Database Facilities

One of the main benefits from centralising the implementation data model of a DBMS is that a number of critical facilities can be programmed once against this model and thus be available to all databases using the DBMS

This section provides a discussion of:

- Providing **Security** in Data Access
- **Query Optimisation**
- **Concurrent** Access to Databases
- **Recovery** From System Crashes
- **Distributed** Databases

Security Mechanisms I

The **database authorisation subsystem** controls who may or may not access particular information in the database

There may be up to six mechanisms used

1/ **User Accounts**

- Just like any complex computer system, the user must be authorised to use a DBMS, by being issued with a login and a password
- The DBMS will have its own login and password, but insist that the user must be registered by a system administrator before they can use it
  - this information is held in a table which holds all the user information
- Microsoft Access can have a password system or just allow anyone logged in to use the system

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Security Mechanisms II

Key Slide

2/ **Privileges**

Given an account, the system can then restrict access to particular parts of the data.

Oracle provides two kinds of privileges:

- **System Privileges** - the right to perform a particular action on all data:
  - e.g. to create tablespaces or delete records anywhere
- **Object Privileges** - the right to perform a particular action on a specific table or view
  - e.g. to read data from a particular table

The creator of a relation is its owner & can grant access to others, e.g.:

grant privilege **on** relation **to all**/userLogin/role/group

where privilege is one of **select**, **update**, **delete**, **insert** or **all**

This allows either everyone or one user to access the relation in the specified way

There is also a **revoke** command to remove a privilege

Security Mechanisms III

Key Slide

3/ Logical Users

DBMS provide two additional constructs to provide security checks which are not tied to particular users (c.f. mail aliases):

- **roles** - indicate a logical user (e.g. manager) rather than a specific person
- **groups** - indicate a set of users who all have the same rights - not Oracle

4/ **Views**

To restrict information further, a view may be used.

For instance to restrict access to reading CS student date:

```
create view CS as
        select  *  from STUDENT where Dept = 'CS'
grant select  on CS  to rich
```

5/ **Profiles**

A profile is a named set of resource limits, assigned to a user or role:

e.g. cpu usage per session, number of reads, etc.

6/ **Statistical Access** (Not available in Oracle)

To permit a user to access statistical information but not individual details, a user may be restricted to use only COUNT, SUM, AVG, MAX, MIN, etc.

Auditing

Auditing is the monitoring and recording of selected user database activities

Auditing is used for the following three reasons:

- i) to gather statistics from which a system can be optimised
- ii) to gather information on data use which is legally required
- iii) to investigate suspicious activity

The auditing system maintains an **audit trail** which is a series of time-stamped records which describe user activity

Oracle provides the following kinds of auditing:

- **statement auditing** - e.g. use of delete statement
- **privilege auditing** - use of system privileges - e.g. create table
- **object auditing** - use of a particular table

Particular roles and users can be audited and an audit command can be made specific to successful or unsuccessful use

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Query Processing and Optimisation

Key Slide

NB – this is why the Relational Algebra is important!

When responding to a query, the DBMS knows:

(i) what the **query** is

(ii) **statistical information** about the database (how many rows/columns)

and (iii) the **storage structures used** (i.e. are there any indexes, etc.)

From these it can estimate the cost of performing the queries in various ways and implement it accordingly. The strategy is as follows:

(i) **Decompose the query** into (relational algebra) components

(ii) **Estimate the cost** (i.e. time to execute) of each component

(iii) **Re-organise the components** into equivalent forms that are probably faster

- using equivalences between algebraic expressions

(iv) **Estimate the new version** and use it if it seems better

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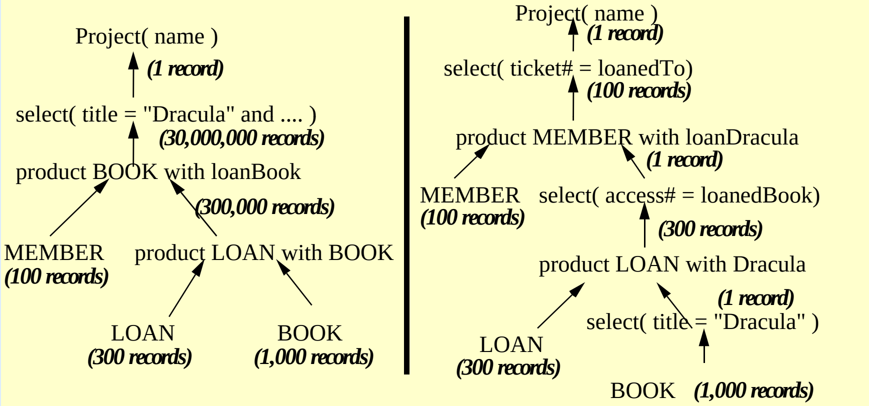
Example

Key Slide

select member, name **from** book, loan, member
where book. title = "Dracula" **and** member. ticket = loan.loaned To
and loan.loaned Book = book.access#



Project(name)
(1 record)
select(title = "Dracula" and ....)
(30,000,000 records)
product BOOK with loanBook
(300,000 records)
MEMBER
(100 records)
product LOAN with BOOK
LOAN
(300 records)
BOOK
(1,000 records)

Project(name)
(1 record)
select(ticket# = loanedTo)
(100 records)
product MEMBER with loanDracula
(1 record)
MEMBER
(100 records)
select(access# = loanedBook)
(300 records)
product LOAN with Dracula
(1 record)
LOAN
(300 records)
select(title = "Dracula")
BOOK *(1,000 records)*

Supporting Concurrent Multi-User Access

Key Slide

Many applications require a lot of users to access the data simultaneously (e.g. airline booking systems)

Uncontrolled simultaneous access can result in chaos, so some controlling mechanism is required

We introduce the notion of the **transaction** to aid the discussion

A transaction is a **logical** unit of work which takes the DB from one consistent state to another, i.e. obeying constraints

It will probably be made up of smaller operations which temporarily cause inconsistency

Example

Key Slide

The transaction to transfer £27 from the University account to RC's account is made up of two updates:

UniversityAC.balance = UniversityAC.balance - 27 U_1

and RCAC.balance = RCAC.balance + 27 U_2

The DBMS ensures that even if the system crashes or someone asks for the sum of all balances between U_1 and U_2, then it never appears that only U_1 has been executed

That is the transaction is either wholly completed or fails - transactions are **atomic**!

The transaction gives a single user the illusion of being the sole user of the database

A **Transaction Processing Monitor** (TP) accepts transactions and integrates their effects on the database

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The ACID Properties of Transactions

Key Slide

The four ACID properties, which transactions must respect, are:

Atomicity - all components of a transaction must be performed or none at all

Consistency - the database must be consistent at the beginning and the end of a transaction

where consistency means that the integrity constraints and enterprise rules all hold

Isolation - a transaction must not reveal the effect of updates to other transactions until it completes

Durability - once a transaction and its changes are made permanent, these changes must never be lost

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How Transactions are Used

Transactions are used for three purposes in DBMS:

- to determine when **integrity constraint checks** should occur (only at the end of transactions)
- to control **concurrent access**
- to manage **recovery** from system crashes

Concurrent Access

In introducing many users, we can either **serialise** their transactions or **interleave** them

We wish to do the latter as we want to use the processor to perform other work while one transaction waits for a disc access

However, we must **not** allow the transactions to conflict with each other

This is what is meant by **Isolation**

Conflict may occur when two transactions are trying to use the same piece of data and at least one of them is trying to change it

Potential Problems with Interleaved Transactions I

Lost Updates

Consider two transactions A and B which add 10 and 20 respectively to a value V

A and B both take a copy of the original value of V

They both change the value in memory

A puts back its new value first and then B puts back its new value which **immediately overwrites** A’s change

A's update is lost!

Transaction A	Transaction B	Value of V
		5
get V		5
	get V	5
add 10		5
	add 20	5
put V		15
	put V	25

Key Slide

Potential Problems with Interleaved Transactions II

Temporary Update

A updates V

B uses A's updated value

A aborts and V's old value is restored

B continues with erroneous value!

Transaction A	Transaction B	Value of V
		5
store 20 in V		20
	get V	20
Crash and Rollback		5
	use wrong value of V	5

Key Slide

Potential Problems with Interleaved Transactions III

Incorrect Summary

A updates all the values in a set V

B calculates an average while A is half-way through

B uses inconsistent data

Transaction A	Transaction B
update V_1	
update V_2	read the V_is
....	
	calculate average
update V_n	

The solution to these problems is to use **locks**

Key Slide

Locks I

Key Slide

Every time a transaction makes use of a piece of data it notifies the DBMS of this and acquires a lock on that item

This gives it certain access rights, usually one of two types:

- an **exclusive** Lock (X-lock) means that no-one else can use it
- a **shared** Lock (S-lock) means that anyone else can also have an S-lock but not an X-lock
- (NB - Oracle has more than this)

"One writer or many readers"

- When updating, the transaction needs an X-lock
- When retrieving, the transaction only needs an S-lock

Locks II

If a transaction tries to acquire a lock but someone else already holds an incompatible lock, the transaction must wait

The database system might provide locks at different levels of **granularity**:

- e.g. locking a cell, a record or the whole table
- the bigger the locking unit the more the system will be slowed down by blocked transactions
- the smaller the locking unit the more lock management needs to be done

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Solving the Problems I

Key Slide

Lost Updates

Transaction A	Transaction B	Value of V
Request X-lock on V		5
	Request X-lock on V	5
Acquire X-lock on V		5
	Wait	5
Get V	....	5
	....	5
Update V	Wait	15
Release X-lock on V		15
	Acquire X-lock on V	15
	Get V	15
	Update V	35
	Release X-lock on V	35

Solving the Problems II

Key Slide

Temporary Update

Transaction A	Transaction B	Value of V
Request X-lock on V		5
Acquire X-lock on V	Request S-lock on V	5
	Wait	5
Set V to 20		20
Crash		20
Roll back		5
Release lock		5
	Acquire an S-lock on V	5
	Get V	5

Solving the Problems III

Key Slide

Incorrect Summary

Transaction A	Transaction B
Request X-lock on V1	
Acquire X-lock on V1	Request S-lock on V1
Update V1	Wait
Request X-lock on V2	
. . . .	
Release all locks	
	Acquire S-lock on V1 etc.

Three New Problems

Key Slide

1) Which transaction should we start next?

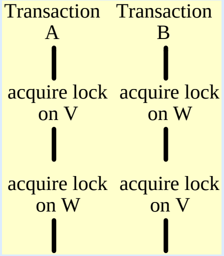
If you make each TX acquire all of its locks before releasing any (**two phase** or **pessimistic** locking), you can ensure that you know which can precede which

- this is known as **serialising** the transactions

Alternatively, you might assume there will be few clashes (**optimistic** locking) and cope with problems as they occur. A copy is taken (check-out), changes are made and, if all is well, the copy is merged back into the database (check-in)

2) If we have the situation shown left, where two transactions are waiting on each other we have **deadlock**

The DBMS must carry out deadlock detection and roll back of one of the transactions



3) Support for **co-operative work** and long transactions

There is a need for more sophisticated locks!

Transaction Management Commands

Key Slide

The user of a DBMS needs mechanisms for grouping updates into transactions. Five different facilities are usually provided:

begin transaction - this starts a sequence of queries which will be treated atomically

commit - end the transaction making all changes permanent and public. This may or may not also automatically be the start a new transaction

abort or **rollback** - undo all the changes of the current transaction. This may also start a new transaction automatically

checkpoint, **validate** or **savepoint** *SpointName* - mark the current point as a potential point to roll back to

rollback *SpointName* - roll back only as far as the check point

In some systems, transactions may be **nested** - i.e. you can start one transaction inside another

Important note - the goal of atomicity is achieved by making transaction commit a **single write** operation:

i.e. recording a "transaction committed" record in the log (see below)

Transactions in Oracle

There are two possible set ups for transaction management in Oracle. They are controlled by the variable **autocommit**:

set autocommit on makes every SQL query a transaction which automatically commits - the default inAqua Data Studio

set autocommit off provides the following:

starting a session begins the first transaction automatically

commit - end the transaction making all changes permanent and public - this start a new transaction

rollback - undo all the changes of the current transaction and start a new transaction

savepoint *SpointName* - mark the current point as a potential point to roll back to

rollback to *SpointName* - roll back only as far as the save point

on quitting the user may either commit or rollback

Oracle also allows explicit locking of tables:

lock table Employee **in** Share **mode**

Isolation Levels

In fact, it is possible to use the DBMS without being strict about isolation

- The **isolation level** is an indication of how tough you want to be in isolating transaction

The American National Standards Institute defines four levels:

- **read uncommitted** - Tx reads data without a read lock
  - reading uncommitted data (called **dirty reads**) is possible
- **read committed** - Tx locks reads but releases lock immediately and the same read later might follow a Tx which changes the data
  - reads may be **unrepeatable** – i.e. two reads of the same data can give different values
- **repeatable read** – you always get the same value of existing data but it is still possible to work with a set of records into which other transactions might add new records part way through (these are called **phantoms**)
- **serializable** – everything locked – as above

SQL has

- SET TRANSACTION [READ ONLY | READ WRITE] [ISOLATION LEVEL READ UNCOMMITTED | READ COMMITTED | REPEATABLE READ | SERIALIZABLE]

Reasons for Transaction Failure

A transaction fails (and rolls back) if:

- the user invokes rollback
- after a user-specified timeout period (INGRES and possibly Oracle)
- the user quits and doesn't commit (rollback in INGRES and Oracle)
- an abnormal process termination
- the DBMS detects deadlock
- the log fills up
- the system crashes - see recovery - next

Recovery

Key Slide

If the computer crashes while a DBMS is running, each database must be returned to a consistent state when a computer starts up again

- This is achieved by a **recovery algorithm**
- The ACID property **Durability** summarises this requirement

A DBMS use a number of techniques for achieving this:

- **explicit backup** - e.g. Oracle allows the user to backup all or part of a database
- using an **undo** or **redo log** - all changes are kept in a separate file which is faster to write to and which can be used to undo or redo work
- **shadow pages** - an automatic copy of the changed part of the data:
  - users either work with the copy which gets merged in at the end - the **after image**
  - or with the actual database and the copy can be used to undo work - the **before image**
  - Oracle provides **rollback segments** - which can be used to undo work in an aborted transaction

Logging Techniques

The DBMS keeps a **log** or **journal** of all work, which will be faster to update than the database

- In particular, it records every time:
  - a transaction starts, commits or aborts
  - a piece of data is changed, recording the old and new values
  - a piece of data is read

When a crashed system restarts, each transaction will have either

(i) completed successfully and commit all of its changes - i.e. make them permanent

or (ii) failed in the middle and rollback to the checkpoint

In some systems, the log is used to undo work that is not complete

- In Oracle, all the work in successfully completed transactions is re-written to the store

In fact, the person specifying the transaction can perform a checkpoint in the middle if they are sure this will not cause an inconsistent state - this saves undoing work that has completed successfully

Two Main Recovery Techniques

Using **Deferred Update**, nothing is changed in the database until commit is performed

- i.e. during the transaction, updates are only recorded in the log and then written to the database later
- this means that recovery from a crash before commit needs no undoing of updates that have reached the database
- but uncompleted updates after the commit will need to be redone
- hence this called **NO-UNDO / REDO**

Using **Immediate Update** updates are still made to the log first but may then be made to the database before commit

- this means that changes from partially completed transactions may need to be undone, replacing the new values with the old values in the log
- this is called **UNDO / REDO** as it may also need to complete the database update of committed transactions

Distributing Processing and Data

There is an increasing requirement to create database systems which are distributed over remote computer systems connected by network

Reasons:

- the users are distributed
- the data is inherently distributed
- reliability - if one machine is down another may still work
- controlling who can share your data - you keep your data locally, but others can use it
- improving performance - by having many small DB's

It is important to distinguish two kinds of distribution:

- keeping the data centralised, but distributing processing so that many users can access the data simultaneously
  - i.e. client-server systems
- distributing the data - so that many database systems are together providing what looks like a single database

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Client Server Architecture

Early DBMS assumed that most computation was carried out on a large mainframe machine with the users sitting at "dumb" terminals

- Commands from a keyboard were sent to the DBMS for processing

Now the processing is distributed among a variety of machines of differing processing power, although the data remains centralised

Client server architectures exploit that by distinguishing two kinds of process:

- a **server** process is connected to disk holding the data and deals with all aspects of recovering the data from the files, selecting data and transmitting the selected data to the client
- a **client** process controls the interaction with the user, generates the queries and presents the results

Some different flavours of client server architecture:

- there are usually many clients, but there may be one or more servers
- computation with the data may occur either at the server or the client end
- there may be intermediary processes which migrate – N-tier architectures

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Distributed Databases

Key Slide

A distributed db is one in which the data resides in more than one physical database but can be made to look like just one database

The database systems may

either be all be the same - **homogeneous databases** - e.g. all Oracle

or can be different - **heterogeneous databases** - a mixture

Two techniques are combined:

i) making the database systems all look the same – e.g. using ODBC or JDBC

ii) using SQL queries as pipelines

Some issues:

- **transparency** - a transparent system does not require the user to know where the data being used is.
- **fragmentation** - how is the data divided?
  - **vertically** - i.e. keep the whole of each column together.
  - **horizontally** - keep the whole of each row together.
- **replication** - is the same data stored in more than one place?

Two Phase Commit

The most difficult task for a distributed system is committing data updates which might be on different machines

Remember the transaction must be committed all or nothing!

Oracle provides a technique called Two Phase Commit to try to help with this, i.e. reduce each commit to a single write at each point, which works as follows:

Prepare Phase: The application on the co-ordinating node sends to all participating nodes a message asking them to prepare to commit

They check that have their redo-log and locks in place and answer:

"prepared" - ready to commit

"read-only" - don't need to commit

or "abort" - cannot commit

Commit Phase - the co-ordinator gets the participants to write "transaction committed" to the log