attributes employee.Name and Employee.Address and this record can be described in pseudo-code as

```
Type    Employee = record
                Employee.name : string
                Employee.address : string
        End
```

Application 2 will have:

```
Type    Employee = record
                Employee.name: String
                Employee.soc_sec_No: Integer
                Employee.Adress: String
                Employee. Annual_salary:integer
        End
```

In a non-database environment each application is responsible for maintaining the currency of data and a change in data item.

In a database environment, data can be stored in this application and their requirement be integrated by whoever is responsible for centralized control (DBA).
The integrated version would appear as recorded containing attributes required by both applications.

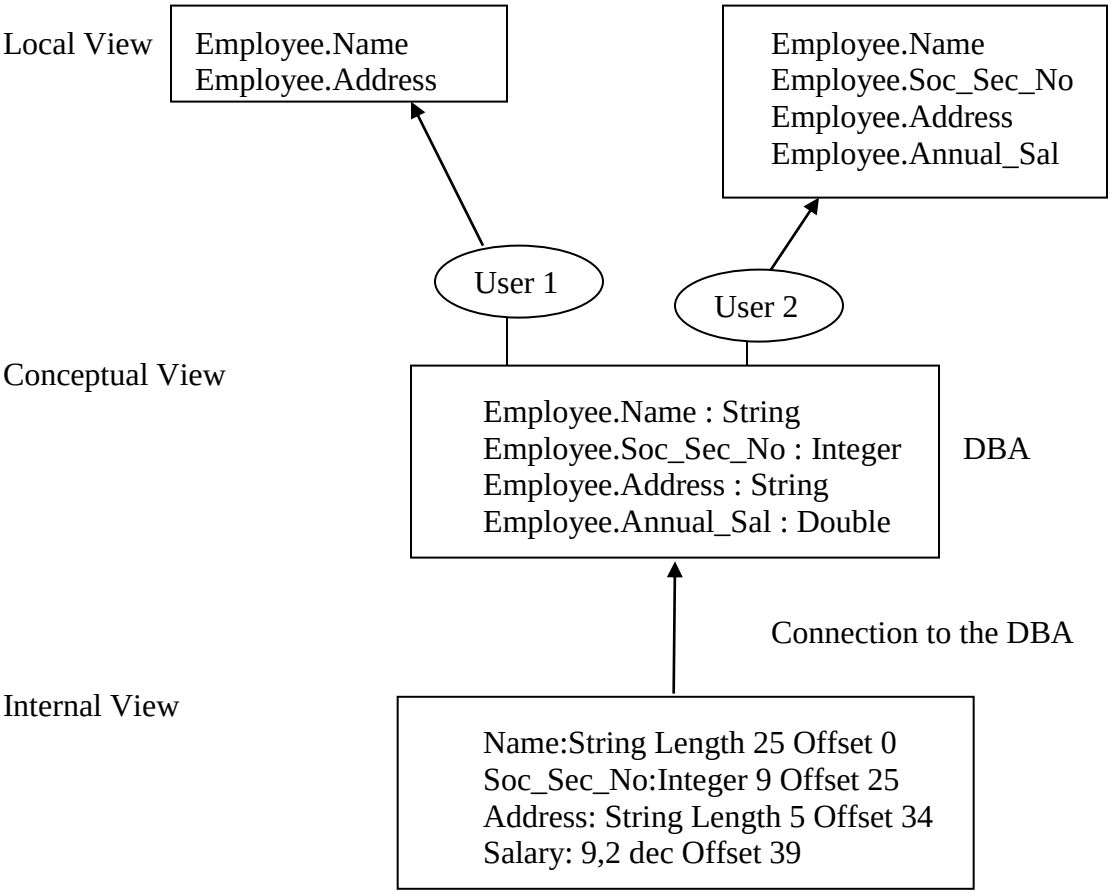
The record will appear as:

```
Type    Employee = record
                Employee.Name : string
                Employee.soc-sec.no : Integer
                Employee.Address : string
                Employee.Annual_Salary : double
        End
```

The views supported are derived from the conceptual record by using appropriate mapping.
The application programs no longer require information about the storage structure; storage device types or access methods. These are absorbed by the DBMS.

There are 3 level abstractions corresponding to 3 views:

i. The highest level which is seen by the application programs or user is called “external or user view"
ii. A sum total of users view is called global view a conceptual view.
iii. Lower level which is the description of the actual method of storing the data. It is also referred to as the internal view.



The 3 level scheme architecture is called the ANSI/SPARC model (American National Standard Institute/Standards Planning and Requirements Committee.)
It is divided into 3 levels:

- External
- Conceptual
- Internal

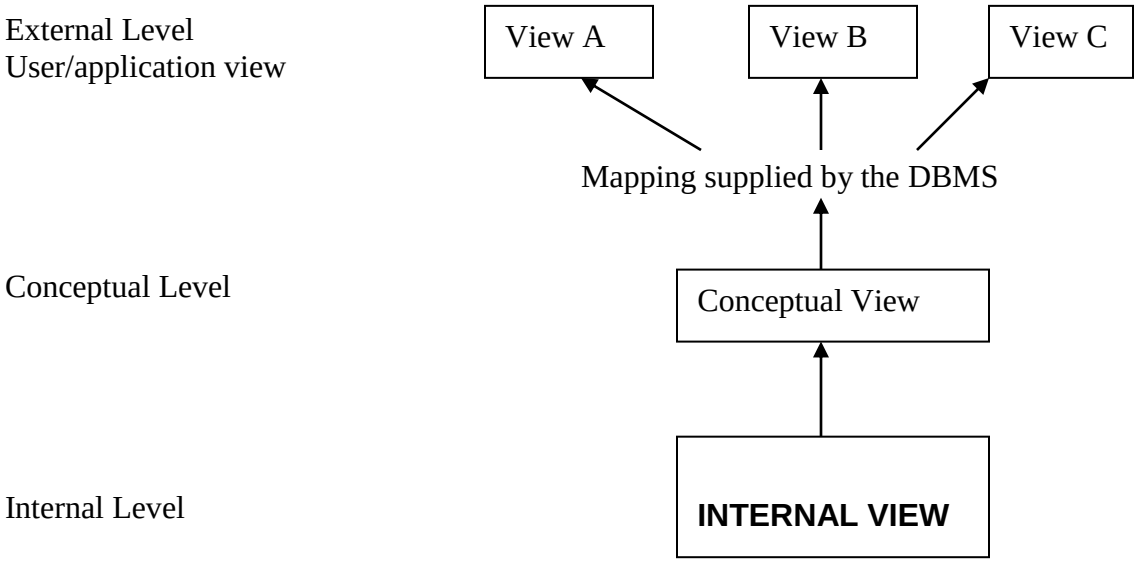
The view of each level is described as a scheme, which is an outline or a plan that describes the records and relations existing in the view. It also describes the way in which entities at one level of abstraction can be mapped onto the next level.

External Level (External or User view)
This is at the highest level of database abstraction where only those portions of the database of concern to the user or application programs are included.

Any number of user views may be possible, some of which may be identical.
Each external view is described by means of a scheme called external scheme, which consists of a definition of the logical records and the relationships in the external view.
It also contains the method of devising the objects in the external view from the objects in the conceptual view (entities, attributes and relationships).

Conceptual Or Global View
Contains all database entities and the relationships among them are included and one conceptual view represents the entire database.
It is defined by the conceptual scheme. Also contains the methods of deriving the objects in the conceptual view from the objects in the internal view.
It is independent of the physical presentation.

Internal View
This is the lowest level of abstraction closest to the physical storage method used.
It indicates how data would be stored and describe the data structures and access methods to be used by the database. The internal schema implements it.



The 3 levels of architecture of a DBMS

Mapping between views
Two mappings are required, one between external and conceptual views and another between the conceptual records to internal ones.

Data Independence

This is the immunity of users/application programs from changes in storage structure and access mechanism.
The 3 levels of abstractions along with the mappings from internal to conceptual and from conceptual to external provide 2 distinct levels of data independence i.e.:

- Logical Data Independence
- Physical Data Independence

(i) Logical Data Independence

This indicates that the conceptual schema can be changed without affecting the existing external schema.
The mapping between the external and conceptual levels would absorb the change.

It also insulates application programs from operations such as combining two records into one or splitting an existing record into 2 or more records. The LDI is achieved by providing the external level or user view database.

The application programs or users see the database as described by the respective external view.
DBMS provided a mapping from this view to the conceptual view.
NB: The view at conceptual level of the database is the sum total of the current and anticipated views of the database.

(ii) Physical Data Independence

This indicates that the physical storage structures or devices used for storing the data can be changed without necessitating a change in the conceptual view or any of the external view. Any change is absorbed by the mapping between the conceptual and internal views.

2.3 Components Of The DBMS

A DBMS is software used to build, maintain and control database systems. It allows a systematic approach to the storage and retrieval of data in a computer.
Most DBMS(s) have several major components, which include the following:

1. **Data Definition Language (DDL*)*** - These are commands used for creating and altering the structure of the database.
   The structures comprise of Field Names, Field sizes, Type of data for each field, File organizational technique. The DDL commands are used to create new objects, alter the structure of existing ones or completely remove objects from the system.

2. **Data Manipulation language (DML**) - This is the user language interface and is used for executing and modifying the contents of the database. These commands allow a ccess and manipulation of data for output. They include commands for adding, inserting, deleting, sorting, displaying, painting etc. These are the most frequently used commands once the database has been created.

3. **Data Control Language (DCL)** - These are commands used to control access to the database in response to DML commands. It acts as an interface between the DML and the OS. It provides security and control to the data.

4. **Query Languages** - A query language is a formalized method of constructing queries in database system. It provides the ways in which the user interrogates the database for data without using conventional programs. For relation database, structures query languages (SQL) has emerged as the standard language. Almost all the DBMS(s) use SQL running on machines ranging from microcomputers to large main frames.

5. **Form Generator** - A form is a screen display version of a paper form, which can be used for both input and output.

6. **Menu Generator** - This is used to generate different types of menus to suit user requirements.

7. **Report Generator** - This is a tool that gives non-specialized users the capability of providing reports from one or more files through easily constructed statements. The reports may be produced from constructed statements. The reports may be produced either on screen or paper. A report generator has the following features:
   - Page headings and footings
   - Page Numbering
   - Sorting
   - Combining data from several files
   - Column headings
   - Totaling and subtotaling
   - Grouping of data

- Reports titling

8. **Business Graphics** - Some DBMS may provide means of generating graphical output e.g. bar charts, pie charts scatter graphics line plots etc. others will allow users to export data into graphics software.

9. **Application Generators** - This is a type of 4th generation language used to create complete application programs. The user describes what need to be done, the data and files that are to be used and the application generator then translates the description into a program. They are also referred to as rapid application tools.

10. **Data Dictionary (DD)** - This provides the following facilities:
    - Documentation of data items
    - Provision of Standard definition an names for data items.
    - Data item description.
    - Removal of redundancy in documentation of data item.
    - Documentation of relationships between data items;

11. **Fourth Generation Languages (4GLS'S)** - A 4GL'S is a non-procedural language in which the programs flows and not designed by the programmer but by the 4G software itself.. The user requests for the result rather than a detailed procedure to obtain these results.

2.4 Typical DBMS Functions

A DBMS performs several functions that guarantee the integrity and consistency of the data in the database. Most of these functions are transparent to end-users and can be achieved only through the use of a DBMS. They include:

i. ***Data Dictionary Management*** - The DBMS enquires that definitions of the data element and their relationships (metadata) be stored in a data dictionary. The DBMS uses the DD to look up the required data component, structures and relationships thus relieving us from having to code such complex relationships in each program. Any changes made in the database structure are automatically recorded in the DD thereby freeing us from having to modify all the programs that access the changed structure. So, the DBMS provides data obstruction and removes structural or data dependency of the system.

ii. ***Data Storage Management*** - Creation of complex structure required for data storage is done by DBMS thus relieving us from the difficult task of defining and programming the physical data characteristics. A modern DBMS system provides storage for data and related data entry forms or screen definitions, report definition, data validation rules, procedural code structures to handle video and picture formats etc.

iii. ***Data Transformation and Presentation*** - Transformation of entered data to conform the data structures that are required to store the data is done by the DBMS relieving

us the core issue of making a distinction between the data logical formats and data physical format. By maintaining data independence the DBMS translates logical requests it no commands that physically locate and retrieve the requested data. That is the DBMS transform the physically retrieved data to conform to the users logical expectations. This is by providing application programs with software independence and data abstraction.

iv. ***Security Management*** - The DBMS creates the systems security that enforces users security and data privacy within the database. Security rules determine which users can access database which data item each user can access and which data operations (read, add, delete, modify) the user may perform. This is important in multi user database system where many users can access the database simultaneously.

v. ***Multi User Access Control*** - The database creates complex structures that allow multi-user access to the structure. In order to provide data integrity and consistency the DBMS users sophisticated algorithms to ensure that multiple users can access the database con-currently and still guarantee integrity of the database.

vi. ***Back-up and recovery management*** - To ensure data safety and integrity current DBMS systems provide special utilities that allow the DBA to perform routing and special backup and restore procedures. Recovery management deals with recovery of the database after a failure such as a bad sector in the disk, a power failure etc. Such capability is critical to the preservation of the database integrity.

vii. ***Data integrity Management*** - The DBMS promotes and enforces integrity rules to eliminate data integrity problems thus minimizing data redundancy and maximizing data consistency. The relationships stored in the Data Dictionary are used to enforce data integrity. Data integrity is especially important in transaction oriented database systems.

viii. ***Data base Access Language and Application Programming Interfaces*** - The DBMS provides data access via a query language. It contains 2 components, DDL and DML. The DDL defines the structures in which the data are housed and the DML allows end users to extract the data from the database. It also allows data access to programmers via procedural languages such as Cobol, C, Pascal, and Visual Basic etc. It also provides utilities used by the DBA and the Database Designer to create, implement, monitor and maintain the database.

ix. ***Database Communication interfaces*** - Current generation of DBMS's provide special communication routines designed to allow the database to accept end-use r requests within a computer network environment. The DBMS may provide communication functions to access the database through the internet using internet browsers e.g. Netscape or Explorer as the front-ends

2.5 Overall System Structure

A database system is partitioned into modules that deal with each of the responsibilities of the overall systems. The design of the database system must include consideration of the interface between the database system and the O.S. The functional components of a database system include:

- File Manager
- Data base manager
- Query processor
- DML pre-compiler
- DDL compiler

File Manager
This manages the allocation of space in the disk storage and the data structures used to represent information stored on the disk. It deals more on the physical aspects.

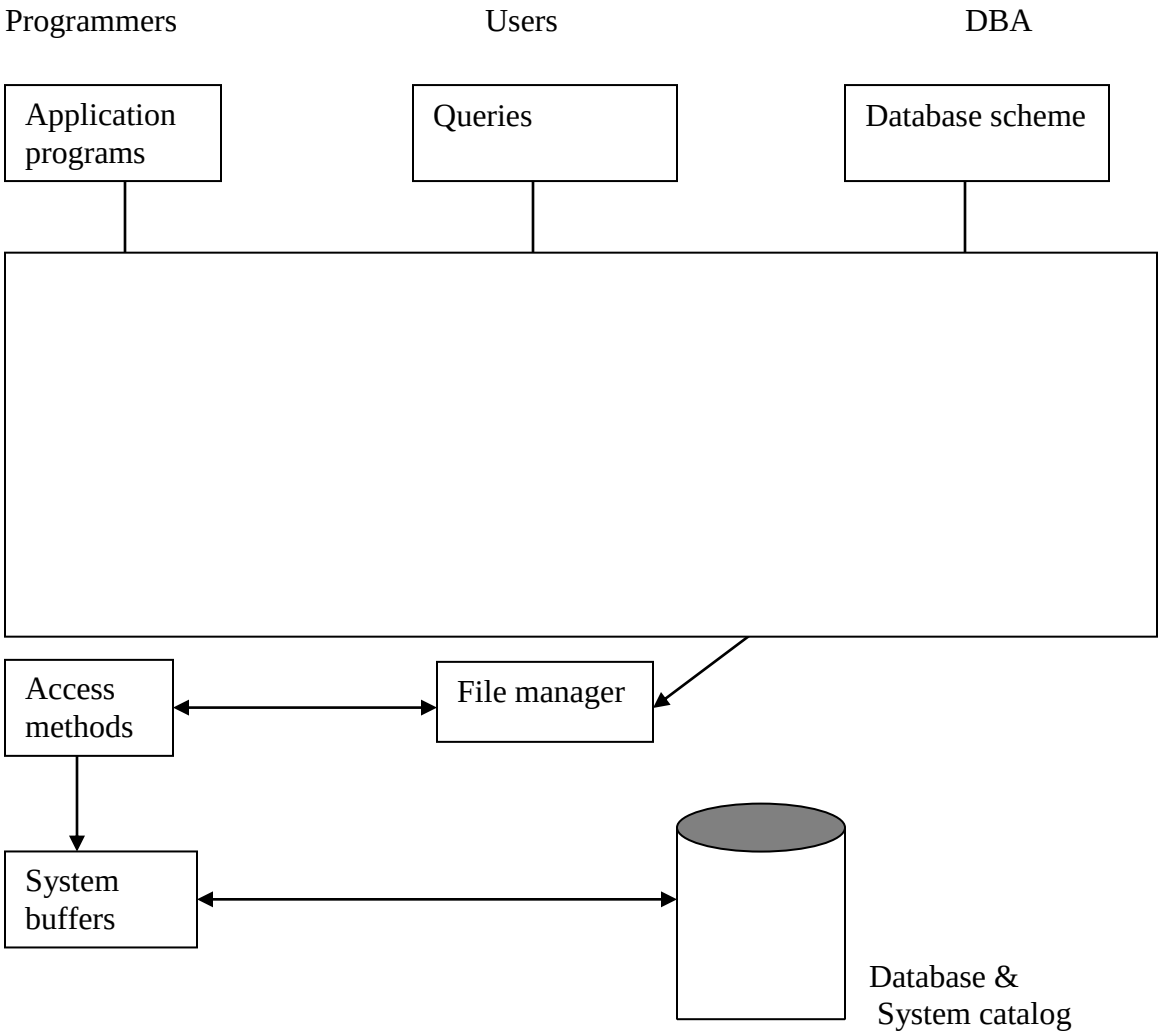
Database Manager
Provides the interface between the low level data stored in the database and the application and programs the queries submitted to the system.

Query Processor
This translates statements in a query language into low-level instruction that the DB manager understands. In addition the query processor attempts to transform a user request into more efficient statement, thus finding a good strategy for executing the query.

DML Pre-compiler
This converts the DML statements embedded in an application program to normal procedure calls in the language. The pre-compiler must interact with the query processor order generate the appropriate code.

DDL Compiler - This converts DDL statements to a set of table containing metadata.

Major Components Of Dbms



Database Life Cycle (DBLC)

1. The Database Initial Study

   - Examine the current system operation.
   - Try to establish how and why the current system fails.
   - Define the problems and constraints
   - Define the objectives
   - Define scope and boundaries

2. Database Design

- This involves the conceptual design, selection of database management system software.
- Creation of the logical design
- Creation of the physical design

3. Implementation

- This involves installation of the DBMS
- Creation of the database
- Loading or conversion of data

4. Testing and evaluation
   The activities involve:

- Testing the database
- Tune the database
- Evaluate the database application programs
- Provide the required information flow

5. Operation

Once the database has passed the evaluation stage it is considered to be operational, the database, its management, its users and its application programs constitute a complete I.S. The beginning of the operational phase starts the process of system evaluation.

6. Maintenance and Evaluation

It involves the following:

- Preventive Maintenance
- Corrective maintenance
- Adaptive maintenance
- Assignment and maintenance of access permission to new and old user
- Generation of database access statistics to improve the efficiency and usefulness of audits and to monitor system persons.
- Periodic security based on the system generated statistics
- Periodic (monthly, quarterly or yearly) system using summaries for internal billing or budgeting purposes.

3.0 CONCEPTUAL DATA MODEL

A database model is a collection of logical constructs used to represent the data structure and relationships found within the database.

3.1 Types Of Data Models

1. Object Based Logical Models

They are used in describing data at the conceptual and view levels. They provide fairly flexible structuring capabilities and allow data constraints to be specified explicitly. They include:

- E - R Model
- Object Oriented Model
- Binary Model
- Semantic Data Models
- Info-logical Data Model
- Function

2. Record Based Logical Models

These are models used in describing data at the conceptual and view levels. They are used to specify the overall logical structure of the database and to provide a higher-level description implementation. It is hard to understand.

3. Physical Data Models

These are models that are used to describe data at the lowest level. They are very few in number and the two widely known ones are:

i. Unifying model
ii. Frame memory model

NB: Like the E-R model, the object-oriented model is based on a collection of object where an object contains values stored in instance variables with the object.

3.2 The E- R Model (Entity Relationship)

It is based on a perception over a real world, which consists of a collection of basic objects called entities and relationships among this objects. An entity is an object that is distinguished from other objects via a specific set of attributes.

3.2.1 E-R Model Basic Concepts

The model employs the following components:

- Entity sets
- Relationship sets
- Attributes

1. Entity sets

An entity is a thing or object in the real world that is distinguishable from all other objects. It may be concrete e.g. a person or a book or it may be abstract e.g. a loan, holiday a concept etc. An entity set is a set of entities of the same type that share the same properties or attitudes e.g. a set of all persons who are customers of a bank.

2. Relationship sets

An association between two or more entities is called a relationship.

3. Attributes

They are descriptive properties or characteristics possessed by each member of an entity set.

3.2.2 Characteristics Of Attributes

Simple and Composite attributes - e.g. a customer name or first name, middle name, last name. Composite attributes are necessary if a user wishes to refer to entire attribute on some occasions and to only a component of the attributes on other occasions.

Single valued and Multi valued Attribute - The social security number or ID number can only have a single value at any instance and therefore its said to be single valued. An attribute like dependant name can take several values ranging from o-n thus it is said to be multi valued.

Null Attributes - A null value is used when an entity does not have a value for an attribute e.g. dependent name.

Calculated attribute - The value for this type of attribute can be derived from the values of other related attributes or entities e.g.

i. Employment length value can be derived from the value for the start date and the current date.
ii. Loans held can be a count of the number of loans a customer has.

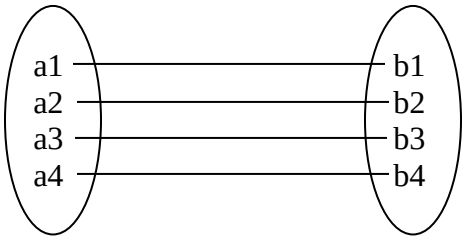
3.2.3 Relationship Sets

A relationship is an association amongst several entities while a relationship set is a set of relationships of the same tuple. It is a mathematical relation on n>2 possible non-distinct entity sets e.g. consider 2 entity sets, loan and branch. A relationship set loan, branch can be defined to denote association between a bank loan and the branch in which that loan is obtained.

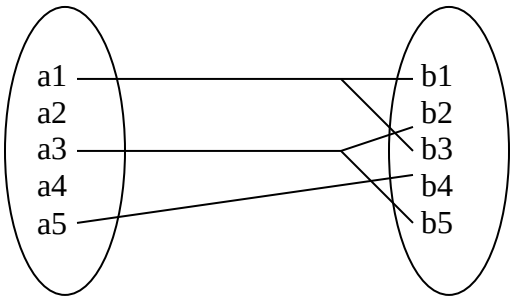
Example
Consider 2 entity sets Customer and loan.
A relationship set - A borrower can be defined to denote the association between customers and the bank loans that the customers have.

Types Of Relationships

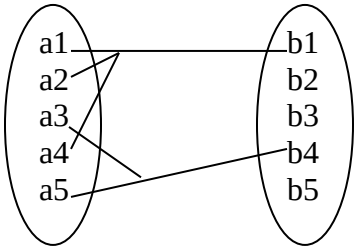
i. One to one relationship (**1:1**) - An entity in **A** is associated with utmost one entity in **B** is associated with at utmost one entity in **A**.



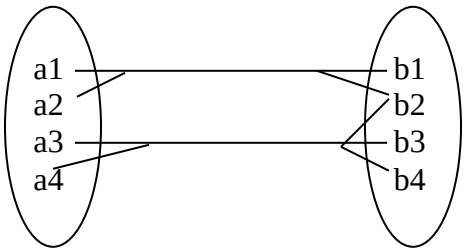
ii. One to Many relationship ***(1:M)*** - An entity in **A** is associated with any number of entities in **B** while an entity in **B** can be associated with at most one entity in **A** .



iii. Many to one relationship (**M:1**) **-** An entity in **A** is associated with at most one entity in **B** and an entity in **B** can be associated with a number of entities in **A**.



iv. Many to many (**M:N**) - An entity in **A** is associated with at least one entity in **B** and an entity in **B** can be associated with a number of entities in **A**.



Existence Dependencies

If the existence of an entity X depends on the existence of entity Y, then X is said to be existence dependent on Y. If Y is deleted, so is X. Y is said to be the dominant entity and X is said to be subordinate entity.

Exercise.

Differentiate between super key, primary candidates and candidate keys.

3.3 Entity-Relationship Diagram

Components of E-R diagram

(i) Rectangles: - They represent entity sets.
(ii) Ellipses: - represent attributes
(iii) Diamond: - represents relationship sets
(iv) Lines - Link attributes to entities and entity sets to relationship sets
(v) Double ellipses: - represent multi-value attributes
(vi) Dashed ellipses: - denote derived attributes
(vii) Double lines: - indicate total participation of an entity in relationship sets.

Weak Entity Set
This is an entity set that does not have sufficient attributes to form a primary Key e.g. an entity set payments comprising of the attributes payment number, payment date and payment amount. Although each payment entity is distinct, payment for different loan e.g. may share the same payment number thus this entity set does not have a primary key.

Strong Entity Set
This is an entity set that has a primary key. For weak entity set to be meaningful it must be part of a one to many relationships.

Specialisation
An entity set may include sub-groupings of entities that are distinct in some way from other entities in the set. This is called specialization of the entity set e.g. the entity bank account could have different types e.g.

Credit account
Checking account
Savings account - interest rate
Checking account - overdraft amount

Under checking account you could have type:

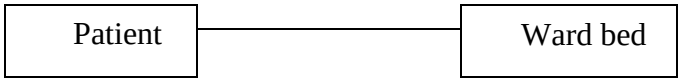
i. Standard check account
ii. Gold checking account
iii. Senior checking account

For the standard it may be divided by the number count of checks gold minimum balance and an interest payment.
Senior checking account - age limit
A specialised entity set may be specialised by one or more distinguishing features.

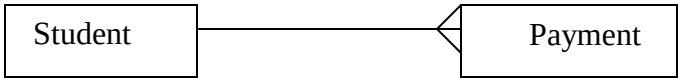
Aggregation
This is abstraction through which relationship are treated as higher-level entities e.g. the relationship set borrower and the entity sets customer and loan can be treated as a higher set called borrower as a whole.

3.4 Entity modeling (Diagrammatic representation) relationships

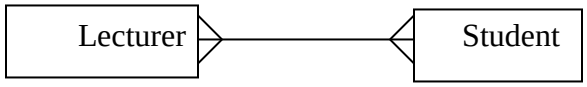
i. One to one relationship



ii. One to many relationship



iii. Many to many relationship



NB: Whenever the degree of a relationship is many to many we must decompose the relationship to one-to -one or one-to-many. The decomposition process will create a new entity.

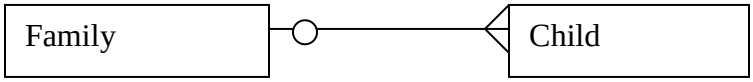
Exercise

A company consists of a number of departments each having a number of employees, each department has a manager who must be on a monthly payroll, other employees are either on a monthly or weekly payroll and are members of the sports club if they so wish. Construct an entity - relationship diagram depicting the scenario.

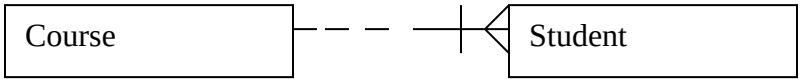
Mandatory and Optional

Optional relationships are shown by either, use of a small circle drawn along the line or a dotted line while mandatory relationships are shown by use of either a bar drawn across the line or a continuous line.

Optional



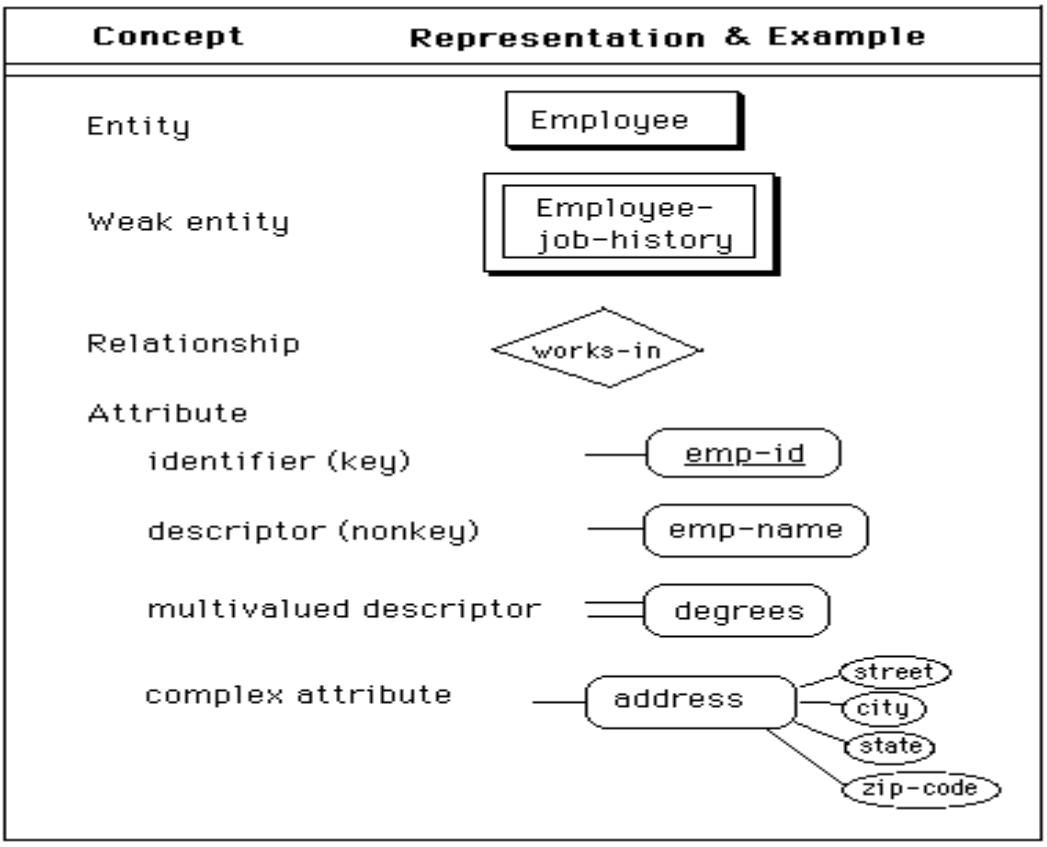
Mandatory

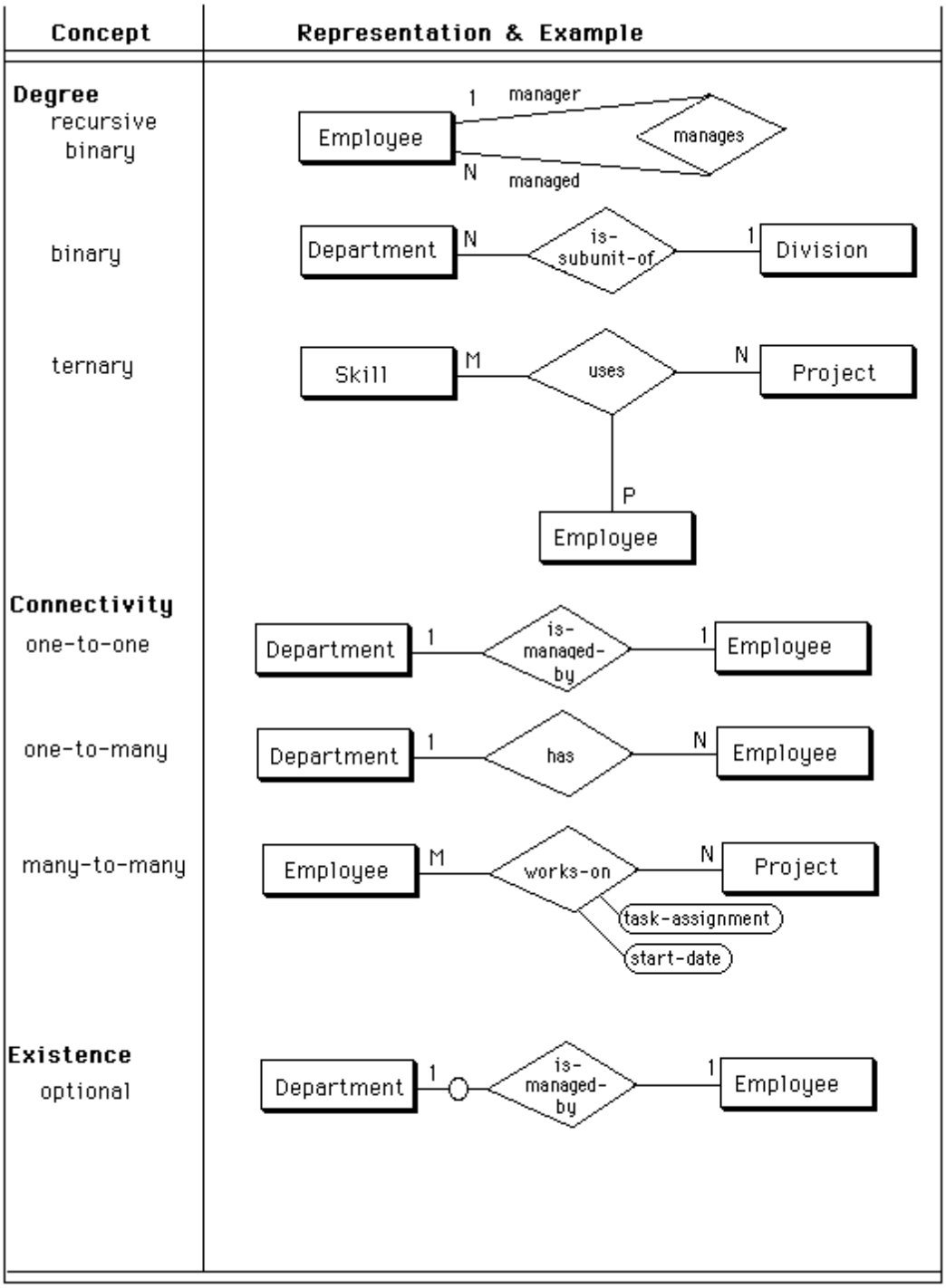


Representing Attributes

Although E-R diagrams describe many of the features of the logical model, they do not show the attributes associated with each entity, this additional information is represented conveniently in form of a table.

Diagrammatic representation of E-R Modelling Concepts





Schema integration Methods

Goals in Schema integration

- to create a non-redundant unified (global) conceptual schema

(1) completeness - all components must appear in the global schema

(2) minimality - remove redundant concepts in the global schema

(3) understandability - does global schema make sense?

1 . Comparing of schemas

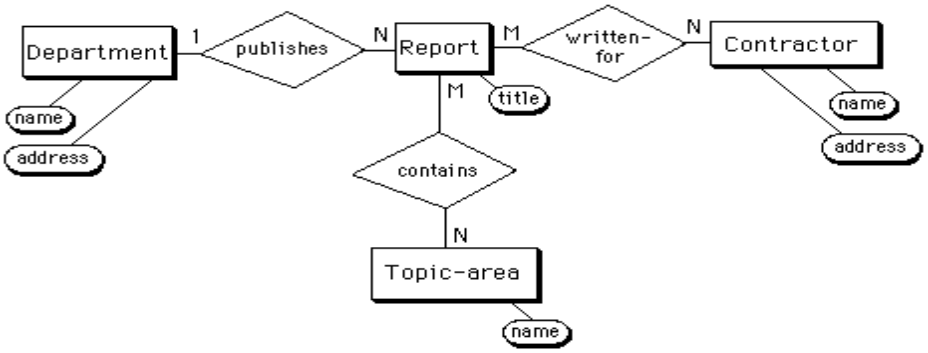
- look for correspondence (identity) among entities
- detect possible conflicts
    - naming conflicts
        - homonyms - same name for different concepts
        - synonyms - different names for the same concept
    - structural conflicts
        - type conflicts - different modeling construct for the same concept (e. g. "order" as an entity, attribute, relationship)
    - dependency conflicts - connectivity is different for different views (e.g. job-title vs. job-title-history)
    - key conflicts - same concept but different keys are assigned (e.g. ID-no vs. SSN)
    - behavioral conflicts - different integrity constraints (e.g. null rules for optional/mandatory: insert/delete rules)
- determine inter-schema properties
    - possible new relationships to combine schemas
    - possible abstractions on existing entities or create new super-classes (super-types)

2. Conforming of schemas

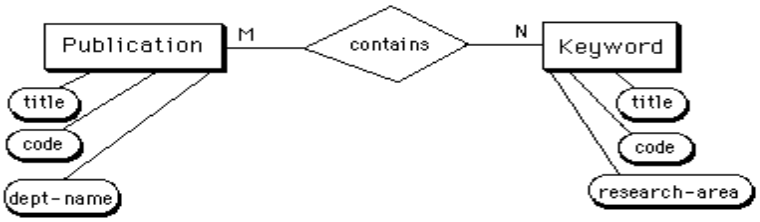
- resolve conflicts (often user interaction is required)
- conform or align schemas to make compatible for integration
- transform the schema via
    - renaming (homonyms, synonyms, key conflicts)
    - type transformations (type or dependency conflicts)
    - modify assertions (behavioral conflicts)

3. Merging and restructuring

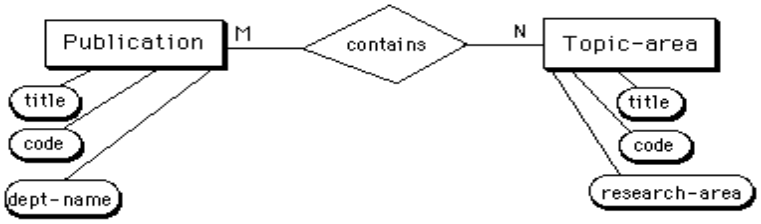
- superimpose entities
- restructure result of superimposition



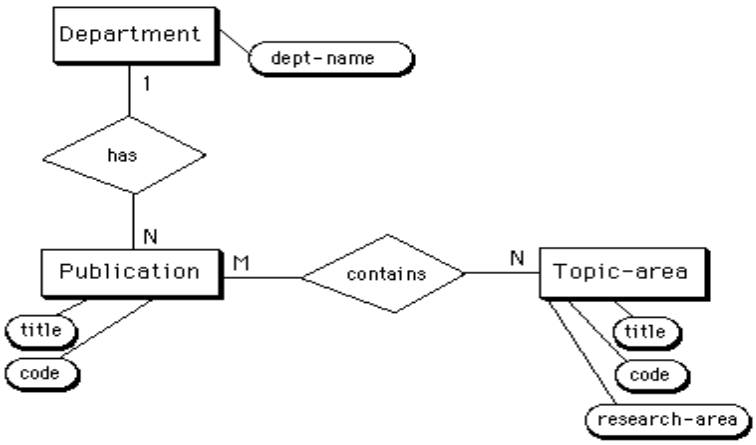
(a) Original schema 1, focused on reports



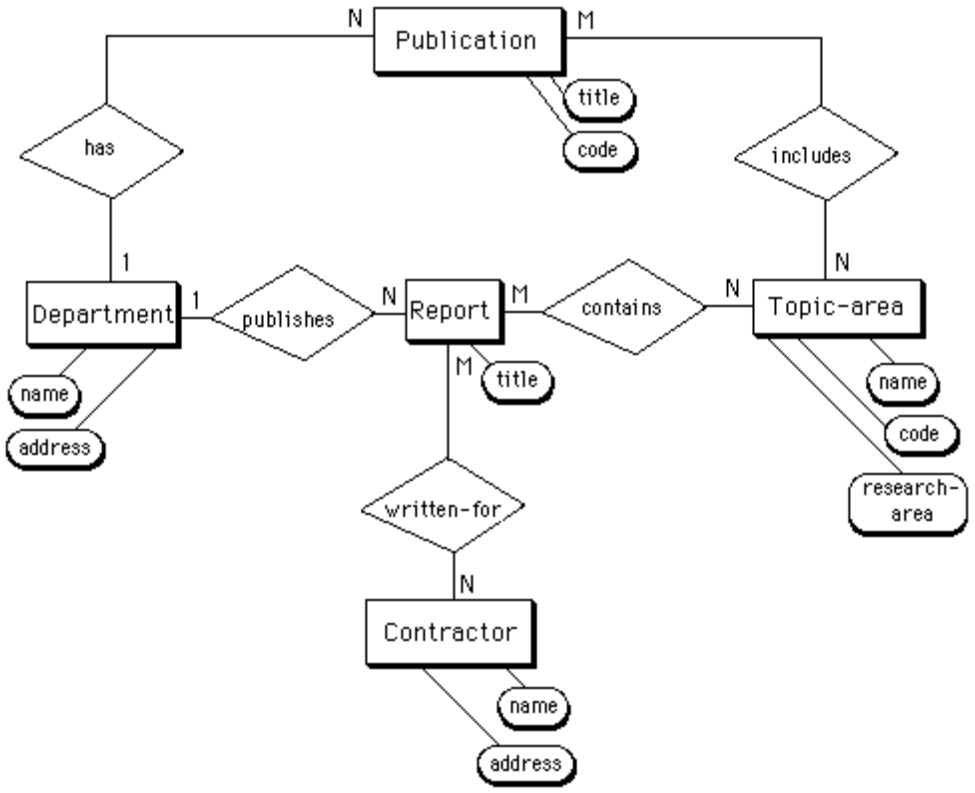
(b) Original schema 2, focused on publications



(a) Schema 2.1, in which Keyword has changed to Topic-area



(b) Schema 2.2, in which the attribute dept-name has changed to an attribute and an entity



Exercise

Consider the entity relationship Student_Course that defines a course undertaken by many students.
Generate a sample tabular representation of the above assuming key attributes are course-code and stud-no respectively.

A HOSPITAL DATABASE SYSTEM.

A hospital wishes to maintain a database to assist the administration of its wards and operating theatres, and to maintain information relating to its patients, surgeons and nurses.

Information in relation to patients is captured on admission and patients are assigned to a ward. A nurse is assigned to a ward. Nurses are identified by their staff numbers and their names, address, phone numbers and grades are also recorded. Each ward has a unique number and is dedicated to a type of patient (e.g. pediatric, maternity, etc)

A patient may have a number of operations. The information to be recorded about an operation include the type of operation, the patient, the surgeons involved , date, time and location.

Only one surgeon may perform an operation, any other surgeons present being considered as assisting at the operation. Surgeons come under the direction of senior surgeons, called

consultants, who may also perform or assist at operations. Information recorded about a surgeon includes name, address and phone number.

An operation can be performed in only one theatre but a given theatre may be the location of many operations.

A nurse may or may not be assigned to a theatre and he/she cannot be assigned to more than one theatre. A theatre may have many nurses assigned to it.

Required.

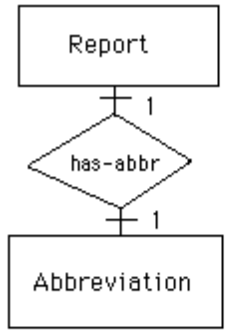
- Design and develop a database system for the above application. This should include:
- Logical data model.
- Forms for data entry.
- Integrity and security features.
- Reports including the following:

    i.) List of all operations scheduled for the following week.
    ii.) List of all in-patients and their ailments.
    iii.) Details of bed occupancy/availability.
    iv.) Summary list of all patients for specified doctors.
    v.) Theatre occupancy/availability

Transformations from ER diagrams to SQL Tables

- **Entity** – directly to a SQL table
- **Many-to-many binary relationship** – directly to a SQL table, taking the 2 primary keys in the 2 entities associated with this relationship as foreign keys in the new table
- **One-to-many binary relationship** – primary key on "one" side entity copied as a foreign key in the "many" side entity's table
- **Recursive binary relationship** – same rules as other binary relationships
- **Ternary relationship** – directly to a SQL table, taking the 3 primary keys of the 3 entities associated with this relationship as foreign keys in the new table
- **Attribute of an entity** – directly to be an attribute of the table transformed from this entity
- **Generalization super-class (super-type) entity** – directly to a SQL table
- **Generalization subclass (subtype) entity** – directly to a SQL table, but with the primary key of its super-class (super-type) propagated down as a foreign key into its table

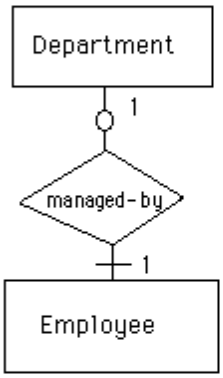
Mandatory constraint (1 lower bound) on the "one" side of a one-to-many relationship – the foreign key in the "many" side table associated with the primary key in the "one" side table should be set as "not null" (when the lower bound is 0, nulls are allowed as the default in SQL)



(a) one-to-one, both entities mandatory

Every report has one abbreviation, and every abbreviation represents exactly one report.

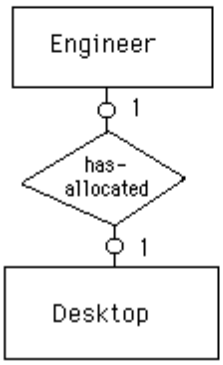
```
create table report
       (report_no  integer,
        report_name  varchar(256),
        primary key(report_no);
create table abbreviation
       (abbr_no  char(6),
        report_no  integer not null unique,
        primary key (abbr_no),
        foreign key (report_no) references report
          on delete cascade on update cascade);
```



(b) one-to-one, one entity optional, one mandatory

Every department must have a manager, but an employee can be a manager of at most one department.

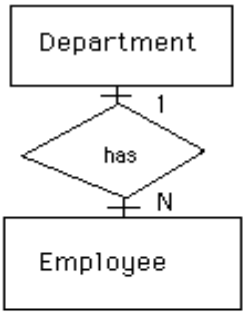
```
create table department
       (dept_no  integer,
        dept_name  char(20),
        mgr_id  char(10) not null unique,
        primary key (dept_no),
        foreign key (mgr_id) references employee
          on delete set default on update cascade);
create table employee
       (emp_id  char(10),
        emp_name  char(20),
        primary key (emp_id));
```



(c) one-to-one, both entities optional

Some desktop computers are allocated to engineers, but not necessarily to all engineers.

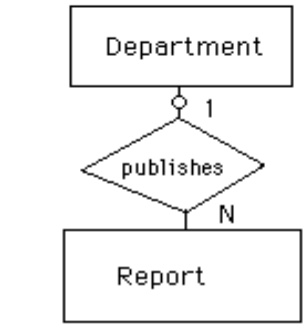
```
create table engineer
       (emp_id  char(10),
        desktop_no  integer,
        primary key (emp_id));

create table desktop
       (desktop_no  integer,
        emp_id  char(10),
        primary key (desktop_no),
        foreign key (emp_id) references engineer
          on delete set null on update cascade);
```



(d) one-to-many, both entities mandatory

Every employee works in exactly one department, and each department has at least one employee.

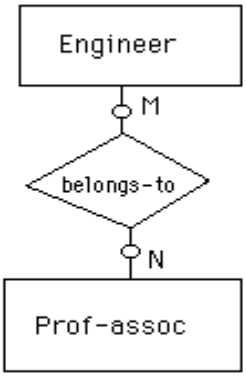
```
create table department
       (dept_no  integer,
        dept_name  char(20),
        primary key (dept_no));
create table employee
       (emp_id  char(10),
        emp_name  char(20),
        dept_no  integer not null,
        primary key (emp_id),
        foreign key (dept_no) references department
          on delete set default on update cascade);
```



(e) one-to-many, one entity optional, one unknown

Each department publishes one or more reports. A given report may not necessarily be published by a department.

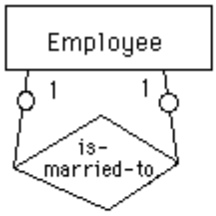
```
create table department
       (dept_no  integer,
        dept_name  char(20),
        primary key (dept_no));
create table report
       (report_no  integer,
        dept_no  integer,
        primary key (report_no),
        foreign key (dept_no) references department
          on delete set null on update cascade);
```



(f) many-to-many, both entities optional

Every professional association could have none, one, or many engineer members. Each engineer could be a member of none, one, or many professional associations.

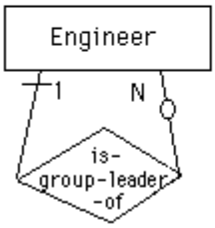
```
create table engineer
       (emp_id  char(10),
        primary key (emp_id));
create table prof_assoc
       (assoc_name  varchar(256),
        primary key (assoc_name));
create table belongs_to
       (emp_id  char(10),
        assoc_name  varchar(256),
        primary key (emp_id, assoc-name),
        foreign key (emp_id) references engineer
          on delete cascade on update cascade,
        foreign key (assoc_name ) references prof-assoc
          on delete cascade on update cascade);
```



(a) one-to-one, both sides optional

Any employee is allowed to be married to another employee in this company.

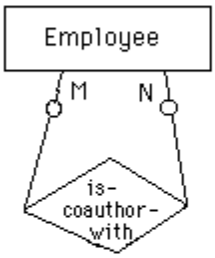
```
create table employee
       (emp_id  char(10),
        emp_name  char(20),
        spouse_id  char(10),
        primary key (emp_id),
        foreign key (spouse_id) references employee
          on delete set null on update cascade);
```



(b) one-to-many, one side mandatory, many side optional

Engineers are divided into groups for certain projects. Each group has a leader.

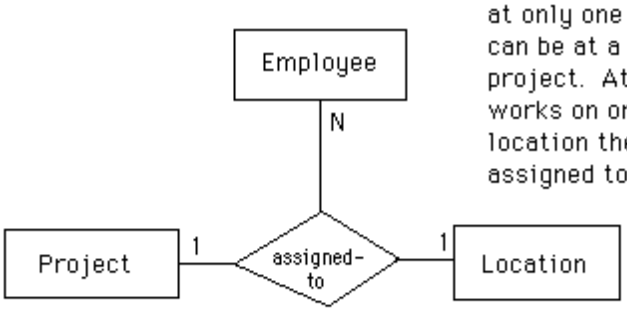
```
create table engineer
       (emp_id  char(10),
        leader_id  char(10) not null,
        primary key (emp_id),
        foreign key (leader_id) references engineer
          on delete set default on update cascade);
```



(c) many-to-many, both sides optional

Each employee has the opportunity to coauthor a report with one or more other employees, or to write the report alone.

```
create table employee
       (emp_id  char(10),
        emp_name  char(20),
        primary key (emp_id));

create table coauthor
       (author_id  char(10),
        coauthor_id  char(10),
        primary key (author_id, coauthor-id),
        foreign key (author_id) references employee
          on delete cascade on update cascade,
        foreign key (coauthor_id) references employee
          on delete cascade on update cascade);
```



Each employee assigned to a project works at only one location for that project, but can be at a different location for a different project. At a given location, an employee works on only one project. At a particular location there can be many employees assigned to a given project.

```
create table employee (emp_id  char(10),
                       emp_name  char(20),
                       primary key (emp_id));

create table project (project_name  char(20),
                      primary key (project_name));

create table location (loc_name  char(15),
                       primary key (loc_name));

create table assigned_to (emp_id  char(10),
                          project_name  char(20),
                          loc_name  char(15) not null,
                          primary key (emp_id, project_name),
                          foreign key (emp_id) references employee
                            on delete cascade on update cascade,
                          foreign key (project_name) references project
                            on delete cascade on update cascade,
                          foreign key (loc_name) references location
                            on delete cascade on update cascade),
                          unique (emp_id, loc_name));
```

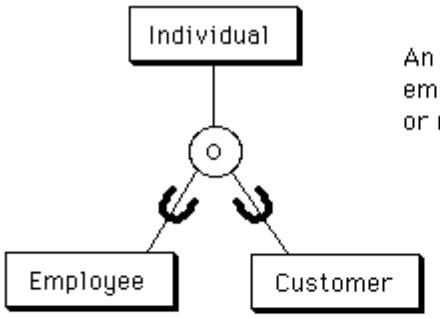
assigned_to

emp_id	project_name	loc_name
48101	forest	B66
48101	ocean	E71
20702	ocean	A12
20702	river	D54
51266	river	G14
51266	ocean	A12
76323	hills	B66

Functional dependencies

emp_id, loc_name -> project_name
emp_id, project_name -> loc_name

(b) one-to-one-to-many ternary relationships



An individual may be either an employee or a customer, or both, or neither.

```
create table individual (indiv_id  char(10),
                         indiv_name  char(20),
                         indiv_addr  char(20),
                         primary key (indiv_id));
create table employee (emp_id  char(10),
                       job_title  char(15),
                       primary key (emp_id),
                       foreign key (emp_id) references individual
                         on delete cascade on update cascade);
create table  customer (cust_no  char(10),
                        cust_credit  char(12),
                        primary key (cust_no),
                        foreign key (cust_no) references individual
                          on delete cascade on update cascade);
```

3.5 DATA NORMALIZATION

The Relational Model

The database development process usually follow steps below:

1. Gather user/business requirements.
2. Develop the conceptual E-R Model (shown as an E-R Diagram) based on the user/business requirements.
3. Convert the E-R Model to a set of relations in the (logical) relational model
4. **Normalize the relations to remove any anomalies.**
5. Implement the database by creating a table for each normalized relation in a relational database management system.

Normalization

- Normalization is a *process* in which we systematically examine relations for *anomalies* and, when detected, remove those anomalies by splitting up the relation into two new, related, relations.
- Normalization is an important part of the database development process:
    - Often during normalization, the database designers get their first real look into how the data are going to interact in the database.
- Finding problems with the database structure at this stage is strongly preferred to finding problems further along in the development process because at this point it is fairly easy to cycle back to the conceptual model (Entity Relationship model) and make changes.
- Normalization can also be thought of as a trade-off between data redundancy and performance. Normalizing a relation reduces data redundancy but introduces the need for joins when all of the data is required by an application such as a report query.

Functional Dependencies

- A *Functional Dependency* describes a relationship between *attributes* within a single relation.
- An attribute is *functionally dependent* on another if we can use the value of one attribute to determine the value of another.
- Example: Employee_Name is functionally dependent on Social_Security_Number because Social_Security_Number can be used to uniquely determine the value of Employee_Name.
- We use the arrow symbol → to indicate a functional dependency.

  X → Y is read as *X functionally determines Y*

Examples:

Student_ID → Student_Major
Student_ID, CourseNumber, Semester → Grade
Course_Number, Section → Professor, Classroom, NumberOfStudents
SKU → Compact_Disk_Title, Artist
CarModel, Options, TaxRate → Car_Price

- The attributes listed on the left hand side of the → are called *determinants*.

  One can read A → B as, "A determines B". Or more specifically: Given a value for A, we can uniquely determine one value for B.

Keys and Uniqueness

- **Key**: One or more attributes that uniquely identify a tuple (row) in a relation.
- The selection of keys will depend on the particular application being considered.
- In most cases the key for a relation will already be specified during the conversion from the E-R model to a set of relations.
- Users can also offer some guidance as to what would make an appropriate key.
- Recall that no two relations should have exactly the same values, thus a candidate key would consist of all of the attributes in a relation.
- A key functionally determines a tuple (row). So one functional dependency that can always be written is:
- The Key → All other attributes
- Not all *determinants* are *keys*.

Normalization Process

- Relations can fall into one or more categories (or classes) called *Normal Forms*
- **Normal Form**: A class of relations free from a certain set of modification anomalies.
- Normal forms are given names such as:
  - First normal form (1NF)
  - Second normal form (2NF)
  - Third normal form (3NF)
- These forms are cumulative. A relation in Third normal form is also in 2NF and 1NF.
- The *Normalization Process* for a given relation consists of:

  1. Specify the *Key* of the relation
  2. Specify the *functional dependencies* of the relation.
     Sample data (tuples) for the relation can assist with this step.
  3. Apply the definition of each normal form (starting with 1NF).

4. If a relation fails to meet the definition of a normal form, change the relation (most often by splitting the relation into two new relations) until it meets the definition.
5. Re-test the modified/new relations to ensure they meet the definitions of each normal form.

First normal form (1NF)

- A relation is in first normal form if it meets the definition of a relation:
    1. Each attribute (column) value must be a single value only.
    2. All values for a given attribute (column) must be of the same type.
    3. Each attribute (column) name must be unique.
    4. The order of attributes (columns) is insignificant
    5. No two tuples (rows) in a relation can be identical.
    6. The order of the tuples (rows) is insignificant.
- If you have a KEY defined for the relation, then you can meet the UNIQUE ROW requirement.
- Example relation in 1NF (note that key attributes are underlined):
- STOCKS (Company, Symbol, Headquarters, Date, Close_Price)

Company	**Symbol**	**Headquarters**	**Date**	**Close Price**
Microsoft	MSFT	Redmond, WA	09/07/2023	23.96
Microsoft	MSFT	Redmond, WA	09/08/2023	23.93
Microsoft	MSFT	Redmond, WA	09/09/2023	24.01
Oracle	ORCL	Redwood Shores, CA	09/07/2023	24.27
Oracle	ORCL	Redwood Shores, CA	09/08/2023	24.14
Oracle	ORCL	Redwood Shores, CA	09/09/2023	24.33

Note that the key (which consists of the Symbol and the Date) can uniquely determine the Company, headquarters and Close Price of the stock. Here was assume that Symbol must be unique but Company, Headquarters, Date and Price are not unique

Second Normal Form (2NF)

- A relation is in second normal form (2NF) if all of its non-key attributes are dependent on all of the KEY.
- Another way to say this: A relation is in second normal form if it is free from partial-key dependencies
- Relations that have a single attribute for a key are automatically in 2NF.
- This is one reason why we often use artificial identifiers (non-composite keys) as keys.
- In the example below, Close Price is dependent on Company, Date
- The following example relation IS NOT in 2NF:

STOCKS (Company, Symbol, Headquarters, Date, Close_Price)

Company	**Symbol**	**Headquarters**	**Date**	**Close Price**
Microsoft	MSFT	Redmond, WA	09/07/2023	23.96
Microsoft	MSFT	Redmond, WA	09/08/2023	23.93
Microsoft	MSFT	Redmond, WA	09/09/2023	24.01
Oracle	ORCL	Redwood Shores, CA	09/07/2023	24.27
Oracle	ORCL	Redwood Shores, CA	09/08/2023	24.14
Oracle	ORCL	Redwood Shores, CA	09/09/2023	24.33

- To start the normalization process, list the functional dependencies (FD):

  FD1: Symbol, Date → Company, Headquarters, Close Price

  FD2: Symbol → Company, Headquarters

- Consider that Symbol, Date → Close Price.
  So we might use Symbol, Date as our key.
- However we also see that: Symbol → Headquarters
- This violates the rule for 2NF in that a *part of our key* key determines a non-key attribute.
- Another name for this is a *Partial key dependency*. Symbol is only a "part" of the key and it determines a non-key attribute.
- Also, consider the insertion and deletion anomalies.
- **One Solution:** Split this up into two new relations:
  COMPANY (Company, Symbol, Headquarters)
  STOCK_PRICES (Symbol, Date, Close_Price)
- At this point we have two new relations in our relational model. The original "STOCKS" relation we started with is removed form the model.
- Sample data and functional dependencies for the two new relations:
- COMPANY Relation:

Company	**Symbol**	**Headquarters**
Microsoft	MSFT	Redmond, WA
Oracle	ORCL	Redwood Shores, CA

FD1: Symbol → Company, Headquarters

- STOCK_PRICES relation:

Symbol	**Date**	**Close Price**
MSFT	09/07/2023	23.96
MSFT	09/08/2023	23.93
MSFT	09/09/2023	24.01
ORCL	09/07/2023	24.27
ORCL	09/08/2012	24.14
ORCL	09/09/2012	24.33

FD1: Symbol, Date → Close Price

- In checking these new relations we can confirm that they meet the definition of 1NF (each one has well defined unique keys) and 2NF (no partial key dependencies).

Third Normal Form (3NF)

- A relation is in third normal form (3NF) if it is in second normal form and it contains no TRANSITIVE DEPENDENCIES.
- Consider relation R containing attributes A, B and C. R(A, B, C)
- If A → B and B → C then A → C
- **Transitive Dependency**: Three attributes with the above dependencies.
- Example: At CUNY:

  Course_Code → Course_Number, Section
  Course_Number, Section → Classroom, Professor

- Consider one of the new relations we created in the STOCKS example for 2nd normal form:

Company	**Symbol**	**Headquarters**
Microsoft	MSFT	Redmond, WA
Oracle	ORCL	Redwood Shores, CA

- The functional dependencies we can see are:
  FD1: Symbol → Company
  FD2: Company → Headquarters
  so therefore:
  Symbol → Headquarters
- This is a transitive dependency.
- What happens if we remove Oracle?
  We loose information about 2 different facts.
- The solution again is to split this relation up into two new relations:
  STOCK_SYMBOLS(Company, Symbol)
  COMPANY_HEADQUARTERS(Company, Headquarters)
- This gives us the following sample data and FD for the new relations

Company	**Symbol**
Microsoft	MSFT
Oracle	ORCL

FD1: Symbol → Company

	Company	**Headquarters**
	Microsoft	Redmond, WA
	Oracle	Redwood Shores, CA

FD1: Company → Headquarters

- Again, each of these new relations should be checked to ensure they meet the definition of 1NF, 2NF and now 3NF

3.6 FURTHER ILLUSTRATION OF DATA NORMALIZATION

Normalization is the process of applying a number of rules to the tables, which have been identified in order to simplify. The aim is to highlight dependencies between the various data items so that we can reduce these dependencies.

The rules applied are referred to as: -

- First Normal Form (1NF)
- Second Normal Form (2NF)
- Third Normal Form (3NF)

1NF

A table or relation is said to be in first normal form, if and only if it contains no repeating groups i.e. it has no repeated values for particular attributes in a simple record. If there are repeating groups and attributes they should be isolated to form a new entity.

2NF

A table is said to be in 2NF if and only if it is in 1NF and every non-key attribute is fully dependent on the key attribute. Attributes not fully dependent should be isolated to form a new entity.

3NF

A table is said to be in 3NF if and only if it is 2nd NF and every non-key attribute is not dependent on any other non-key attribute. All non-key attributes that are dependent on other non-key attributes, should be isolated to form a new entity

Example: An invoice

Invoice No. _____ Date _____

Customer _____ Delivery to _____

Address _____

_____

Product Code	Description	Quantity	Price	Amount

Thank you. Amount_____

Un-normalised data.

Invoice (Invoice_no., Date, Customer, Cust_address, Deliv_To, Product_code, Quantity, Unit Price, amount, Invoice amount)

INF (Identify and separate repeating groups to form a new entity)

INVOICE (Invoice_Number, Date, Customer_Address, Deliv_Address, Invoice_Amount)

PRODUCT (Product_Code, Invoice_Number, Product_Description, Quantity, Unit_Price, Amount)

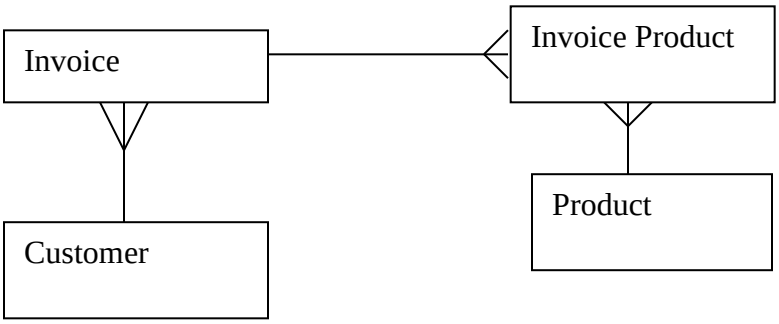
2NF (identity and separate non-key attributes not fully dependent on key attribute)

INVOICE (Invoice_No, Date, Customer_Address, Del_Address, Invoice_Total)
PRODUCT (Prod-Code, Prod_Description, unit_price)
INVOICE_PRODUCT (Prod_Code, Invoice_No, Quantity, Amount)

3NF (Identify non-key attributes dependent on other non-key attributes)

INVOICE (Invoice_No, Customer_Number, Date, Invoice_Total)
PRODUCT (Prod_Code, Prod_Description, Unit_Price)
INVOICE_PRODUCT (Prod_Code, Invoice_No, Quantity, Amount)
CUSTOMER (Customer_Number, Customer_Name, Customer_Address, Del_Address)
NB: Whenever there is no composite key the table is in 3N

Corresponding ERD



3.5.1 Advantages of Normalization Approach

1. It is a formal technique with each stage of normalization process elimination a particular type of undesirable dependency as well as each stage of normalization eliminating a certain type of redundancy.
2. It highlights constraints and dependencies in the data and helps in understanding the nature of the data.
3. The 3NF produces well-designed databases, which provide a high degree of independence.

3.5.2 Disadvantages

1. It depends on a thorough understanding of the entities and their relationships.
2. It's a complex process particularly if the entities are many.

Exercise

- A customer account details in a bank are stored in a table that has the following structure, normalize this data to 3NF. Customer (branch-no, account no, address, postcode, tel)

- A hospital drug dispensing record requires that, for each patient, the pharmacy must record the following information.

- Pharmacy drug dispensing card

Patient No ……. Surname ……Sex …….
Date of Birth ……. Address ……
Ward No …….. Ward name ……Date …….
Name of company paying…… Company address ……..

Date	Drug code	Drug name	Quantity	Unit price	Amount

Total …….
Paid ……..
Balance ……

(a) Explain what you understand by data normalization stating each of the three normal forms.

(b) Perform data normalization for the table to 3NF. Showing clearly the results of each stage.

4.0 RELATIONAL DATABASE SYSTEM

Motivation
1. To shield programmers and users from the structural complexities of the database.
2. For conceptual simplicity

4.1 Relational Data Structure

Relation: A relation corresponds to a table
Field: Corresponds to a column in a table
Tuple: Corresponds to a row of a table
Entity instance: Is a table with records
Degree: Is the number of columns in a table
Cardinality: Is the number of rows in a table
Domain: Is a pool of values from which one or 2 values draw their actual values e.g. the Town Domain is a set of all legal town names. A relation on domains D_1, D_2, D_3.....,D_n (not necessarily all distinct) consists of a heading and a body, the heading consists of a fixed head of attributes a_1, a_2, a_3, ... an such that each attribute ai corresponds to exactly one of the underlying domain Di. The body consists of a time varying set of tuples where each tuple in turn consists of a set of attribute value pairs (a_i, r_i)

Properties of Relations

There is no duplicate tuples – The body of a relation is a mathematical set, which by definition does not include duplicate elements.
Tuples are unordered - Sets are unordered
Attributes are unordered - The heading of a relation is a set that is unordered.
All simple attributes values are atomic meaning that relations do not contain repeating groups (normalized)

Primary Keys
These are special type of more general construct candidate keys. A candidate key is a unique identifier and each relation has at least one candidate key. For a given relation, one of the candidate keys is chosen to be the primary key and the rest are called alternate keys.

Let r be a relation with attributes a_1, a_2, a_n. The set of attributes K= (A_i, A_i .....A_K) of R is said to be a candidate key of R. If it satisfies the following 2 time independent properties:

i. Uniqueness - At any given time, no 2 distinct types of R have the same values for A_i, A_j ----------A_K.
ii. Minimality - None of A_i, A_j -------- A_k can be discarded from K without destroying the uniqueness property.

4.2 Relational Database Language

Structured Query Language

Components of SQL

i. Data Definition Language (DDL) - DDL provides commands for defining relation schemes, deletion relation, creating indices and modifying relation schemers
ii. Interactive Data Manipulation Language (DML) - DML includes a query language based on both relational calculus. It includes commands to insert tuples into, delete tuples from and modify tuples in the database.
iii. Embedded DML - This is designed for use within general purpose programming languages such as PL/1. Cobol, Pascal, Fortran and C.
iv. View Definition - The SQL DDL includes commands for specifying access rights to relations and view.
v. Integrity - The SQL DDL includes commands for specifying integrity constraints that the data stored in the database must satisfy. Updates that violate integrity constraints as disallowed.
vi. Transaction Control - SQL includes commands for specifying the beginning and ending of transactions. Several implementations also allow explicit locking of data for concurrency control.

4.2.1 Basic Structure Of SQL Statement

Basic structure of an SQL expression consists of 3 clauses;
i. SELECT
ii. FROM
iii. WHERE

SELECT
This corresponds to a projection operation of the relational algebra. It is used to list the attributed desired in the result of a query.
FROM
This corresponds to a Cartesian product operation of the relational algebra. It lists the relations to be scanned in the evaluation of the expression
WHERE
Corresponds to the predicate of the relational algebra. It consist of a predicate involving attributes of the relations that appear in the **FROM** clause.

A typical SQL query will be of the form:

SELECT

$A_1, A_2, A_3, \ldots\ldots\ldots\ldots A_n$

FROM

$R_1, R_2, R_3, \ldots\ldots\ldots\ldots\ldots R_n$

WHERE

P

A_i represents an attribute; each r is a relation and P is a predicate.

Select clause

Examples (i) **SELECT** Branch name
FROM Loan

(ii) **SELECT DISTINCT** Branch-name
FROM Loan

The symbol * can be used to denote all attributes of a given relation

(iii) **SELECT** *
FROM Loan

STUDENT

Code	***Stud.id***	***Name***
IMIS	001	Charles
BIT	002	Mary
BIT	003	Maina
CIT	004	Judy

COURSE

Code	***Title***
IMIS	Info. Systems
BIT	Bachelor of IT
CIT	Cert in IT
DIT	Dip in IT

Select Stud-Id, Name, Code, Title
From Student, Course
Where Student.Code = Course.Code

The select clause can also contain arithmetical expressions involving operations +, -, *, and operating on constants or attributes of tables e.g.

SELECT Branch_name, Loan_number, Amount*100
FROM loan

Where Clause

Specifies a condition that has to be met. SQL uses the logical connectives AND, OR and NOT in the where clause. It also uses operands of logical connectives <, < =, >, >=, = and < >. It also includes a BETWEEN operations e.g.

(i) **Select** loan_number
From loan

(ii) **Select** loan_number
From loan
Where branch_name = "River Road" and Amount **Between** 10,000 **And** 15,000.

From Clause
This specifies the source (relations), which is a Cartesian product. The SQL uses the notion relation-name. Attribute-name to avoid ambiguity in case where an attribute appears in the schemer of more than one relation e.g.

Example
Select Customer_name, borrower. loan number
From borrower, loan
Where borrower.loan_number = loan.loan_number
AND branch_name= "Moi Avenue"

This will return the name of the customer the loan-number is the customer loan no. appears in Moi Avenue.

SQL provides a mechanism for renaming both relations and attributes by use of the As clause, it is of the form
Old_name **AS** New_name. e.g.

Select distinct Customer_name, Borrower. Loan_number **AS** loan_Id
From Borrower, loan
Where Borrower. Loan_number = loan.loan_number
AND Branch_name = "Koinange Street"

Ordering Display of Tuples

The "order by" clause case the tuples in the result for a query to appear in sorted order e.g.

Select distinct Customer - name
From borrower, loan
Where borrower.loan_number = loan.loan_number
And Branch name = "University way"
Order by customer_name

By default the order by clause lists items in ascending order. To specify the sort order use '**desc**' for descending order or '**asc**' for ascending e.g.

Select *
From loan
Order by amount desc, loan-number desc

4.2.2 Aggregate Functions

These are functions that take a collection (set or multi-set) of values as input and return a single value. These are

Average: **Avg**
Minimum: **Min**
Maximum: **Max**
Total: **Sum**
Count: **Count**

The input to sum and average must be a collection of numbers but the other operators can operate on collection of non-numeric data-types e.g. strings

Example

(i) **SELECT** Branch name, Avg(balance)
FROM Account
GROUP BY Branch -name

(ii) **SELECT** Branch_name, count (**distinct** customer_name)
FROM Depositor, account
WHERE Depositor, account-number = account - number
GROUP BY Branch name

(ii) **SELECT** Branch_name, Avg(balance)
FROM Account
GROUP BY Branch_name
HAVING Average (balance) > 1200

Null Values

Null values indicate absence of information about the value of an attribute. e.g.

SELECT loan-number
FROM loan
WHERE Amount is **Null**

Assignment: look into Inner Join and Outer Join

4.2.3 Tuple Variables

- A tuple variable in SQL must be associated with a particular relation

They are defined in the FROM clause via the use of the AS clause. e.g.

SELECT DISTINCT Customer_name, T**.**loan_number
FROM Borrower **AS** T, loan **AS** S
WHERE T**.**loan_number = S**.**Loan_number

Query to find the names of all branches that have assets greater than at least one branch located in Brooklyn would be.

SELECT Distinct T**.**Branch_name
FROM Branch **AS** T, Branch **AS** S
WHERE T**.**assets > S**.**assets **AND** S**.**Branch_city = "BROOKLYN"

When expressions of the form relation_name**.**Attribute_name are written, the relation name is an implicitly defined tuple variable.

4.2.4 String Operations

- Most commonly used operation on strings is pattern matching using "LIKE".
- Two characters are used
  - Percent (%) - matches any sub-string
  - Underscore (-) - matches any character
- Patterns are case sensitive i.e. uppercase do not match lower case characters.

Examples
(i) "Mary %" matches any string beginning with "Mary"
(ii) "%ry" Matches any string containing "ry" as a sub-string e.g. very, mary, ary etc.
(iii) "- - -" Matches any string of exactly three characters.
(iv) "- - -%" Matches any string of at least 3 characters.

The query to find customer names for all customers whose addresses include the sub-string "main" would be:-

SELECT Customer-name
FROM Customer
WHERE Customer -street LIKE "%main %"

For patterns to include special pattern characters (i.e. % and _) SQL allows the specification of an escape character. The escape character is placed immediately before a special pattern character to indicate the special pattern. Character is to be treated like a normal character. The key work **ESCAPE** is used.

Examples.

- **LIKE** "ab\%cd%"**ESCAPE** "\" - matches all strings beginning with "ab%cd"
- **LIKE** "ab\\cd%" **ESCAPE**"\" - matches all strings beginning with "ab\cd"

Mismatches.
SQL allows the search for mismatches using the **NOT LIKE** comparison operator Set Operations.

4.2.5 SQL and Set

SQL operations **Union**, **Intersect** and **Except** operate on relations and correspond to the relational operations ∪, ∩ and -,

(i) Union

To find all customers having a loan, an account or both at the bank

(**SELECT** Customer_name **FROM** depositor)

UNION
(**SELECT** Customer_name
FROM Borrower)

To indicate duplicates

(**SELECT** Customer_name **FROM** Depositor)

UNION ALL
(**SELECT** Customer_name
FROM Borrower)

(ii) The Intersection

To find customers who have both a loan and an account at the bank

(**SELECT Distinct** Customer_name
FROM Depositor)
INTERSECT
(**SELECT Distinct** Customer_name
FROM Borrower)

To include duplicates we use "intersect all"

(iii) The Exception

To find customers who have an account but no loan at the bank we write

(**SELECT Distinct** Customer_name **FROM** Depositor)

EXCEPT
(**SELECT** Customer_name
FROM Borrower)

To include duplicate we use "Except all"
Null Values

- The keyword is used in the predicate test.

Example

SELECT Loan_number
FROM Loan
WHERE Amount is **NULL**

- To test for the absence of a null value we use the predicate "IS NOT NULL"

4.4.6 VIEWS

Use **CREATE VIEW** command
Syntax

CREATE VIEW V **AS** <*query expression*>
Where query expression is a legal query expression.

Example
CREATE VIEW Customer **AS**
(**SELECT** Branch_name, Customer_name
FROM Depositor**.**account)
WHERE Depositor**.**Account_number, Account**.**account_number

The names of the attribute of a view can be specified as

CREATE VIEW Branch_total_loan(branch-name, total(loan)
AS
SELECT Branch_name, SUM (amount)
FROM loan
GROUP BY Branch_name

NB: A create view clause creates a view definition in the database which stays there until a command **DROP** View (view name) is executed.

4.4.7 Modification Of The Database

Involves **Add**, **REMOVE** or **CHANGE** of information in the database.

(i) Deletion

DELETE FROM r
WHERE P

- P represents the predicate, r represent the relation.
- The statement first finds all tuples t in r which P(t) is true & then deletes them from r
- Where clause can be omitted in which case all tuples in P are deleted.

Example
DELETE FROM Loan
- Deletes all tuples from the loan relation.

To delete all loans with loan amounts between 1300 &1500

DELETE FROM loan
WHERE amount **BETWEEN** 1300 **AND** 1500

To delete all accounts at city square branch

DELETE FROM account
WHERE Branch-name = ”City Square”

(ii) Insertion
To insert data into a relation:-
- Specify a tuple to be inserted or
- Write a query whose result is a set of tuples to be inserted

Tuples to be inserted must be in the correct arity.

Example

INSERT INTO Account
VALUES (“City Square”, “ Account”, 6000)
or
INSERT INTO Account (branch-name, account-number, balance)
VALUES (“City Square”, ”Account”, 6000)

(iii) Updates

To change a value in a tuple without changing all values the **UPDATE** statement can be used.
Examples
(i) **UPDATE** Account
SET Balance = Balance * 1.05
(ii) **UPDATE** Account
SET Balance = Balance *1.06
WHERE balance >10,000

Update Of A View

- A modification is permitted through a view only if the view in question is defined in terms of one relation of the actual relational database i.e. of a logical level db

Example
CREATE VIEW Branch_loan **AS**
SELECT Branch_name, loan_number
FROM loan
INSERT INTO Branch_loan
VALUES ("Moi Avenue", "Accoo8")

4.2.7 Schema Definition in SQL

Syntax
CREATE TABLE r(A1D1, A2D2, -----, A_nD_n,
[Integrity Constraints],
……
……...
……...
[Integrity - constraints]

Examples
(i) **CREATE TABLE** Customer
(Customer_name **CHAR**(20) **NOT NULL,**
Customer_street **CHAR**(30),
Customer_city **CHAR**(30),
PRIMARY KEY (customer_name))

(ii) **CREATE TABLE** Branch
(Branch_name **CHAR** (15) **NOT NULL,**
Branch_city **CHAR** (30),
Assets Integer,
PRIMARY KEY (Branch_name)
Check (assets> = 0))

(iii) **CREATE TABLE** Depositor
(customer_name, **CHAR**(20) **NOT NULL**,
Account_name **CHAR**(20) **NOT NULL**,
PRIMARY KEY (Customer_name, Account_number))

The create table commands includes other integrity constraints.

- Primary key - includes a list of the attributes that constitute the primary key
- Unique - includes a list of the attributes that constitute a candidate key
- Foreign key - includes both a list of the attributes that constitute the foreign key & the name of the relation referenced by the foreign key.

5.0 TRANSACTIONS MANAGEMENT AND CONCURRENCY CONTROL

A transaction is a series of actions carried out by a single user or application program, which must be treated as a single logical unit of work. It results from the execution of a user program delimited by statements (or function calls) of the form begin transactions and end transactions.

5.1 Properties Of Transactions

(i) Atomicity

It is the all or nothing property.
Either all the operations of the transactions are reflected in the database properly or none are. This means that a transaction is an indivisible unit.

(ii) Consistency

Execution of a transaction in isolation preserves the consistency of the database. So a transaction will normally transform a database from one consistent state to another consistent state.

(iii) Isolation (Independent)

Transaction execute independently of one another i.e. even though multiple transactions may execute concurrently the system quantities that forever pair of transactions T_i and T_j it appears to T_i that either T_j finished execution after T_i started or T_j started execution after T_i finished each transactions is unaware of other transactions executing concurrently in the system.

(iv) Durability /Persistence

The effects of a successfully completed (committed) transaction are permanently recorded in the database and cannot be undone.
These properties are usually referred to as ACID properties.

5.2 Interference between Concurrent transactions

Concurrency transactions can present the following problems among others.

(i) Lost update problem
(ii) Uncommitted dependency problem
(iii) Inconsistency analysis problem

(i) **Lost Update Problem**

Another user can override an apparently successfully completed update operation by one user.

Consider this situation.

Transaction A	**Time**	**Transaction B**
Fetch R	t_1	__
	t_2	Fetch R
Update R	t_3	
	t_4	Update R

Transaction A retrieves some record R at time t_1.
Transaction B retrieves the same record R at the time t_2.
Transaction A updates the record at time t_3 on the basis of values read at time t_1.
Transaction B updates the same record at time t_4 on the basis of values read at time t_2.
Update at t_3 is lost

(ii) Uncommitted Dependency Problem

Violations of integrity constraints governing the database can arise when 2 transactions are allowed to execute concurrently without being synchronized.
Consider.

Transaction A	***Time***	***Transaction B***
__	t_1	Fetch R
__	t_2	Update R
Fetch R	t_3	__
	t_4	Roll back

Transaction B reads R at t_1 and updates it at t_2 .
Transaction A reads an uncommitted update at time t3, and then the update is undone at time t_4.
Transaction A is therefore operating on false assumption. Transaction A becomes dependent on an uncommitted update at time t_2.

(iii) Inconsistency Analysis Problem

Transactions that only read the database can obtain the wrong result if they're allowed to read partial result or incomplete transactions, which has simultaneously updated the database. Consider 2 transactions A & B operating on an account records. Transaction A is summing account balances while transaction B is transferring amount 10 from account 3 to account 1.

Transaction A	*Time*	*Transaction B*
Fetch account1 (40) (Sum = 40)	t_1	____
Fetch account2 (50) (Sum = 90)	t_2	____
	t_3	Fetch account 3 (30)
___	t_4	Update account 3 by subtracting the mount of 10 (30-10) = 20
___	t_5	Fetch account 1 (40)
___	t_6	Updates account 1(40 + 10 = 50)
___	t_7	Commit
Fetch account 3(20) (Sum 110 instead of 120)	t_8	____

5.3 Schedules And Serialisation

A transaction consists of a sequence of reads and writes of database. The entire sequence of reads and writes by all concurrent transactions in a database taken together is known as schedule. The order of interleaving of operations from different transactions is crucial to maintaining consistency of the database.

A serial schedule is the way in which all the reads and writes of each transaction are run sequentially one after another.

A schedule is said to be serialised if all reads and writes of each transaction can be re ordered in such a way that when they are grouped together as in a serial schedule, the net effect of executing this re-organised schedule is the same as that of the original schedule.

5.4 Concurrency Control Techniques

There are 3 basic concurrency control techniques:

(i) Locking Method
(ii) Time Stamp Method
(iii) Optimistic Method

(i) Locking method

A lock guarantees exclusive use of data item to a current transaction. Transaction T_1 does not have access to a data item that is currently used by transaction T_2. A transaction acquires a lock prior to data access. The lock is released (Unlock) when the transaction is completed so that another transaction can lock the data item for its exclusive use.

Shared Locks

These are used during read operations since read operations cannot conflict. More than one transaction is permitted to hold read locks simultaneously of the same data item.

Exclusive Locks (White Locks)

These give a transaction exclusive access to a data item. As long as a transaction holds an exclusive lock no other transaction can read or update that data item.

2-Phase locking

To ensure serialisability the 2- phase locking protocol defines how transaction acquire and relinquish locks. 2-phase locking guarantees serialisability but it does not prevent deadlocks. The 2-phases are:

(a) Growing phase in which a transaction acquires all the required locks without unlocking any data. Once all the locks have been acquired the transaction is in its locked point.
(b) Stinking phase in which a transaction releases all locks and cannot obtain any new lock.

Rules governing the 2-Phase protocol are:

(i) 2 transactions cannot have conflicting locks
(ii) No unlock operation can precede an unlock operation in the same transaction.
(iii) No data is affected until all locks are obtained i.e. until the transaction is in the locked point.

Deadlocks

It is used when 2 transactions T_1 and T_2 exist in the following modes:

T_1 = access data items X and Y
T_2 = access data item Y and X

If T_1 has not unlocked Y then T_2 cannot begin.
If T_2 has not unlocked data item X, T_1 cannot continue.
Consequently T_1 and T_2 wait indefinitely each waiting for the other to unlock the required data item. Such a deadlock is known as **deadly embrace**.

Techniques To Control Deadlocks

1. **Deadlock Prevention**

A transaction requesting a new lock is aborted if there is a possibility that a dead lock can occur. If the transaction is aborted, all the changes made by this transaction are rolled back and all locks obtained by the transaction are released. The transaction is then rescheduled for execution. Deadlock prevention works because it avoids the conditions that lead to deadlock.

2. **Deadlock Detection**

The DBMS periodically tests the database for deadlocks. If the deadlock is found one of the transactions (the "victim") is aborted (rolled back and restarted) and the other transaction continues.

3. **Deadlock Avoidance**

The transaction must obtain all the locks it needs before it can be executed. This technique avoids rolled up of conflicting transactions by requiring that locks be obtained in successions, but the serial lock assignment increase action response times.

Conclusion:

The best deadlock control method depends on the database environment, if the probability is low, deadlock detection is recommended, if probability is high, deadlock prevention is recommended and if response time is not high on the system priority list deadlock avoidance might be employed.

(ii) Time Stamping Method

The time stamping approach, to schedule concurrent transactions assign a global unique time stamp to each transaction. The time stamp value uses an explicit order in which transactions are submitted to the DBMS. The stamps must have 2 properties;

i. Uniqueness - which assures that no equal time stamp values can exist.
ii. Monotonicity - which assures that time stamp values always increase.

All database operations read and write within the same transaction must have the same time stamp. The DBMS executes conflicting operations in the time stamp order thereby ensuring serialisability of the transactions.

If 2 transactions conflict, one is often stopped, re-scheduled and assigned a new time stamp value. The main draw back of time stamping approach is that each value stored in the database requires 2 additional time- stamp fields, one for the last time the field was read and one for the last update. Time stamping thus increases the memory needs and the databases.

(iii) Optimistic Methods

The optimistic approach is based on the assumption that the majority of database operations do not conflict. The optimistic approach does not require locking or time stamping techniques; instead a transaction is executed without restrictions until it is committed. In this approach, each transaction moves through 2 or 3 phases; read, validation and write phase.

Read Phase

The transaction reads the database, executes the needed computations and makes the updates to private copy of the database values. All update operations of the transaction are recorded in a temporary update file, which is not accessed by the remaining transactions.

Validation Phase

The transaction is validated to ensure that the changes made will not affect the integrity and consistency of the database. If a validation phase is negative, the transaction is restarted and the changes are discarded.

Write Phase

The changes are permanently applied (written) to the database.

Conclusion

The optimistic approach is acceptable for mostly read or query database system that require very few update transactions.