A Course Material on

CS6302 - DATABASE MANAGEMENT SYSTEMS

By

Mr.K.LOHESWARAN

ASSISTANT PROFESSOR

DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING

SASURIE COLLEGE OF ENGINEERING

VIJAYAMANGALAM – 638 056

QUALITY CERTIFICATE

This is to certify that the e-course material

Subject Code : CS6302

Subject : DATABASE MANAGEMENT SYSTEMS

Class : II Year CSE

being prepared by me and it meets the knowledge requirement of the university curriculum.

Signature of the Author

Name: Mr.K.LOHESWARAN

Designation: ASSISTANT PROFESSOR

This is to certify that the course material being prepared by Mr. K.LOHESWARAN is of adequate quality. He has referred more than five books among them minimum one is from aboard author.

Signature of HD

Name: Mr.J.SATHISHKUMAR

SEAL

CS6302 DATABASE MANAGEMENT SYSTEMS L T P C
3 0 0 3

UNIT I INTRODUCTION TO DBMS 10

File Systems Organization - Sequential, Pointer, Indexed, Direct - Purpose of Database System- Database System Terminologies-Database characteristics- Data models – Types of data models –Components of DBMS- Relational Algebra. LOGICAL DATABASE DESIGN: Relational DBMS -Codd's Rule - Entity-Relationship model - Extended ER Normalization – Functional Dependencies, Anomaly- 1NF to 5NF- Domain Key Normal Form – Denormalization

UNIT II SQL & QUERY OPTIMIZATION 8

SQL Standards - Data types - Database Objects- DDL-DML-DCL-TCL-Embedded SQL-Static Vs Dynamic SQL - QUERY OPTIMIZATION: Query Processing and Optimization - Heuristics and Cost Estimates in Query Optimization.

UNIT III TRANSACTION PROCESSING AND CONCURRENCY CONTROL 8

Introduction-Properties of Transaction- Serializability- Concurrency Control – Locking Mechanisms-Two Phase Commit Protocol-Dead lock.

UNIT IV TRENDS IN DATABASE TECHNOLOGY 10

Overview of Physical Storage Media – Magnetic Disks – RAID – Tertiary storage – File Organization –Organization of Records in Files – Indexing and Hashing –Ordered Indices – B+ tree Index Files – B tree Index Files – Static Hashing – Dynamic Hashing - Introduction to Distributed Databases- Client server technology- Multidimensional and Parallel databases- Spatial and multimedia databases-Mobile and web databases- Data Warehouse-Mining- Data marts.

UNIT V ADVANCED TOPICS 9

DATABASE SECURITY: Data Classification-Threats and risks – Database access Control – Types of Privileges –Cryptography- Statistical Databases.- Distributed Databases-Architecture-Transaction Processing-Data Warehousing and Mining-Classification-Association rules-Clustering-Information Retrieval- Relevance ranking-Crawling and Indexing the Web- Object Oriented Databases-XML Databases.

TOTAL: 45 PERIODS

TEXT BOOK:

1. Ramez Elmasri and Shamkant B. Navathe, “Fundamentals of Database Systems”, Fifth Edition, Pearson Education, 2008.

REFERENCES:

1. Abraham Silberschatz, Henry F. Korth and S. Sudharshan, “Database System Concepts”, Sixth Edition, Tata Mc Graw Hill, 2011.
2. C.J.Date, A.Kannan and S.Swamynathan, “An Introduction to Database Systems”, Eighth Edition, Pearson Education, 2006.
3. Atul Kahate, “Introduction to Database Management Systems”, Pearson Education, New Delhi,2006.
4. Alexis Leon and Mathews Leon, “Database Management Systems”, Vikas Publishing House Private Limited, New Delhi, 2003.
5. Raghu Ramakrishnan, “Database Management Systems”, Fourth Edition, Tata Mc Graw Hill, 2010.
6. G.K.Gupta, “Database Management Systems”, Tata Mc Graw Hill, 2011.
7. Rob Cornell, “Database Systems Design and Implementation”, Cengage Learning, 2011.

UNIT I INTRODUCTION TO DBMS **10/10**

File Systems Organization - Sequential, Pointer, Indexed, Direct - Purpose of Database System- Database System Terminologies-Database characteristics- Data models – Types of data models – Components of DBMS- Relational Algebra. LOGICAL DATABASE DESIGN: Relational DBMS - Codd's Rule - Entity-Relationship model - Extended ER Normalization – Functional Dependencies, Anomaly- 1NF to 5NF- Domain Key Normal Form – Denormalization

What is database?

Database:

A very large collection of related data

Models a real world enterprise:

Entities (e.g., teams, games / students, courses)

Relationships (e.g., The Celtics are playing in the Final!)

Even active components (e.g. "business logic")

DBMS: A software package/system that can be used to store, manage and retrieve data form databases

Database System: DBMS+data (+ applications)

Why Study Database:

Shift from computation to information

Always true for corporate computing

More and more true in the scientific world and of course, Web

DBMS encompasses much of CS in a practical discipline

OS, languages, theory, AI, logic

Why Databases

Why not store everything on flat files: use the file system of the OS, cheap/simple…

Name, Course, Grade

John Smith, CS112, B

Mike Stonebraker, CS234, A

Jim Gray, CS560, A

John Smith, CS560, B+

Yes, but not scalable…

Problem 1

Data redundancy and inconsistency

- **Multiple file formats, duplication of information in different files**

Name, Course, Email, Grade

John Smith, js@cs.bu.edu, CS112, B

Mike Stonebraker, ms@cs.bu.edu, CS234, A

Jim Gray, CS560, jg@cs.bu.edu, A

John Smith, CS560, js@cs.bu.edu, B+

Why this a problem?

- **Wasted space**
- **Potential inconsistencies (multiple formats, John Smith vs Smith J.)**

Problem 2

Data retrieval:

Find the students who took CS560

Find the students with GPA > 3.5

For every query we need to write a program!

We need the retrieval to be:

Easy to write

Execute efficiently

Problem 3

Data Integrity

No support for sharing:

- Prevent simultaneous modifications

No coping mechanisms for system crashes

No means of Preventing Data Entry Errors

Security problems

Database systems offer solutions to all the above problems**.**

A database is a collection of data elements (facts) stored in a computer in a systematic way, such that a computer program can consult it to answer questions. The answers to those questions become information that can be used to make decisions that may not be made with the data elements alone. The computer program used to manage and query a database is known as a database management system (DBMS). So a database is a collection of related data that we can use for

- Defining - specifying *types* of data
- Constructing - storing & populating
- Manipulating - querying, updating, reporting

A Database Management System (DBMS) is a software package to facilitate the creation and maintenance of a computerized database. A Database System (DBS) is a DBMS together with the data itself.

Features of a database:

- It is a persistent (stored) collection of related data.
- The data is input (stored) only once.
- The data is organized (in some fashion).
- The data is accessible and can be queried (effectively and efficiently).

DBMS:

- Collection of interrelated data
- Set of programs to access the data
- DMBS contains information about a particular enterprise
- DBMS provides an environment that it both convenient and efficient to use

Purpose of DBMS:

Database management systems were developed to handle the following difficulties of typical file-processing systems supported by conventional operating systems:

- Data redundancy and inconsistency
- Difficulty in accessing data
- Data isolation – multiple files and formats
- Integrity problems
- Atomicity of updates
- Concurrent access by multiple users
- Security problems

Introduction to Databases

We live in an information age. By this we mean that, first, we accept the universal fact that information is required in practically all aspects of human enterprise. The term 'enterprise' is used broadly here to mean any organisation of activities to achieve a stated purpose, including socio-economic activities. Second, we recognise further the importance of efficiently providing timely relevant information to an enterprise and of the importance of the proper use of technology to achieve that. Finally, we recognise that the unparallelled development in the technology to handle information has and will continue to change the way we work and live, ie. not only does the technology support existing enterprises but it changes them and makes possible new enterprises that would not have otherwise been viable.

The impact is perhaps most visible in business enterprises where there are strong elements of competition. This is especially so as businesses become more globalised. The ability to coordinate activities, for example, across national borders and time zones clearly depends on the timeliness and quality of information made available. More important perhaps, strategic decisions made by top management in response to perceived opportunities or threats will decide the future viability of an enterprise, one way or the other. In other words, in order to manage a business (or any) enterprise, future development must be properly estimated. Information is a *vital* ingredient in this regard.

Information must therefore be collected and analysed in order to make decisions. It is here that the proper use of technology will prove to be crucial to an enterprise. Up-to-date management techniques should include computers, since they are very powerful tools for processing large quantities of information. Collecting and analysing information using computers

is facilitated by current Database Technology, a relatively mature technology which is the subject of this book.

Purpose of Database Systems

1. **To see why database management systems are necessary, let's look at a typical ``file-processing system'' supported by a conventional operating system.**

The application is a savings bank:

- Savings account and customer records are kept in permanent system files.
- Application programs are written to manipulate files to perform the following tasks:
  - Debit or credit an account.
  - Add a new account.
  - Find an account balance.
  - Generate monthly statements.

2. **Development of the system proceeds as follows:**
   - New application programs must be written as the need arises.
   - New permanent files are created as required.
   - **but** over a long period of time files may be in different formats, and
   - Application programs may be in different languages.
3. **So we can see there are problems with the straight file-processing approach:**
   - Data redundancy and inconsistency
     - Same information may be duplicated in several places.
     - All copies may not be updated properly.
   - Difficulty in accessing data
     - May have to write a new application program to satisfy an unusual request.
     - E.g. find all customers with the same postal code.
     - Could generate this data manually, but a long job...
   - **Data isolation**
     - Data in different files.
     - Data in different formats.
     - Difficult to write new application programs.
   - **Multiple users**
     - Want concurrency for faster response time.

        - Need protection for concurrent updates.
        - E.g. two customers withdrawing funds from the same account at the same time - account has $500 in it, and they withdraw $100 and $50. The result could be $350, $400 or $450 if no protection.
    - **Security problems**
        - Every user of the system should be able to access only the data they are permitted to see.
        - E.g. payroll people only handle employee records, and cannot see customer accounts; tellers only access account data and cannot see payroll data.
        - Difficult to enforce this with application programs.
    - **Integrity problems**
        - Data may be required to satisfy constraints.
        - E.g. no account balance below $25.00.
        - Again, difficult to enforce or to change constraints with the file-processing approach.

These problems and others led to the development of **database management systems**.

File systems vs Database systems:

DBMS are expensive to create in terms of software, hardware, and time invested. So why use them? Why couldn't we just keep all our data in files, and use word processors to edit the files appropriately to insert, delete, or update data? And we could write our own programs to query the data! This solution is called maintaining data in flat files. So what is bad about flat files?

- Uncontrolled redundancy
- Inconsistent data
- Inflexibility
- Limited data sharing
- Poor enforcement of standards
- Low programmer productivity
- Excessive program maintenance
- Excessive data maintenance

File System

- Data is stored in Different Files in forms of Records
- The programs are written time to time as per the requirement to manipulate the data within files.
    - A program to debit and credit an account
    - A program to find the balance of an account
    - A program to generate monthly statements

Disadvantages of File system over DBMS

Most explicit and major disadvantages of file system when compared to database managementsystem are as follows:

✍ ***Data Redundancy***- The files are created in the file system as and when required by anenterprise over its growth path. So in that case the repetition of information about anentity cannot be avoided.

Eg. The addresses of customers will be present in the file maintaining information about customers holding savings account and also the address of the customers will be present in file maintaining the current account. Even when same customer have a saving account and current account his address will be present at two places.

✍ ***Data Inconsistency***: Data redundancy leads to greater problem than just wasting thestorage i.e. it may lead to inconsistent data. Same data which has been repeated at severalplaces may not match after it has been updated at some places.

For example: Suppose the customer requests to change the address for his account in the Bank and the Program is executed to update the saving bank account file only but hiscurrent bank account file is not updated. Afterwards the addresses of the same customerpresent in saving bank account file and current bank account file will not match.Moreover there will be no way to find out which address is latest out of these two.

✍ ***Difficulty in Accessing Data***: For generating ad hoc reports the programs will not alreadybe present and only options present will to write a new program to generate requestedreport or to work manually. This is going to take impractical time and will be more expensive.

For example: Suppose all of sudden the administrator gets a request to generate a list of all the customers holding the saving banks account who lives in particular locality of the city. Administrator will not have any program already written to generate that list but say he has a program which can generate a list of all the customers holding the savings account. Then he can either provide the information by going thru the list manually to select the customers living in the particular locality or he can write a new program to generate the new list. Both of these ways will take large time which would generally be impractical.

✍ ***Data Isolation***: Since the data files are created at different times and supposedly bydifferent people the structures of different files generally will not match. The data will be scattered in different files for a particular entity. So it will be difficult to obtain appropriate data.

For example: Suppose the Address in Saving Account file have fields: ***Add line1, Add line2, City, State, Pin*** while the fields in address of Current account are: ***House No., Street No., Locality*****, City, State, Pin**. Administrator is asked to provide the list of customers living in a particular locality. Providing consolidated list of all the customers will require looking in both

files. But they both have different way of storing the address. Writing a program to generate such a list will be difficult.

✍ ***Integrity Problems****:* All the consistency constraints have to be applied to database through appropriate checks in the coded programs. This is very difficult when number such constraint is very large.

For example: An account should not have balance less than Rs. 500. To enforce this constraint appropriate check should be added in the program which add a record and the program which withdraw from an account. Suppose later on this amount limit is increased then all those check should be updated to avoid inconsistency. These time to time changes in the programs will be great headache for the administrator.

✍ ***Security and access control****:* Database should be protected from unauthorized users. Every user should not be allowed to access every data. Since application programs are added to the system

For example: The Payroll Personnel in a bank should not be allowed to access accounts information of the customers.

✍ ***Concurrency Problems****:* When more than one users are allowed to process the database. If in that environment two or more users try to update a shared data element at about the same time then it may result into inconsistent data. For example: Suppose Balance of an account is Rs. 500. And User A and B try to withdraw Rs 100 and Rs 50 respectively at almost the same time using the Update process.

Update:

1. Read the balance amount.
2. Subtract the withdrawn amount from balance.
3. Write updated Balance value.

Suppose A performs Step 1 and 2 on the balance amount i.e it reads 500 and subtract100 from it. But at the same time B withdraws Rs 50 and he performs the Update process and he also reads the balance as 500 subtract 50 and writes back 450. User A will also write his updated Balance amount as 400. They may update the Balance value in any order depending on various reasons concerning to system being used by both of the users. So finally the balance will be either equal to 400 or 450. Both of these values are wrong for the updated balance and so now the balance amount is having inconsistent value forever.

Sequential Access

The simplest access method is Sequential Access. Information in the file is processed in order, one record after the other. This mode of access is by far the most common; for example, editors and compilers usually access files in this fashion.

The bulk of the operations on a file is reads and writes. A read operation reads the next portion of the file and automatically advances a file pointer, which tracks the I/O location. Similiarly, a write appends to the end of the file and advances to the end of the newly written material (the new end of file).

File Pointers

When a file is opened, Windows associates a *file pointer* with the default stream. This file pointer is a 64-bit offset value that specifies the next byte to be read or the location to receive the next byte written. Each time a file is opened, the system places the file pointer at the beginning of the file, which is offset zero. Each read and write operation advances the file pointer by the number of bytes being read and written. For example, if the file pointer is at the beginning of the file and a read operation of 5 bytes is requested, the file pointer will be located at offset 5 immediately after the read operation. As each byte is read or written, the system advances the file pointer. The file pointer can also be repositioned by calling the **SetFilePointer** function.

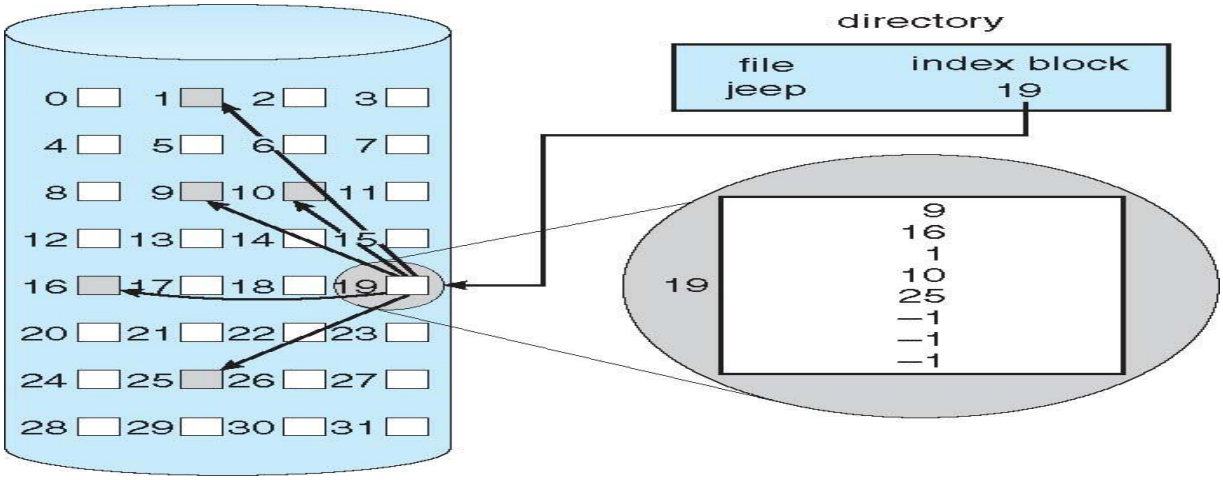
When the file pointer reaches the end of a file and the application attempts to read from the file, no error occurs, but no bytes are read. Therefore, reading zero bytes without an error means the application has reached the end of the file. Writing zero bytes does nothing.

An application can truncate or extend a file by using the **SetEndOfFile** function. This function sets the end of file to the current position of the file pointer.

Indexed allocation

- Each file has its own index block(s) of pointers to its data blocks

• Logical view



Need index table

Random access

- Dynamic access without external fragmentation, but have overhead of index block
- Mapping from logical to physical in a file of maximum size of 256K bytes and block size of 512 bytes. We need only 1 block for index table

Q

- **LA Q512**

R

- Q = displacement into index table
- R = displacement into block

Mapping from logical to physical in a file of unbounded length (block size of 512 words)

Linked scheme – Link blocks of index table (no limit on size

Q1

- **LA Q512 ×511**

R1

Q_1 = block of index table R_1 is used as follows:

Q2

- **R1 /512**

R2

Q_2 = displacement into block of index table

R_2 displacement into block of file:

Two-level index (4K blocks could store 1,024 four-byte pointers in outer index -> 1,048,567 data blocks and file size of up to 4GB)

Q1

LA 512 / 512

R1

Q_1 = displacement into outer-index

R_1 is used as follows:

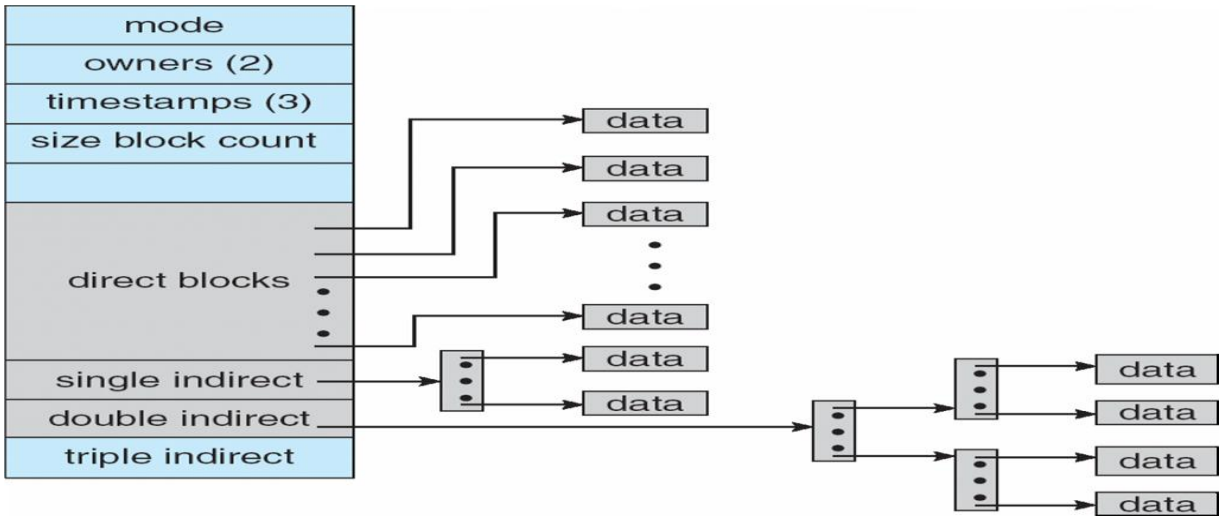
Q2

R1 /512

R2

Q_2 = displacement into block of index table

R_2 displacement into block of file



- **Best method depends on file access type**
  - **Contiguous great for sequential and random**
- **Linked good for sequential, not random**
- **Declare access type at creation -> select either contiguous or linked**
- **Indexed** more complex
  - Single block access could require 2 index block reads then data block read
  - Clustering can help improve throughput, reduce CPU overhead
- Adding instructions to the execution path to save one disk I/O is reasonable
  - Intel Core i7 Extreme Edition 990x (2011) at 3.46Ghz = 159,000 MIPS
    - http://en.wikipedia.org/wiki/Instructions_per_second
  - Typical disk drive at 250 I/Os per second
    - 159,000 MIPS / 250 = 630 million instructions during one disk I/O
  - Fast SSD drives provide 60,000 IOPS
    - 159,000 MIPS / 60,000 = 2.65 millions instructions during one disk I/O

DIRECT ACCESS

Method useful for disks.

- The file is viewed as a numbered sequence of blocks or records.
- There are no restrictions on which blocks are read/written in any order.

- User now says "read n" rather than "read next".
- "n" is a number relative to the beginning of file, not relative to an absolute physical disk location.

purpose of database system

Database management systems were developed to handle the following difficulties of typical file-processing systems supported by conventional operating systems:

- Data redundancy and inconsistency
- Difficulty in accessing data
- Data isolation – multiple files and formats
- Integrity problems
- Atomicity of updates
- Concurrent access by multiple users
- Security problems

Purpose of Database Systems

4. **To see why database management systems are necessary, let's look at a typical ``file-processing system'' supported by a conventional operating system.**

   The application is a savings bank:
   - Savings account and customer records are kept in permanent system files.
   - Application programs are written to manipulate files to perform the following tasks:
     - Debit or credit an account.
     - Add a new account.
     - Find an account balance.
     - Generate monthly statements.
5. **Development of the system proceeds as follows:**
   - New application programs must be written as the need arises.
   - New permanent files are created as required.
   - **but** over a long period of time files may be in different formats, and
   - Application programs may be in different languages.
6. **So we can see there are problems with the straight file-processing approach:**
   - Data redundancy and inconsistency

        - Same information may be duplicated in several places.
        - All copies may not be updated properly.
    - Difficulty in accessing data
        - May have to write a new application program to satisfy an unusual request.
        - E.g. find all customers with the same postal code.
        - Could generate this data manually, but a long job...
    - **Data isolation**
        - Data in different files.
        - Data in different formats.
        - Difficult to write new application programs.
    - **Multiple users**
        - Want concurrency for faster response time.
        - Need protection for concurrent updates.
        - E.g. two customers withdrawing funds from the same account at the same time - account has $500 in it, and they withdraw $100 and $50. The result could be $350, $400 or $450 if no protection.
    - **Security problems**
        - Every user of the system should be able to access only the data they are permitted to see.
        - E.g. payroll people only handle employee records, and cannot see customer accounts; tellers only access account data and cannot see payroll data.
        - Difficult to enforce this with application programs.
    - **Integrity problems**
        - Data may be required to satisfy constraints.
        - E.g. no account balance below $25.00.
        - Again, difficult to enforce or to change constraints with the file-processing approach.

These problems and others led to the development of **database management systems**.

TERMINOLOGY

Database

- Collection of related data (logically coherent)
- Known facts that can be recorded and that have implicit meaning
- Represents some aspect(s) of the real world (**miniworld**)
- Built for a specific purpose

Examples of large databases

•Amazon.com, Canadian Census, The Bay's product inventory, data collection underlying Quest

Database management system (**DBMS**)

Collection of programs

Enables users to create and maintain a database

Allows multiple users and programs to access and manipulate the database concurrently

Provides protection against unauthorized access and manipulation

Provides means to evolve database and program behaviour as requirements change over time

Examples of database management systems

IBM's DB2, Microsoft's Access and SQL Server, Oracle, MySQL, SAP's SQL Anywhere

Defining a database

Specifying the data types, structures, and constraints of the data to be stored

Uses a *Data Definition Language*

Meta-data

Database definition or descriptive information

Stored by the DBMS in the form of a *database catalog* or *data dictionary*

Phases for designing a database:

Requirements specification and analysis

Conceptual design

e.g., using the *Entity-Relationship model*

Logical design

e.g., using the *relational model*

Physical design

Populating a database

Inserting data to reflect the miniworld

Query

Interaction causing some data to be retrieved

uses a *Query Language*

Manipulating a database

Querying and updating the database to understand/reflect miniworld

Generating reports

Uses a *Data Manipulation Language*

Application program

Accesses database by sending queries and updates to DBMS

Transaction

An atomic unit of queries and updates that must be executed as a whole

e.g., buying a product, transferring funds, switching co-op streams

Data Models:

A characteristic of the database approach is that it provides a level of data abstraction, by hiding details of data storage that are not needed by most users.

A data model is a collection of concepts that can be used to describe the structure of a database. The model provides the necessary means to achieve the abstraction.

The structure of a database is characterized by data types, relationships, and constraints that hold for the data. Models also include a set of operations for specifying retrievals and updates.

Data models are changing to include concepts to specify the behaviour of the database application. This allows designers to specify a set of user defined operations that are allowed.

Categories of Data Models

Data models can be categorized in multiple ways.

- **High level/conceptual data models** – provide concepts close to the way users perceive the data.
- **Physical data models** – provide concepts that describe the details of how data is stored in the computer. These concepts are generally meant for the specialist, and not the end user.
- **Representational data models** – provide concepts that may be understood by the end user but not far removed from the way data is organized.

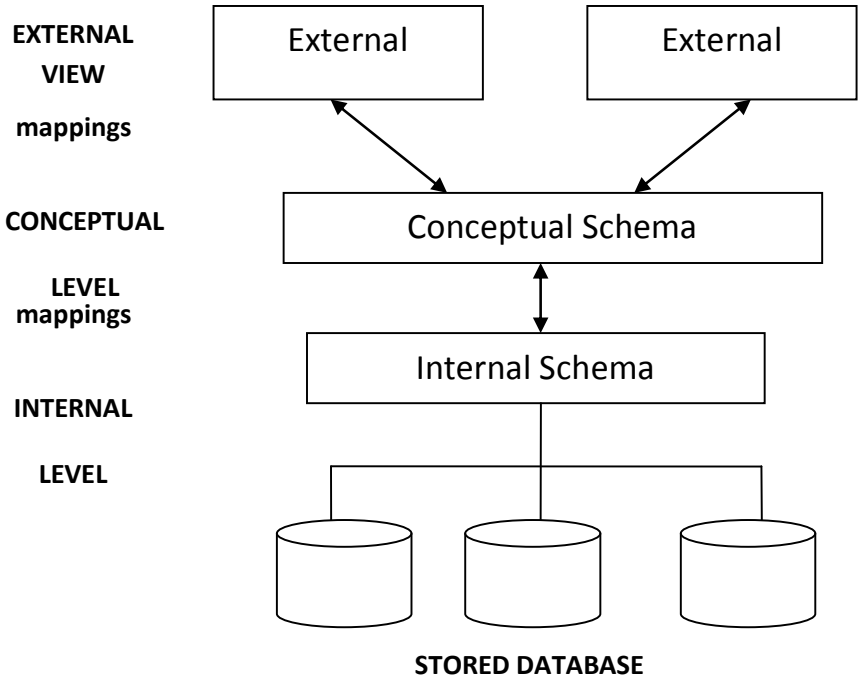
Conceptual data models use concepts such as entities, attributes and relationships.

- **Entity** – represents a real world object or concept
- **Attribute** - represents property of interest that describes an entity, such as name or salary.
- **Relationships** – among two or more entities, represents an association among two or more entities.

Representational data models are used most frequently in commercial DBMSs. They include relational data models, and legacy models such as network and hierarchical models.

Physical data models describe how data is stored in files by representing record formats, record orderings and access paths.

Object data models – a group of higher level implementation data models closer to conceptual data models



Three Schema Architecture

The goal of the three schema architecture is to separate the user applications and the physical database. The schemas can be defined at the following levels:

1. **The internal level** – has an internal schema which describes the physical storage structure of the database. Uses a physical data model and describes the complete details of data storage and access paths for the database.
2. **The conceptual level** – has a conceptual schema which describes the structure of the database for users. It hides the details of the physical storage structures, and concentrates on describing entities, data types, relationships, user operations and constraints. Usually a representational data model is used to describe the conceptual schema.
3. **The External or View level** – includes external schemas or user vies. Each external schema describes the part of the database that a particular user group is interested in and hides the rest of the database from that user group. Represented using the representational data model.

The three schema architecture is used to visualize the schema levels in a database. The three schemas are only descriptions of data, the data only actually exists is at the physical level.

Internal Level:

- Deals with physical storage of data

- Structure of records on disk - files, pages, blocks
- Indexes and ordering of records
- Used by database system programmers
  Internal Schema

RECORD EMP

LENGTH=44

HEADER: BYTE(5)

OFFSET=0

NAME: BYTE(25)

OFFSET=5

SALARY: FULLWORD

OFFSET=30

DEPT: BYTE(10)

OFFSET=34

.**Conceptual Schema**:

- Deals with the organisation of the data as a whole
- Abstractions are used to remove unnecessary details of the internal level
- Used by DBAs and application programmers
- Conceptual Schema

CREATE TABLE Employee (Name VARCHAR(25), Salary DOUBLE, Dept_Name VARCHAR(10));

External Level:

- Provides a view of the database tailored to a user
- Parts of the data may be hidden
- Data is presented in a useful form
- Used by end users and application programmers

External Schemas **Payroll:**

String Name

double Salary

Personnel:

char *Name

char *Department

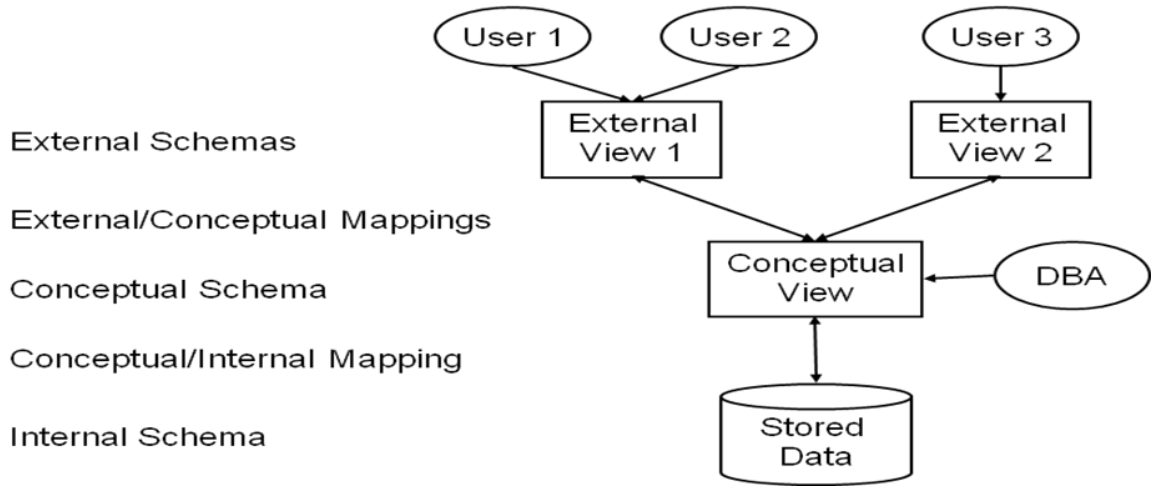
Mappings

- Mappings translate information from one level to the next
  - External/Conceptual
  - Conceptual/Internal
- These mappings provide data independence

- Physical data independence
  - Changes to internal level shouldn't affect conceptual level

- Logical data independence
  - Conceptual level changes shouldn't affect external levels

Data Model Architecture:



Components of DBMS

A database management system (DBMS) consists of several components. Each component plays very important role in the database management system environment. The major components of database management system are:

- Software
- Hardware
- Data
- Procedures
- Database Access Language

Software

The main component of a DBMS is the software. It is the set of programs used to handle the database and to control and manage the overall computerized database

1. DBMS software itself, is the most important software component in the overall system
2. Operating system including network software being used in network, to share the data of database among multiple users.
3. Application programs developed in programming languages such as C++, Visual Basic that are used to to access database in database management system. Each program contains statements that request the DBMS to perform operation on database. The operations may include retrieving, updating, deleting data etc . The application program may be conventional or online workstations or terminals.

Hardware

Hardware consists of a set of physical electronic devices such as computers (together with associated I/O devices like disk drives), storage devices, I/O channels, electromechanical devices that make interface between computers and the real world systems etc, and so on. It is impossible to implement the DBMS without the hardware devices, In a network, a powerful computer with high data processing speed and a storage device with large storage capacity is required as database server.

Data

Data is the most important component of the DBMS. The main purpose of DBMS is to process the data. In DBMS, databases are defined, constructed and then data is stored, updated and retrieved to and from the databases. The database contains both the actual (or operational) data and the metadata (data about data or description about data).

Procedures

Procedures refer to the instructions and rules that help to design the database and to use the DBMS. The users that operate and manage the DBMS require documented procedures on hot use or run the database management system. These may include.

1. Procedure to install the new DBMS.
2. To log on to the DBMS.
3. To use the DBMS or application program.
4. To make backup copies of database.
5. To change the structure of database.
6. To generate the reports of data retrieved from database.

Database Access Language

The database access language is used to access the data to and from the database. The users use the database access language to enter new data, change the existing data in database and to retrieve required data from databases. The user write a set of appropriate commands in a database access language and submits these to the DBMS. The DBMS translates the user commands and sends it to a specific part of the DBMS called the Database Jet Engine. The database engine generates a set of results according to the commands submitted by user, converts these into a user readable form called an Inquiry Report and then displays them on the screen. The administrators may also use the database access language to create and maintain the databases.

The most popular database access language is SQL (Structured Query Language). Relational databases are required to have a database query language.

Users

The users are the people who manage the databases and perform different operations on the databases in the database system.There are three kinds of people who play different roles in database system

1. Application Programmers
2. Database Administrators
3. End-Users

Application Programmers
The people who write application programs in programming languages (such as Visual Basic, Java, or C++) to interact with databases are called Application Programmer.

Database Administrators

A person who is responsible for managing the overall database management system is called database administrator or simply DBA.

End-Users

The end-users are the people who interact with database management system to perform different operations on database such as retrieving, updating, inserting, deleting data etc.

Relational Query Languages

- Languages for describing queries on a relational database
- *Structured Query Language* (SQL)
  - Predominant application-level query language
  - Declarative
- *Relational Algebra*
  - Intermediate language used within DBMS
  - Procedural

What is Algebra?

- A language based on operators and a domain of values
- Operators map values taken from the domain into other domain values
- Hence, an expression involving operators and arguments produces a value in the domain
- When the domain is a set of all relations (and the operators are as described later), we get the *relational algebra*
- We refer to the expression as a *query* and the value produced as the *query result*

Relational Algebra

- *Domain*: set of relations
- *Basic operators*: select, project, union, set difference, Cartesian product
- *Derived operators*: set intersection, division, join
- *Procedural*: Relational expression specifies query by describing an algorithm (the sequence in which operators are applied) for determining the result of an expression

Select Operator

- Produce table containing subset of rows of argument table satisfying condition

  $\sigma_{condition}\, relation$

- Example:

  Person $\sigma_{Hobby='stamps'}(Person)$

Id	*Name*	*Address*	*Hobby*
1123	John	123 Main	stamps
1123	John	123 Main	coins
5556	Mary	7 Lake Dr	hiking
9876	Bart	5 Pine St	stamps

Id	*Name*	*Address*	*Hobby*
1123	John	123 Main	stamps
9876	Bart	5 Pine St	stamps

Selection Condition

- Operators: $<, \leq, \geq, >, =, \neq$
- Simple selection condition:
  - <*attribute*> *operator* <*constant*>
  - <*attribute*> *operator* <*attribute*>
- <*condition*> AND <*condition*>
- <*condition*> OR <*condition*>
- NOT <*condition*>

Project Operator

Produces table containing subset of columns of argument table

$$\Pi_{attribute\ list}(relation)$$

- Example:

Person

Id	*Name*	*Address*	*Hobby*
1123	John	123 Main	stamps
1123	John	123 Main	coins
5556	Mary	7 Lake Dr	hiking
9876	Bart	5 Pine St	stamps

$\Pi_{Name,Hobby}$**(Person)**

Name	*Hobby*
John	stamps
John	coins
Mary	hiking
Bart	stamps

Set Operators

- Relation is a set of tuples => set operations should apply
- Result of combining two relations with a set operator is a relation => all its elements must be tuples having same structure
- Hence, scope of set operations limited to *union compatible relations*

Union Compatible Relations

- Two relations are *union compatible* if
  - Both have same number of columns
  - Names of attributes are the same in both
  - Attributes with the same name in both relations have the same domain
- Union compatible relations can be combined using *union*, *intersection*, and *set difference*

Cartesian product

- If *R* and *S* are two relations, $R \times S$ is the set of all concatenated tuples <*x,y*>, where *x* is a tuple in *R* and *y* is a tuple in *S*
  - (*R* and *S* need not be union compatible)
- $R \times S$ is expensive to compute:
  - Factor of two in the size of each row
  - Quadratic in the number of rows

a	b
x1	x2
x3	x4

R

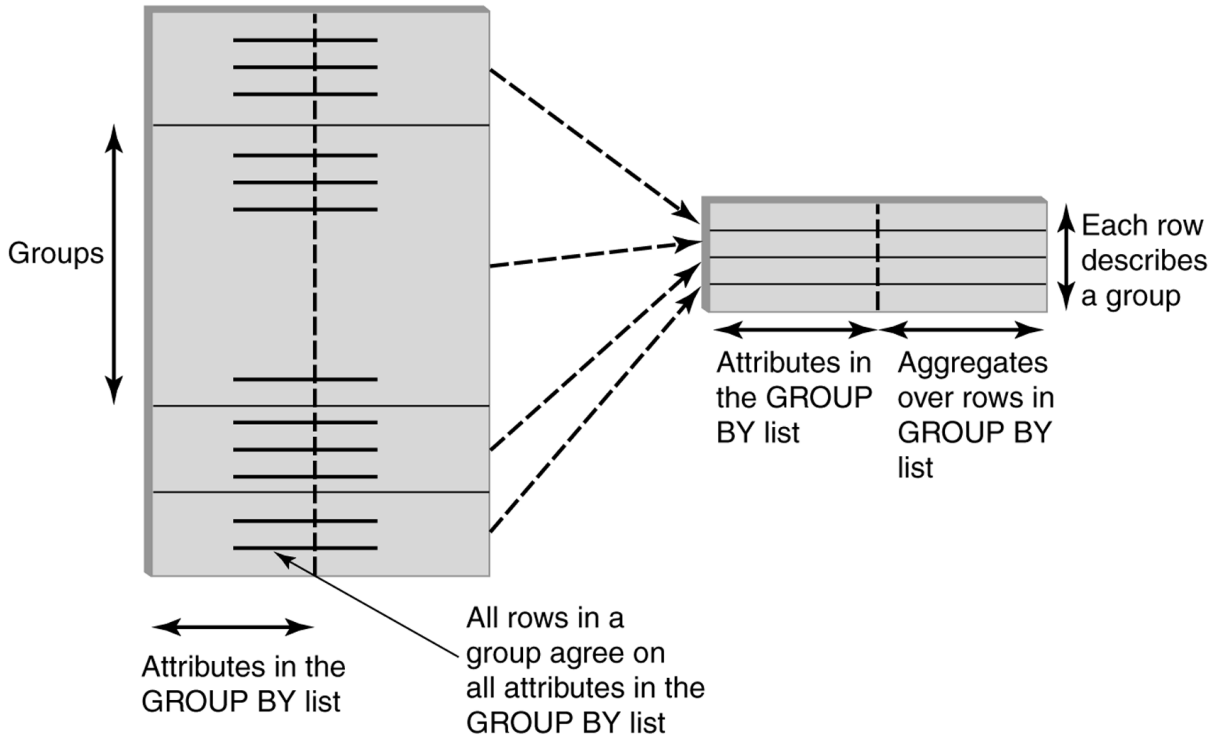
c	d
y1	y2
y3	y4

S

a	b	c	d
x1	x2	y1	y2
x1	x2	y3	y4
x3	x4	y1	y2
x3	x4	y3	y4

$R \times S$

GROUP BY



HAVING Clause

- Eliminates unwanted groups (analogous to WHERE clause)
- HAVING condition constructed from attributes of GROUP BY list and aggregates of attributes not in list

SELECT T.*StudId*, AVG(T.*Grade*) AS *CumGpa*,

COUNT (*) AS *NumCrs*

FROM Transcript T

```
WHERE  T.CrsCode  LIKE  'CS%'

GROUP BY  T.StudId

HAVING  AVG (T.Grade) > 3.5.
```

A Database Management System is a software environment that structures and manipulatesdata, and ensures data security, recovery, and integrity. The Data Platform relies on a database management system (RDBMS) to store and maintain all of its data as well as execute all the associated queries. There are two types of RDBMS : the first group consists of single software packages which support only a single database, with a single user access and are not scalable (i.e. cannot handle large amounts of data). Typical examples of this first group are MS Access and FileMaker. The second group is formed by DBMS composed of one or more programs and their associated services which support one or many databases for one or many users in ascalable fashion. For example an enterprise database server can support the HR database,the accounting database and the stocks database all at the same time. Typical examples ofthis second group include MySQL, MS SQL Server, Oracle and DB2. The DBMS selected for the Data Platform is MS SQL Server from the second group.

Table
A table is set of data elements that has a horizontal dimension (rows) and a vertical dimension (columns) in a relational database system. A table has a specified number of columns but can have any number of rows. Rows stored in a table are structurally equivalent to records from flat files. Columns are often referred as attributes or fields. In a database managed by a DBMS the format of each attribute is a fixed datatype. For example the attribute date can only contain information in the date time format.

Identifier
An identifier is an attribute that is used either as a primary key or as a foreign key. The integer datatype is used for identifiers. In cases where the number of records exceed the allowed values by the integer datatype then a biginteger datatype is used.

Primary key
A column in a table whose values uniquely identify the rows in the table. A primary key value cannot be NULLto matching columns in other tables\

Foreign key
A column in a table that does not uniquely identify rows in that table, but is used as a link to matching columns in other tables.

Relationship
A relationship is an association between two tables. For example the relationship between the table "hotel" and "customer" maps the customers to the hotels they have used.

Index
An index is a data structure which enables a query to run at a sublinear-time. Instead of having to go through all records one by one to identify those which match its criteria the query uses the index to filter out those which don't and focus on those who do.

View
A view is a virtual or logical table composed of the result set of a pre-compiled query. Unlike ordinary tables in a relational database, a view is not part of the physical schema: it is a dynamic, virtual table computed or collated from data in the database. Changing the data in a view alters the data stored in the database

Query
A query is a request to retrieve data from a database with the SQL SELECT instruction or to manipulate data stored in tables.

SQL
Structured Query Language (SQL), pronounced "sequel", is a language that provides an interface to relational database systems. It was developed by IBM in the 1970s for use in System R. SQL is a de facto standard, as well as an ISO and ANSI standard.
Relational Database Management System

E. F. Codd's Twelve Rules for Relational Databases

Codd's twelve rules call for a language that can be used to define, manipulate, and query the data in the database, expressed as a string of characters. Some references to the twelve rules include a thirteenth rule - or rule zero:

1. Information Rule: All information in the database should be represented in one and only one way -- as values in a table.

2. Guaranteed Access Rule: Each and every datum (atomic value) is guaranteed to be logically accessible by resorting to a combination of table name, primary key value, and column name.

3. Systematic Treatment of Null Values: Null values (distinct from empty character string or a string of blank characters and distinct from zero or any other number) are supported in the fully relational DBMS for representing missing information in a systematic way, independent of data type.

4. Dynamic Online Catalog Based on the Relational Model: The database description is represented at the logical level in the same way as ordinary data, so authorized users can apply the same relational language to its interrogation as they apply to regular data.

5. Comprehensive Data Sublanguage Rule: A relational system may support several languages and various modes of terminal use. However, there must be at least one language whose statements are expressible, per some well-defined syntax, as character strings and whose ability to support all of the following is comprehensible:

a. data definition
b. view definition
c. data manipulation (interactive and by program)
d. integrity constraints
e. authorization
f. transaction boundaries (begin, commit, and rollback).

6. View Updating Rule: All views that are theoretically updateable are also updateable by the system.

7. High-Level Insert, Update, and Delete: The capability of handling a base relation or a derived relation as a single operand applies not only to the retrieval of data, but also to the insertion, update, and deletion of data.

8. Physical Data Independence: Application programs and terminal activities remain logically unimpaired whenever any changes are made in either storage representation or access methods.

9. Logical Data Independence: Application programs and terminal activities remain logically unimpaired when information preserving changes of any kind that theoretically permit unimpairment are made to the base tables.

10. Integrity Independence: Integrity constraints specific to a particular relational database must be definable in the relational data sublanguage and storable in the catalog, not in the application programs.

11. Distribution Independence: The data manipulation sublanguage of a relational DBMS must enable application programs and terminal activities to remain logically unimpaired whether and whenever data are physically centralized or distributed.

12. Nonsubversion Rule: If a relational system has or supports a low-level (single- record-at-a-time) language, that low-level language cannot be used to subvert or bypass the integrity rules or constraints expressed in the higher-level (multiple- records-at-a-time) relational language.

ER MODEL

Entities:

Entity-a thing (animate or inanimate) of independent physical or conceptual existence and *distinguishable*.

In the University database context, an individual *student*, *faculty member*, a *class room*, a *course*are entities.

Entity Set or *Entity Type*-Collection of entities all having the same properties.

Student entity set –collection of all *student* entities.

Course entity set –collection of all *course* entities.

Attributes:

AttributesEach entity is described by a set of attributes/properties.*student*entity

StudName–name of the student.

RollNumber–the roll number of the student.

Sex–the gender of the student etc.

All entities in an Entity set/type have the same set of attributes.

Cardinality

A business rule indicating the number of times a particular object or activity may occur.

Data Models

- A collection of tools for describing:
  - Data
  - Data relationships
  - Data semantics
  - Data constraints
- Object-based logical models
  - Entity-relationship model
  - Object-oriented model
  - Semantic model
  - Functional model
- Record-based logical models
  - Relational model (e.g., SQL/DS, DB2)
  - Network model
  - Hierarchical model (e.g., IMS)

Entity Relation Model

Perhaps the simplest approach to data modelling is offered by the *Relational Data Model*, proposed by Dr. Edgar F. Codd of IBM in 1970. The model was subsequently expanded and refined by its creator and very quickly became the main focus of practically all research activities in databases. The basic relational model specifies a data structure, the so-called *Relation*, and several forms of high-level languages to manipulate relations.

The term *relation* in this model refers to a two-dimensional table of data. In other words, according to the model, information is arranged in columns and rows. The term *relation*, rather than matrix, is used here because data values in the table are not necessarily homogenous (ie. not all of the same type as, for example, in matrices of integers or real numbers). More specifically, the values in any row are not homogenous. Values in any given column, however, are all of the

Customer			
C#	Cname	Ccity	Cphone
1	Codd	London	2263035
2	Martin	Paris	5555910
3	Deen	London	2234391

Row

Column

same type (see Figure).

Figure 1 A Relation

A relation has a unique name and represents a particular entity. Each row of a relation, referred to as a *tuple*, is a collection of facts (values) about a particular individual of that entity. In other words, a tuple represents an *instance* of the entity represented by the relation.

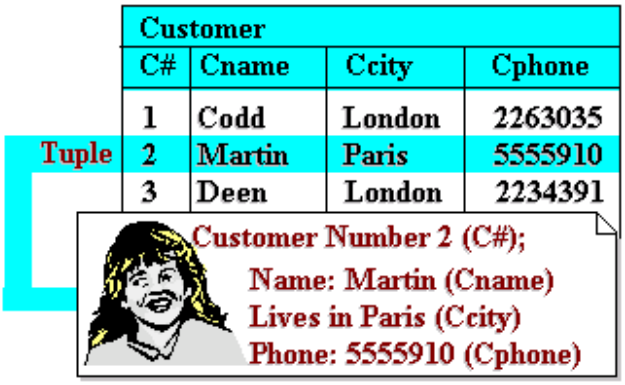


Figure 0 Relation and Entity

Figure 2 illustrates a relation called 'Customer', intended to represent the set of persons who are customers of some enterprise. Each tuple in the relation therefore represents a single customer.

The columns of a relation hold values of attributes that we wish to associate with each entity instance, and each is labelled with a distinct attribute name at the top of the column. This name, of course, provides a unique reference to the entire column or to a particular value of a tuple in the relation. But more than that, it denotes a *domain* of values that is defined *over all relations* in the database.

The term *domain* is used to refer to a set of values of the same kind or type. It should be clearly understood, however, that while a domain comprises values of a given type, it is *not* necessarily

the same as that type. For example, the column ‘Cname’ and ‘Ccity’ in figure 2 both have values of type string (ie. valid values are any string). But they denote different domains, ie. ‘Cname’ denotes the domain of customer names while ‘Ccity’ denotes the domain of city names. They are different domains even if they share common values. For example, the string ‘Paris’ can conceivably occur in the Column ‘Cname’ (a person named Paris). Its meaning, however, is quite different to the occurrence of the string ‘Paris’ in the column ‘Ccity’ (a city named Paris)! Thus it is quite meaningless to compare values from different domains even if they are of the same type.

Moreover, in the relational model, the term domain refers to the *current set* of values found under an attribute name. Thus, if the relation in Figure 2 is the only relation in the database, the domain of ‘Cname’ is the set {Codd, Martin, Deen}, while that of ‘Ccity’ is {London, Paris}. But if there were other relations and an attribute name occurs in more than one of them, then its domain is the *union* of values in all columns with that name. This is illustrated in Figure 3 where two relations each have a column labelled ‘C#’. It also clarifies the statement above that a domain is defined over all relations, ie. an attribute name always denotes the same domain in whatever relation in occurs.

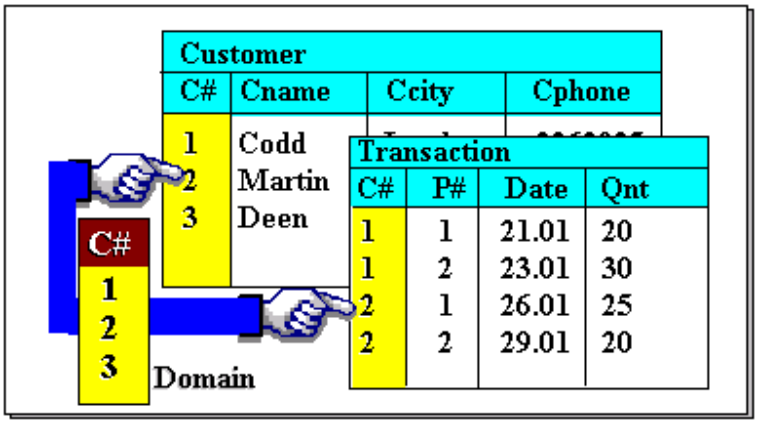


Figure 3 Domain of an attribute

This property of domains allows us to represent relationships between entities. That is, when two relations share a domain, identical domain values act as a *link* between tuples that contain them (because such values mean the same thing). As an example, consider a database comprising three relations as shown in Figure . It highlights a Transaction tuple and a Customer tuple linked through the C# domain value ‘2’, and the same Transaction tuple and a Product tuple linked through the P# domain value ‘1’. The Transaction tuple is a record of a purchase by customer

number ‘2’ of product number ‘1’. Through such links, we are able to retrieve the name of the customer and the product, ie. we are able to state that the customer ‘Martin’ bought a ‘Camera’. They help to avoid redundancy in recording data. Without them, the Transaction relation in Figure will have to include information about the appropriate Customer and Product in its table. This duplication of data can lead to integrity problems later, especially when data needs to be modified.

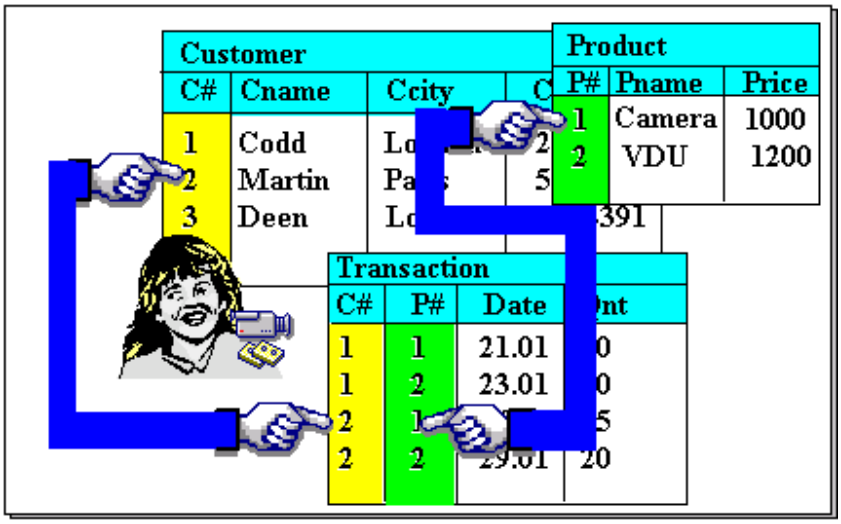


Figure 4 Links through domain sharing

Properties of a Relation

A relation with N columns and M rows (tuples) is said to be of *degree* N and *cardinality* M. This is illustrated in Figure which shows the Customer relation of degree four and cardinality three. The product of a relation’s degree and cardinality is the number of attribute values it contains.

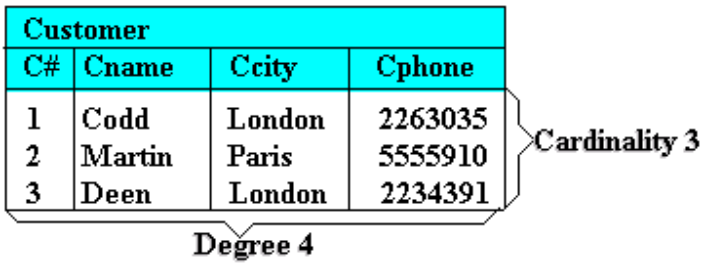


Figure 5 Degree and Cardinality of a Relation

The characteristic properties of a relation are as follows:

1. All entries in a given column are of the same kind or type
2. The ordering of columns is immaterial. This is illustrated in Figure where the two tables shown are identical in every respect except for the ordering of their columns. In the relational model, column values (or the value of an attribute of a given tuple) are not referenced by their position in the table but by name. Thus the display of a relation in tabular form is free to arrange columns in any order. Of course, once an order is chosen, it is good practice to use it everytime the relation (or a tuple from it) is displayed to avoid confusion.

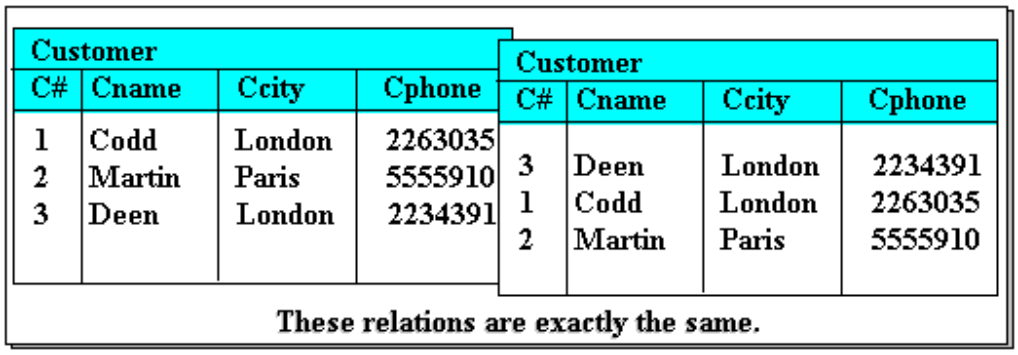


Figure 6 Column ordering is unimportant

3. No two tuples are exactly the same. A relation is a *set* of tuples. Thus a table that contains duplicate tuples is not a relation and cannot be stored in a relational database.
4. There is only one value for each attribute of a tuple. Thus a table such as in Figure is not allowed in the relational model, despite the clear intended representation, ie. that of customers with two abodes (eg. Codd has one in London and one in Madras). In situations like this, the multiple values must be split into multiple tuples to be a valid relation.

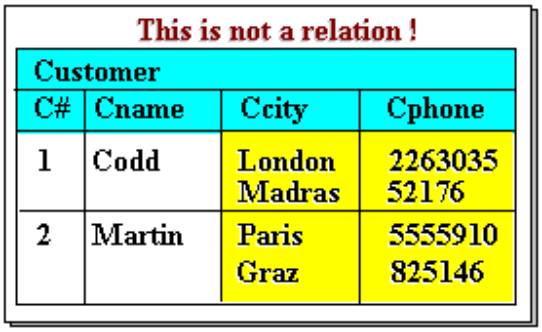


Figure 7 A tuple attribute may only have one value

5. The ordering of tuples is immaterial. This follows directly from defining a relation as a *set* of tuples, rather than a sequence or list. One is free therefore to display a relation in any convenient way, eg. sorted on some attribute.

The *extension* of a relation refers to the current set of tuples in it (see Figure). This will of course vary with time as the database changes, ie. as we insert new tuples, or modify or delete existing ones. Such changes are effected through a DML, or put another way, a DML operates on the extensions of relations.

The more permanent parts of a relation, viz. the relation name and attribute names, are collectively referred to as its *intension* or *schema*. A relation's schema effectively describes (and constrains) the structure of tuples it is permitted to contain. DML operations on tuples are allowed only if they observe the expressed intensions of the affected relations (this partially addresses database integrity concerns raised in the last chapter). Any given database will have a database schema which records the intensions of every relation in it. Schemas are defined using a DDL.

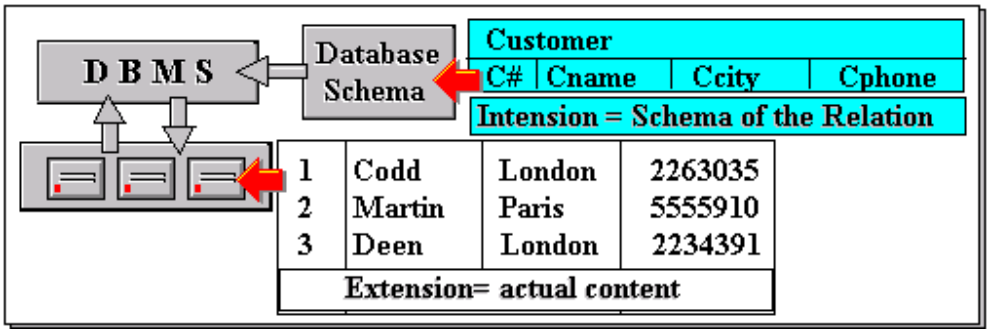


Figure 8 The Intension and Extension of a Relation

Keys of a Relation

A *key* is a part of a tuple (one or more attributes) that uniquely distinguishes it from other tuples in a given relation. Of course, in the extreme, the entire tuple is the key since each tuple in the relation is guaranteed to be unique. However, we are interested in smaller keys if they exist, for a number of practical reasons. First, keys will typically be used as links, ie. key values will appear in other relations to represent their associated tuples (as in Figure above). Thus keys should be as small as possible and comprise only non redundant attributes to avoid unnecessary duplication of data across relations. Second, keys form the basis for constructing indexes to speed up retrieval of tuples from a relation. Small keys will decrease the size of indexes and the time to look up an index.

Consider Figure below. The customer number (C#) attribute is clearly designed to uniquely identify a customer. Thus we would not find two or more tuples in the relation having the same customer number and it can therefore serve as a unique key to tuples in the relation. However, there may be more than one such key in any relation, and these keys may arise from natural attributes of the entity represented (rather than a contrived one, like customer number). Examining again Figure , no two or more tuples have the same value combination of Ccity and Cphone. If we can safely assume that no customer will share a residence and phone number with any other customer, then this combination is one such key. Note that Cphone alone is not - there are two tuples with the same Cphone value (telephone numbers in different cities that happen to be the same). And neither is Ccity alone as we may expect many customers to live in a given city.

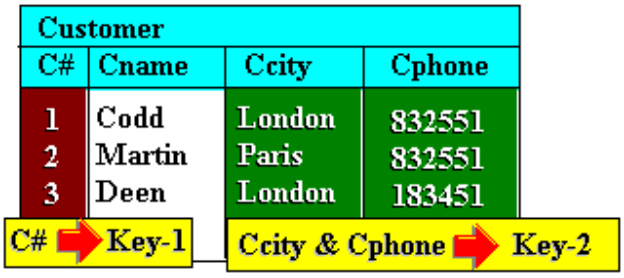


Figure 9 Candidate Keys

While a relation may have two or more *candidate keys*, one must be selected and designated as the *primary key* in the database schema. For the example above, C# is the obvious choice as a primary key for the reasons stated earlier. When the primary key values of one relation appear in

other relations, they are termed *foreign keys*. Note that foreign keys may have duplicate occurrences in a relation, while primary keys may not. For example, in Figure , the C# in Transaction is a foreign key and the key value '1' occurs in two different tuples. This is allowed because a foreign key is only a reference to a tuple in another relation, unlike a primary key value, which must uniquely identify a tuple in the relation.

Relational Schema

A Relational Database Schema comprises

1. the definition of all domains
2. the definition of all relations, specifying for each

a) its intension (all attribute names), and

b) a primary key

Figure 10 shows an example of such a schema which has all the components mentioned above. The primary keys are designated by shading the component attribute names. Of course, this is only an informal view of a schema. Its formal definition must rely on the use of a specific DDL whose syntax may vary from one DBMS to another.

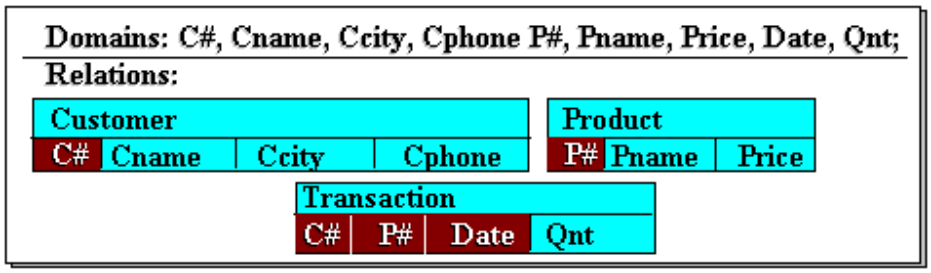


Figure 10 An Example Relational Schema

There is, however, a useful notation for relational schemas commonly adopted to document and communicate database designs free of any specific DDL. It takes the simple form:

<relation name>: <list of attribute names>

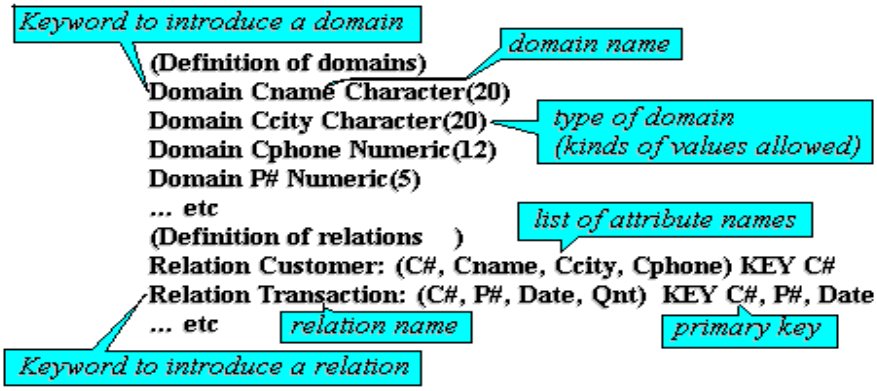
Additionally, attributes that are part of the primary key are underlined.

Thus, for the example in Figure , the schema would be written as follows:

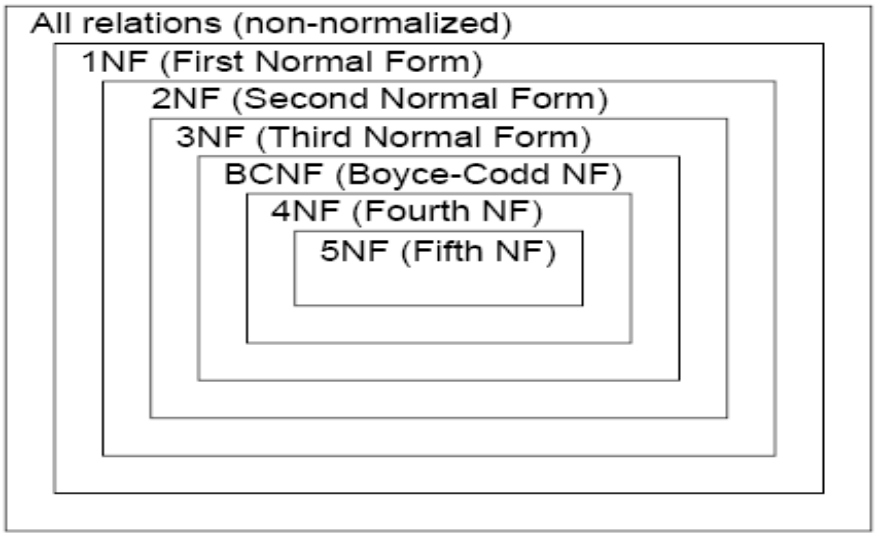
Customer: (C#, Cname, Ccity, Cphone)

Transaction: (C#, P#, Date, Qnt)

Product: (P#, Pname, Price)



This notation is useful in clarifying the overall organisation of the database but omits some details, particularly the properties of domains. As an example of a more complete definition using a more concrete DDL, we rewrite some the schema above using Codd's original notation. The principal components of his notation are annotated alongside.



Functional Dependencies Definition

Functional dependency (FD) is a constraint between two sets of attributes from the database.

o A functional dependency is a property of the semantics or meaning of the attributes. In every relation R(A1, A2,…, An) there is a FD called the PK -> A1, A2, …, An Formally the FD is defined as follows

o If X and Y are two sets of attributes, that are subsets of T

For any two tuples t1 and t2 in r , if t1[X]=t2[X], we must also have t1[Y]=t2[Y].

Notation:

o If the values of Y are determined by the values of X, then it is denoted by X -> Y

o Given the value of one attribute, we can determine the value of another attribute

X f.d. Y or X -> y

Example: Consider the following,

Student Number -> Address, Faculty Number -> Department,

Department Code -> Head of Dept

 Functional dependencies allow us to express constraints that cannot be expressed using supe keys. Consider the schema:

Loan-info-schema = (customer-name, loan-number,

branch-name, amount).

We expect this set of functional dependencies to hold:

loan-number amount

loan-number branch-name

but would not expect the following to hold:

loan-number customer-name

Use of Functional Dependencies

We use functional dependencies to:

o test relations to see if they are legal under a given set of functional dependencies.

o If a relation *r* is legal under a set *F* of functional dependencies, we say that *r* satisfies *F.*

o specify constraints on the set of legal relations

o We say that *F* holds on *R* if all legal relations on *R* satisfy the set of functional dependencies *F.*

 Note: A specific instance of a relation schema may satisfy a functional dependency even if the functional dependency does not hold on all legal instances.

o For example, a specific instance of *Loan-schema* may, by chance, satisfy *loan-number* *customer-name.*

Example

Employee

SSN	**Name**	**JobType**	**DeptName**
557-78-6587	**Lance Smith**	**Accountant**	**Salary**
214-45-2398	**Lance Smith**	**Engineer**	**Product**

Note: Name is functionally dependent on SSN because an employee's name can be uniquely determined from their SSN. Name does not determine SSN, because more than one employee can have the same name.

Keys

- Whereas a key is a set of attributes that uniquely identifies an entire tuple, a functional dependency allows us to express constraints that uniquely identify the values of certain attributes.

- However, a candidate key is always a determinant, but a determinant doesn't need to be a key.

Axioms

- Before we can determine the closure of the relation, Student, we need a set of rules.
- Developed by Armstrong in 1974, there are six rules (axioms) that all possible functional dependencies may be derived from them.

Axioms Cont.

1. ***Reflexivity Rule*** --- If *X* is a set of attributes and *Y* is a subset of *X*, then $X \rightarrow Y$ holds. each subset of *X* is functionally dependent on *X*.

2. ***Augmentation Rule*** --- If $X \rightarrow Y$ holds and *W* is a set of attributes, and then $WX \rightarrow WY$ holds.

3. ***Transitivity Rule*** --- If $X \rightarrow Y$ and $Y \rightarrow Z$ holds, then $X \rightarrow Z$ holds.

Derived Theorems from Axioms

4. ***Union Rule*** --- If $X \rightarrow Y$ and $X \rightarrow Z$ holds, then $X \rightarrow YZ$ holds.

5. ***Decomposition Rule ---*** If $X \rightarrow YZ$ holds, then so do $X \rightarrow Y$ and $X \rightarrow Z$.

6. ***Pseudo transitivity Rule*** --- If $X \rightarrow Y$ and $WY \rightarrow Z$ hold then so does $WX \rightarrow Z$.

Back to the Example

SNo SName CNo CName Addr Instr. Office

Based on the rules provided, the following dependencies can be derived.

$(SNo, CNo) \rightarrow SNo$ (Rule 1) -- subset

$(SNo, CNo) \rightarrow CNo$ (Rule 1)

$(SNo, CNo) \rightarrow (SName, CName)$ (Rule 2) -- augmentation

$CNo \rightarrow office$ (Rule 3) -- transitivity

$SNo \rightarrow (SName, address)$ (Union Rule) etc.

Properties of FDs

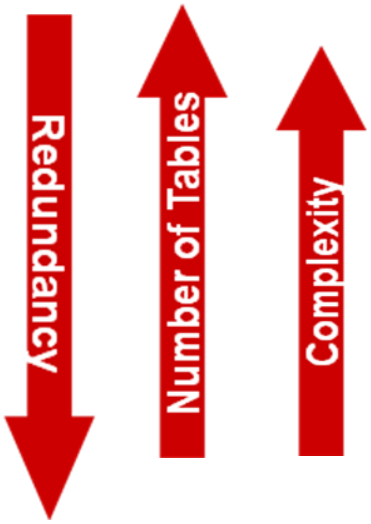
- X → Y says redundant X-values always cause the redundancy of Y-values.
- FDs are given by DBAs or DB designers.
- FDs are enforced/guaranteed by DBMS.
- Given an instance r of a relation R, we can only determine that some FD is not satisfied by R, but can not determine if an FD is satisfied by R.

Database Normalization

- **Database normalization** is the process of removing redundant data from your tables in to improve storage efficiency, data integrity, and scalability.
- In the relational model, methods exist for quantifying how efficient a database is. These classifications are called **normal forms** (or **NF**), and there are algorithms for converting a given database between them.
- Normalization generally involves splitting existing tables into multiple ones, which must be re-joined or linked each time a query is issued.

Levels of Normalization

- Levels of normalization based on the amount of redundancy in the database.
- Various levels of normalization are:
  - First Normal Form (1NF)
  - Second Normal Form (2NF)
  - Third Normal Form (3NF)
  - Boyce-Codd Normal Form (BCNF)
  - Fourth Normal Form (4NF)
  - Fifth Normal Form (5NF)
  - Domain Key Normal Form (DKNF)



- **Most databases should be 3NF or BCNF in order to avoid the database anomalies.**

Data Anomalies

- Data anomalies are inconsistencies in the data stored in a database as a result of an operation such as update, insertion, and/or deletion.
- Such inconsistencies may arise when have a particular record stored in multiple locations and not all of the copies are updated.
- We can prevent such anomalies by implementing 7 different level of normalization called Normal Forms (NF) We'll only look at the first three.First Normal Form (1NF)

1st Normal Form:

The Requirements:

- The requirements to satisfy the 1st NF:
  - Each table has a primary key: minimal set of attributes which can uniquely identify a record
  - The values in each column of a table are atomic (No multi-value attributes allowed).

There are no repeating groups: two columns do not store similar information in the same table

1st Normal Form

Example 1:

Un-normalized Students table:

Student#	AdvID	AdvName	AdvRoom	Class1	Class2
123	123A	James	555	102-8	104-9
124	123B	Smith	467	209-0	102-8

Normalized Students table:

Student#	**AdvID**	**AdvName**	**AdvRoom**	**Class#**
123	123A	James	555	102-8
123	123A	James	555	104-9
124	123B	Smith	467	209-0
124	123B	Smith	467	102-8

Example 2:

Title	**Author1**	**Author2**	**ISBN**	**Subject**	**Pages**	**Publisher**
Database System Concepts	Abraham Silberschatz	Henry F. Korth	0072958863	MySQL, Computers	1168	McGraw-Hill
Operating System Concepts	Abraham Silberschatz	Henry F. Korth	0471694665	Computers	944	McGraw-Hill

Table 1 problems

- This table is not very efficient with storage.
- This design does not protect data integrity.
- Third, this table does not scale well.
- In our Table 1, we have two violations of First Normal Form:
- First, we have more than one author field,
- Second, our subject field contains more than one piece of information. With more than one value in a single field, it would be very difficult to search for all books on a given subject.

Table 2

Title	Author	ISBN	Subject	Pages	Publisher
Database System Concepts	Abraham Silberschatz	0072958863	MySQL	1168	McGraw-Hill
Database System Concepts	Henry F. Korth	0072958863	Computers	1168	McGraw-Hill
Operating System Concepts	Henry F. Korth	0471694665	Computers	944	McGraw-Hill
Operating System Concepts	Abraham Silberschatz	0471694665	Computers	944	McGraw-Hill

- We now have two rows for a single book. Additionally, we would be violating the Second Normal Form…
- A better solution to our problem would be to separate the data into separate tables- an Author table and a Subject table to store our information, removing that information from the Book table:
- Each table has a primary key, used for joining tables together when querying the data. A primary key value must be unique with in the table (no two books can have the same ISBN number), and a primary key is also an index, which speeds up data retrieval based on the primary key.
- Now to define relationships between the tables

Relationships

Book_Author Table

ISBN	Author_ID
0072958863	1
0072958863	2

Book_Subject Table

ISBN	Subject_ID
0072958863	1

Second Normal Form (2NF)

- a form is in 2NF if and only if it is in 1NF and has no attributes which require only part of the key to uniquely identify them
- To do - remove part-key dependencies:
    1. where a key has more than one attribute, check that each non-key attribute depends on the whole key and not part of the key
    2. for each subset of the key which determines an attribute or group of attributes create a new form. Move the *dependant* attributes to the new form.
    3. Add the part key to new form, making it the primary key.
    4. Mark the part key as a foreign key in the original form.
- **Result: 2NF forms**

If each attribute A in a relation schema R meets one of the following criteria:

- It must be in first normal form.
- It is not partially dependent on a candidate key.
- Every non-key attribute is fully dependent on each candidate key of the relation.

Second Normal Form (or 2NF) deals with redundancy of data in vertical columns.

Example of Second Normal Form:

Here is a list of attributes in a table that is in First Normal Form:

Department

Project_Name

Employee_Name

Emp_Hire_Date

Project_Manager

Project_Name and Employee_Name are the candidate key for this table. Emp_Hire_Date and Project_Manager are partially depend on the Employee_Name, but not depend on the Project_Name. Therefore, this table will not satisfy the Second Normal Form

In order to satisfy the Second Normal Form, we need to put the Emp_Hire_Date and Project_Manager to other tables. We can put the Emp_Hire_Date to the Employee table and put the Project_Manager to the Project table.

So now we have three tables:

Department	**Project**
Project_Name	Project_ID
Employee_Name	Project_Name
	Project_Manager

Employee

Employee_ID

Employee_Name

Employee_Hire_Date

Now, the Department table will only have the candidate key left.

Third Normal Form

A relation R is in Third Normal Form (3NF) if and only if it is:

- in Second Normal Form.
- Every non-key attribute is non-transitively dependent on the primary key.

An attribute C is transitively dependent on attribute A if there exists an attribute B such that A → B and B → C, then A → C.

Example of Third Normal Form:

Here is the Second Normal Form of the table for the invoice table:

Complies with Normalization Form 2, Violate's Normalization Form 3

Invoice table

Invoice#	Customer Information		
	Cust#	Name	Address
1001	43	Jones	121 1st
1002	55	Smith	222 2nd
1003	43	Jones	121 1st

Line item table

Invoice#	LIne#	Quant1	Part1	Amt1
1001	1	200	Screw	2.00
1001	2	300	Nut	2.25
1001	3	100	Washr	0.75
1002	1	1	Motor	52.00
1002	2	10	Saw	121.00
1003	1	5	Brace	44.44

It violates the Third Normal Form because there will be redundancy for having multiple invoice number for the same customer. In this example, Jones had both invoice 1001 and 1003.

To solve the problem, we will have to have another table for the Customers

Complies with Normalization Form 3

Invoice table

Invoice#	Cust#
1001	43
1002	55
1003	43

Customer table

Cust#	Name	Address
43	Jones	121 1st
55	Smith	222 2nd

Line item table

Invoice#	LIne#	Quant1	Part1	Amt1
1001	1	200	Screw	2.00
1001	2	300	Nut	2.25
1001	3	100	Washr	0.75
1002	1	1	Motor	52.00
1002	2	10	Saw	121.00
1003	1	5	Brace	44.44

By having Customer table, there will be no transitive relationship between the invoice number and the customer name and address. Also, there will not be redundancy on the customer information

There will be more examples for the First, Second, and Third Normal Forms.

The following is the example of a table that change from each of the normal forms.

Third Normal Form:

Functional Dependency of the Second Normal Form:

SUPPLIER.s# —> SUPPLIER.status (Transitive dependency)

SUPPLIER.s# —> SUPPLIER.city

SUPPLIER.city —> SUPPLIER.status

SUPPLIER_CITY

s#	city
s1	London
s2	Paris
s3	Paris
s4	London
s5	Athens

CITY_STATUS

city	status
London	20
Paris	10
Athens	30
Rome	50

Dependency Preservation:

A FD X! Y is preserved in a relation R if R contains all the attributes of X and Y.

Why Do We Preserve The Dependency?

- We would like to check easily that updates to the database do not result in illegal relations being created.
- It would be nice if our design allowed us to check updates without having to compute natural joins.

Definition

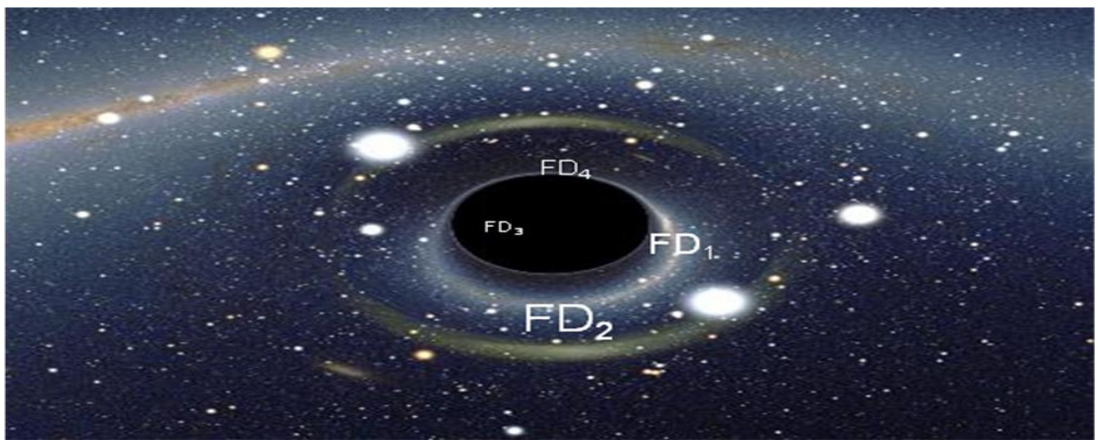
- A decomposition D = {R_1, R_2, ..., R_n} of R is dependency-preserving with respect to F if the union of the projections of F on each R_i in D is equivalent to F; that is

  if $(F_1 \cup F_2 \cup \ldots \cup F_n)^+ = F^+$

Property of Dependency-Preservation

- If decomposition is not dependency-preserving, therefore, that dependency is lost in the decomposition.

Example:



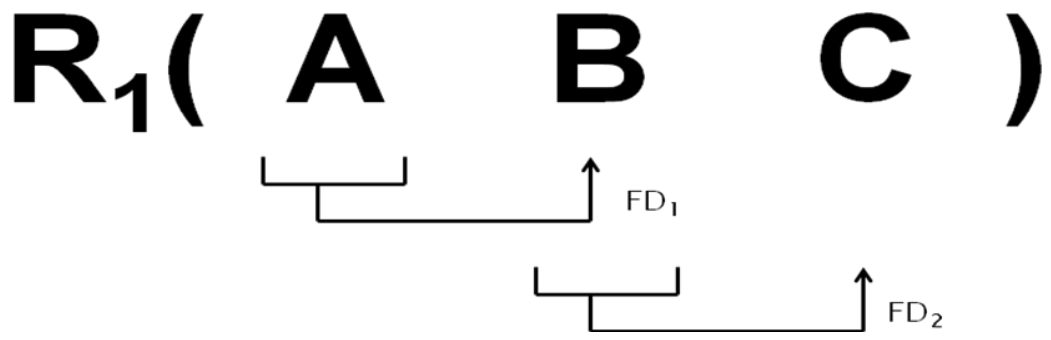
- R(A B C D)
- FD_1: A ➔ B
- FD_2: B ➔ C
- FD_3: C ➔ D
- Decomposition:

  R_1(A B C) R_2(C D)

FD_1: A ➔ B

FD_2: B ➔ C

FD_3: C ➔ D

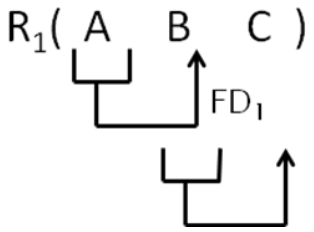


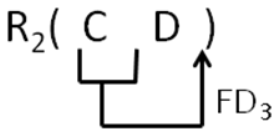
- FD_1: A ➔ B
- FD_2: B ➔ C
- FD_3: C ➔ D

- FD_1: A ➔ B

- FD_2: B ➔ C
- FD_3: C ➔ D

- FD_1: A ➔ B
- FD_2: B ➔ C
- FD_3: C ➔ D



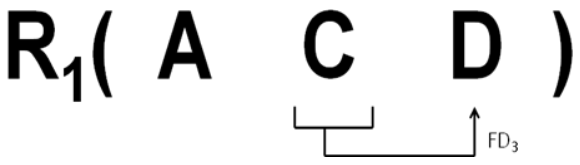


Have all 3 functional dependencies! Therefore, it's preserving the dependencies

Example of Non-Dependency Preservation

- R(A B C D)
- FD_1: A ➔ B
- FD_2: B ➔ C
- FD_3: C ➔ D
- **Decomposition:**

  R_1(A C D) R_2(B C)
- FD_1: A ➔ B
- FD_2: B ➔ C
- FD_3: C ➔ D



- FD_1: A ➔ B
- FD_2: B ➔ C
- FD_3: C ➔ D

- FD_1: A → B
- FD_2: B → C
- FD_3: C → D

Boyce-Codd Normal Form:

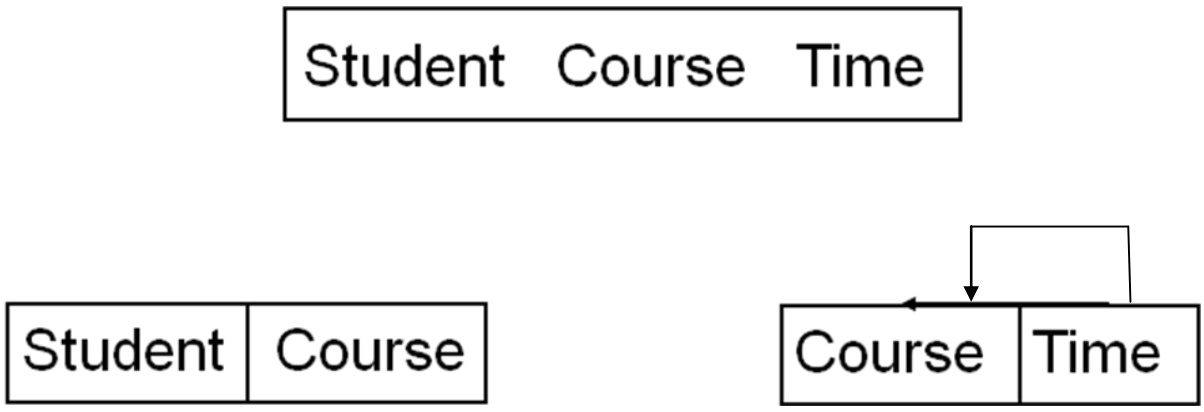
- A relation is in Boyce-Codd normal form (BCNF) if for every FD A → B either
  - B is contained in A (the FD is trivial), or
  - A contains a candidate key of the relation,
- In other words: every determinant in a non-trivial dependency is a (super) key.
- The same as 3NF except in 3NF we only worry about non-key Bs
- If there is only one candidate key then 3NF and BCNF are the same

Stream and BCNF

- Stream is not in BCNF as the FD {Time} → {Course} is non-trivial and {Time} does not contain a candidate key

Student	Course	Time
John	Databases	12:00
Mary	Databases	12:00
Richard	Databases	15:00
Richard	Programming	10:00
Mary	Programming	10:00
Rebecca	Programming	13:00

Conversion to BCNF

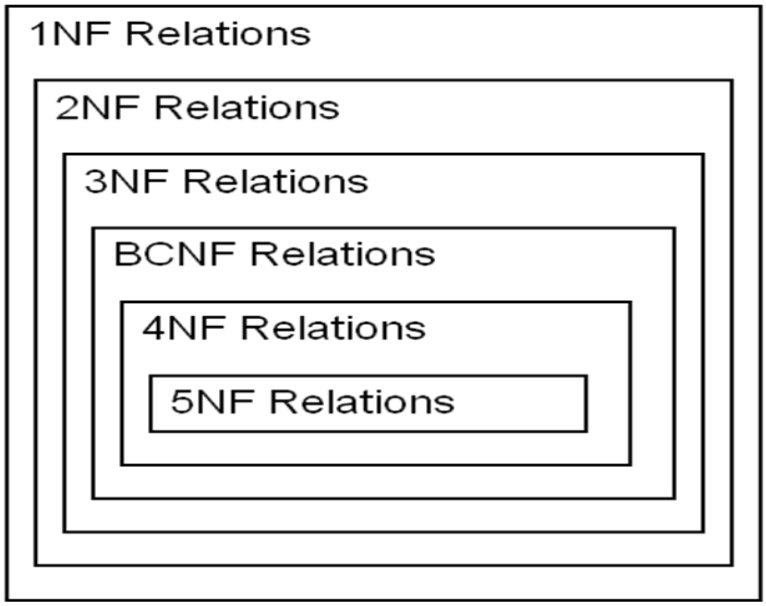


Stream has been put into BCNF but we have lost the FD {Student, Course} → {Time}

Decomposition Properties

- Lossless: Data should not be lost or created when splitting relations up
- Dependency preservation: It is desirable that FDs are preserved when splitting relations up
- Normalisation to 3NF is always lossless and dependency preserving
- Normalisation to BCNF is lossless, but may not preserve all dependencies

Higher Normal Forms:



Converting to BCNF

1. The determinant, Offering#, becomes part of the key and the dependant attribute T_Code, becomes a non key attribute. So the Dependency diagram is now

   S_Num, Offering# → T_Code, Review Date

2. There are problems with this structure as T_Code is now dependant on only part of the key. This violates the rules for 2NF, so the table needs to be divided with the partial dependency becoming a new table. The dependencies would then be

   S_Num, Offering# → T_Code, Review Date

   Offering# → T_Code.

3. The original table is divided into two new tables. Each is in 3NF and in BCNF.

Student Review:

S_num	Offering#	Review Date
123599	01764	2nd march
123599	01765	12th april
123599	01789	2nd may
246700	01764	3rd march
346700	01765	7th may

OfferingTeacher:

Offering#	T_code#

01764	FIT104
01765	PIT305
01789	PIT107

Note that even relations in BCNF can have anomalies.

Anomalies:

INSERT: We cannot record the city for a supplier_no without also knowing the supplier_name

DELETE: If we delete the row for a given supplier_name, we lose the information that the supplier_no is associated with a given city.

UPDATE: Since supplier_name is a candidate key (unique), there are none.

Definition of MVD

- A multivalued dependency is a *full constraint* between two sets of attributes in a relation.
- In contrast to the *functional independency*, the multivalued dependency requires that certain tuples be present in a relation. Therefore, a multivalued dependency is also referred as a *tuple-generating* dependency. The multivalued dependency also plays a role in 4NF normalization.

Full constraint

- A constraint which expresses something about *all* attributes in a database. (In contrary to an **embedded constraint**.) That a multivalued dependency is a *full constraint* follows from its definition, where it says something about the attributes $R - \beta$.

Tuple-generating dependency

- A dependency which explicitly requires certain tuples to be present in the relation.

A Formal Definition

Let *R* be a relation schema and let and . The multivalued dependency α ->> β holds on *R* if, in any legal relation *r*(*R*), for all pairs of tuples *t*1 and

*t*2 in *r* such that *t*1[α] = *t*2[α], there exist tuples *t*3 and *t*4 in *r* such that

*t*1[α] = *t*2[α] = *t*3[α] = *t*4[α]

*t*3[β] = *t*1[β]

$t3[R - \beta] = t2[R - \beta]$

$t4[\beta] = t2[\beta]$

$t4[R - \beta] = t1[R - \beta]$

- A multivalued dependency on R, X ->>Y, says that if two tuples of R agree on all the attributes of X, then their components in Y may be swapped, and the result will be two tuples that are also in the relation.

i.e., for each value of *X*, the values of *Y* are independent of the values of *R-X-Y*

Tuples Implied by name->->phones

If we have tuples:

name	addr	phones	beersLiked
sue	a	p1	b1
sue	a	p2	b2
sue	a	p2	b1
sue	a	p1	b2

Then these tuples must also be in the relation.

Example

Here is possible data satisfying these MVD's:

name	areaCode	phone	beersLiked	manf
Sue	650	555-1111	Bud	A.B.
Sue	650	555-1111	WickedAle	Pete's
Sue	415	555-9999	Bud	A.B.
Sue	415	555-9999	WickedAle	Pete's

But we cannot swap area codes or phones by themselves. That is, neither name->->areaCode nor name->->phone holds for this relation.

Properties of MVD

- f α ->> β, Then α ->> *R* – β
- If α ->> β and δ ⊆ γ , Then αδ ->> βγ
- If α ->> β and If β ->> γ, then α ->> γ - β

The following also involve functional dependencies:

- If α ->> β , then α ->> β
- If α -> β and β -> γ, then α -> γ – β
- A decomposition of R into (X, Y) and (X, R-Y) is a lossless-join decomposition if and only if X ->> Y holds in R.

MVD Rules

• Every FD is an MVD

– If *X* ->*Y*, then swapping *Y*'s between two tuples that agree on *X* doesn't change the tuples.

– Therefore, the "new" tuples are surely in the relation, and we know *X* ->->*Y*.

• Definition of keys depend on FDs and not MDs.

- Requires that other tuples of a certain form be present in the relation.
- Also referred to as:

"Tuple-generating dependency"

We can use multivalued dependencies

- To test relations to determine whether they are legal under a given set of functional and multivalued dependencies
- To specify constraints on the set of legal relations.

4th Normal Form

A Boyce Codd normal form relation is in fourth normal form if

- there is no multi value dependency in the relation or
- there are multi value dependency but the attributes, which are multi value dependent on a specific attribute, are dependent between themselves.
- This is best discussed through mathematical notation.
- Assume the following relation

(a) **R(a:pk1, b:pk2, c:pk3)**

- Recall that a relation is in BCNF if all its determinant are candidate keys, in other words each determinant can be used as a primary key.
- Because relation **R** has only one determinant **(a, b, c)**, which is the composite primary key and since the primary is a candidate key therefore R is in BCNF.

Now R may or may not be in fourth normal form.

- If R contains **no multi value dependency** then R will be in Fourth normal form.
- Assume R has the following two-multi value dependencies:
- **a --->> b** **and** **a --->> c**

- In this case R will be in the fourth normal form if **b** and **c <u>dependent on each other</u>.**
- However if b and **c are independent of each other** then **<u>R is not</u>** in **<u>fourth</u>** <u>normal form</u> and the relation has to be projected to following two non-loss projections. These non-loss projections will be in fourth normal form.

Many-to-many relationships

- Fourth Normal Form applies to situations involving many-to-many relationships.
- In relational databases, many-to-many relationships are expressed through cross-reference tables.

Note about FDs and MVDs

- Every Functional Dependency is a MVD

(if $A_1A_2…A_n$ ® $B_1B_2…B_n$, then $A_1A_2…A_n$ Þ $B_1B_2…B_n$)

- FDs rule out certain tuples (i.e. if A ® B then two tuples will not have the same value for A and different values for B)
- MVDs do not rule out tuples. They guarantee that certain tuples must exist.

4th NF and Anomalies

- As an example of the anomalies that can occur, realize that it is not possible to add a new class taught by some teacher without adding at least one student who is enrolled in this class.
- To achieve 4NF, represent each independent many-to-many relationship through its own cross-reference table.

<u>Case 1:</u>

Assume the following relation:

Employee (Eid:pk1, Language:pk2, Skill:pk3)

No multi value dependency, therefore R is in fourth normal form.

<u>Case 2:</u>

Assume the following relation with multi-value dependency:

Employee (Eid:pk1, Languages:pk2, Skills:pk3)

Eid --->> Languages **Eid --->> Skills**

- Languages and Skills are dependent.
- This says an employee speak several languages and has several skills. However for each skill a specific language is used when that skill is practiced
- **Thus employee 100 when he/she teaches speaks English but when he cooks speaks French. This relation is in fourth normal form and does not suffer from any anomalies.**

Eid	Language	Skill
100	English	Teaching
100	Kurdish	Politic
100	French	Cooking
200	English	Cooking
200	Arabic	Singing

Case 3:

- Assume the following relation with multi-value dependency:

  Employee (Eid:pk1, Languages:pk2, Skills:pk3)

  Eid --->> Languages **Eid --->> Skills**

  Languages and Skills are independent.
- This relation is not in fourth normal form and suffers from all three types of anomalies.

Eid	Language	Skill
100	English	Teaching
100	Kurdish	Politic
100	English	Politic
100	Kurdish	Teaching
200	Arabic	Singing

Insertion anomaly: To insert row (200 English Cooking) we have to insert two extra rows (200 Arabic cooking), and (200 English Singing) otherwise the database will be inconsistent. Note the table will be as follow:

Eid	Language	Skill
100	English	Teaching
100	Kurdish	Politics
100	English	Politics
100	Kurdish	Teaching
200	Arabic	Singing
200	English	Cooking
200	Arabic	Cooking
200	English	Singing

Deletion anomaly: If employee 100 discontinues politic skill we have to delete two rows: (100 Kurdish Politic), and (100 English Politic) otherwise the database will be inconsistent.

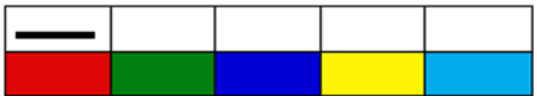
Eid	Language	Skill
100	English	Teaching
100	Kurdish	Politics
100	English	Politics
100	Kurdish	Teaching
200	Arabic	Singing
200	English	Cooking
200	Arabic	Cooking
200	English	Singing

FIFTH NORMAL FORM

- R is in 5NF if and only if every join dependency in R is implied by the candidate keys of R
- 5NF is always achievable.

- a join dependency, * (A, B, …, Z), is implied by the candidate keys, K1, …, Km of R if
- the fact that K1, …, Km are candidate keys for R determine the fact that R has the JD * (A, B, …, Z)

R



A relation R is in 5NF iff

for all JD * (R_1, R_2, R_3, ..., R_m) in R,
every R_i is a superkey for R.

if

JD* ( , ) holds for R

does not contain key

then R is not in 5NF

if

JD* ( , )

JD* ( , )

then R is in 5NF

Problems in bringing a relation to 5NF

- check whether all JDs are implied by the candidate keys
    - Fagin : provides an algorithm for doing this for any relation, given all its JDs and all candidate keys
- discover **all** JDs for a given relation
    - they do not have that intuitive meaning as FDs or MVDs
- A relation is in 5NF if every join dependency in the relation is implied by the keys of the relation
- Implies that relations that have been decomposed in previous normal forms can be recombined via natural joins to recreate the original relation.

Usage

Only in rare situations does a 4NF table not conform to 5NF. These are situations in which a complex real-world constraint governing the valid combinations of attribute values in the 4NF table is not implicit in the structure of that table. If such a table is not normalized to 5NF, the burden of maintaining the logical consistency of the data within the table must be carried partly by the application responsible for insertions, deletions, and updates to it; and there is a heightened risk that the data within the table will become inconsistent. In contrast, the 5NF design excludes the possibility of such inconsistencies.

Example 2:

- Consider a relation Supply (sname, partName, projName). Add the additional constraint that:
- If project j requires part p
- and supplier s supplies part p
- and supplier s supplies at least one item to project j Then
- supplier s also supplies part p to project j

Original Supply Relation

sname	partName	projName
Smith	Bolt	X
Smith	Nut	Y
Adam	Bolt	Y
Walton	Nut	Z
Adam	Nail	X

Supply Relation with new constraint

sname	partName	projName
Smith	Bolt	X
Smith	Nut	Y
Adam	Bolt	Y
Walton	Nut	Z
Adam	Nail	X
Adam	**Bolt**	**X**
Smith	**Bolt**	**Y**

As Adam supplies X (Nail) and Adam supplies Bolt and X uses Bolt.

As Smith supplies Y (Nut) and Smith supplies Both and Y uses Bolt.

sname	partName	projName
Smith	Bolt	X
Smith	Nut	Y
Adam	Bolt	Y
Walton	Nut	Z
Adam	Nail	X
Adam	Bolt	X
Smith	Bolt	Y

sname	partName
Smith	Bolt
Smith	Nut
Adam	Bolt
Walton	Nut
Adam	Nail

sname	projName
Smith	X
Smith	Y
Adam	Y
Walton	Z
Adam	X

partName	projName
Bolt	X
Nut	Y
Bolt	Y
Nut	Z
Nail	X

Let R be in BCNF and let R have no composite keys. Then R is in 5NF

Note: That only joining all three relations together will get you back to the original relation. Joining any two will create spurious tuples!

UNIT II SQL & QUERY OPTIMIZATION 8

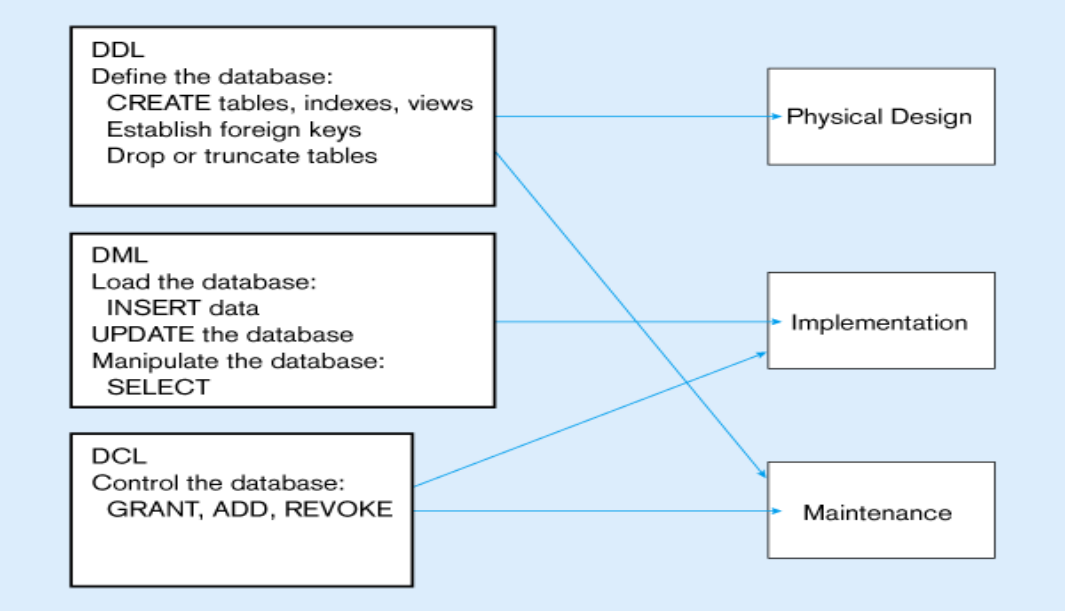
SQL Standards - Data types - Database Objects- DDL-DML-DCL-TCL-Embedded SQL-Static Vs Dynamic SQL - QUERY OPTIMIZATION: Query Processing and Optimization - Heuristics and Cost Estimates in Query Optimization.

Textbook:

Ramez Elmasri and Shamkant B. Navathe, "Fundamentals of Database Systems", Fifth Edition, Pearson Education, 2008.

SQL Overview

- Structured Query Language
- The standard for relational database management systems (RDBMS)
- SQL-92 and SQL-99 Standards – Purpose:
  - Specify syntax/semantics for data definition and manipulation
  - Define data structures
  - Enable portability
  - Specify minimal (level 1) and complete (level 2) standards
  - Allow for later growth/enhancement to standard
- Catalog
  - A set of schemas that constitute the description of a database
- Schema
  - The structure that contains descriptions of objects created by a user (base tables, views, constraints)
- Data Definition Language (DDL)
  - Commands that define a database, including creating, altering, and dropping tables and establishing constraints
- Data Manipulation Language (DML)
  - Commands that maintain and query a database
- Data Control Language (DCL)
  - Commands that control a database, including administering privileges and committing data



SQL Database Definition

- Data Definition Language (DDL)
- Major CREATE statements:
  - CREATE SCHEMA – defines a portion of the database owned by a particular user
  - CREATE TABLE – defines a table and its columns
  - CREATE VIEW – defines a logical table from one or more views
- Other CREATE statements: CHARACTER SET, COLLATION, TRANSLATION, ASSERTION, DOMAIN
- In SQL, a VIEW is a virtual relation based on the result-set of a SELECT statement.
- A view contains rows and columns, just like a real table. The fields in a view are fields from one or more real tables in the database. In some cases, we can modify a view and present the data as if the data were coming from a single table.
- Syntax:

CREATE VIEW view_name **AS SELECT** column_name(s) **FROM** table_name **WHERE** condition

SQL – Relations, Tables & Views

- When we say Relation, it could be a Table or a View. There are three kind of relations:

1. Stored relations → tables

We sometimes use the term "base relation" or "base table"

1. Virtual relations → views
2. Temporary results

SQL – Create View

- Example: Create a view with title and year and made by Paramount studio. Movie (title, year, length, inColor, studioName, producerC#)

CREATE VIEW ParamountMovie **AS SELECT** title,year **FROM** Movie **WHERE** studioName = 'Paramount';

SQL – Querying View

- A view could be used from inside a query, a stored procedure, or from inside another view. By adding functions, joins, etc., to a view, it allows us to present exactly the data we want to the user.

SELECT title **FROM** ParamountMovie **WHERE** year = '1979';

- Have same result as

SELECT title **FROM** Movie **WHERE** studioName = 'Paramount' **AND** year = '1979';

Example:

Movie (title, year, length, inColor, studioName, producerC#) MovieExec (name, address, cert#, netWorth)

CREATE VIEW MovieProd **AS SELECT** title, name **FROM** Movie, MovieExec **WHERE** producerC# = cert#; **SELECT** name **FROM** MovieProd **WHERE** title = 'Gone With the Wind';

- Same result as query from tables

SELECT name **FROM** Movie, MovieExec **WHERE** producerC# = cert# **AND** title = 'The War Of the World';

Data Types in SQL

Numeric types	integer	integer, int, smallint, long
	floating point	float, real, double precision
	formatted	decimal(i,j), dec(i,j)
Character-string types	fixed length	char(n), character(n)
	varying length	varchar(n), char varying(n), character varying(n)
Bit-string types	fixed length	bit(n)
	varying length	bit varying(n)
Date and time types		date, time, datetime, timestamp, time with time zone, interval
Large types	character	long varchar(n), clob, text
	binary	blob

- String types
  - CHAR(n) – fixed-length character data, n characters long Maximum length = 2000 bytes
  - VARCHAR2(n) – variable length character data, maximum 4000 bytes
  - LONG – variable-length character data, up to 4GB. Maximum 1 per table
- Numeric types
  - NUMBER(p,q) – general purpose numeric data type
  - INTEGER(p) – signed integer, p digits wide
  - FLOAT(p) – floating point in scientific notation with p binary digits precision
- Date/time type
  - DATE – fixed-length date/time in dd-mm-yy form

-
  -

An **object database** (also **object-oriented database management system**) is a database management system in which information is represented in the form of objects as used in object-oriented programming. Object databases are different from relational databases which are table-oriented. Object-relational databases are a hybrid of both approaches.

Object-oriented database management systems (OODBMSs) combine database capabilities with object-oriented programming language capabilities. OODBMSs allow object-oriented programmers to develop the product, store them as objects, and replicate or modify existing objects to make new objects within the OODBMS. Because the database is integrated with the programming language, the programmer can maintain consistency within one environment, in that both the OODBMS and the programming language will use the same model of representation. Relational DBMS projects, by way of contrast, maintain a clearer division between the database model and the application.

class Dbms()
Creates a Dbms object. Dbms objects support basic operations on a database.

Dbms objects have the following methods:

begin()
Begins a transaction on the database.
close()
Closes the database object. It is safe to try to close a database object even if it is not open.
commit()
Commits the current transaction.

compact()
Compacts the database, reclaiming unused space in the database file.
create(*dbname*)
Creates a database with path *dbname*.
execute(*query*)
Executes an SQL *query*. On success, returns 0 if a DDL (SQL schema update) statement was executed. Returns the number of rows inserted, updated, or deleted, if a DML (SQL data update) statement was executed.
open(*dbname*)
Opens the database in file *dbname*. This should be a full Unicode path name, for example, u'c:\\foo.db'.
rollback()
Rolls back the current transaction.

Data Definition Language:

A **data definition language** or **data description language** (**DDL**) is a syntax similar to a computer programming language for defining data structures, especially database schemas. Many data description languages use a declarative syntax to define fields and data types. SQL, however, uses a collection of imperative verbs whose effect is to modify the schema of the database by adding, changing, or deleting definitions of tables or other objects. These statements can be freely mixed with other SQL statements, so the DDL is not truly a separate language.

CREATE statements

Create - To make a new database, table, index, or stored procedure.

A CREATE statement in SQL creates an object in a relational database management system (RDBMS). In the SQL 1992 specification, the types of objects that can be created are schemas, tables, views, domains, character sets, collations, translations, and assertions. Many implementations extend the syntax to allow creation of additional objects, such as indexes and user profiles. Some systems (such as PostgreSQL) allow CREATE, and other DDL commands, inside a transaction and thus they may be rolled back.

CREATE TABLE statement

A commonly used CREATE command is the CREATE TABLE command. The typical usage is:

CREATE TABLE *[table name]* (*[column definitions]*) *[table parameters]*.

column definitions: A comma-separated list consisting of any of the following

- Column definition: *[column name] [data type] {NULL | NOT NULL} {column options}*
- Primary key definition: *PRIMARY KEY* (*[comma separated column list]*)
- Constraints: *{CONSTRAINT} [constraint definition]*
- RDBMS specific functionality

For example, the command to create a table named **employees** with a few sample columns would be:

```
CREATE TABLE employees (
   id          INTEGER     PRIMARY KEY,
   first_name    VARCHAR(50)  NULL,
   last_name     VARCHAR(75)  NOT NULL,
   fname         VARCHAR(50)  NOT NULL,
   dateofbirth   DATE        NULL
);
```

DROP statements

Drop - To destroy an existing database, table, index, or view.

A **DROP** statement in SQL removes an object from a relational database management system (RDBMS). The types of objects that can be dropped depends on which RDBMS is being used, but most support the dropping of tables, users, and databases. Some systems (such as PostgreSQL) allow DROP and other DDL commands to occur inside of a transaction and thus be rolled back.

DROP *objecttype objectname*.

For example, the command to drop a table named **employees** would be:

DROP employees;

The DROP statement is distinct from the DELETE and TRUNCATE statements, in that DELETE and TRUNCATE do not remove the table itself. For example, a DELETE statement might delete some (or all) data from a table while leaving the table itself in the database, whereas a DROP statement would remove the entire table from the database.

ALTER statements

Alter - To modify an existing database object.

An ALTER statement in SQL changes the properties of an object inside of a relational database management system (RDBMS). The types of objects that can be altered depends on which RDBMS is being used. The typical usage is:

ALTER *objecttype objectname parameters*.

For example, the command to add (then remove) a column named **bubbles** for an existing table named **sink** would be:

```
ALTER TABLE sink ADD bubbles INTEGER;
ALTER TABLE sink DROP COLUMN bubbles;
```

Rename statement

Rename - to rename the table. for example

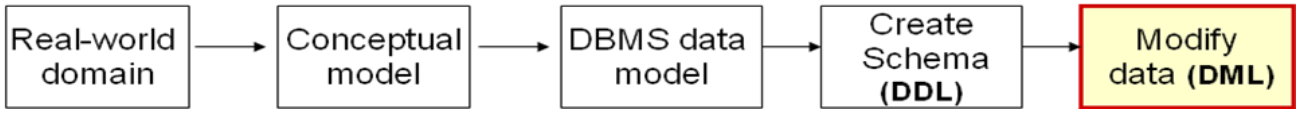

```
RENAME TABLE old_name TO new_name;
```

Referential integrity statements

Finally, another kind of DDL sentence in SQL is one used to define referential integrity relationships, usually implemented as primary key and foreign key tags in some columns of the tables. These two statements can be included inside a CREATE TABLE or an ALTER TABLE sentence.

Data Manipulation Language (DML)

A **data manipulation language** (**DML**) is a family of syntax elements similar to a computer programming language used for Selecting , inserting, deleting and updating data in a database. Performing read-only queries of data is sometimes also considered a component of DML.



A popular data manipulation language is that of Structured Query Language (SQL), which is used to retrieve and manipulate data in a relational database. Other forms of DML are those used by IMS/DLI, CODASYL databases, such as IDMS and others.

A data manipulation language (DML) is a family of computer languages including commands permitting users to manipulate data in a database. This manipulation involves inserting data into database tables, retrieving existing data, deleting data from existing tables and modifying existing data. DML is mostly incorporated in SQL databases.

Data manipulation language comprises the SQL data change statements, which modify stored data but not the schema or database objects. Manipulation of persistent database objects, e.g., tables or stored procedures, via the SQL schema statements, rather than the data stored within them, is considered to be part of a separate data definition language. In SQL these two categories are similar in their detailed syntax, data types, expressions etc., but distinct in their overall function.

DML resembles simple English language and enhances efficient user interaction with the system. The functional capability of DML is organized in manipulation commands like SELECT, UPDATE, INSERT INTO and DELETE FROM, as described below:

- SELECT: This command is used to retrieve rows from a table. The select syntax is SELECT [column name(s)] from [table name] where [conditions]. Select is the most widely used DML command in SQL.
- UPDATE: This command modifies data of one or more records. An update command syntax is UPDATE table name SET column name = value where [condition].
- INSERT: This command adds one or more records to a database table. The insert command syntax is INSERT INTO table name [column(s)] VALUES [value(s)].
- DELETE: This command removes one or more records from a table according to specified conditions. Delete command syntax is DELETE FROM table name where [condition].

- Data manipulation languages have their functional capability organized by the initial word in a statement, which is almost always a verb. In the case of SQL, these verbs are:

SELECT ... FROM ... WHERE ...
INSERT INTO ... VALUES ...
UPDATE ... SET ... WHERE ...
DELETE FROM ... WHERE ...

1.Select Command

Syntax

SELECT [DISTINCT|ALL]{*|column|column_expression [AS new_name][,…]}

FROM table_name [alias] [, …]

[WHERE condition]

[GROUP BY column_list]

[HAVING condition]

[ORDER BY column_list [ASC|DESC]];

- *column* represents a column name.
- *column_expression* represents an expression on a column.
- *table_name* is the name of an existing database table or view.
- FROM specifies the table(s) to be used.
- WHERE filters the rows subject to some condition.
- GROUP BY forms groups of rows with the same column name.
- SELECT specifies which column are to appear in the output.
- ORDER BY specifies the order of the output.
- Order of the clauses in the SELECT statement can not be changed.
- The result of a query is another table.
- Asterisk (*) means all columns.

Five aggregation functions defined in SQL:

- COUNT returns the number of rows in a specified column.
- SUM returns the sum of the values in a specified column.
- AVG returns the average of the values in a specified column.
- MIN returns the smallest value in a specified column.
- MAX returns the largest value in a specified column.

Examples:

Property (PropertyNo, Street, City, postcode, Type, OwnerNo, Rooms, Rent)

How many properties cost more than 350 per month to rent?

SELECT COUNT(*) AS count FROM property WHERE rent > 350;

Subqueries

- A complete SELECT statement can be embedded (subselect) within another SELECT statement.
- A subselect can be used in the WHERE and HAVING clauses of the outer SELECT statement (nested query).
- A subquery can be used immediately following a relational operator.
- Subquery always enclosed in parentheses.

Type of subquery:

- A *scalar subquery* returns a single column and a single row (singlevalue).
- A *row subquery* returns multiple columns, but a single row.
- A *table subquery* returns one or more columns and multiple rows.

STAFF (sno, fname, lname, position, sex, DOB, salary, bno)
BRANCH (bno, street, city, postcode)

Example:

List the staff who work in the branch at '163 Main St'.

SELECT sno, fname, lname, position FROM staff WHERE bno = (SELECT bno FROM branch WHERE street = '163 Main St');

Modifying Data in the DB (UPDATE)

Syntax

UPDATE table_name
SET column_name1 = data_value1 [, column_namei = data_valuei ...]
[WHERE search_condition]

- *table_name* may be either a base table or an updatable view.
- The SET clause specifies the names of one or more columns that are updated for all rows in the table.
- Only rows that satisfy the *search_condition* are updated.
- *data_values* must be compatible with the data types for the corresponding columns.

Data Control Language

A data control language (DCL) is a syntax similar to a computer programming language used to control access to data stored in a database. In particular, it is a component of Structured Query Language (SQL).

It is used to create roles, permissions, and referential integrity as well it is used to control access to database by securing it. These SQL commands are used for providing security to database objects. These commands are GRANT and REVOKE.

Examples of DCL commands include:

- GRANT to allow specified users to perform specified tasks.
- REVOKE to cancel previously granted or denied permissions.

The **Data Control Language (DCL)** component of the SQL language is used to create privileges to allow users access to, and manipulation of, the database. There are two main commands:

GRANT to grant a privilege to a user
REVOKE to revoke (remove) a privilege from a user

The operations for which privileges may be granted to or revoked from a user or role may include CONNECT, SELECT, INSERT, UPDATE, DELETE, EXECUTE, and USAGE. In the Oracle database, executing a DCL command issues an implicit commit. Hence you cannot roll back the command. In PostgreSQL, executing DCL is transactional, and can be rolled back.

SQL GRANT REVOKE Commands

DCL commands are used to enforce database security in a multiple user database environment. Two types of DCL commands are GRANT and REVOKE. Only Database Administrator's or owner's of the database object can provide/remove privileges on a database object.

SQL GRANT Command

SQL GRANT is a command used to provide access or privileges on the database objects to the users.

The Syntax for the GRANT command is:

GRANT privilege_name ON object_name TO {user_name |PUBLIC |role_name} [WITH GRANT OPTION];

- **privilege_name** is the access right or privilege granted to the user. Some of the access rights are ALL, EXECUTE, and SELECT.
- **object_name** is the name of an database object like TABLE, VIEW, STORED PROC and SEQUENCE.
- **user_name** is the name of the user to whom an access right is being granted.
- **user_name** is the name of the user to whom an access right is being granted.
- **PUBLIC** is used to grant access rights to all users.
- **ROLES** are a set of privileges grouped together.
- **WITH GRANT OPTION** - allows a user to grant access rights to other users.

For Example: GRANT SELECT ON employee TO user1; This command grants a SELECT permission on employee table to user1.You should use the WITH GRANT option carefully because

for example if you GRANT SELECT privilege on employee table to user1 using the WITH GRANT option, then user1 can GRANT SELECT privilege on employee table to another user, such as user2 etc. Later, if you REVOKE the SELECT privilege on employee from user1, still user2 will have SELECT privilege on employee table.

SQL REVOKE Command:

The REVOKE command removes user access rights or privileges to the database objects.

The Syntax for the REVOKE command is:

REVOKE privilege_name ON object_name FROM {user_name |PUBLIC |role_name}

For Example: REVOKE SELECT ON employee FROM user1;This command will REVOKE a SELECT privilege on employee table from user1.When you REVOKE SELECT privilege on a table from a user, the user will not be able to SELECT data from that table anymore. However, if the user has received SELECT privileges on that table from more than one users, he/she can SELECT from that table until everyone who granted the permission revokes it.

Privileges and Roles:

Privileges: Privileges defines the access rights provided to a user on a database object. There are two types of privileges.

1) System privileges - This allows the user to CREATE, ALTER, or DROP database objects.
2) Object privileges - This allows the user to EXECUTE, SELECT, INSERT, UPDATE, or DELETE data from database objects to which the privileges apply.

Few CREATE system privileges are listed below:

System Privileges	Description
CREATE object	allows users to create the specified object in their own schema.
CREATE ANY object	allows users to create the specified object in any schema.

The above rules also apply for ALTER and DROP system privileges.

Few of the object privileges are listed below:

Object Privileges	Description

INSERT	allows users to insert rows into a table.
SELECT	allows users to select data from a database object.
UPDATE	allows user to update data in a table.
EXECUTE	allows user to execute a stored procedure or a function.

Roles: Roles are a collection of privileges or access rights. When there are many users in a database it becomes difficult to grant or revoke privileges to users. Therefore, if you define roles, you can grant or revoke privileges to users, thereby automatically granting or revoking privileges. You can either create Roles or use the system roles pre-defined by oracle.

Some of the privileges granted to the system roles are as given below:

System Role	Privileges Granted to the Role
CONNECT	CREATE TABLE, CREATE VIEW, CREATE SYNONYM, CREATE SEQUENCE, CREATE SESSION etc.
RESOURCE	CREATE PROCEDURE, CREATE SEQUENCE, CREATE TABLE, CREATE TRIGGER etc. The primary usage of the RESOURCE role is to restrict access to database objects.
DBA	ALL SYSTEM PRIVILEGES

Creating Roles:

The Syntax to create a role is:

CREATE ROLE role_name [IDENTIFIED BY password];

For Example: To create a role called "developer" with password as "pwd",the code will be as follows

CREATE ROLE testing [IDENTIFIED BY pwd];

It's easier to GRANT or REVOKE privileges to the users through a role rather than assigning a privilege directly to every user. If a role is identified by a password, then, when you GRANT or REVOKE privileges to the role, you definitely have to identify it with the password.

We can GRANT or REVOKE privilege to a role as below.

For example: To grant CREATE TABLE privilege to a user by creating a testing role:

First, create a testing Role

CREATE ROLE testing

Second, grant a CREATE TABLE privilege to the ROLE testing. You can add more privileges to the ROLE.

GRANT CREATE TABLE TO testing;

Third, grant the role to a user.

GRANT testing TO user1;

To revoke a CREATE TABLE privilege from testing ROLE, you can write:

REVOKE CREATE TABLE FROM testing;

The Syntax to drop a role from the database is as below:

DROP ROLE role_name;

For example: To drop a role called developer, you can write:

DROP ROLE testing;

GRANT command

In order to do anything within an Oracle database you must be given the appropriate privileges. Oracle operates a closed system in that you cannot perform any action at all unless you have been authorized to do so. This includes logging onto the database, creating tables, views, indexes and synonyms, manipulating data (ie select, insert, update and delete) in tables created by other users, etc.

The SQL command to grant a privilege on a table is:

GRANT SELECT, INSERT, UPDATE, DELETE ON tablename TO username;

There are many more forms of the GRANT command, but this is sufficient for this Unit.

Any combination of the above privileges is allowed. You can issue this command on any tables that you have created. For example:

GRANT SELECT ON employee TO hn23;
GRANT SELECT, UPDATE, DELETE ON employee TO hn44;

REVOKE command

The SQL command to revoke a privilege on a table is:

REVOKE SELECT, INSERT, UPDATE, DELETE ON tablename FROM username;

For example:

REVOKE SELECT ON employee FROM hn23;

REVOKE SELECT, UPDATE, DELETE FROM hn44;

Transaction Control Language (TCL)

A Transaction Control Language (TCL) is a computer language and a subset of SQL, used to control transactional processing in a database. A transaction is logical unit of work that comprises one or more SQL statements, usually a group of Data Manipulation Language (DML) statements.

A series of one or more SQL statements that are logically related, or a series of operation performed on Oracle table data is termed as a Transaction. Oracle treats changes to table data as a two step process. First the changes requested are done. To make these changes permanent a COMMIT statement has to be given at the SQL prompt. A ROLLBACK statement given at the SQL prompt can be used to undo a part of or the entire Transaction.

A Transaction begins with the first executable SQL statement after a Commit, Rollback or Connection made to the Oracle engine. All changes made to an Oracle table data via a transaction are made or undo at one instance.

Specially, a Transaction is a group of events that occurs between any of the following events:

- Connecting to Oracle
- Disconnecting from Oracle
- Committing changes to the table
- Rollback

TCL is abbreviation of Transactional Control Language. It is used to manage different transactions occurring within a database.

Examples of TCL commands include:

- COMMIT to apply the transaction by saving the database changes.
- ROLLBACK to undo all changes of a transaction.
- SAVEPOINT to divide the transaction into smaller sections. It defines breakpoints for a transaction to allow partial rollbacks.

COMMIT

PURPOSE: To end your current transaction and make permanent all changes performed in the transaction. This command also erases all savepoints in the transaction and releases the transaction's locks. You can also use this command to manually commit an in-doubt distributed transaction.

SYNTAX:

```
COMMIT [WORK]  [ COMMENT 'text'   | FORCE 'text' [, integer] ]
```


Where:

- WORK : is supported only for compliance with standard SQL. The statements COMMIT and COMMIT WORK are equivalent.
- COMMENT : specifies a comment to be associated with the current transaction. The 'text' is a quoted literal of up to 50 characters that Oracle stores in the data dictionary view DBA_2PC_PENDING along with the transaction ID if the transaction becomes in-doubt.
- FORCE : manually commits an in-doubt distributed transaction. The transaction is identified by the 'text' containing its local or global transaction ID. To find the IDs of such transactions, query the data dictionary view DBA_2PC_PENDING. You can also use the integer to specifically assign the transaction a system change number (SCN). If you omit the integer, the transaction is committed using the current SCN. COMMIT statements using the FORCE clause are not supported in PL/SQL.

PREREQUISITES:

You need no privileges to commit your current transaction.
To manually commit a distributed in-doubt transaction that you originally committed, you must have FORCE TRANSACTION system privilege. To manually commit a distributed in-doubt transaction that was originally committed by another user, you must have FORCE ANY TRANSACTION system privilege.

Example:

To commit your current transaction, enter

SQL> COMMIT WORK;
Commit complete.

ROLLBACK

PURPOSE:

To undo work done in the current transaction. You can also use this command to manually und the work done by an in-doubt distributed transaction.

SYNTAX:

ROLLBACK [WORK][TO [SAVEPOINT] savepoint | FORCE 'text']

Where:

- WORK : is optional and is provided for ANSI compatibility.
- TO : rolls back the current transaction to the specified savepoint. If you omit this clause, the ROLLBACK statement rolls back the entire transaction.
- FORCE : manually rolls back an in-doubt distributed transaction. The transaction is identified by the 'text' containing its local or global transaction ID. To find the IDs of such transactions, query the data dictionary view DBA_2PC_PENDING. ROLLBACK statements with the FORCE clause are not supported in PL/SQL.

PREREQUISITES:

To roll back your current transaction, no privileges are necessary.
To manually roll back an in-doubt distributed transaction that you originally committed, you must

have FORCE TRANSACTION system privilege. To manually roll back an in-doubt distributed transaction originally committed by another user, you must have FORCE ANY TRANSACTION system privilege.

Example:

To rollback your current transaction, enter

```
SQL> ROLLBACK;

Rollback complete.
```

CLOSING TRANSACTION:

A Transaction can be closed by using either a Commit or a Rollback statement. By using these statement, table data can be changed or all the changes made to the table data undo.

Using COMMIT:

A **COMMIT** ends the current transaction and makes permanent any changes made during the transaction. All transaction locks acquired on tables are released.

Syntax:
COMMIT;

Using ROLLBACK:

A **ROLLBACK** does exactly the opposite of COMMIT. It ends the transaction but undoes any changes made during the transaction. All transaction locks acquired on tables are released.

Syntax:

ROLLBACK [WORK] [TO SAVEPOINT] < Save-point_Name>

WORK: It is optional and is provided for ANSI compatibility
SAVEPOINT : It is optional and it is used to rollback a partial transaction, as far as the specified savepoint.
SAVEPOINTNAME: It is a savepoint created during the current transaction

Crating a SAVEPOINT:

SAVEPOINT marks and saves the current point in the processing of a transaction. When a SAVEPOINT is used with a ROLLBACK statement, parts of a transaction can be undone. An active savepoint is one that is specified since the last COMMIT or ROLLBACK.

Syntax:

SAVEPOINT <SavePointName>

Example:

DECLARE

```
        Total_Sal  number(9);
BEGIN
        INSERT INTO Emp  VALUES('E101', 'Aamir', 10, 7000');
        INSERT INTO Emp  VALUES('E102', 'Aatif', 11, 6500');

SAVEPOINT   no_update;

UPDATE Emp SET salary =salary+2000 WHERE Emp_Name = 'Aamir';
UPDATE Emp SET salary =salary+2000 WHERE Emp_Name = 'Aatif';

SELECT sum(Salary) INTO Total_sal  FROM Emp;

IF  Total_Sal > 15000  THEN
      ROLLBACK  To  SAVEPOINT   no_update;
 END IF;

COMMIT;
END;
```

The bove PL/SQL block, it will insert two records in the table **Emp,** then after **no_update** SavePoint has been declared.
on both of record the updated with 2000 respectively, now calculated all the salary in **Emp** Table, If Salary has been reached more than 15000 in its table, then it is automatically rolled back, it means undo that was updated earlier by 2000. If this type situation is coming then you can use these commands.

Embedded SQL

Embedded SQL is a method of combining the computing power of a programming language and the database manipulation capabilities of SQL. Embedded SQL statements are SQL statements written inline with the program source code of the host language. The embedded SQL statements are parsed by an embedded SQL preprocessor and replaced by host-language calls to a code library. The output from the preprocessor is then compiled by the host compiler. This allows programmers to embed SQL statements in programs written in any number of languages such as: C/C++, COBOL and Fortran.

The SQL standards committee defined the embedded SQL standard in two steps: a formalism called **Module Language** was defined, then the embedded SQL standard was derived from Module Language.

Embedded SQL is a robust and convenient method of combining the computing power of a programming language with SQL's specialized data management and manipulation capabilities.

Static Vs Dynamic SQL:

Static SQL

- The source form of a static SQL statement is embedded within an application program written in a host language such as COBOL.

- The statement is prepared before the program is executed and the operational form of the statement persists beyond the execution of the program.
- Static SQL statements in a source program must be processed before the program is compiled. This processing can be accomplished through the DB2 precompiler or the SQL statement coprocessor.
- The DB2 precompiler or the coprocessor checks the syntax of the SQL statements, turns them into host language comments, and generates host language statements to invoke DB2.
- The preparation of an SQL application program includes precompilation, the preparation of its static SQL statements, and compilation of the modified source program.

Dynamic SQL:

- Programs that contain embedded dynamic SQL statements must be precompiled like those that contain static SQL, but unlike static SQL, the dynamic statements are constructed and prepared at run time.
- The source form of a dynamic statement is a character string that is passed to DB2 by the program using the static SQL statement PREPARE or EXECUTE IMMEDIATE.

Query Processing and Optimization (QPO)

- Basic idea of QPO
  - In SQL, queries are expressed in high level declarative form
  - QPO translates a SQL query to an execution plan
    - over physical data model
    - using operations on file-structures, indices, etc.

- Ideal execution plan answers Q in as little time as possible
- Constraints: QPO overheads are small
    - Computation time for QPO steps << that for execution plan

Three Key Concepts in QPO

- Building blocks
    - Most cars have few motions, e.g. forward, reverse
    - Similar most DBMS have few building blocks:
        - select (point query, range query), join, sorting, ...
    - A SQL queries is decomposed in building blocks
- 2. Query processing strategies for building blocks
    - Cars have a few gears for forward motion: 1st, 2nd, 3rd, overdrive
    - DBMS keeps a few processing strategies for each building block
        - e.g. a point query can be answer via an index or via scanning data-file
- 3. Query optimization
    - Automatic transmission tries to picks best gear given motion parameters
    - For each building block of a given query, DBMS QPO tries to choose
        - "Most efficient" strategy given database parameters
        - Parameter examples: Table size, available indices, …

Ex. Index search is chosen for a point query if the index is available

QPO Challenges

- Choice of building blocks
    - SQL Queries are based on relational algebra (RA)
    - Building blocks of RA are select, project, join
        - Details in section 3.2 (Note symbols sigma, pi and join)
    - SQL3 adds new building blocks like transitive closure
        - Will be discussed in chapter 6
- Choice of processing strategies for building blocks

- Constraints: Too many strategies=> higher complexity
- Commercial DBMS have a total of 10 to 30 strategies
    - 2 to 4 strategies for each building block

- How to choose the "best" strategy from among the applicable ones?
    - May use a fixed priority scheme
    - May use a simple cost model based on DBMS parameters

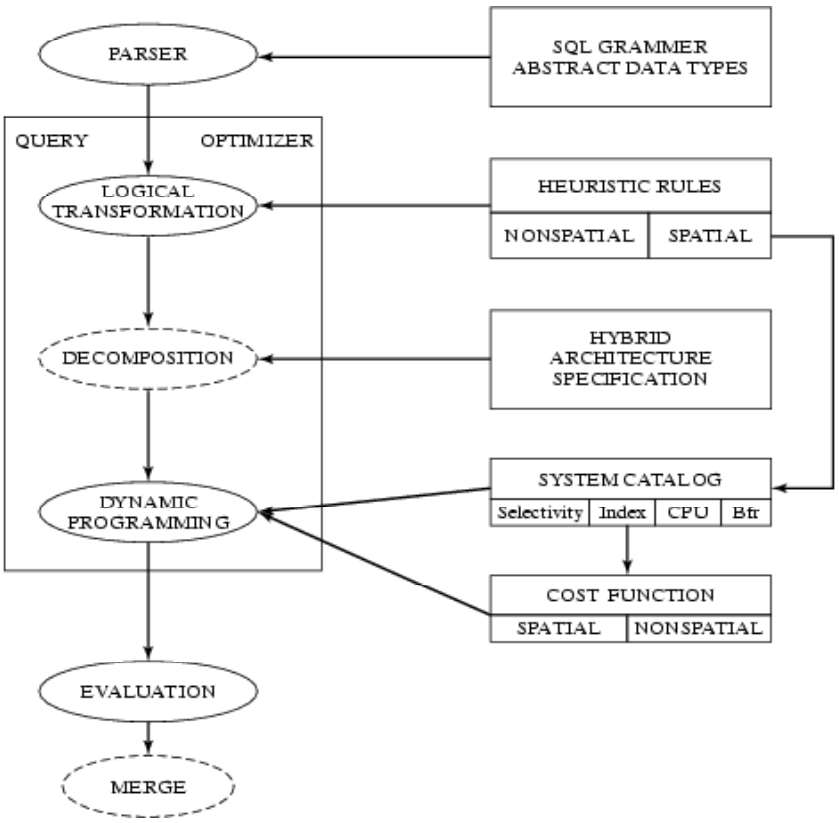
QPO Challenges in SDBMS

- Building Blocks for spatial queries
    - Rich set of spatial data types, operations
    - A consensus on "building blocks" is lacking
    - Current choices include spatial select, spatial join, nearest neighbor
- Choice of strategies
    - Limited choice for some building blocks, e.g. nearest neighbor
- Choosing best strategies
    - Cost models are more complex since
        - Spatial Queries are both CPU and I/O intensive
        - while traditional queries are I/O intensive

Cost models of spatial strategies are in not mature.

Query Processing and Optimizer process

- A site-seeing trip
    - Start : A SQL Query
    - End: An execution plan
    - Intermediate Stopovers
        - query trees
        - logical tree transforms
        - strategy selection

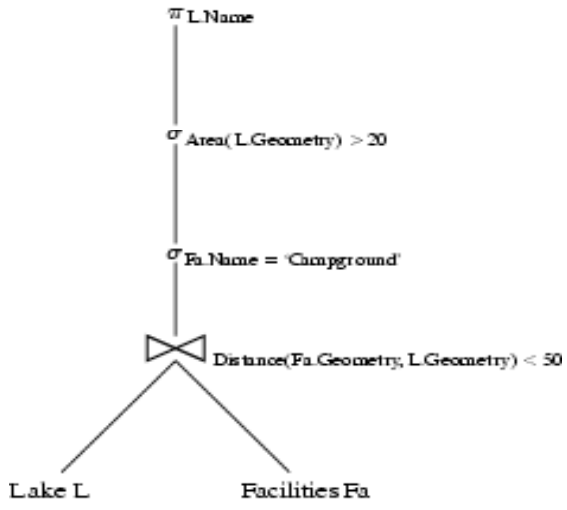


Query Trees

- Nodes = building blocks of (spatial) queries
    - symbols sigma, pi and join
- Children = inputs to a building block
- Leafs = Tables

Example SQL query and its query tree follows:

```
SELECT  L.Name
FROM    Lake L, Facilities Fa
WHERE   Area(L.Geometry) > 20 AND
        Fa.Name = 'campground' AND
        Distance(Fa.Geometry, L.Geometry) < 50
```



Logical Transformation of Query Trees

- Motivation
    - Transformation do not change the answer of the query
    - But can reduce computational cost by
        - reducing data produced by sub-queries
        - reducing computation needs of parent node
- Example Transformation
    - Push down select operation below join
    - Example: Fig. 5.4 (compare w/ Fig 5.3, last slide)
    - Reduces size of table for join operation
- Other common transformations
    - Push project down
    - Reorder join operations
- Traditional logical transform rules
    - For relational queries with simple data types and operations
        - CPU costs are much smaller and I/O costs
    - Need to be reviewed for spatial queries
        - complex data types, operations
        - CPU cost is higher

Execution Plans

- An execution plan has 3 components
    - A query tree
    - A strategy selected for each non-leaf node
    - An ordering of evaluation of non-leaf nodes

Query Decomposition

- Normalization
    - manipulate query quantifiers and qualification

- Analysis
  - detect and reject “incorrect” queries
  - possible for only a subset of relational calculus
- Simplification
  - eliminate redundant predicates
- Restructuring
  - calculus query Þ algebraic query
  - more than one translation is possible
  - use transformation rules

Trends in Query Processing and Optimization

- Motivation
  - SDBMS and GIS are invaluable to many organizations
  - Price of success is to get new requests from customers
    - to support new computing hardware and environment
    - to support new applications
- New computing environments
  - Distributed computing
  - Internet and web
- Parallel computers
- New applications
  - Location based services, transportation
  - Data Mining
  - Raster data

Distributed Spatial Databases

- Distributed Environments
  - Collection of autonomous heterogeneous computers
  - Connected by networks

- Client-server architectures
    - Server computer provides well-defined services
    - Client computers use the services

- New issues for SDBMS
    - Conceptual data model -
        - Translation between heterogeneous schemas
    - Logical data model
        - Naming and querying tables in other SDBMSs
        - Keeping copies of tables (in other SDBMs) consistent with original table
    - Query Processing and Optimization
        - Cost of data transfer over network may dominate CPU and I/O costs
        - New strategies to control data transfer costs

- Process for heuristics optimization
    1. The parser of a high-level query generates an initial internal representation;
    2. Apply heuristics rules to optimize the internal representation.
    3. A query execution plan is generated to execute groups of operations based on the access paths available on the files involved in the query.
- The main heuristic is to apply first the operations that reduce the size of intermediate results.

E.g., Apply SELECT and PROJECT operations before applying the JOIN or other binary operations.

- **Query tree**:
    - A tree data structure that corresponds to a relational algebra expression. It represents the input relations of the query as **leaf nodes** of the **tree**, and represents the relational algebra operations as internal nodes.
- An execution of the query tree consists of executing an internal node operation whenever its operands are available and then replacing that internal node by the relation that results from executing the operation.

Query graph:

A graph data structure that corresponds to a relational calculus expression. It does *not* indicate an order on which operations to perform first. There is only a *single* graph corresponding to each query.

- Example:
  - For every project located in 'Stafford', retrieve the project number, the controlling department number and the department manager's last name, address and birthdate.
- Relation algebra:

$$\mathbf{p}_{\text{PNUMBER, DNUM, LNAME, ADDRESS, BDATE}}(((\mathbf{s}_{\text{PLOCATION='STAFFORD'}}(\text{PROJECT}))\ _{\text{DNUM=DNUMBER}}\ (\text{DEPARTMENT}))\ _{\text{MGRSSN=SSN}}\ (\text{EMPLOYEE}))$$

- SQL query:

```
Q2:     SELECT   P.NUMBER,P.DNUM,E.LNAME,
                 E.ADDRESS, E.BDATE

        FROM     PROJECT AS P,DEPARTMENT AS D, EMPLOYEE AS E

        WHERE    P.DNUM=D.DNUMBER AND
                      D.MGRSSN=E.SSN                AND
    P.PLOCATION='STAFFORD';
```

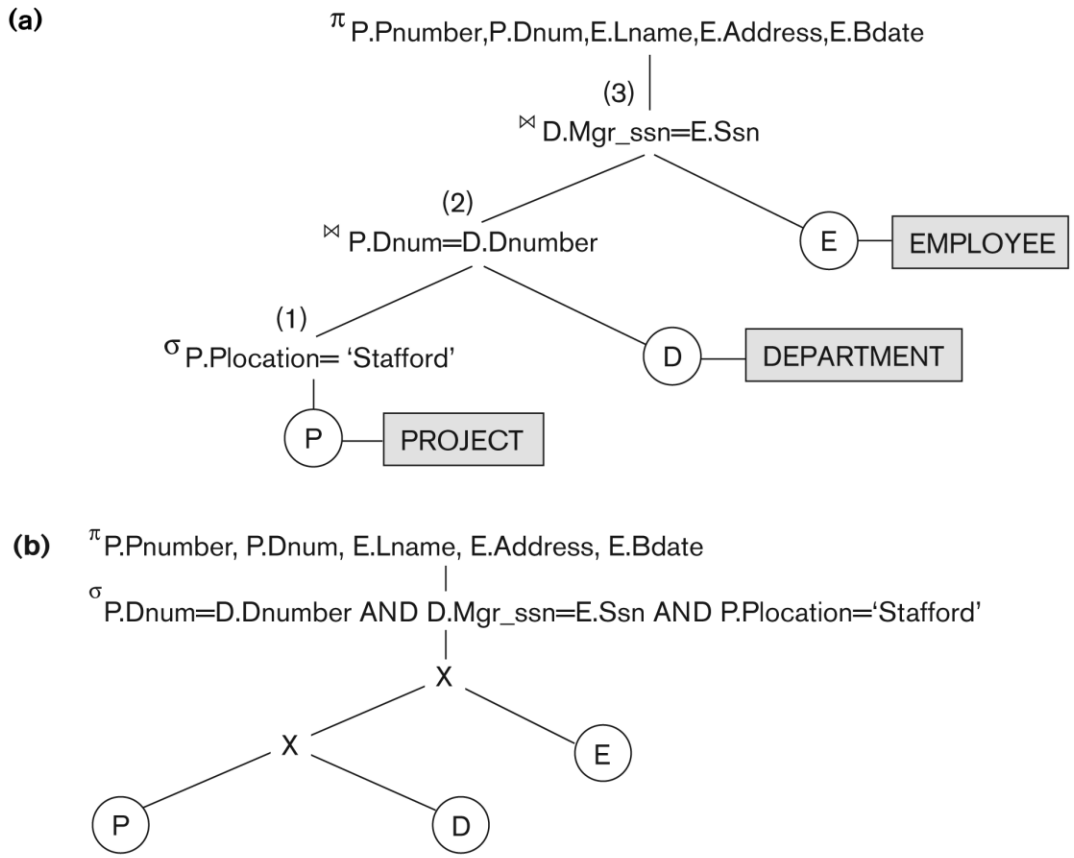


Figure 15.4
Two query trees for the query Q2. (a) Query tree corresponding to the relational algebra expression for Q2. (b) Initial (canonical) query tree for SQL query Q2. (c) Query graph for Q2.

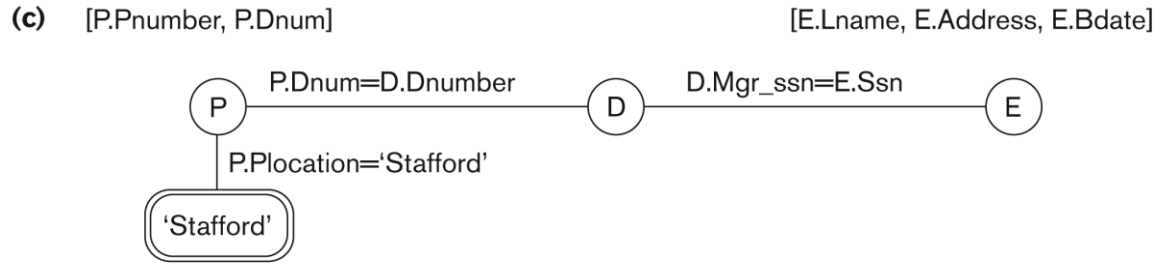


Figure 15.4
Two query trees for the query Q2. (a) Query tree corresponding to the relational algebra expression for Q2. (b) Initial (canonical) query tree for SQL query Q2. (c) Query graph for Q2.

- Heuristic Optimization of Query Trees:
  - The same query could correspond to many different relational algebra expressions — and hence many different query trees.
  - The task of heuristic optimization of query trees is to find a **final query tree** that is efficient to execute.

- Example:

Q: SELECT LNAME

FROM EMPLOYEE, WORKS_ON, PROJECT

WHERE PNAME = 'AQUARIUS' AND
PNMUBER=PNO AND ESSN=SSN AND BDATE > '1957-12-31';

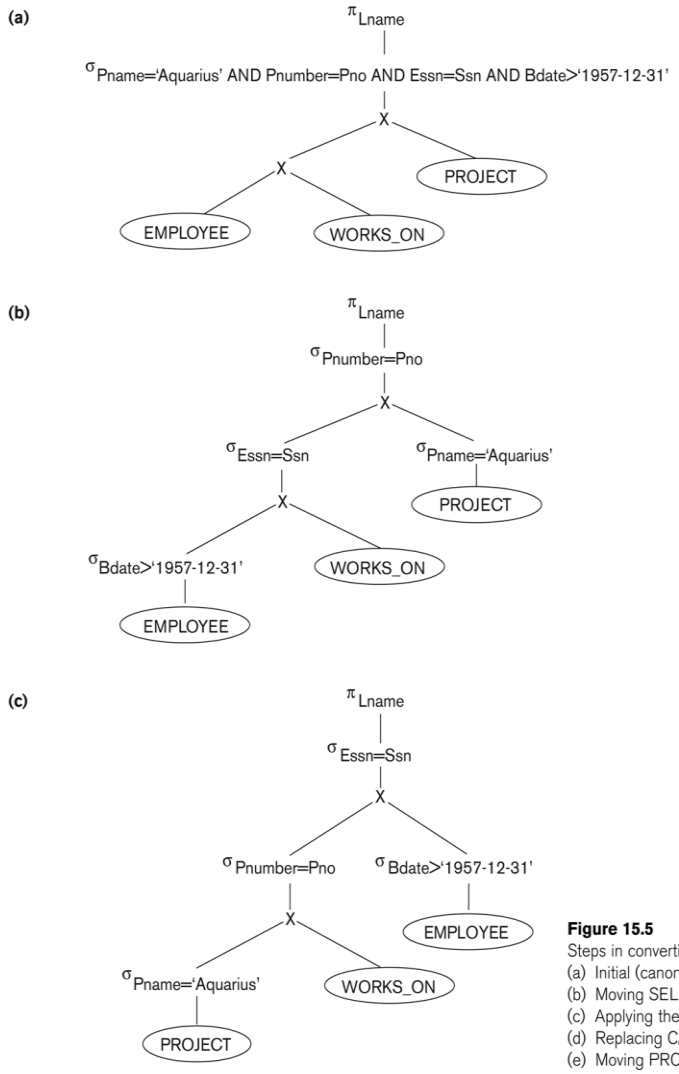
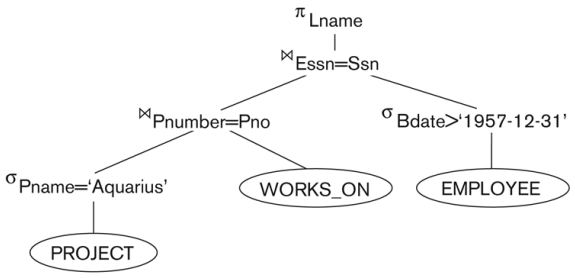


Figure 15.5
Steps in converting a query tree during heuristic optimization.
(a) Initial (canonical) query tree for SQL query Q.
(b) Moving SELECT operations down the query tree.
(c) Applying the more restrictive SELECT operation first.
(d) Replacing CARTESIAN PRODUCT and SELECT with JOIN operations.
(e) Moving PROJECT operations down the query tree.

(d)



(e)

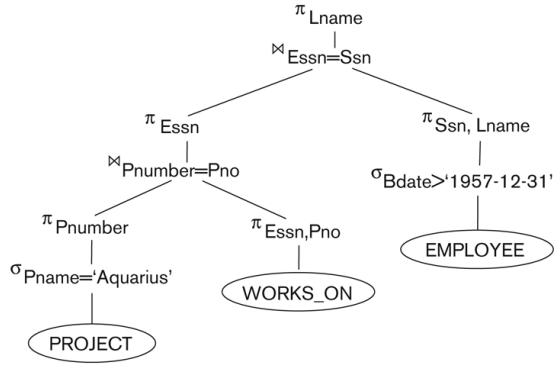


Figure 15.5
Steps in converting a query tree during heuristic optimization.
(a) Initial (canonical) query tree for SQL query Q.
(b) Moving SELECT operations down the query tree.
(c) Applying the more restrictive SELECT operation first.
(d) Replacing CARTESIAN PRODUCT and SELECT with JOIN operations.
(e) Moving PROJECT operations down the query tree.

- General Transformation Rules for Relational Algebra Operations:

1. Cascade of s: A conjunctive selection condition can be broken up into a cascade (sequence) of individual s operations:

- $\sigma_{c1 \text{ AND } c2 \text{ AND } \ldots \text{ AND } cn}(R) = \sigma_{c1}(\sigma_{c2}(\ldots(\sigma_{cn}(R))\ldots))$

2. Commutativity of s: The s operation is commutative:

- $\sigma_{c1}(\sigma_{c2}(R)) = \sigma_{c2}(\sigma_{c1}(R))$

3. Cascade of p: In a cascade (sequence) of p operations, all but the last one can be ignored:

- $\pi_{List1}(\pi_{List2}(\ldots(\pi_{Listn}(R))\ldots)) = \pi_{List1}(R)$

4. Commuting s with p: If the selection condition c involves only the attributes A1, ..., An in the projection list, the two operations can be commuted:

$\pi_{A1, A2, \ldots, An}(\sigma_c(R)) = \sigma_c(\pi_{A1, A2, \ldots, An}(R))$

. Commutativity of (and x): The operation is commutative as is the x operation:

- $R \ {}_C S = S \ {}_C R$; $R \times S = S \times R$

6. Commuting s with (or x): If all the attributes in the selection condition c involve only the attributes of one of the relations being joined—say, R—the two operations can be commuted as follows:

- $s_c (R \quad S) = (s_c (R)) \quad S$

- Alternatively, if the selection condition c can be written as (c1 and c2), where condition c1 involves only the attributes of R and condition c2 involves only the attributes of S, the operations commute as follows:

  - $s_c (R \quad S) = (s_{c1} (R)) \quad (s_{c2} (S))$

Commuting p with (or x): Suppose that the projection list is L = {A1, ..., An, B1, ..., Bm}, where A1, ..., An are attributes of R and B1, ..., Bm are attributes of S. If the join condition c involves only attributes in L, the two operations can be commuted as follows:

- $p_L (R \quad _C S) = (p_{A1, ..., An} (R)) \quad _C (p_{B1, ..., Bm} (S))$

- If the join condition C contains additional attributes not in L, these must be added to the projection list, and a final p operation is needed.

Commutativity of set operations: The set operations υ and ∩ are commutative but "–" is not.

9. Associativity of , x, υ, and ∩ : These four operations are individually associative; that is, if q stands for any one of these four operations (throughout the expression), we have

- $(R \; q \; S) \; q \; T = R \; q \; (S \; q \; T)$

10. Commuting s with set operations: The s operation commutes with υ , ∩ , and –. If q stands for any one of these three operations, we have

- $s_c (R \; q \; S) = (s_c (R)) \; q \; (s_c (S))$

- The p operation commutes with υ. $p_L (R \; \upsilon \; S) = (p_L (R)) \; \upsilon \; (p_L (S))$

- Converting a (s, x) sequence into : If the condition c of a s that follows a x Corresponds to a join condition, convert the (s, x) sequence into a as follows:
  $(s_C (R \times S)) = (R \quad _C S)$

- Other transformations

- Outline of a Heuristic Algebraic Optimization Algorithm:

1. Using rule 1, break up any select operations with conjunctive conditions into a cascade of select operations.

2. Using rules 2, 4, 6, and 10 concerning the commutativity of select with other operations, move each select operation as far down the query tree as is permitted by the attributes involved in the select condition.

3. Using rule 9 concerning associativity of binary operations, rearrange the leaf nodes of the tree so that the leaf node relations with the most restrictive select operations are executed first in the query tree representation.

4. Using Rule 12, combine a Cartesian product operation with a subsequent select operation in the tree into a join operation.

5. Using rules 3, 4, 7, and 11 concerning the cascading of project and the commuting of project with other operations, break down and move lists of projection attributes down the tree as far as possible by creating new project operations as needed.

   Identify subtrees that represent groups of operations that can be executed by a single algorithm.

- Heuristics for Algebraic Optimization:

    1. The main heuristic is to apply first the operations that reduce the size of intermediate results.

    2. Perform select operations as early as possible to reduce the number of tuples and perform project operations as early as possible to reduce the number of attributes. (This is done by moving select and project operations as far down the tree as possible.)

    3. The select and join operations that are most restrictive should be executed before other similar operations. (This is done by reordering the leaf nodes of the tree among themselves and adjusting the rest of the tree appropriately.)

- Query Execution Plans

    1. An execution plan for a relational algebra query consists of a combination of the relational algebra query tree and information about the access methods to be used for each relation as well as the methods to be used in computing the relational operators stored in the tree.

    2. **Materialized evaluation**: the result of an operation is stored as a temporary relation.

Pipelined evaluation: as the result of an operator is produced, it is forwarded to the next operator in sequence.

- **Cost-based query optimization**:
    - Estimate and compare the costs of executing a query using different execution strategies and choose the strategy with the lowest cost estimate.
    - (Compare to heuristic query optimization)
- Issues
    - Cost function

Number of execution strategies to be considered

- Cost Components for Query Execution
    1. Access cost to secondary storage
    2. Storage cost
    3. Computation cost
    4. Memory usage cost
    5. Communication cost
- Note: Different database systems may focus on different cost components.
- Catalog Information Used in Cost Functions
    1. Information about the size of a file
        - number of records (tuples) (r),
        - record size (R),
        - number of blocks (b)
        - blocking factor (bfr)
    2. Information about indexes and indexing attributes of a file
        - Number of levels (x) of each multilevel index
        - Number of first-level index blocks (bI1)
        - Number of distinct values (d) of an attribute
        - Selectivity (sl) of an attribute

- Selection cardinality (s) of an attribute. (s = sl * r)

- Examples of Cost Functions for SELECT
- S1. Linear search (brute force) approach
    1. $C_{S1a} = b$;
    2. For an equality condition on a key, $C_{S1a} = (b/2)$ if the record is found; otherwise $C_{S1a} = b$.
- S2. Binary search:
    1. $C_{S2} = \log_2 b + (s/bfr)\rceil - 1$
    2. For an equality condition on a unique (key) attribute, $C_{S2} = \log_2 b$
- S3. Using a primary index (S3a) or hash key (S3b) to retrieve a single record
    1. $C_{S3a} = x + 1$; $C_{S3b} = 1$ for static or linear hashing;

$C_{S3b} = 1$ for extendible hashing;

- S4. Using an ordering index to retrieve multiple records:
    - For the comparison condition on a key field with an ordering index, $C_{S4} = x + (b/2)$
- S5. Using a clustering index to retrieve multiple records:
    - $C_{S5} = x + \lceil (s/bfr) \rceil$
- S6. Using a secondary (B+-tree) index:
    - For an equality comparison, $C_{S6a} = x + s$;
    - For an comparison condition such as >, <, >=, or <=,
    - $C_{S6a} = x + (b_{I1}/2) + (r/2)$
- S7. Conjunctive selection:
    - Use either S1 or one of the methods S2 to S6 to solve.
    - For the latter case, use one condition to retrieve the records and then check in the memory buffer whether each retrieved record satisfies the remaining conditions in the conjunction.
- S8. Conjunctive selection using a composite index:
    - Same as S3a, S5 or S6a, depending on the type of index.
- Examples of Cost Functions for JOIN

- Join selectivity (js)
- js = | (R $_C$ S) | / | R x S | = | (R $_C$ S) | / (|R| * |S |)
  - If condition C does not exist, js = 1;
  - If no tuples from the relations satisfy condition C, js = 0;
  - Usually, 0 <= js <= 1;

- Size of the result file after join operation
  - | (R $_C$ S) | = js * |R| * |S |
- J1. Nested-loop join:
  - $C_{J1} = b_R + (b_R * b_S) + ((js * |R| * |S|)/bfr_{RS})$
  - (Use R for outer loop)
- J2. Single-loop join (using an access structure to retrieve the matching record(s))
  - If an index exists for the join attribute B of S with index levels x_B, we can retrieve each record s in R and then use the index to retrieve all the matching records t from S that satisfy t[B] = s[A].
  - The cost depends on the type of index.
- J2. Single-loop join (contd.)
  - For a secondary index,
    - $C_{J2a} = b_R + (|R| * (x_B + s_B)) + ((js * |R| * |S|)/bfr_{RS})$;
  - For a clustering index,
    - $C_{J2b} = b_R + (|R| * (x_B + (s_B/bfr_B))) + ((js * |R| * |S|)/bfr_{RS})$;
  - For a primary index,
    - $C_{J2c} = b_R + (|R| * (x_B + 1)) + ((js * |R| * |S|)/bfr_{RS})$;
  - If a hash key exists for one of the two join attributes — B of S
    - $C_{J2d} = b_R + (|R| * h) + ((js * |R| * |S|)/bfr_{RS})$;
- J3. Sort-merge join:
    - $C_{J3a} = C_S + b_R + b_S + ((js * |R| * |S|)/bfr_{RS})$;
    - (CS: Cost for sorting files)

- **Multiple Relation Queries and Join Ordering**
    - A query joining n relations will have n-1 join operations, and hence can have a large number of different join orders when we apply the algebraic transformation rules.
    - Current query optimizers typically limit the structure of a (join) query tree to that of left-deep (or right-deep) trees.
- **Left-deep tree**:
    - A binary tree where the right child of each non-leaf node is always a base relation.
        - Amenable to pipelining

      Could utilize any access paths on the base relation (the right child) when executing the join.
- Oracle DBMS V8
    - **Rule-based query optimization**: the optimizer chooses execution plans based on heuristically ranked operations.
        - (Currently it is being phased out)
    - **Cost-based query optimization**: the optimizer examines alternative access paths and operator algorithms and chooses the execution plan with lowest estimate cost.
        - The query cost is calculated based on the estimated usage of resources such as I/O, CPU and memory needed.
    - Application developers could specify hints to the ORACLE query optimizer.
    - The idea is that an application developer might know more information about the data.
- **Semantic Query Optimization**:
    - Uses constraints specified on the database schema in order to modify one query into another query that is more efficient to execute.
- Consider the following SQL query,

```
SELECT    E.LNAME, M.LNAME
FROM EMPLOYEE E M
WHERE     E.SUPERSSN=M.SSN AND E.SALARY>M.SALARY
```

- Explanation:
    - Suppose that we had a constraint on the database schema that stated that no employee can earn more than his or her direct supervisor. If the semantic query optimizer checks

for the existence of this constraint, it need not execute the query at all because it knows that the result of the query will be empty. Techniques known as theorem proving can be used for this purpose.

Transaction:

Action, or series of actions, carried out by user or application, which accesses or changes contents of database. It Transforms database from one consistent state to another, although consistency may be violated during transaction

Logical unit of database processing that includes one or more access operations (read -retrieval, write - insert or update, delete).

Transaction is an executing program forming a logical unit of database access operations that involves one or more database operations (read -retrieval, write - insert or update, delete).

A transaction may be stand-alone set of operations specified in a high level language like SQL submitted interactively, or may be embedded within a program.

A transaction must see a consistent database.

During transaction execution the database may be inconsistent.

When the transaction is committed, the database must be consistent.

Transaction boundaries:

Begin and End transaction.

An application program may contain several transactions separated by the Begin and End transaction boundaries.

Two Basic operations are read and write

1) read_item(X): Reads a database item named X into a program variable. To simplify our notation, we assume that the program variable is also named X.

2) write_item(X): Writes the value of program variable X into the database item named X.

Why Do We Need Transactions?

- It's all about fast query response time and correctness
- DBMS is a multi-user systems
  - Many different requests
  - Some against same data items

❖ Figure out how to interleave requests to shorten response time while guaranteeing correct result

How does DBMS know which actions belong together?

Group database operations that must be performed together into transactions

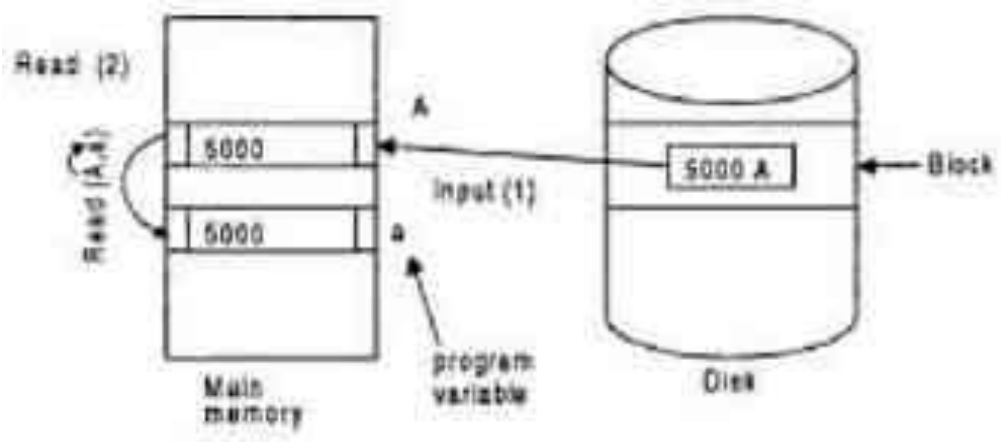
Either execute all operations or none

READ AND WRITE OPERATIONS:

Basic unit of data transfer from the disk to the computer main memory is one block. In general, a data item (what is read or written) will be the field of some record in the database, although it may be a larger unit such as a record or even a whole block.

read_item(X) command includes the following steps:

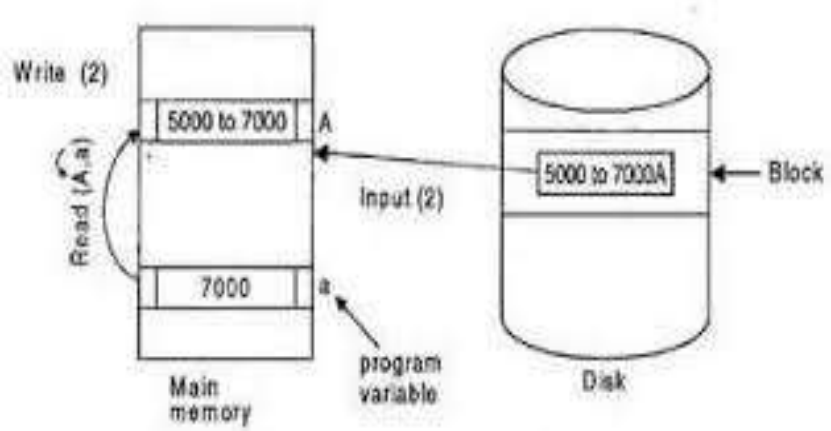
1. Find the address of the disk block that contains item X.
2. Copy that disk block into a buffer in main memory (if that disk block is not already in some main memory buffer).
3. Copy item X from the buffer to the program variable named X.



Read Operation

write_item(X) command includes the following steps:

1. Find the address of the disk block that contains item X.
2. Copy that disk block into a buffer in main memory (if that disk block is not already in some main memory buffer).
3. Copy item X from the program variable named X into its correct location in the buffer.
4. Store the updated block from the buffer back to disk (either immediately or at some later point in time).



Write Operation

Example Transactions:

(a)	T_1	(b)	T_2
	read_item (X); X:=X-N; write_item (X); read_item (Y); Y:=Y+N; write_item (Y);		read_item (X); X:=X+M; write_item (X);

Issues to deal with:

o Failures of various kinds, such as hardware failures and system crashes
o Concurrent execution of multiple transactions

A **transaction** is an atomic unit of work that is either completed in its entirety or not done at all. For recovery purposes, the system needs to keep track of when the transaction starts, terminates, and commits or aborts.

Transaction States

A transaction can be in one of several states:

Active - Reading and Writing data items ,if something wrong happens during reading and writing aborts to Failed.

Partially Committed - All reading and writing operations are done aborts to Failed when rollback occurs or committed when commit occurs.

Committed - Transaction successfully completed and all write operations made permanent in the Database

Failed - Transaction halted and all operations rolled back

Terminated - terminates either commits or failed

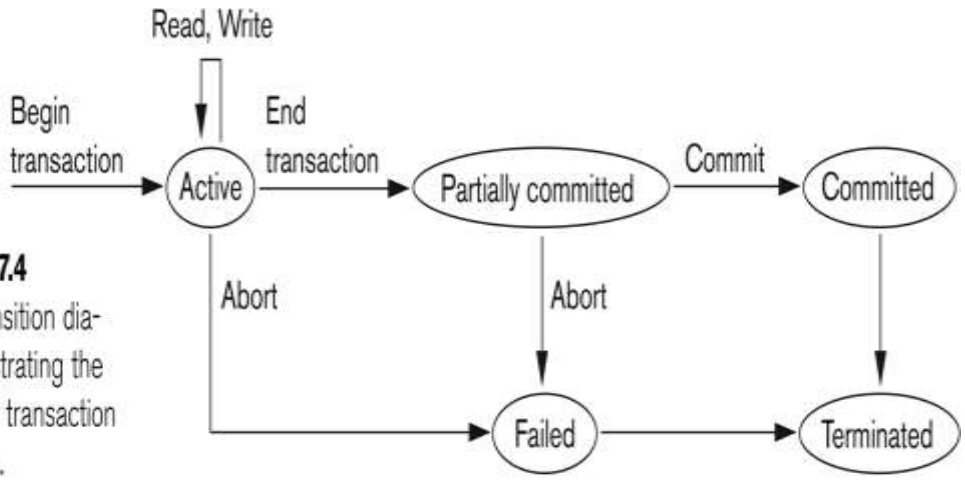
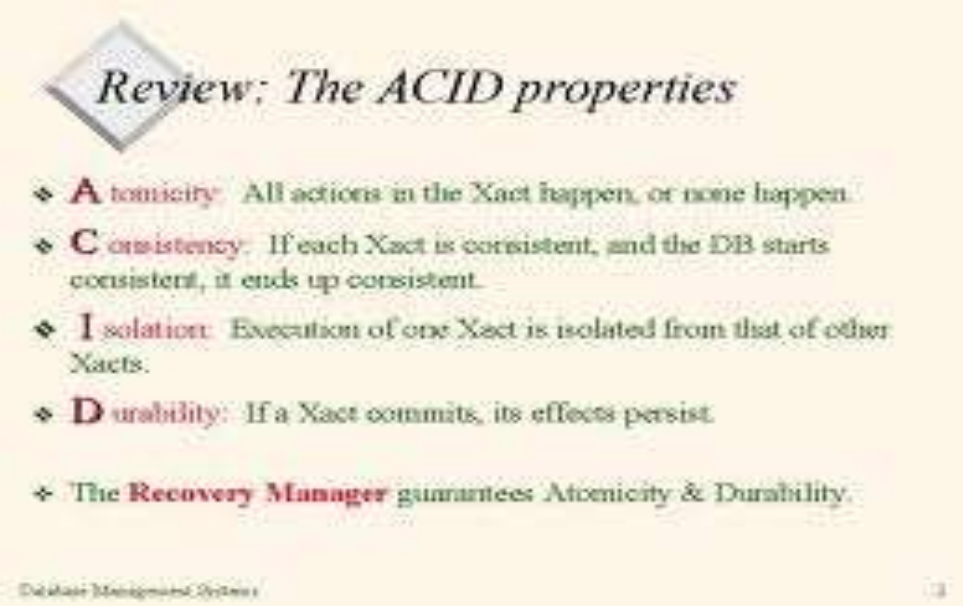


Figure 17.4
State transition diagram illustrating the states for transaction execution.

nt of **database management systems**

ACID Properties



To preserve the integrity of data, the database system must ensure:

Atomicity. Either all operations of the transaction are properly reflected in the database or none are.

Consistency. Execution of a transaction in isolation preserves the consistency of the database.

Isolation. Although multiple transactions may execute concurrently, each transaction must be unaware of other concurrently executing transactions. Intermediate transaction results must be hidden from other concurrently executed transactions. That is, for every pair of transactions Ti and Tj, it appears to Ti that either Tj finished execution before Ti started, or Tj started execution after Ti finished.

Durability. After a transaction completes successfully, the changes it has made to the database persist, even if there are system failures.

Example of Fund Transfer

Transaction to transfer $50 from account A to account B:

1. **read**(A)

2. A:= A- 50

3. **write**(A)

4. **read**(B)

5. B:= B+ 50

6. **write**(B)

Atomicity requirement :

1. if the transaction fails after step 3 and before step 6, money will be "lost" leading to an inconsistent database state
2. The system should ensure that updates of a partially **executed transaction are not reflected in the database**

Durability requirement :

once the user has been notified that the transaction has completed (i.e., the transfer of the $50 has taken place), the updates to the database by the transaction must persist even if there are software or hardware failures.

Consistency requirement :

- the sum of A and B is unchanged by the execution of the transaction

In general, consistency requirements include

Explicitly specified integrity constraints such as primary keys and foreign keys

Implicit integrity constraints

A transaction must see a consistent database.

During transaction execution the database may be temporarily inconsistent.

When the transaction completes successfully the database must be consistent

- Erroneous transaction logic can lead to inconsistency

Isolation requirement :

if between steps 3 and 6, another transaction T2 is allowed to access the partially updated database, it will see an inconsistent database (the sum *A+B* will be less than it should be). Isolation can be ensured trivially by running transactions serially, that is, one after the other. However, executing multiple transactions concurrently has significant benefits.

Transaction states:

Active state

Partially committed state

Committed state

Failed state

Terminated State

- Recovery manager keeps track of the following operations:
  - **begin_transaction**: This marks the beginning of transaction execution.
  - **read** or **write**: These specify read or write operations on the database items that are executed as part of a transaction.

- **end_transaction**: This specifies that read and write transaction operations have ended and marks the end limit of transaction execution.
  - At this point it may be necessary to check whether the changes introduced by the transaction can be permanently applied to the database or whether the transaction has to be aborted because it violates concurrency control or for some other reason.

- **commit_transaction**: This signals a successful end of the transaction so that any changes (updates) executed by the transaction can be safely committed to the database and will not be undone.

- **rollback** (or **abort**): This signals that the transaction has ended unsuccessfully, so that any changes or effects that the transaction may have applied to the database must be undone.

- Recovery techniques use the following operators:

  - **undo**: Similar to rollback except that it applies to a single operation rather than to a whole transaction.

  - **redo**: This specifies that certain *transaction operations* must be *redone* to ensure that all the operations of a committed transaction have been applied successfully to the database.

Two Main Techniques

□ Deferred Update

No physical updates to db until after a transaction commits.

During the commit, log records are made then changes are made permanent on disk.

What if a Transaction fails?

No UNDO required

REDO may be necessary if the changes have not yet been made permanent before the failure.

 Immediate Update

Physical updates to db may happen before a transaction commits.

All changes are written to the permanent log (on disk) before changes are made to the DB.

What if a Transaction fails?

After changes are made but before commit – need to UNDO the changes

REDO may be necessary if the changes have not yet been made permanent before the failure

Recovery based on Deferred Update

Deferred update

 Changes are made in memory and after T commits, the changes are made permanent on disk.

 Changes are recorded in buffers and in log file during T's execution.

 At the commit point, the log is force-written to disk and updates are made in database.

 No need to ever UNDO operations because changes are never made permanent

 REDO is needed if the transaction fails after the commit but before the changes are made on disk.

 Hence the name is NO UNDO/REDO algorithm

 2 lists are maintained:

Commit list**: committed transactions since last checkpoint**

Active list**: active transactions**

 REDO all write operations from commit list **in order that they were written to the log**

 Active transactions are cancelled & must be resubmitted.

Recovery based on Immediate Update

Immediate update:

 Updates to disk can happen at any time

 But, updates must still first be recorded in the system logs (on disk) before changes are made to the database.

 Need to provide facilities to UNDO operations which have affected the db

 2 flavors of this algorithm

UNDO/NO_REDO recovery algorithm

if the recovery technique ensures that all updates are made to the database on disk before T commits, we do not need to REDO any committed transactions

UNDO/REDO recovery algorithm

Transaction is allowed to commit before all its changes are written to the database

o (Note that the log files would be complete at the commit point)

UNDO/REDO Algorithm

 2 lists maintained:

 Commit list**: committed transactions since last checkpoint**

 Active list**: active transactions**

 UNDO all write operations of active transactions.

 Undone in the reverse of the order in which they were written to the log

 REDO all write operations of the committed transactions

 In the order in which they were written to the log.

Transaction:

Action, or series of actions, carried out by user or application, which accesses or changes contents of database. It Transforms database from one consistent state to another, although consistency may be violated during transaction

Logical unit of database processing that includes one or more access operations (read -retrieval, write - insert or update, delete).

Transaction is an executing program forming a logical unit of database access operations that involves one or more database operations (read -retrieval, write - insert or update, delete).

A transaction may be stand-alone set of operations specified in a high level language like SQL submitted interactively, or may be embedded within a program.

A transaction must see a consistent database.

During transaction execution the database may be inconsistent.

When the transaction is committed, the database must be consistent.

Transaction boundaries:

Begin and End transaction.

An application program may contain several transactions separated by the Begin and End transaction boundaries.

Two Basic operations are read and write

3) read_item(X): Reads a database item named X into a program variable. To simplify our notation, we assume that the program variable is also named X.

4) write_item(X): Writes the value of program variable X into the database item named X.

Why Do We Need Transactions?

- It's all about fast query response time and correctness
- DBMS is a multi-user systems
  - Many different requests
  - Some against same data items

❖ Figure out how to interleave requests to shorten response time while guaranteeing correct result

How does DBMS know which actions belong together?

Group database operations that must be performed together into transactions

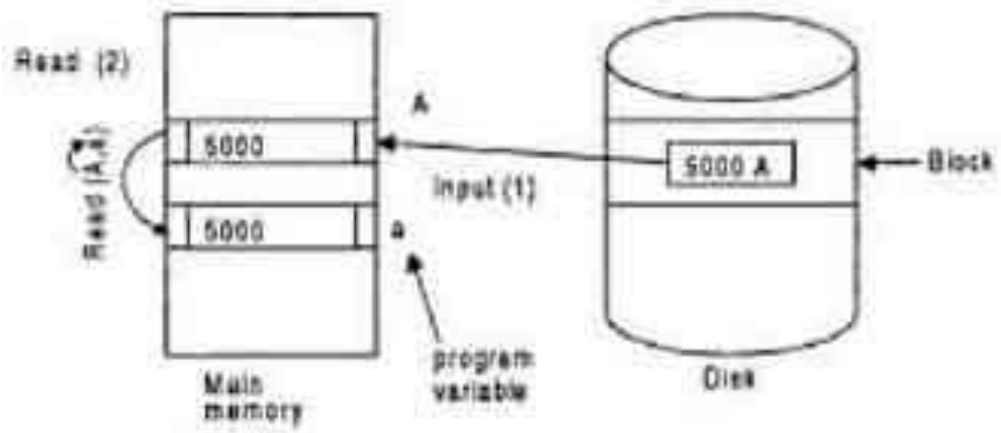
Either execute all operations or none

READ AND WRITE OPERATIONS:

Basic unit of data transfer from the disk to the computer main memory is one block. In general, a data item (what is read or written) will be the field of some record in the database, although it may be a larger unit such as a record or even a whole block.

read_item(X) command includes the following steps:

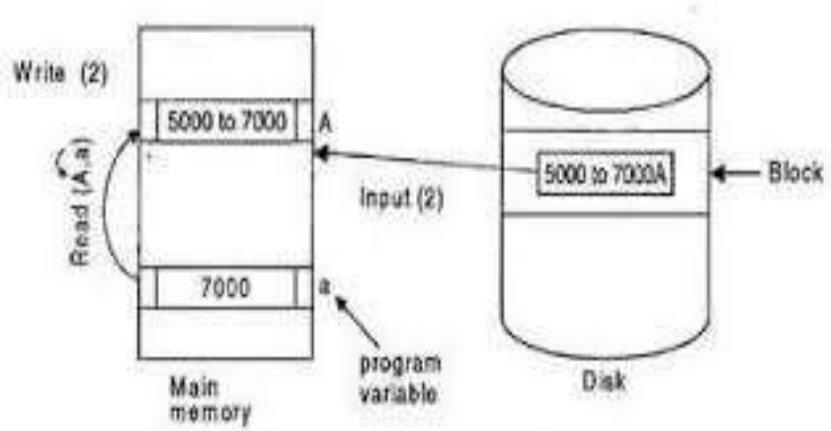
4. Find the address of the disk block that contains item X.
5. Copy that disk block into a buffer in main memory (if that disk block is not already in some main memory buffer).
6. Copy item X from the buffer to the program variable named X.



Read Operation

write_item(X) command includes the following steps:

5. Find the address of the disk block that contains item X.
6. Copy that disk block into a buffer in main memory (if that disk block is not already in some main memory buffer).
7. Copy item X from the program variable named X into its correct location in the buffer.
8. Store the updated block from the buffer back to disk (either immediately or at some later point in time).



Write Operation

Example Transactions:

(a)

T_1
read_item (X);
X:=X-N;
write_item (X);
read_item (Y);
Y:=Y+N;
write_item (Y);

(b)

T_2
read_item (X);
X:=X+M;
write_item (X);

Issues to deal with:

o Failures of various kinds, such as hardware failures and system crashes
o Concurrent execution of multiple transactions

A **transaction** is an atomic unit of work that is either completed in its entirety or not done at all. For recovery purposes, the system needs to keep track of when the transaction starts, terminates, and commits or aborts.

Transaction States

A transaction can be in one of several states:

Active - Reading and Writing data items ,if something wrong happens during reading and writing aborts to Failed.

Partially Committed - All reading and writing operations are done aborts to Failed when rollback occurs or committed when commit occurs.

Committed - Transaction successfully completed and all write operations made permanent in the Database

Failed - Transaction halted and all operations rolled back

Terminated - terminates either commits or failed

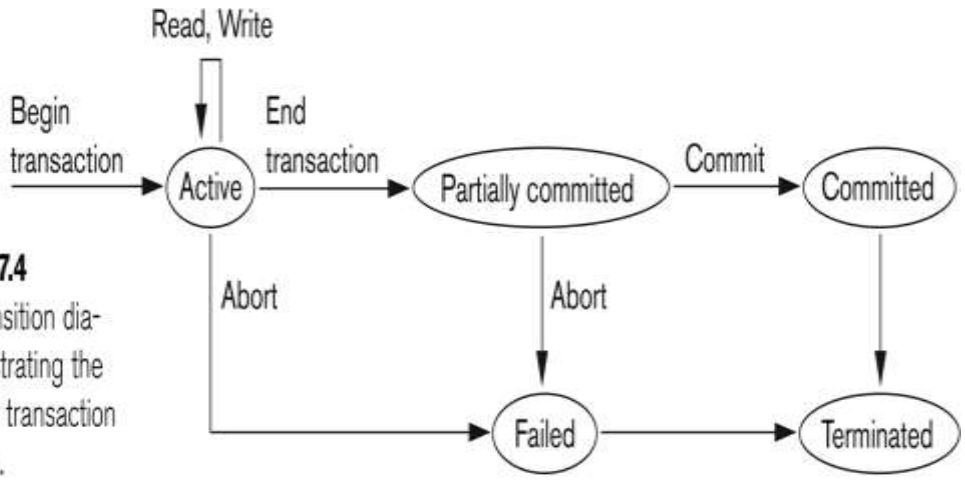
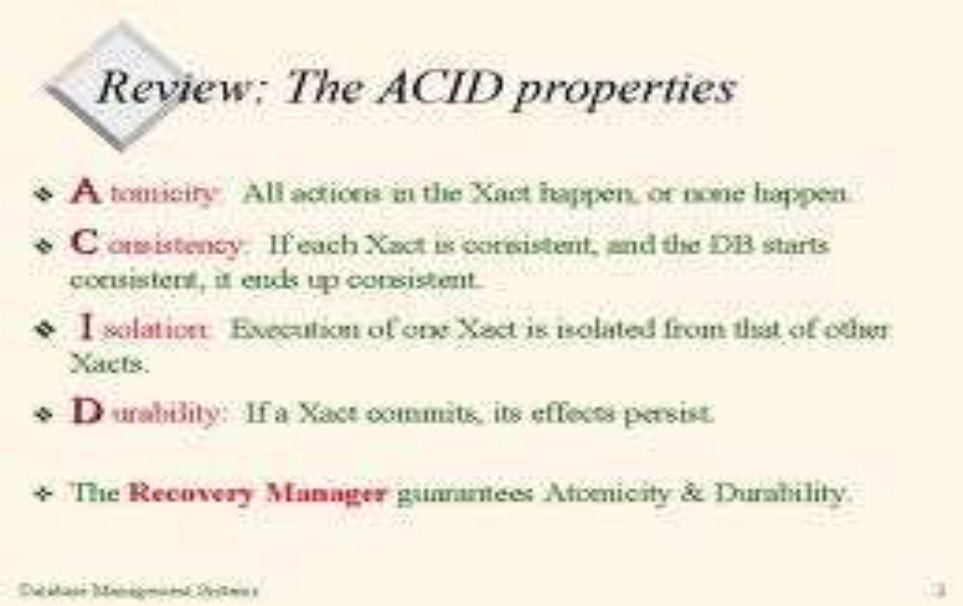


Figure 17.4
State transition diagram illustrating the states for transaction execution.

nt of **database management systems**

ACID Properties



To preserve the integrity of data, the database system must ensure:

Atomicity. Either all operations of the transaction are properly reflected in the database or none are.

Consistency. Execution of a transaction in isolation preserves the consistency of the database.

Isolation. Although multiple transactions may execute concurrently, each transaction must be unaware of other concurrently executing transactions. Intermediate transaction results must be hidden from other concurrently executed transactions. That is, for every pair of transactions Ti and Tj, it appears to Ti that either Tj finished execution before Ti started, or Tj started execution after Ti finished.

Durability. After a transaction completes successfully, the changes it has made to the database persist, even if there are system failures.

Example of Fund Transfer

Transaction to transfer $50 from account A to account B:

1. **read**(A)

2. A:= A- 50

3. **write**(A)

4. **read**(B)

5. B:= B+ 50

6. **write**(B)

Atomicity requirement :

3. if the transaction fails after step 3 and before step 6, money will be "lost" leading to an inconsistent database state
4. The system should ensure that updates of a partially **executed transaction are not reflected in the database**

Durability requirement :

once the user has been notified that the transaction has completed (i.e., the transfer of the $50 has taken place), the updates to the database by the transaction must persist even if there are software or hardware failures.

Consistency requirement :

- the sum of A and B is unchanged by the execution of the transaction

In general, consistency requirements include

Explicitly specified integrity constraints such as primary keys and foreign keys

Implicit integrity constraints

A transaction must see a consistent database.

During transaction execution the database may be temporarily inconsistent.

When the transaction completes successfully the database must be consistent

- Erroneous transaction logic can lead to inconsistency

Isolation requirement :

if between steps 3 and 6, another transaction T2 is allowed to access the partially updated database, it will see an inconsistent database (the sum *A+B* will be less than it should be). Isolation can be ensured trivially by running transactions serially, that is, one after the other. However, executing multiple transactions concurrently has significant benefits.

Transaction states:

Active state

Partially committed state

Committed state

Failed state

Terminated State

- Recovery manager keeps track of the following operations:
  - **begin_transaction**: This marks the beginning of transaction execution.
  - **read** or **write**: These specify read or write operations on the database items that are executed as part of a transaction.

- **end_transaction**: This specifies that read and write transaction operations have ended and marks the end limit of transaction execution.
  - At this point it may be necessary to check whether the changes introduced by the transaction can be permanently applied to the database or whether the transaction has to be aborted because it violates concurrency control or for some other reason.

- **commit_transaction**: This signals a successful end of the transaction so that any changes (updates) executed by the transaction can be safely committed to the database and will not be undone.

- **rollback** (or **abort**): This signals that the transaction has ended unsuccessfully, so that any changes or effects that the transaction may have applied to the database must be undone.

- Recovery techniques use the following operators:

  - **undo**: Similar to rollback except that it applies to a single operation rather than to a whole transaction.

  - **redo**: This specifies that certain *transaction operations* must be *redone* to ensure that all the operations of a committed transaction have been applied successfully to the database.

Two Main Techniques

□ Deferred Update

No physical updates to db until after a transaction commits.

During the commit, log records are made then changes are made permanent on disk.

What if a Transaction fails?

No UNDO required

REDO may be necessary if the changes have not yet been made permanent before the failure.

 Immediate Update

Physical updates to db may happen before a transaction commits.

All changes are written to the permanent log (on disk) before changes are made to the DB.

What if a Transaction fails?

After changes are made but before commit – need to UNDO the changes

REDO may be necessary if the changes have not yet been made permanent before the failure

Recovery based on Deferred Update

Deferred update

 Changes are made in memory and after T commits, the changes are made permanent on disk.

 Changes are recorded in buffers and in log file during T's execution.

 At the commit point, the log is force-written to disk and updates are made in database.

 No need to ever UNDO operations because changes are never made permanent

 REDO is needed if the transaction fails after the commit but before the changes are made on disk.

 Hence the name is NO UNDO/REDO algorithm

 2 lists are maintained:

Commit list**: committed transactions since last checkpoint**

Active list**: active transactions**

 REDO all write operations from commit list **in order that they were written to the log**

 Active transactions are cancelled & must be resubmitted.

Recovery based on Immediate Update

Immediate update:

 Updates to disk can happen at any time

 But, updates must still first be recorded in the system logs (on disk) before changes are made to the database.

 Need to provide facilities to UNDO operations which have affected the db

 2 flavors of this algorithm

UNDO/NO_REDO recovery algorithm

if the recovery technique ensures that all updates are made to the database on disk before T commits, we do not need to REDO any committed transactions

UNDO/REDO recovery algorithm

Transaction is allowed to commit before all its changes are written to the database

o (Note that the log files would be complete at the commit point)

UNDO/REDO Algorithm

 2 lists maintained:

 Commit list**: committed transactions since last checkpoint**

 Active list**: active transactions**

 UNDO all write operations of active transactions.

 Undone in the reverse of the order in which they were written to the log

 REDO all write operations of the committed transactions

 In the order in which they were written to the log.

Introduction to Concurrency

What is concurrency?

Concurrency in terms of databases means allowing multiple users to access the data contained within a database at the same time. If concurrent access is not managed by the Database Management System (DBMS) so that simultaneous operations don't interfere with one another problems can occur when various transactions interleave, resulting in an inconsistent database.

Concurrency is achieved by the DBMS, which interleaves actions (reads/writes of DB objects) of various transactions. Each transaction must leave the database in a consistent state if the DB is consistent when the transaction begins. Concurrent execution of user programs is essential for good DBMS performance. Because disk accesses are frequent, and relatively slow, it is important to keep the CPU humming by working on several user programs concurrently. Interleaving actions of different user programs can lead to inconsistency: e.g., check is cleared while account balance is being computed. DBMS ensures such problems don't arise: users can pretend they are using a single-user system.

Purpose of Concurrency Control

- To enforce Isolation (through mutual exclusion) among conflicting transactions.
- To preserve database consistency through consistency preserving execution of transactions.
- To resolve read-write and write-write conflicts.

Example: In concurrent execution environment if T1 conflicts with T2 over a data item A, then the existing concurrency control decides if T1 or T2 should get the A and if the other transaction is rolled-back or waits.

Timestamp based concurrency control algorithm

Timestamp

- A monotonically increasing variable (integer) indicating the age of an operation or a transaction. A larger timestamp value indicates a more recent event or operation.
- Timestamp based algorithm uses timestamp to serialize the execution of concurrent transactions.

Basic Timestamp Ordering

1. Transaction T issues a write_item(X) operation:

    - If read_TS(X) > TS(T) or if write_TS(X) > TS(T), then an younger transaction has already read the data item so abort and roll-back T and reject the operation.
    - If the condition in part (a) does not exist, then execute write_item(X) of T and set write_TS(X) to TS(T).

2. Transaction T issues a read_item(X) operation:

    - If write_TS(X) > TS(T), then an younger transaction has already written to the data item so abort and roll-back T and reject the operation.
    - If write_TS(X) ≤ TS(T), then execute read_item(X) of T and set read_TS(X) to the larger of TS(T) and the current read_TS(X).

Strict Timestamp Ordering

1. Transaction T issues a write_item(X) operation:

    - If TS(T) > read_TS(X), then delay T until the transaction T' that wrote or read X has terminated (committed or aborted).
2. Transaction T issues a read_item(X) operation:

    - If TS(T) > write_TS(X), then delay T until the transaction T' that wrote or read X has terminated (committed or aborted).

Multiversion concurrency control techniques

- This approach maintains a number of versions of a data item and allocates the right version to a read operation of a transaction. Thus unlike other mechanisms a read operation in this mechanism is never rejected.
- Side effect:
    - Significantly more storage (RAM and disk) is required to maintain multiple versions. To check unlimited growth of versions, a garbage collection is run when some criteria is satisfied.

- This approach maintains a number of versions of a data item and allocates the right version to a read operation of a transaction.
  - Thus unlike other mechanisms a read operation in this mechanism is never rejected.

Multiversion technique based on timestamp ordering

- Assume X1, X2, …, Xn are the version of a data item X created by a write operation of transactions. With each Xi a read_TS (read timestamp) and a write_TS (write timestamp) are associated.

  read_TS(Xi): The read timestamp of Xi is the largest of all the timestamps of transactions that have successfully read version Xi.

  write_TS(Xi): The write timestamp of Xi that wrote the value of version Xi.

  A new version of Xi is created only by a write operation.

To ensure serializability, the following two rules are used.

1. . If transaction T issues write_item (X) and version i of X has the highest write_TS(Xi) of all versions of X that is also less than or equal to TS(T), and read _TS(Xi) > TS(T), then abort and roll-back T; otherwise create a new version Xi and read_TS(X) = write_TS(Xj) = TS(T).
2. If transaction T issues read_item (X), find the version i of X that has the highest write_TS(Xi) of all versions of X that is also less than or equal to TS(T), then return the value of Xi to T, and set the value of read _TS(Xi) to the largest of TS(T) and the current read_TS(Xi).

Rule 2 guarantees that a read will never be rejected.

Multiversion Two-Phase Locking Using Certify Locks

- Concept
  - Allow a transaction T' to read a data item X while it is write locked by a conflicting transaction T.

- This is accomplished by maintaining two versions of each data item X where one version must always have been written by some committed transaction. This means a write operation always creates a new version of X.

Multiversion Two-Phase Locking Using Certify Locks

- Steps
  1. X is the committed version of a data item.
  2. T creates a second version X' after obtaining a write lock on X.
  3. Other transactions continue to read X.
  4. T is ready to commit so it obtains a certify lock on X'.
  5. The committed version X becomes X'.
  6. T releases its certify lock on X', which is X now.

Compatibility tables for basic 2pl and 2pl with certify locks:-

	Read	Write
Read	yes	no
Write	no	no

	Read	Write	Certify
Read	yes	no	no
Write	no	no	no
Certify	no	no	no

Note:

- In multiversion 2PL read and write operations from conflicting transactions can be processed concurrently.
- This improves concurrency but it may delay transaction commit because of obtaining certify locks on all its writes. It avoids cascading abort but like strict two phase locking scheme conflicting transactions may get deadlocked.

Validation (Optimistic) Concurrency Control Schemes

- In this technique only at the time of commit serializability is checked and transactions are aborted in case of non-serializable schedules.
- Three phases:
  1. **Read phase**
  2. **Validation phase**
  3. **Write phase**

1. **Read phase**:

A transaction can read values of committed data items. However, updates are applied only to local copies (versions) of the data items (in database cache).

2.**Validation phase**: Serializability is checked before transactions write their updates to the database.

- This phase for Ti checks that, for each transaction Tj that is either committed or is in its validation phase, one of the following conditions holds:
  - Tj completes its write phase before Ti starts its read phase.
  - Ti starts its write phase after Tj completes its write phase, and the read_set of Ti has no items in common with the write_set of Tj
  - Both the read_set and write_set of Ti have no items in common with the write_set of Tj, and Tj completes its read phase.
  - When validating Ti, the first condition is checked first for each transaction Tj, since (1) is the simplest condition to check. If (1) is false then (2) is checked and if (2) is false then (3) is checked. If none of these conditions holds, the validation fails and Ti is aborted.

3.Write phase: On a successful validation transactions' updates are applied to the database; otherwise, transactions are restarted.

LOCK

Definition : Lock is a variable associated with data item which gives the status whether the possible operations can be applied on it or not.

Two-Phase Locking Techniques:

Binary locks: Locked/unlocked

The simplest kind of lock is a binary on/off lock. This can be created by storing a lock bit with each database item. If the lock bit is on (e.g. = 1) then the item

cannot be accessed by any transaction either for reading or writing, if it is off (e.g. = 0) then the item is available. Enforces mutual exclusion

Binary locks are:

- Simple but are restrictive.
- Transactions must lock every data item that is read or written
- No data item can be accessed concurrently

Locking is an operation which secures

(a) permission to Read

(b) permission to Write a data item for a transaction.

Example: Lock (X). Data item X is locked in behalf of the requesting transaction.

Unlocking is an operation which removes these permissions from the data item.

Example:Unlock (X): Data item X is made available to all other transactions.

- Lock and Unlock are Atomic operations.
- Lock Manager:
  Managing locks on data items.

- Lock table:
- Lock manager uses it to store the identify of transaction locking a data item, the data item, lock mode . One simple way to implement a lock table is through linked list.
  < locking_transaction ,data item, LOCK >

The following code performs the lock operation:

```
B:    if LOCK (X) = 0 (*item is unlocked*)
      then LOCK (X) ← 1 (*lock the item*)
      else begin
           wait (until lock (X) = 0) and
           the lock manager wakes up the transaction);
```

goto B

end;

The following code performs the unlock operation:

LOCK (X) ← 0 (*unlock the item*)

if any transactions are waiting then

wake up one of the waiting the transactions;

Multiple-mode locks: Read/write

- a.k.a. Shared/Exclusive

- Three operations
  - read_lock(X)
  - write_lock(X)
  - unlock(X)
- Each data item can be in one of three lock states
  - Three locks modes:
    - (a) shared (read) (b) exclusive (write) (c) unlock(release)
  - **Shared mode**: shared lock (X)
    More than one transaction can apply share lock on X for reading its value but no write lock can be applied on X by any other transaction.
  - **Exclusive mode**: Write lock (X)
    Only one write lock on X can exist at any time and no shared lock can be applied by any other transaction on X.
  - **Unlock mode**: Unlock(X)
    After reading or writing the corresponding transaction releases by issuing this.

The rules for multiple-mode locking schemes are a transaction T:

- Issue a **read_lock(X)** or a **write_lock(X)** before **read(X)**
- Issue a **write_lock(X)** before **write(X)**
- Issue an **unlock(X)** after all **read(X)** and **write(X)** are finished

The transaction T

- Will not issue **read_lock (X)** or **write_lock(X)** if it already holds a lock on **X**
- Will not issue **unlock(X)** unless it already holds a lock on X

Lock table:

Lock manager uses it to store the identify of transaction locking a data item, the data item, lock mode and no of transactions that are currently reading the data item . It looks like as below

<data item,read_ LOCK,nooftransactions,transaction id >

This protocol isn't enough to guarantee serializability. If locks are released too early, you can create problems. This usually happens when a lock is released before another lock is acquired.

The following code performs the **read operation**:

```
B: if LOCK (X) = "unlocked" then
begin LOCK (X) ← "read-locked";
        no_of_reads (X) ← 1;
end
else if LOCK (X) ← "read-locked" then
            no_of_reads (X) ← no_of_reads (X) +1
 else  begin wait (until LOCK (X) = "unlocked" and
              the lock manager wakes up the transaction);
               go to B
end;
```

The following code performs the **write lock operation**:

```
B: if LOCK (X) = "unlocked" then
        LOCK (X) ← "write-locked";
        else  begin wait (until LOCK (X) = "unlocked" and
          the lock manager wakes up the transaction);
          go to B
        end;
```

The following code performs the **unlock operation**:

```
        if LOCK (X) = "write-locked" then
begin LOCK (X) ← "unlocked";
         wakes up one of the transactions, if any
end
else if LOCK (X) ← "read-locked" then
        begin
          no_of_reads (X) ← no_of_reads (X) -1
          if  no_of_reads (X) = 0 then
          begin
           LOCK (X) = "unlocked";
          wake up one of the transactions, if any
          end
        end;
```

Lock conversion:

Lock upgrade: existing read lock to write lock

if Ti has a read-lock (X) and Tj has no read-lock (X) ($i \neq j$) then convert read-lock (X) to write-lock (X)

else

force Ti to wait until Tj unlocks X

Lock downgrade: existing write lock to read lock

Ti has a write-lock (X) (*no transaction can have any lock on X*)

convert write-lock (X) to read-lock (X)

Two-Phase Locking Techniques: The algorithm

The timing of locks is also important in avoiding concurrency problems. A simple requirement to ensure transactions are serializable is that all read and write locks in a transaction are issued before the first unlock operation known as a two-phase locking protocol.

Transaction divided into 2 phases:

- *growing* - new locks acquired but none released
- *shrinking* - existing locks released but no new ones acquired

During the shrinking phase no new locks can be acquired!

  - Downgrading ok
  - Upgrading is not

Rules of 2PL are as follows:

- If T wants to read an object it needs a read_lock
- If T wants to write an object, it needs a write_lock
- Once a lock is released, no new ones can be acquired.

The 2PL protocol guarantees serializability

- Any schedule of transactions that follow 2PL will be serializable

- We therefore do not need to test a schedule for serializability

But, it may limit the amount of concurrency since transactions may have to hold onto locks longer than needed, creating the new problem of deadlocks.

Two-Phase Locking Techniques: The algorithm

Here is a example without 2PL:-

T1	**T2**	**Result**
read_lock (Y);	read_lock (X);	Initial values: X=20; Y=30
read_item (Y);	read_item (X);	Result of serial execution
unlock (Y);	unlock (X);	T1 followed by T2
write_lock (X);	Write_lock (Y);	X=50, Y=80.
read_item (X);	read_item (Y);	Result of serial execution
X:=X+Y;	Y:=X+Y;	T2 followed by T1
write_item (X);	write_item (Y);	X=70, Y=50
unlock (X);	unlock (Y);	

T1	**T2**	**Result**
read_lock (Y);		X=50; Y=50
read_item (Y);		Nonserializable because it.
unlock (Y);		violated two-phase policy.
	read_lock (X);	
	read_item (X);	
	unlock (X);	
	write_lock (Y);	
	read_item (Y);	

Y:=X+Y;

write_item (Y);

unlock (Y);

write_lock (X);

read_item (X);

X:=X+Y;

write_item (X);

unlock (X);

Here is a example with 2PL:-

T'1	**T'2**	**Result**
read_lock (Y);	read_lock (X);	T1 and T2 follow two-phase
read_item (Y);	read_item (X);	policy but they are subject to
write_lock (X);	Write_lock (Y);	deadlock, which must be
unlock (Y);	unlock (X);	dealt with.
read_item (X);	read_item (Y);	
X:=X+Y;	Y:=X+Y;	
write_item (X);	write_item (Y);	
unlock (X);	unlock (Y);	

Two-phase policy generates four locking algorithms:-

1. BASIC
2. CONSERVATIVE
3. STRICT
4. RIGOUROUS

- Previous technique knows as *basic 2PL*
- ***Conservative* 2PL (static) 2PL**: Lock all items needed BEFORE execution begins by predeclaring its read and write set
  - If any of the items in read or write set is already locked (by other transactions), transaction waits (does not acquire any locks)
  - Deadlock free but not very realistic
- ***Strict* 2PL**: Transaction does not release its write locks until AFTER it aborts/commits
  - Not deadlock free but guarantees recoverable schedules (strict schedule: transaction can neither read/write X until last transaction that wrote X has committed/aborted)
  - Most popular variation of 2PL
- ***Rigorous* 2PL**: No lock is released until after abort/commit

Transaction is in its expanding phase until it ends

The Two-Phase Locking Protocol

Introduction

This is a protocol, which ensures conflict-serializable schedules.

Phase 1: Growing Phase

– Transaction may obtain locks.

– Transaction may not release locks.

Phase 2: Shrinking Phase

– Transaction may release locks.

– Transaction may not obtain locks.

– The protocol assures serializability. It can be proved that the transactions

can be serialized in the order of their lock points.

– **Lock points:** It is the point where a transaction acquired its final lock.

– Two-phase locking does not ensure freedom from deadlocks

– Cascading rollback is possible under two-phase locking.

– There can be conflict serializable schedules that cannot be obtained if

two-phase locking is used.

Given a transaction Ti that does not follow two-phase locking, we can find a

transaction Tj that uses two-phase locking, and a schedule for Ti and Tj that is not

conflict serializable.

Lock Conversions

Two-phase locking with lock conversions:

First Phase:

_ can acquire a **lock-S** on item

_ can acquire a **lock-X** on item

_ can convert a **lock-S** to a **lock-X** (**upgrade**)

Second Phase:

_ can release a **lock-S**

_ can release a **lock-X**

_ can convert a **lock-X** to a **lock-S** (**downgrade**)

This protocol assures serializability. But still relies on the programmer to insert

the various locking instructions.

Automatic Acquisition of Locks

A transaction Ti issues the standard read/write instruction, without explicit locking calls.

The operation read(D) is processed as:

if Ti has a lock on D

then

read(D)

else

begin

if necessary wait until no other

transaction has a **lock-X** on D

grant Ti a **lock-S** on D;

read(D)

end;

write(D) is processed as:

if Ti has a **lock-X** on D

then

write(D)

else

begin

if necessary wait until no other trans. has any lock on D,

if Ti has a **lock-S** on D

then

upgrade lock on Dto **lock-X**

else

grant Ti a **lock-X** on D

write(D)

end;All locks are released after commit or abort

Graph-Based Protocols

It is an alternative to two-phase locking.

Impose a partial ordering on the set **D** = *f* d1, d2 , ..., dh*g* of all data items.

If di*!* dj, then any transaction accessing both di and dj must access di before accessing dj.

Implies that the set **D** may now be viewed as a directed acyclic graph, called a database graph.

Tree-protocol is a simple kind of graph protocol.

Tree Protocol

Only exclusive locks are allowed.

The first lock by Ti may be on any data item. Subsequently, Ti can lock a data item Q, only if Ti currently locks the parent of Q.

Data items may be unlocked at any time.

A data item that has been locked and unlocked by Ti cannot subsequently be re-locked by Ti.

The tree protocol ensures conflict serializability as well as freedom from deadlock.

Unlocking may occur earlier in the tree-locking protocol than in the twophase locking protocol.

However, in the tree-locking protocol, a transaction may have to lock data items that it does not access.

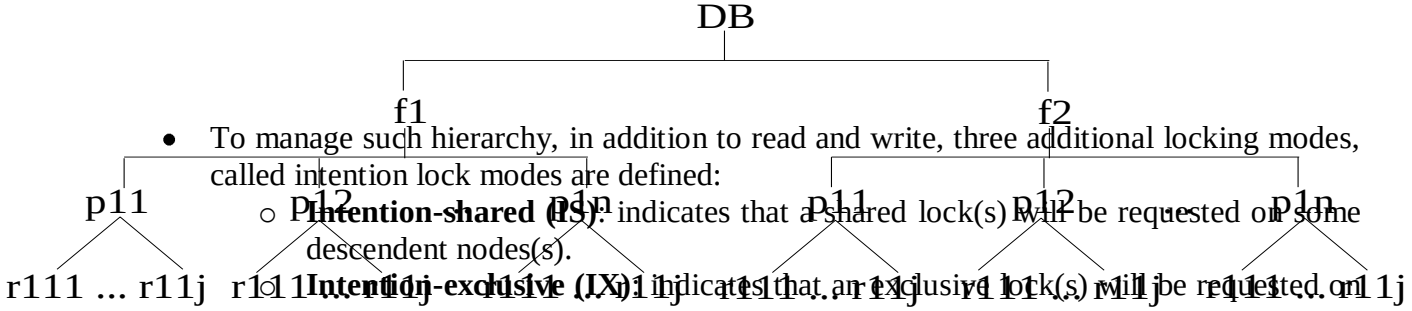
Increased locking overhead, and additional waiting time. Schedules not possible under two-phase locking are possible under tree

protocol, and vice versa.

Granularity of data items and Multiple Granularity Locking

- A lockable unit of data defines its granularity. Granularity can be coarse (entire database) or it can be fine (a tuple or an attribute of a relation).
- Data item granularity significantly affects concurrency control performance. Thus, the degree of concurrency is low for coarse granularity and high for fine granularity.
- Example of data item granularity:
  1. A field of a database record (an attribute of a tuple)
  2. A database record (a tuple or a relation)
  3. A disk block
  4. An entire file
  5. The entire database

■ The following diagram illustrates a hierarchy of granularity from coarse (database) to fine (record).



- To manage such hierarchy, in addition to read and write, three additional locking modes, called intention lock modes are defined:
  - **Intention-shared (IS):** indicates that a shared lock(s) will be requested on some descendent nodes(s).
  - **Intention-exclusive (IX):** indicates that an exclusive lock(s) will be requested on some descendent node(s).

- **Shared-intention-exclusive (SIX)**: indicates that the current node is locked in shared mode but an exclusive lock(s) will be requested on some descendent nodes(s).

These locks are applied using the following compatibility matrix:

	IS	IX	S	SIX	X
IS	yes	yes	yes	yes	no
IX	yes	yes	no	no	no
S	yes	no	yes	no	no
SIX	yes	no	no	no	no
X	no	no	no	no	no

- The set of rules which must be followed for producing serializable schedule are
  1. The lock compatibility must adhered to.
  2. The root of the tree must be locked first, in any mode..
  3. A node N can be locked by a transaction T in S or IX mode only if the parent node is already locked by T in either IS or IX mode.
  4. A node N can be locked by T in X, IX, or SIX mode only if the parent of N is already locked by T in either IX or SIX mode.
  5. T can lock a node only if it has not unlocked any node (to enforce 2PL policy).
  6. T can unlock a node, N, only if none of the children of N are currently locked by T.

Granularity of data items and Multiple Granularity Locking: An example of a serializable execution:

T1 T2 T3

IX(db)

IX(f1)

IX(db)

IS(db)

IS(f1)

IS(p11)

IX(p11)

X(r111)

IX(f1)

X(p12)

S(r11j)

IX(f2)

IX(p21)

IX(r211)

Unlock (r211)

Unlock (p21)

Unlock (f2)

S(f2)

DEAD LOCKS:-

Two Problems with Locks

- **Deadlock**
- **Starvation**

Dead locks occurs when each transaction Ti in a set of two or more is waiting on an item locked by some other transaction Tj in the set

Dead lock example:

T'1	**T'2**	
read_lock (Y);		**T1 and T2 did follow two-phase**
read_item (Y);		**policy but they are deadlock**
	read_lock (X);	

	read_item (X);
write_lock (X);	
(waits for X)	**write_lock (Y);**
	(waits for Y)

Deadlock Prevention

- *Locking* as deadlock prevention leads to very inefficient schedules (e.g., conservative 2PL)
- Better, use *transaction timestamp* TS(T)
  - TS is unique identifier assigned to each transaction
  - if T1 starts before T2, then TS(T1) < TS(T2) (older has smaller timestamp value)
  - *Wait-die* and *wound-wait* schemes

Wait-Die Scheme

- Assume Ti tries to lock X which is locked by Tj
- If TS(Ti) < TS(Tj) (Ti older than Tj), then Ti is allowed to wait
- Otherwise, Ti younger than Tj, abort Ti (Ti dies) and restart later with SAME timestamp
- Older transaction is allowed to wait on younger transaction
- Younger transaction requesting an item held by older transaction is aborted and restarted

Wound-Wait Scheme

- Assume Ti tries to lock X which is locked by Tj
- If TS(Ti) < TS(Tj) (Ti older than Tj), abort Tj (Ti wounds Tj) and restart later with SAME timestamp
- Otherwise, Ti younger than Tj, Ti is allowed to wait
- Younger transaction is allowed to wait on older transaction
- Older transaction requesting item held by younger transaction preempts younger one by aborting it
- Both schemes abort younger transaction that may be involved in deadlock
- Both deadlock free but may cause needless aborts

More Deadlock Prevention

- *Waiting schemes* (require no timestamps)
- No waiting: if transaction cannot obtain lock, aborted immediately and restarted after time *t* needless restarts
- Cautious waiting:
  - Suppose Ti tries to lock item X which is locked by Tj
  - If Tj is not blocked, Ti is blocked and allowed to wait
  - O.w. abort Ti
  - Cautious waiting is deadlock-free

Deadlock Detection

- DBMS checks if deadlock has occurred
  - Works well if few short transactions with little interference
  - O.w., use deadlock prevention
- Two approaches to deadlock detection:

1. Wait-for graph
   - If cycle, abort one of the transactions (victim selection)
2. Timeouts

Starvation

- Transaction cannot continue for indefinite amount of time while others proceed normally
- When? Unfair waiting scheme with priorities for certain transactions E.g., in deadlock detection, if we choose victim always based on cost factors, same transaction may always be picked as victim
  - Include rollbacks in cost factor

UNIT IV
TRENDS IN DATABASE TECHNOLOGY

Classification o f Physical Storage Media

Based on Speed with which data can be accessed Based on Cost per unit of data Based on eliability Data loss on power failure or system crash Physical failure of the storage device H Based on life of storage Volatile storage: loses contents when power is switched off 4 Non-volatile storage:

Contents persist even when power is switched off. Includes secondary and tertiary storage, as well as batterbacked up main-memory.

Physical Storage Media

Cache

The fastest and most costly form of storage Volatile Managed by the computer system hardware.

Main memory

4 Fast access (10s to 100s of nanoseconds; 1 nanosecond = 10–9 seconds) 4 Generally too small (or too expensive) to store the entire database

Capacities of up to a few Gigabytes widely used currently Capacities have gone up and per-byte costs have decreased steadily and rapidly

Volatile — contents of main memory are usually lost if a power failure or system crash occurs.

Flash memory

Data survives power failureData can be written at a location only once, but location can be erased and written to again **Can support only a limited number of write/erase cycles.**

Erasing of memory has to be done to an entire bank of memory.

Reads are roughly as fast as main memory But writes are slow (few microseconds), erase is slower Cost per unit of storage roughly similar to main memory Widely used in embedded devices such as digital cameras Also known as EEPROM

Magnetic-disk

Data is stored on spinning disk,and read/written magneticallyPrimary medium for the long-term storage of data;typically stores entire database.Data must be moved from disk to main memory foraccess, and written back for storage

Much slower accessthan main memory (more on this later)

Direct-access – possible to read data on disk in any order,unlike magnetic tapeHard disks vs. floppy disks Capacities range up to roughly 100 GB currently

Much larger capacity and cost/byte than main memory/ flash memory Growing constantly and rapidly with technology improvements

Survives power failures and system crashes

Disk failure candestroy data, but is very rare.

Optical storage

Non-volatile, data is read optically from a spinning disk using a laser CD-ROM (640 MB) and DVD (4.7 to 17 GB) most popular forms Write-one, read-many (WORM) optical disks used for archival storage (CD-R and DVD-R) Multiple write versions also available (CD-RW, DVDRW,

and DVD-RAM) 4 Reads and writes are slower than with magnetic disk Juke-box systems, with large numbers of removable disks, a few drives, and a mechanism for automatic loading/unloading of disks available for storing large volumes of data.

Optical Disks

Compact disk-read only memory (CD-ROM) Disks can be loaded into or removed from a drive 4 High storage capacity (640 MB per disk) High seek times or about 100 msec (optical read head is heavier and slower) Higher latency (3000 RPM) and lower data-transfer rates (3-6 MB/s) compared to magnetic disks

Digital Video Disk (DVD)

DVD-5 holds 4.7 GB, and DVD-9 holds 8.5 GB DVD-10 and DVD-18 are double sided formats with capacities of 9.4 GB & 17 GB Other characteristics similar to CD-ROM 4 Record once versions (CD-R and DVD-R) Data can only be written once, and cannot be erased. High capacity and long lifetime; used for archival storage 4Multi-write versions (CD-RW, DVD-RW and DVDRAM) also available

Tape storage

Non-volatile, used primarily for backup (to recover from disk failure), and for archival data Sequential-access – much slower than disk Very high capacity (40 to 300 GB tapes available) Tape can be removed from drive storage costs much cheaper than disk, but drives are expensive
4 Tape jukeboxes available for storing massive amounts of data Hundreds of terabytes (1 terabyte = 109 bytes) to even apetabyte (1 petabyte = 1012 bytes)

Storage Hierarchy

Primary storage: Fastest media but volatile (cache, main memory).

Secondary storage: next level in hierarchy, non-volatile, moderately fast access time. Also called on-line storage

4E.g. flash memory, magnetic disks

Tertiary storage: lowest level in hierarchy, non-volatile, slow access time Also called off-line storage
E.g. magnetic tape, optical storage

Magnetic Hard Disk Mechanism

n Read-write head Positioned very close to the platter surface (almost touching it) Reads or writes magnetically encoded information. Surface of platter divided into circular tracks Over 17,000 tracks per platter on typical hard disks Each track is divided into sectors. A sector is the smallest unit of data that can be read or written. H Sector size typically 512 bytes Typical sectors per track: 200 (on inner tracks) to 400 (on outer tracks) To read/write a sector Disk arm swings to position head on right track Platter spins continually; data is read/written as sector passes

under head Head-disk assemblies Multiple disk platters on a single spindle (typically 2 to 4) One head per platter, mounted on a common arm. Cylinder i consists of i_{th} track of all the platters

Performance Measures of Disks

Access Time – the time it takes from when a read or write request is issued to when data transfer begins. Consists of:

Seek Time – time it takes to reposition the arm over the correct track.

Average Seek Time **is 1/2 the worst case seek time.**

– Would be 1/3 if all tracks had the same number of sectors, and we ignore the time to start and stop arm movement 4 to 10 milliseconds on typical disks

Rotational latency – time it takes for the sector to be accessed to appear under the head.

Average latency is 1/2 of the worst-case latency. 4 to 11 milliseconds on typical disks (5400 to 15000 r.p.m.) n **Data-Transfer Rate** – the rate at which data can be retrieved from or stored to the disk. H4 to 8 MB per second is typical

Multiple disks may share a controller, so rate that controller can handle is also important

Mean Time To Failure (MTTF) – the average time the disk is expected to run continuously without any failure. Typically 3 to 5 years Probability of failure of new disks is quite low, corresponding to a ―theoretical MTTF‖ of 30,000 to 1,200,000 hours for a new disk.

RAID

RAID: Redundant Arrays of Independent Disks

disk organization techniques that manage a large numbers of disks, providing a view of a single disk of high reliability by storing data redundantly, so that data can be recovered even if a disk fails. The chance that some disk out of a set of *N* disks will fail is much higher than the chance that a specific single disk will fail.

E.g., a system with 100 disks, each with MTTF of 100,000 hours (approx. 11 years), will have a system MTTF of 1000 hours (approx. 41 days)

o Techniques for using redundancy to avoid data loss are critical with large numbers of disks

 Originally a cost-effective alternative to large, expensive disks.

o I in RAID originally stood for ―inexpensive‘‘

o Today RAIDs are used for their higher reliability and bandwidth.

 The ―I‖ is interpreted as independent

 Improvement of Reliability viaRedundancy

 Redundancy– store extra information that can be used to rebuild information lost in a disk failure.

 E.g., Mirroring (or shadowing)

o Duplicate every disk. Logical disk consists of two physical disks.

o Every write is carried out on both disks

 Reads can take place from either disk

o If one disk in a pair fails, data still available in the other

 Data loss would occur only if a disk fails, and its mirror disk also fails before the system is repaired.

Prob ability of combined event is very small o Except for dependent failure modes

such as fire or building collapse or electrical power surges.
 Mean time to data loss depends on mean time to failure, and mean time to repair.
o E.g. MTTF of 100,000 hours, mean time to repair of 10 hours
gives mean time to data loss of 500*106 hours (or 57,000 years)
for a mirrored pair of disks (ignoring dependent failure modes)
 Improvement in Performance via Parallelism
o Two main goals of parallelism in a disk system:
1. Load balance multiple small accesses to increase throughput
2. Parallelize large accesses to reduce response time.
o Improve transfer rate by striping data across multiple disks.
o Bit-level striping – split the bits of each byte across multiple disks
 In an array of eight disks, write bit*i* of each byte to disk *i.*
 Each access can read data at eight times the rate of a single disk.
 But seek/access time worse than for a single disk
Bit level striping is not used much any more
o Block-level striping – with *n* disks, block *i* of a file goes to disk (*i* mod *n*) + 1
 Requests for different blocks can run in parallel if the blocks reside on different disks.
 A request for a long sequence of blocks can utilize all disks in parallel.

RAID Levels

o Schemes to provide redundancy at lower cost by using disk striping combined with parity bits.
Different RAID organizations, or RAID levels, have differing cost, performance and reliability
 RAID Level 0: Block striping; non-redundant.
    o Used in high-performance applications where data lost is not critical.
 RAID Level 1: Mirrored disks with block striping.
    o Offers best write performance.
    o Popular for applications such as storing log files in a database system.
 RAID Level 2: Memory-Style Error-Correcting-Codes (ECC) with bit striping.
  RAID Level 5: Block-Interleaved Distributed Parity; partitions data and parity amongall *N* + 1 disks, rather than storing data in *N* disks and parity in 1 disk.
o E.g., with 5 disks, parity block for *n*th set of blocks is stored on disk (*n mod* 5) + 1, with the data
blocks stored on the other 4 disks. o Higher I/O rates than Level 4. Block writes occur in parallel if the blocks and their parity blocks are on different disks. o Subsumes Level 4: provides same benefits, but avoids bottleneck of parity disk. RAID Level 6: P+Q Redundancy scheme; similar to Level 5, but stores extra redundant information to guard against multiple disk failures.
o Better reliability than Level 5 at a higher cost; not used as widely.

FILE OPERATIONS

 The database is stored as a collectionof *files*. Each file is a sequence of *records.* A record is a sequence of fields.
 One approach:
o assume record size is fixed.
o each file has records of one particular type only.
o different files are used for different relations.
 This case is easiestto implement; will consider variable length records later.

Fixed-Length Records

- Simple approach:
  - Store record *i* starting from byte *n (i* – 1), where *n* is the size of each record.
  - Record access is simple but records may cross blocks
- Modification: donot allow records to cross block boundaries.
- Free List s
  - Store the address of the first deleted record in the file header.
  - Use this first record to store the address of the second deleted record, and so on.
  - Can think of these stored addresses as pointers since they ―point‖ to the location of a record.
  - More space efficient representation: reuse space for normal attributes of free records to store pointers. (No pointers stored in in-use records.)

Variable-Length Records

o Variable-length records arise in database systems in several ways:

- Storage of multiple record types in a file.
- Record types that allow variable lengths for one or more fields.
- Record types that allow repeating fields (used in some older data models).
  - Byte string representation
- Attach an*end-of-record* ( ) control character to the end of each record.
- Difficulty with deletion.
- Difficulty with growth.
- Variable-Length Records: Slotted Page Structure
- Slotted page header contains: o number of record entries. o end of free space in the block. o location and size of each record.
- Records can be moved around within a page to keep them contiguous with no empty space between them; entry in the header must be up-dated.
- Pointers should not point directly to record— instead they should point to the entry for the record in header.
- Fixed-length representation:
  - reserved space
  - pointers
- Reserved space– can use fixed-length records of a known maximum length; unused space in shorter records filled with a null or end-of-record symbol.

Pointer Method

- Pointer method
- A variable-length record is represented by a list of fixed-length records, chained together via pointers.
- Can be used even if the maximum record length is not known
- Disadvantage to pointer structure; space iswasted in all records except the first in a a chain.
- Solution is to allow two kinds of block in file:
- Anchor block– contains the first records of chain
- Overflow block– contains records other than those that are the first records of chairs.

Organization of Records in Files

 Heap– a record can be placed anywhere in the file where there is space

 Sequential – store records in sequential order, based on the value of the search key of each record

 Hashing– a hash function computed on some attribute of each record; the result specifies in which block of the file the record should be placed

 Records of each relation may be stored in a separate file. In a clustering NOTES file organization records of several different relations can be stored in the same file

 Motivation: store related records on the same block to minimize I/O

Sequential File Organization

 Suitable for applications that require sequential processing of the entire file

 The records in the file are ordered by a search-key

 Deletion– use pointer chains

 Insertion–locate the position where the record is to be inserted

 if there is free space insert there

 if no free space, insert the record in an overflow block

 In either case, pointer chain must be updated

 Need to reorganize the file from time to time to restore sequential order

Clustering File Organization

o Simple file structure stores each relation in a separate file.

o Can instead store several relations in one file using a clustering file organization.

o E.g., clustering organization of *customer* and *depositor:*

Mapping of Objects to Files

 Mapping objects to files is similar to mapping tuples to files in a relational system; object data can be stored using file structures.

 Objects in O-O databases may lack uniformity and may be very large; such objects have to managed differently from records in a relational system.

o Set fields with a small number of elements may be implemented using data structures such as linked lists.

o Set fields with a larger number of elements may be implemented as separate relations in the database.

o Se t fields can also be eliminated at the storage level by normalization.

 Similar to conversion of multivalued attributes of E-R diagrams to relations

 Objects are identified by an object identifier (OID); the storage system needs a mechanism to locate an object given its OID (this action is called dereferencing).

o logical identifiers do not directly specify an object‘s physical location; must maintain an index that maps an OID to the object‘s actual location.

o physical identifiers encode the location of the object so the object can be found directly. Physical OIDs typically have the following parts:

1. a volume or file identifier
2. a page identifier within the volume or file
3. an offset within the page

HASHING

Hashing is a hash function computed on some attribute of each record; the result specifies in which block of the file the record should be placed.

Static Hashing

A bucket is a unit of storage containing one or more records (a bucket is typically a disk block).
Hash function *h* is a function from the set of all search-key values *K* to the set of all bucket addresses *B.*
Hash function is used to locate records for access, insertion as well as deletion.
Records with different search-key values may be mapped to the same bucket; thus entire bucket has to be searched sequentially to locate a record.

Example of Hash File Organization
Hash file organization of *account* file, using *branch-name* as key o There are 10 buckets ,
o The binary representation of the *i*th character is assumed to be the integer *i.*
o The hash function returns the sum of the binary representations of the characters modulo 10.
o E.g. h(Perryridge) = 5 h(Round Hill) = 3 h(Brighton) = 3
o Hash file organization of *account* file, using *branch-name* as key

Hash Functions

o Worst had function maps all search-key values to the same bucket; this makes access time proportional to t he number of search-key values in the file.
o An ideal hash function is uniform, i.e., each bucket is assigned the same number of search-key values from the set of *all* possible values.
o Ideal hash function is random, so each bucket will have the same number of records assigned to
it irrespective of the *actual distribution* of search-key values in the file.
o Typical hash functions perform computation on the internal binary representation of the searchkey.
o For example, for a string search-key, the binary representations of all the characters in the string
could be added and the sum modulo the number of buckets could be returned.

Handling of Bucket Overflows

o Bucket overflow can occur because of
- Insufficient buckets
- Skew in distribution of r ecords. This can occur due to two reasons:
- multiple records have same search-key value
- chosen hash function produces non-uniform distribution of key values

o Although the probability of bucket overflow can be reduced, it cannot be eliminated; it is handled
by using *overflow buckets.*
o Overflow chaining – the overflow buckets of a given bucket are chained together in a linked list.
o The Above scheme is called closed hashing.
o An alternative, called open hashing, which does not use overflow buckets, is not suitable for

database applications.

Hash Indices

o Hashing can be used not only for file organization, but also for index-structure creation.
o A hash index organizes the search keys, with their associated record pointers, into a hash file structure.
o Strictly speaking, hash indices are always secondary indices
o If the file itself is organized using hashing, a separate primary hash index on it using the same search-key is unnecessary.
o However, we use the term hash index to refer to both secondary index structures and hash organized files.
 Example of Hash Index

Deficiencies of Static Hashing

o In static hashing, function *h* maps search-key values to a fixed set of *B* of bucket addresses.
o Databases grow with time. If initial number of buckets is too small, performance will degrade due
to too much overflows.
o If file size at some point in the future is anticipated and number of buck-ets allocated accordingly,
significant amount of space will be wasted initially.
o If database shrinks, again space will be wasted.
o One option is periodic re-organization of the file with a new hash func-tion, but it is very expensive.
o These problems can be avoided by using techniques that allow the number of buckets to be modified dynamically.

Dynamic Hashing

 Good for database that grows and shrinks in size .
 Allows the hash function to be modified dynamically.

Extendable hashing – one form of dynamic hashing

 Hash function generates values over a large range— typically *b*-bit integers, with $b = 32$.
 At any time use only a prefix of the hash function to index into a table of bucket addresses.
 Let the length of the prefix be i bits, $0 \ i \ 32$.
 Bucket address table size = 2^i. Initially $i = 0$.
 Value of i grows and shrinks as the size of the database grows and shrinks.
 Multiple entries in the bucket address table may point to a bucket.
 Thus, actual number of buckets is $< 2^i$.
 The number of buckets also changes dynamically due to coalescing and splitting of buckets.

General Extendable Hash Structure

Use of Extendable Hash Structure

o Each bucket *j* stores a value *ij;* all the entries that point to the same bucket have the same values on the first *ij* bits.

o To locate the bucket containing search-key *Kj*: o 1. Compute *h(Kj) = X*

o 2.Use the first *i* high order bits of *X* as a displacement into bucket address table, and follow the pointer to appropriate bucket

o To insert a record with search-key value *Kj*

o follow same procedure as look-up and locate the bucket, say *j*.

o If there is room in the bucket *j* insert record in the bucket.

o Else the bucket must be split and insertion re-attempted.

o Overflow buckets used instead in some cases.

Updates in Extendable Hash Structure

o To split a bucket *j* when inserting record with search-key value *Kj*:

o If *i > ij* (more than one pointer to bucket *j*)

o allocate a new bucket *z*, and set *ij* and *iz* to the old *ij* -+ 1.

o make the second half of the bucket address table entries pointing to *j* to point to *z*

o remove and reinsert each record in bucket *j*.

o recompute new bucket for *Kj* and insert record in the bucket (fur-ther splitting is required if the bucket is still full)

o If *i = ij* (only one pointer to bucket *j*)

o increment *i* and double the size of the bucket address table.

o replace each entry in the table by two entries that point to the same bucket.

o recompute new bucket address table entry for *Kj* Now *i > ij* so use the first case above.

o When inserting a value, if the bucket is full after several splits (that is, *i* reaches some limit *b*) create an overflow bucket instead of splitting bucket entry table further. o To delete a key value,

o locate it in its bucket and remove it.

o The bucket itself can be removed if it becomes empty (with appro-priate updates to the bucket address table).

o Coalescing of buckets can be done (can coalesce only with a ―buddy‖ bucket having same value of ij and same ij –1 prefix, if it is present).

o Decreasing bucket address table size is also possible.

o Note: decreasing bucket address table size is an expensive opera-tion and should be done only if number of buckets becomes much smaller than the size of the table.

Use of Extendable Hash Structure: Example Initial Hash structure, bucket size = 2

- Hash structure after insertion of one Brighton and two Downtown records
- Hash structure after insertion of Mianus record
- Hash structure after insertion of three Perryridge records
- Hash structure after insertion of Redwood and Round Hill records

Extendable Hashing vs. Other Schemes

 Benefits of extendable hashing :

o Hash performance does not degrade with growth of file

o Minimal space overhead

 Disadvantages of extendable hashing

o Extra level of indirection to find desired record

o Bucket address table may itself become very big (larger than memory)

 Need a tree structure to locate desired record in the structure!

o Changing size of bucket address table is an expensive operation

 Linear hashing is an alternative mechanism which avoids these disadvantages at the possible cost

of more bucket overflows.

INDEXING

 Indexing mechanisms used to speed up access to desired data. o E.g., author catalog in library Search-key Pointer

 Search Key- attribute to set of attributes used to look up records in a file.

 An index file consists of records (called index entries) of the form.

 Index files are typically much smaller than the original file.

Two basic kinds of indices:

o Ordered indices: search keys are stored in sorted order.

o Hash indices: search keys are distributed uniformly across ―buckets‖ using a ―hash function‖. Index Evaluation Metrics

o Access types supported efficiently. E.g.,

o records with a specified value in the attribute

o or records with an attribute value falling in a specified range of values.

o Access time o Insertion time

o Deletion time

o Space overhead

 Ordered Indices

o Indexing techniques evaluated on basis of:

 In an ordered index, index entries are stored, sorted on the search key value. E.g., author catalogin library.

 Primary index: in a sequentially ordered file, the index whose search key specifies the sequentialorder of the file.

 Also called clustering index

 The search key of a primary index is usually but not necessarily the primary key.

 Secondary index: an index whose search key specifies an order different from the sequential order of the file. Also called non-clustering index.

 Index-sequential file: ordered sequential file with

a primary index.

  Dense Index File s

o Dense index — Index record appears for every search key value in the file.

Sparse Index Files

- Sparse Index: contains index records for only some search-key values.
- Applicable when records are sequentially ordered on search-key
- To locate a record with search-key value *K* we:
- Find index record with largest search-key value < *K*
- Search file sequentially starting at the record to which the index record points.
- Less space and less maintenance overhead for insertions and deletions.
- Generally slower than dense index for locating records.
- Good tradeoff: sparse index with an index entry for every block in file, corresponding to least search-key value in the block.
- Example of Sparse Index Files

Multilevel Index

- If primary index does not fit in memory, access becomes expensive .
- To reducen umber of disk accesses to index records, treat primary index kept on disk as a sequential file and construct a sparse index on it. o outer index – a sparse index of primary index o inner index – the primary index file
- If even the outer index is too large to fit in main memory, yet another level of index can be created, and so on.
- Indices at all levels must be updated on insertion or deletion from the file.
- Index Update: Deletion
- If deleted record was the only record in the file with its particular search-key value, the searchkey is deleted from the index also.
- Single-level index deletion:

o Dense indices – deletion of search-key is similar to file record deletion.
o Sparse indices – if an entry for the search key exists in the index, it is deleted by replacing the entry in the index with the next search-key value in the file (in search-key order). If the next search-key value already has an index entry, the entry is deleted instead of being replaced.

- Index Update: Insertion

o Single-level index insertion:
o Perform a lookup using the search-key value appearing in the record to be inserted.
o Dense indices – if the search-key value does not appear in the index, insert it.
o Sparse indices – if index stores an entry for each block of the file, no change needs to be made to the index unless a new block is created. In this case, the first search-key value appearing in the new block is inserted into the index.
o Multilevel insertion (as well as deletion) algorithms are simple extensions of the single-level algorithms.

Secondary Indices

o Frequently, one wants to find all the records whose values in a certain field (which is not the search-key of the primary index satisfy some condition.

o Example 1: In the *account* database stored sequentially by account number, we may want to find all accounts in a particular branch.

o Example 2: as above, but where we want to find all accounts with a specified balance or range of balances

o We can have a secondary index with an index record for each search-key value; index record points to a bucket that contains pointers to all the actual records with that particular search-key value.

 Secondary Index on *balance* field of *account*

 Primary and Secondary Indice s

 Secondary indices have to be dense.

 Indices offer substantial benefits when searching for records.

 When a file is modified, every index on the file must be updated, Updating indices imposes overhead on database modification.

 Sequential scan using primary index is efficient, but a sequential scan using a secondary index is expensive.

 each record access may fetch a new block from disk

 Bitmap Indices

n Bitmap indices are a special type of index designed for efficient querying on multiple keys.

n Records in a relation are assumed to be numbered sequentially from, say,0

 Given a number n it must be easy to retrieve record n

 Particularly easy if records are of fixed size

n Applicable on attributes that take on a relatively small number of distinct values

 E.g. gender, country, state, …

 E.g. income-level (income broken up into a small number of levels such as 0-9999, 10000-19999, 20000-50000, 50000- infinity)

n A bitmap is simply an array of bits.

n In its simplest form a bitmap index on an attribute has a bitmap for each value of the attribute.

 Bitmap has as many bits as records.

 In a bitmap for value v, the bit for a record is 1 if the record has the value v for the attribute, and is 0 otherwise.

n Bitmap indices are useful for queries on multiple attributes

 Not particularly useful for single attribute queries

n Queries are answered using bitmap operations

 Intersection (and)

 Union (or)

 Complementation (not)

n Each operation takes two bitmaps of the same size and applies the operation on corresponding bits to get the result bitmap

 Males with income level L1: 10010 AND 10100 = 10000

 If number of distinct attribute values is 8, bitmap is only 1% of relation size
n Deletion needs to be handled properly
 Existence bitmap to note if there is a valid record at a record location
 Needed for complementation
n Should keep bitmaps for all values, even null value.

B+-Tree Index Files
o B+-tree indices are an alternative to indexed-sequential files.
o Disadvantage of indexed-sequential files: performance degrades as file grows, since many overflow blocks get created. Periodic reorganization of entire file is required.
o Advantage of B+-tree index files: automatically reorganizes itself with small, local, changes, in the face of insertions and deletions. Reorganization of entire file is not required to maintain performance. o Disadvantage of B+-trees: extra insertion and deletion overhead,
space overhead.
o Advantages of B+-trees outweigh disadvantages, and they are used
extensively.
 A B+-tree is a rooted tree satisfying the following properties:
 All paths from root to leaf are of the same length
 Each node that is not a root or a leaf has between [*n*/2] and *n* children.
 A leaf node has between [(*n*–1)/2] and *n*–1 values
 Special cases:
If the root is not a leaf, it has at least 2 children.
If the root is a leaf (that is, there are no other nodes in the tree), it can have between 0 and (*n*–1) values.
 Typical node
o Ki are the search-key values
o Pi are pointers to children (for non-leaf nodes) or pointers to records or buckets of records (for leaf nodes).
 The search-keys in a node are ordered
*K*1 < *K*2 < *K*3 < . . . < *Kn*–1.
Leaf Nodes in B+-Trees
o Properties of a leaf node:
 For *i* = 1, 2, . . ., *n*–1, pointer *Pi* either points to a file record with search-key value *Ki*, or to a bucket of pointers to file records, each record having search-key value *Ki*. Only need bucket structure if search-key does not form a primary key. If *Li*, *Lj* are leaf nodes and *i* < *j*, *Li*'s search-key values are less than *Lj*'s search-key values. *Pn* points to next leaf node in search-key order.
Non-Leaf Nodes in B+-Trees
 Non leaf nodes form a multi-level sparse index on the leaf nodes. For a non-leaf node with *m* pointers:
o All the search-keys in the subtree to which *P*1 points are less than *K*1.
o For 2 *i n* – 1, all the search-keys in the subtree to which *Pi* points have values greater than or equal to *Ki*–1 and less than *Km–1*. Example of a B+-tree
B+-tree for *account* file (*n* = 3)
B+-tree for *account* file (*n* - 5)
o Leaf nodes must have between 2 and 4 values ((*n*–1)/2 and *n* –1, with *n* = 5).

o Non-leaf nodes other than root must have between 3 and 5 children ((*n*/2 and *n* with *n* =5).
o Root must have at least 2 children.
 Observations about B+-trees
o Since the inter-node connections are done by pointers, ―logically‖ close blocks need not be ―physically‖ close.
o Th e non-leaf levels of the B+-tree form a hierarchy of sparse indices.
o The B+-tree contains a relatively small number of levels (logarithmic in the size of the main file),
thus searches can be conducted efficiently.
o Insertions and deletions to the main file can be handled efficiently, as the index can be restructured
in logarithmic time.
Queries on B+-Trees
 Find all records with a search-key value of *k.* o Start with the root node
 Examine the node for the smallest search-key value > *k.*
 If such a value exists, assume it is*Kj.* Then follow *P*i to the child node.
 Otherwise*k Km*–1, where there are *m* pointers in the node. Then follow *Pm* to the child node.
o If the node reached by following the pointer above is not a leaf node, repeat the above procedure
on the node, and follow the
corresponding pointer.
o Eventually reach a leaf node. If for some *i,* key *Ki* = k follow pointer *Pi* to the desired record or
bucket. Else no record with search-key value *k* exists.
Result of splitting node containing Brighton and Downtown on inserting NOTES
Clearview
B+-Tree before and after insertion of ―Clearview‖
 Updates on B+-Trees: Deletion
 Find the record to be deleted, and remove it from the main file and from the bucket (if present).
 Remove (search-key value, pointer) from the leaf node if there is no bucket or if the bucket has
become empty.
 If thenode has too few entries due to the removal, and the entries in the node and a sibling fit into a single node, then
 Insert all the search-key values in the two nodes into a single node (the one on the left), and delete the other node.
 Delete the pair (*Ki*–1, *Pi),* where *Pi* is the pointer to the deleted node, from its parent, recursively using the above procedure.
 Otherwise, if the node has too few entries due to the removal, and the entries in the node and a sibling fit into a single node, then
Redistribute the pointers between the node and a sibling such that both have more than the minimum number of entries.
Update the corresponding search-key value in the parent of the node.
  The node deletions may cascade upwards till a node whichh as
n/2 or more pointers is found. If the root node has only one

pointer after deletion, it is deleted and the sole child becomes the
root.
□ □ Examples of B+-Tree Deletion
Before and after deleting ―Downtown‖
o The removal of the leaf node containing ―Downtown‖ did not result in its parent having too little
pointers. So the cascaded deletions stopped with the deleted leaf node‘s parent.

B+-Tree File Organization
o Index file degradation problem is solved by using B+-Tree indices. Data file degradation problem is solved by using B+-Tree File Organization.
o The leaf nodes in a B+-tree file organization store records, instead of pointers.
o Since records are larger than pointers, the maximum number of records that can be stored in a leaf node is less than the number of pointers in a nonleaf node.
Leaf nodes are still required to be half full.
Insertion and deletion are handled in the same way as insertion and deletion of entries in a B+-tree index
Example of B+-tree File Organization
o Good space utilization is important since records use more space than pointers.
o To improve space utilization, involve more sibling nodes in redistribution during splits and merges.
□ Involving 2 siblings in redistribution (to avoid split / merge where possible) results in each node
having at least entries
Data Warehouse:
➢ Large organizations have complex internal organizations, and have data stored at different locations, on different operational (transaction processing) systems, under different schemas
➢ Data sources often store only current data, not historical data
➢ Corporate decision making requires a unified view of all organizational data, including historical data
➢ A data warehouse is a repository (archive) of information gathered from multiple sources, stored under a unified schema, at a single site
- Greatly simplifies querying, permits study of historical trends
- Shifts decision support query load away from transaction processing systems

When and how to gather data
- Source driven architecture: data sources transmit new information to warehouse, either continuously or periodically (e.g. at night)
- Destination driven architecture: warehouse periodically requests new information from data sources
- Keeping warehouse exactly synchronized with data sources (e.g. using two-phase commit) is too expensive
- Usually OK to have slightly out-of-date data at warehouse
- Data/updates are periodically downloaded form online transaction processing (OLTP)

systems. *What schema to use*
- Schema integration

Data cleansing
- E.g. correct mistakes in addresses
- E.g. misspellings, zip code errors

Merge address lists from different sources and purge duplicates
- Keep only one address record per household (―householding‖)

How to propagate updates
- Warehouse schema may be a (materialized) view of schema from data sources
- Efficient techniques for update of materialized views

What data to summarize
- Raw data may be too large to store on-line
- Aggregate values (totals/subtotals) often suffice
- Queries on raw data can often be transformed by query optimizer to use aggregate values.

Data Mining
- Broadly speaking, data mining is the process of semi-automatically analyzing large databases to find useful patterns.
- Like knowledge discovery in artificial intelligence data mining discovers statistical rules and patterns
- Differs from machine learning in that it deals with large volumes of data stored primarily on disk.
- Some types of knowledge discovered from a database can be represented by a set of rules. e.g.,: ―Young women with annual incomes greater than $50,000 are most likely to buy sports cars‖.
- Other types of knowledge represented by equations, or by prediction functions.
- Some manual intervention is usually required
- Pre-processing of data, choice of which type of pattern to find, postprocessing to find novel patterns

Applications of Data Mining
- **Prediction** based on past history
- Predict if a credit card applicant poses a good credit risk, based on some attributes (income, job type, age, ..) and past history
- Predict if a customer is likely to switch brand loyalty
- Predict if a customer is likely to respond to ―junk mail‖
- Predict if a pattern of phone calling card usage is likely to be fraudulent
- Some examples of prediction mechanisms:

Mobile Databases
- Recent advances in portable and wireless technology led to mobile computing, a new dimension in data communication and processing.
- Portable computing devices coupled with wireless communications allow clients to access data from virtually anywhere and at any time.
- There are a number of hardware and software problems that must be resolved before the capabilities of mobile computing can be fully utilized.

- Some of the software problems – which may involve data management, transaction management, and database recovery – have their origins in distributed database systems.
- In mobile computing, the problems are more difficult, mainly:
- The limited and intermittent connectivity afforded by wireless communications.
- The limited life of the power supply(battery).
- The changing topology of the network.
- In addition, mobile computing introduces new architectural possibilities and challenges.

Mobile Computing Architecture

- **The general architecture of a mobile platform is illustrated in Fig 30.1.**
- It is distributed architecture where a number of computers, generally referred to as Fixed Hosts and Base Stations are interconnected through a high-speed wired network.
- Fixed hosts are general purpose computers configured to manage mobile units.
- Base stations function as gateways to the fixed network for the Mobile Units.
- **Wireless Communications** –
- The wireless medium have bandwidth significantly lower than those of a wired network.
- The current generation of wireless technology has data rates range from the tens to hundreds of kilobits per second (2G cellular telephony) to tens of megabits per second (wireless Ethernet, popularly known as WiFi).
- Modern (wired) Ethernet, by comparison, provides data rates on the order of hundreds of megabits per second.
- The other characteristics distinguish wireless connectivity options:
- interference,
- locality of access,
- range,
- support for packet switching,
- seamless roaming throughout a geographical region.
- Some wireless networks, such as WiFi and Bluetooth, use unlicensed areas of the frequency spectrum, which may cause interference with other appliances, such as cordless telephones.
- Modern wireless networks can transfer data in units called packets, that are used in wired networks in order to conserve bandwidth.
- **Client/Network Relationships –**
- Mobile units can move freely in a **geographic mobility domain**, an area that is circumscribed by wireless network coverage.
- To manage entire mobility domain is divided into one or more smaller domains, called **cells**, each of which is supported by at least one base station.
- Mobile units be unrestricted throughout the cells of domain, while maintaining information **access contiguity**.
- The communication architecture described earlier is designed to give the mobile unit the impression that it is attached to a fixed network, emulating a traditional client-server architecture.
- Wireless communications, however, make other architectures possible. One alternative is a mobile ad-hoc network (**MANET**), illustrated in 29.2.

- In a **MANET**, co-located mobile units do not need to communicate via a fixed network, but instead, form their own using cost-effective technologies such as Bluetooth.
- In a **MANET**, mobile units are responsible for routing their own data, effectively acting as base stations as well as clients.
- Moreover, they must be robust enough to handle changes in the network topology, such as the arrival or departure of other mobile units.
- MANET applications can be considered as peer-to-peer, meaning that a mobile unit is simultaneously a client and a server.
- Transaction processing and data consistency control become more difficult since there is no central control in this architecture.
- Resource discovery and data routing by mobile units make computing in a MANET even more complicated.
- Sample MANET applications are multi-user games, shared whiteboard, distributed calendars, and battle information sharing.

Characteristics of Mobile Environments

- The characteristics of mobile computing include:
- Communication latency
- Intermittent connectivity
- Limited battery life
- Changing client location
- The server may not be able to reach a client.
- A client may be unreachable because it is dozing – in an energy-conserving state in which many subsystems are shut down – or because it is out of range of a base station.
- In either case, neither client nor server can reach the other, and modifications must be made to the architecture in order to compensate for this case.
- Proxies for unreachable components are added to the architecture.
- For a client (and symmetrically for a server), the proxy can cache updates intended for the server.
- Mobile computing poses challenges for servers as well as clients.
- The latency involved in wireless communication makes scalability a problem.
- Since latency due to wireless communications increases the time to service each client request, the server can handle fewer clients.
- One way servers relieve this problem is by broadcasting data whenever possible.
- A server can simply broadcast data periodically.
- Broadcast also reduces the load on the server, as clients do not have to maintain active connections to it.
- Client mobility also poses many data management challenges.
- Servers must keep track of client locations in order to efficiently route messages to them.
- Client data should be stored in the network location that minimizes the traffic necessary to access it.
- The act of moving between cells must be transparent to the client.
- The server must be able to gracefully divert the shipment of data from one base to

another, without the client noticing.

- Client mobility also allows new applications that are location-based.

Spatial Database

Types of Spatial Data

- **Point Data**

 Points in a multidimensional space

 E.g., Raster data such as satellite imagery, where each pixel stores a measured value

 E.g., Feature vectors extracted from text

- **Region Data**

 Objects have spatial extent with location and boundary.

 DB typically uses geometric approximations constructed using line segments, polygons, etc., called vector data.

Types of Spatial Queries

- Spatial Range Queries

 Find all cities within 50 miles of Madison

 Query has associated region (location, boundary)

 Answer includes ovelapping or contained data regions

- Nearest-Neighbor Queries

 Find the 10 cities nearest to Madison

 Results must be ordered by proximity

- Spatial Join Queries

 Find all cities near a lake

 Expensive, join condition involves regions and proximity

Applications of Spatial Data

- Geographic Information Systems (GIS)

 E.g., ESRI‘s ArcInfo; OpenGIS Consortium

 Geospatial information

 All classes of spatial queries and data are common

- Computer-Aided Design/Manufacturing

 Store spatial objects such as surface of airplane fuselage

 Range queries and spatial join queries are common

- Multimedia Databases

 Images, video, text, etc. stored and retrieved by content

 First converted to feature vector form; high dimensionality

 Nearest-neighbor queries are the most common

Single-Dimensional Indexes

 B+ trees are fundamentally single-dimensional indexes.

 When we create a composite search key B+ tree, e.g., an index on <age, sal>, we effectively linearize the 2-dimensional space since we sort entries first by age and then by sal.

Consider entries:

<11, 80>, <12, 10>

<12, 20>, <13, 75>

Multi-dimensional Indexes

 A multidimensional index clusters entries so as to exploit ―nearness‖ in multidimensional space.

 Keeping track of entries and maintaining a balanced index structure presents a challenge!

Consider entries:

<11, 80>, <12, 10>

<12, 20>, <13, 75>

Motivation for Multidimensional Indexes

- Spatial queries (GIS, CAD).

 Find all hotels within a radius of 5 miles from the conference venue.

 Find the city with population 500,000 or more that is nearest to Kalamazoo, MI.

 Find all cities that lie on the Nile in Egypt.

 Find all parts that touch the fuselage (in a plane design).

- Similarity queries (content-based retrieval).

 Given a face, find the five most similar faces.

- Multidimensional range queries.

 50 < age < 55 AND 80K < sal < 90K

Drawbacks

- An index based on spatial location needed.

 One-dimensional indexes don‘t support multidimensional searching efficiently.

 Hash indexes only support point queries; want to support range queries as well.

 Must support inserts and deletes gracefully.

- Ideally, want to support non-point data as well (e.g., lines, shapes).
- The R-tree meets these requirements, and variants are widely used today.

Multimedia databases

- To provide such database functions as indexing and consistency, it is desirable to store multimedia data in a database

 Rather than storing them outside the database, in a file system

- The database must handle large object representation.
- Similarity-based retrieval must be provided by special index structures.
- Must provide guaranteed steady retrieval rates for continuous-media data.

Multimedia Data Formats

- Store and transmit multimedia data in compressed form

 JPEG and GIF the most widely used formats for image data.

 MPEG standard for video data use commonalties among a sequence of frames to achieve a greater degree of compression.

- MPEG-1 quality comparable to VHS video tape.

 Stores a minute of 30-frame-per-second video and audio in approximately 12.5 MB

- MPEG-2 designed for digital broadcast systems and digital video disks; negligible loss of video quality.

 Compresses 1 minute of audio-video to approximately 17 MB.

- Several alternatives of audio encoding

 MPEG-1 Layer 3 (MP3), RealAudio, WindowsMedia format, etc.

Continuous-Media Data

- Most important types are video and audio data.
- Characterized by high data volumes and real-time information-delivery requirements.

 Data must be delivered sufficiently fast that there are no gaps in the audio or video.
 Data must be delivered at a rate that does not cause overflow of system buffers.
 Synchronization among distinct data streams must be maintained
- video of a person speaking must show lips moving synchronously with the audio

Video Servers

- **Video-on-demand** systems deliver video from central video servers, across a network, to terminals

 must guarantee end-to-end delivery rates

- Current video-on-demand servers are based on file systems; existing database systems do not meet real-time response requirements.
- Multimedia data are stored on several disks (RAID configuration), or on tertiary storage for less frequently accessed data.
- Head-end terminals - used to view multimedia data

 PCs or TVs attached to a small, inexpensive computer called a set-top box.

Similarity-Based Retrieval

Examples of similarity based retrieval

- Pictorial data: Two pictures or images that are slightly different as represented in the database may be considered the same by a user.

 e.g., identify similar designs for registering a new trademark.

- Audio data: Speech-based user interfaces allow the user to give a command or identify a data item by speaking.

 e.g., test user input against stored commands.

- Handwritten data: Identify a handwritten data item or command stored in the database

UNIT V
ADVANCED TOPICS

ACCESS CONTROL

Privacy in Oracle•

user gets a password and user name

•**Privileges :**

–Connect : users can read and update tables (can‘t create)

–Resource: create tables, grant privileges and control auditing

–DBA: any table in complete DB

•user owns tables they create

•they grant other users privileges:

–Select : retrieval

–Insert : new rows

–Update : existing rows

–Delete : rows

–Alter : column def.

–Index : on tables

•owner can offer GRANT to other users as well

•Users can get audits of:

–listof successful/unsuccessful attempts to access tables

–selective audit E.g. update only

–control level of detail reported

•DBA has this and logon, logoff oracle, grants/revolts privilege

•Audit is stored in the Data Dictionary.

Integrity

The integrity of a database concerns

–consistency

–correctness

–validity

–accuracy

•that it should reflect real world

•i.e... it reflects the rules of the organization it models.

•rules = integrity rules or integrity constraints

examples

•accidental corruption of the DB,

•invalid PATIENT #

•non serializable schedules

•recovery manager not restoring DB correctly after failure
Basic concepts
•trying to reflect in the DB rules which govern
organization E.g.:
INPATENT(patent#, name, DOB, address, sex, gp) LABREQ (patent#, test-type, date, reqdr)
•E.g. rules
–lab. test can‘t be requested for non
-existent PATIENT (insert to
labreq) (referential)
–every PATIENT must have unique patent number (relation)
–PATIENT numbers are integers in the range 1
-99999. (domain)
real-
world rules = integrity constraints
•Implicit Constraints
-relation, domain, referential
-integral part of Relational model –
Relational constraints
-define relation and attributes supported
by all RDBMS
–Domain constraints
-underlying domains on which attributes
defined
–Referential constraints
-attribute from one table referencing
another
•Integrity subsystem: conceptually responsible for enforcing constraints, violation + action
–monitor updates to the databases, multi user system this
can get expensive
•integrity constraints shared by all applications, stored in system catalogue defined
by data definition
Relation constraints
•how we define relations in SQL
•using CREATE we give relation name and define attributes

E.g.
CREATE TABLE INPATIENT (PATIENT #, INTEGER, NOT NULL,
name,
VARCHAR (20), NOT NULL,
.....
gpn
VARCHAR (20),
PRIMARY KEY PATIENT#);
Domain constraints
•Domains are very important to the relational model
•through attributes defined over common domains that relationships between tuples belonging to different relations can be defined.
•This also ensures consistency in typing.
E.g
CREATE TABLE (PATIENT# DOMAIN (PATIENT #) not
NULL, name DOMAIN (name) not
NULL,
sex DOMAIN
(sex), PRIMARY KEY PATIENT #);
CREATE DOMAIN PATIENT# INTEGER PATIENT# > 0
PATIENT# <10000;
CREATE DOMAIN sex CHAR
(1) in (‗M‘,‗F‘);
Referential integrity
•
refers to foreign keys
•
consequences for updates and deletes
•
3 possibilities for
–
RESTRICTED: disallow the update/deletion of primary keys as long as their are foreign keys referencing that primary key.
–
CASCADES: update/deletion of the primary key has a cascading effect on all tuples whose foreign key references that primary key, (and they too are deleted).

–NULLIFIES: update/deletion of the primary key results in the referencing foreign keys being set to null.
FOREIGN KEY gpn REFERENCES gpname OF TABLE GPLIST NULLS ALLOWED DELETION NULLIFIES UPDATE CASCADES;
. Explicit (semantic) constraints
•defined by
SQL but not widely implemented
•E.g.. can‘t overdraw if you have a poor credit rating
ASSERT OVERDRAFT_CONSTRAINT ON customer,
account: account.balance >0
AND account.acc# =
CUSTOMER.cust# AND
CUSTOMER.credit_rating =‗poor‘;
•Triggers
DEFINE TRIGGER
reord
-constraint ON
STOCK noinstock < reordlevel
ACTION ORDER_PROC (part#);
Static and Dynamic Constraints
•State or Transaction constraints
static refer to legal DB states
•dynamic refer to legitimate transactions of the DB form one state to another ASSERT payrise
-constraint ON UPDATE OF employee:
•Security can protect the database against unauthorized users.
•Integrity can protect it against authorized users
–Domain integrity rules: maintain correctness of attribute values in relations
–Intra
-relational Integrity: correctness of relationships among atts.
in same rel.
–Referential integrity: concerned with maintaining correctness and consistency of relat
ionships between relations.
Recovery and Concurrency
•closely bound to the idea of Transaction Processing.

•important in large multi
-user centralized environment.
Authorization in SQL
•File systems identify certain access privileges on files,
E.g
.,
read, write, execute.
•In partial analogy, SQL identifies six access privileges on relations, of which the most important are:
1.SELECT = the right to query the relation.
2.INSERT = the right to insert tuples
into the relation
–may refer to
one attribute, in which case the privilege is to specify only one column of the inserted tuple.
3.DELETE = the right to delete tuples from the relation.
4.UPDATE = the right to update tuples of the relation
–may refer to
one attribute.
Granting Privileges
•You have all possible privileges to the relations you create.
•You may grant privileges to any user if you have those privileges
—with grant option.||
u You have this option to your own relations.
Example
1.Here, Sally can query Sells and can change prices, but cannot pass on this power:
GRANT SELECT ON Sells,
UPDATE(price) ON
Sells TO sally
DISTRIBUTED DATABASES VS CONVENTIONAL DATABASES

Data Warehouse:

¬
Large
organizations have complex internal organizations, and have data stored at
different locations, on different operational (transaction processing) systems, under
different schemas

¬Data sources often store only current data, not historical data

¬Corporate dec
ision making requires a unified view of all organizational data, including
historical data

¬
A data warehouse
is a repository (archive) of information gathered from multiple
sources, stored under a unified schema, at a single site

•Greatly simplifies
querying, permits study of historical trends

•Shifts decision support query load away from transaction processing systems When and how to gather data

•Source driven architecture: data sources transmit new information to warehouse, either
continuously or pe
riodically (e.g. at night)

•Destination driven architecture: warehouse periodically requests new information from
data sources

•Keeping warehouse exactly synchronized with data sources (e.g. using two
-phase commit) is too expensive

•Usually OK to have slightly out
-of
-date data at warehouse

•Data/updates are periodically downloaded form online transaction processing (OLTP)
systems.
What schema to use
•Schema integration
Data cleansing
•E.g. correct mistakes in addresses
•E.g. misspellings, zip code errors
Merge address lists from different sources and purge duplicates
•Keep only one address record per household (—householding||)
How to propagate updates
•Warehouse schema may be a (materialized) view of schema from data sources
•Efficient techniques for update of materialized views What data to summarize Raw data may be too large to store on
-line
•Aggregate values (totals/subtotals) often suffice
•Queries on raw data can often be transformed by query optimizer to use aggregate values
.Typically warehouse data is
multidimensional, with very large fact tables
•Examples of dimensions: item
-id, date/time of sale, store where sale was made, customer
identifier
•Examples of measures: number of items sold, price of items
Dimension values are usually encoded using small int
egers and mapped to full values via
dimension tables
Resultant schema is called a star schema
More complicated schema structures
•Snowflake schema: multiple levels of dimension tables
•Constellation: multiple fact tables
Data Mining
¬Broadly speaking,
data mining is the process of semi
-automatically analyzing large

databases to find useful patterns.
¬Like knowledge discovery in artificial intelligence data mining discovers statistical rules
and patterns
¬Differs from machine learning in that it deals wit
h large volumes of data stored primarily
on disk.
¬Some types of knowledge discovered from a database can be represented by a set of
rules. e.g.,: —Young women with annual incomes greater than $50,000 are most likely to
buy sports cars||
.¬
Other types of
knowledge represented by equations, or by prediction functions
.
¬Some manual intervention is usually required
•
Pre-processing of data, choice of which type of pattern to find, postprocessing to
find novel patterns
Applications of Data Mining
¬Prediction based on past history
•Predict if a credit card applicant poses a good credit risk, based on some attributes (income, job type, age, ..) and past history
•Predict if a customer is likely to switch brand loyalty
•Predict if a customer is likely to respond to —junk
mail||
•Predict if a pattern of phone calling card usage is likely to be fraudulent
¬Some examples of prediction mechanisms:
¬Classification
•Given a training set consisting of items belonging to different classes, and a new item whose class is unknown, predict which class it belongs to.¬Regressionformulae
•

Given a set of parameter
-value to function
-result mappings for an unknown
function, predict the function
-result for a new parameter
-value
¬Descriptive Patterns
Associations
•Find books that are often
bought by the same customers. If a new customer buys
one such book, suggest that he buys the others too.
•Other similar applications: camera accessories, clothes, etc.
Associations may also be used as a first step in detecting
causation
•
E.g. association be
tween exposure to chemical X and cancer, or new medicine
and cardiac problems
Clusters
•E.g. typhoid cases were clustered in an area surrounding a contaminated well
•Detection of clusters remains important in detecting epidemics
Classification Rules
¬Classification rules help assign new objects to a set of classes. E.g., given a new
automobile insurance applicant, should he or she be classified as low risk, medium risk
or high risk?
¬Classification rules for above example could use a variety of knowledg
e, such as
educational level of applicant, salary of applicant, age of applicant, etc.
person P, P.degree = masters and P.income > 75,000
⇒ P.credit = excellent
person P, P.degree = bachelors and(P.income≥25,000 and P.income

≤75,000)
⇒P.credit = good
¬Rules are not necessarily exact: there may be some misclassifications
¬Classification rules
can be compactly shown as a decision tree.
Decision Tree
•Training set
: a data sample in which the grouping for each tuple is already known.
•Consider credit risk example: Suppose
degree
is chosen to partition the data at the root.
¬Since degree has a small
number of possible values, one child is created for each
value.
•At each child node of the root, further classification is done if required. Here, partitions
are defined by
income
.¬
Since income is a continuous attribute, some number of intervals are chosen,
and
one child created for each interval.
•Different classification algorithms use different ways of choosing which attribute to
partition on at each node, and what the intervals, if any, are.
•In general
¬Different branches of the tree could grow to differen
t levels.
¬Different nodes at the same level may use different partitioning attributes.
•Greedy
top down generation of decision trees.
Each internal node of the tree partitions the data into groups based on a partitioning attribute, and a partitioning conditionfor the node

¬More on choosing partioning attribute/condition shortly
¬Algorithm is greedy: the choice is made once and not revisited as more of the tree
is constructed
The data at a node is not partitioned further if either
¬All (or most) of the itemsat the node belong to the same class, or
¬All attributes have been considered, and no further partitioning is possible. Such a node is a leaf node. Otherwise the data at theode is partitioned further by picking an attribute for partitioning data at the node.Decision
-Tree Construction Algorithm
Procedure Grow.
Tree(S)Partition(S);
Procedure
Partition (S)
116
if (purity(S) > δ_p
or |
S
| <δ
$_s$)
then
return;
for each
attribute
A evaluate splits on attribute
A;
Use best split found (across all attributes) to partition
Sinto
S_1
, S_2
, ..., S
$_r$
,
for
i
= 1, 2, ...,

r
Partition(
S
i
);
Other Types of Classifiers
Further types of classifiers
¬
Neural net classifiers
¬
Bayesian classifiers
Neural net
classifiers use the training data to train artificial neural nets
●
Widely studied in AI, won‘t cover here
Bayesian classifiers use
Bayes theorem
, which says
where
$p(c_j d)$ = probability of instance
d being in class
c_j,
$p(d \mid c_j)$ = probability of generating instance
d
given class
c_j,
$p(c_j)$= probability of occurrence of class
c_j, and
p(d)= probability of instance
doccuring
Naive Bayesian Classifiers
Bayesian classifiers require
¬computation of
$p(d \mid c_j)$
¬precomputation of
$p(c_j)$
¬p(d)

can be ignored since it is the same for all classes .To simplify the task, naïve Bayesian classifiers assume attributes have independent distributions,and thereby estimate

$p(dc_j) = p(d_1|+c_j) *$

$p(d_2c_j) * ....* (p(d_nc_j)$

Each of the

$p(d_i|c)$ can be estimated from a histogram on

d_i

values for each class

c_j

•the histogram is computed from the training instances

Histograms on multiple attributes are more expensive to compute and store

.Regression

Regression deals with the prediction of a value, rather than a class.

¬Given values for a set of variables, $X_1, X_2, ..., X_n$, we wish to predict the value of a variable Y.

One way is to infer coefficients $a_0, a_1, a_1, ..., a_n$ such that

$Y= a_0+ a_1* X_1+a_2* X_2 + ... + a_n * X_n$

Finding such a linear polynomial is called linear regression.

In general, the process of finding a curve that fits the data is also called curve fitting.

The fit may only be approximate

•because of noise in the data, or

•because the relationship is not exactly a polynomial

Regression aims to find coefficients that give the best possible fit.Association RulesRetail shops are often interested in associations between different items that people buy. Someone who buys bread is quite likely also to buy milkA person who bought the book Database System Conceptsis quite likely also to buy the book Operating System Concepts.Associations information can be used in several ways.E.g.

when a customer buys a particular book, an online shop may suggest associated books.
Association rules:
bread
⇒milk DB
-Concepts, OS
-Concepts
⇒Networks
Left hand side: antecedent, right hand side: consequent
An association rule must have an associated population; the population consists of a set of
instances E.g. each transaction (sale) at a shop is an instance, and the set of all transactions is the population.
Rules have an associated support, as well as an associated confidence.
Support is a measure of what fraction of the population satisfies both the antecedent and the consequent of the rule.
E.g. suppose only 0.001 percent of all purchases include milk and screwdrivers. The support for the rule is milk
⇒screwdrivers is low.We usually want rules with a reasonably high support Rules with low support are usually not very useful
Confidence is a measure of how often the consequent is true when the antecedent is true.
E.g. the rule bread
⇒milk has a confide
nce of 80 percent if 80 percent of the purchases that
include bread also include milk.
Usually want rules with reasonably large confidence.
Finding Association Rule We are generally only interested in association rules with reasonably high support (e.g. support
of 2% or greater)
Naïve algorithm
1.Consider all possible sets of relevant items.
2.For each set find its support (i.e. count how many transactions purchase all items
in the set).
HLarge itemsets: sets with sufficiently high support

3.Use large itemsets to generate association rules.
H From itemset
A generate the rule
A -
{b}
$\Rightarrow$ b
for each
b $\in$ A.
4 Support of rule = support (A)
.4 Confidence of rule = support (
A) / support (A
- {
b})
Other Types of Associations Basic association rules have several limitations Deviations from the expected probability are more interesting E.g. if many people purchase bread, and many people purchase cereal, quite a few would be expected to purchase both (prob1 * prob2) We are interested in positive as well as negative correlations between sets of items Positive correlation: co - occurrence is higher than predicted Negative correlation: co - occurrence is lower than predicted Sequence associations/correlations E.g. whenever bonds go up, stock prices go down in 2 days Deviations from tem poral patterns E.g. deviation from a steady growth E.g. sales of winter wear go down in summer Not surprising, part of a known pattern. Look for deviation from value predicted using past patterns Clustering
- Clustering: Intuitively, finding clusters of points in the given data such that similar points lie in the same cluster
- Can be formalized using distance metrics in several ways

E.g. Group points into k sets (for a given k
) such that the average distance of points from
the centroidof their assigned group is minimized
Centroid: point defined by taking average of coordinates in each dimension.
Another metric: minimize average distance between every pair of points in a cluster
-

Has been studied extensively in statistics, but on small d
ata sets
Data mining systems aim at clustering techniques that can handle very large data sets
E.g. the Birch clustering algorithm (more shortly)
Hierarchical Clustering
Example from biological classification
Other examples: Internet directory systems
(e.g. Yahoo, more on this later)
Agglomerative clustering algorithms
Build small clusters, then cluster small clusters into bigger clusters, and so on
Divisive clustering algorithms
Start with all items in a single cluster, repeatedly refine (break) cluste
rs into smaller ones.

OBJECT ORIENTED DATABASE

Basically, an OODBMS is an object database that provides DBMS capabilities to objects that have been created using an object
-oriented programming language (OOPL). The basic
principle is to add persistence to objects and to make objects persistent.
Consequently application programmers who use OODBMSs typically write programs in a native OOPL such as Java, C++ or Smalltalk, and the language has some kind of Persistent class, Database class, Database Interface, orDatabase API that provides DBMS functionality as, effectively, an extension of the OOPL.Object
-oriented DBMSs, however, gomuch beyond simply adding persistence to any one object
-oriented programming language. This is because, historically, many object-oriented DBMSs were built to serve the market for computer
-aided design/computer

-aided manufacturing (CAD/CAM) applications in which features like fast navigational access,versions, and long transactions are extremely important.
Object-oriented DBMSs, therefore, support advanced object-oriented database applications with features like support for persistent objects from more than one programming language, distribution of data, advanced transaction models, versions, schema evolution, and dynamic generation of new types.Object data modelingAn object consists of three parts: structure (attribute, and relationship to other objects like aggregation, and association), behavior (a set of operations) and characteristic of types (generalization/serialization). An object is similar to an entity in ER model; therefore we begin with an example to demonstrate the structure and relationship.
Attributes are like the fields in a relational model.
However in the Book example we have, for attributes publishedBy and writtenBy, complex types Publisher and Author, which are also objects. Attributes with complex objects, in RDNS, are usually other tables linked by keys to the employee table.Relationships: publish and writtenBy ressociations with I: N and 1:1 relationship; composed of is an aggregation (a Book is composed of chapters). The 1: N relationship is usually realized as attributes through complex types and at the behavioral level. For example
,Generalization/Serialization is the is a relationship, which is supported in OODB through class hierarchy. An ArtBook is a Book, therefore the ArtBook class is a subclass of Book class. A subclass inherits all the attribute and methodof its superclass.
Message: means by which objects communicate, and it is a request from one object to another to execute one of its
methods. For example:Publisher_object.insert (||Rose||, 123...) i.e. request to execute the insert method on a Publisher object)
Method: defines the behavior of an object. Methods can
be used to change state by modifying
its attribute values
to query the value of selected attributes The method that responds to the message example is the method insert defied in the Publisher class.