DATA BASES 2

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29 settembre 2020

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1 Introduction

Introduction slides:
../other/professor'sslides/0-Intro.pdf

1.1 Prerequisites: References to Relational Algebra and SQL

1.1.1 Relational Algebra

../other/RelationalAlgebraAndSQL/04-RelationalAlgebra.pdf

../other/RelationalAlgebraAndSQL/05-RelationalAlgebra2.pdf

1.1.2 SQL

../other/RelationalAlgebraAndSQL/08-SQL1.pdf

../other/RelationalAlgebraAndSQL/09-SQL2.pdf

../other/RelationalAlgebraAndSQL/10-SQL3.pdf

1.2 Books

All books can be found at:
../other/books

2 Transactional Systems

`../other/professor'sslides/1_Transactions_NEW.pdf`

A **transaction** is an elementary, atomic, unit of work performed by an application.
Each transaction is conceptually encapsulated within two commands:

- **begin of transaction** (bot);
- **end of transaction** (eot).

Within a transaction, **one** of the commands below is executed (**exactly once**) to signal the end of the transaction:

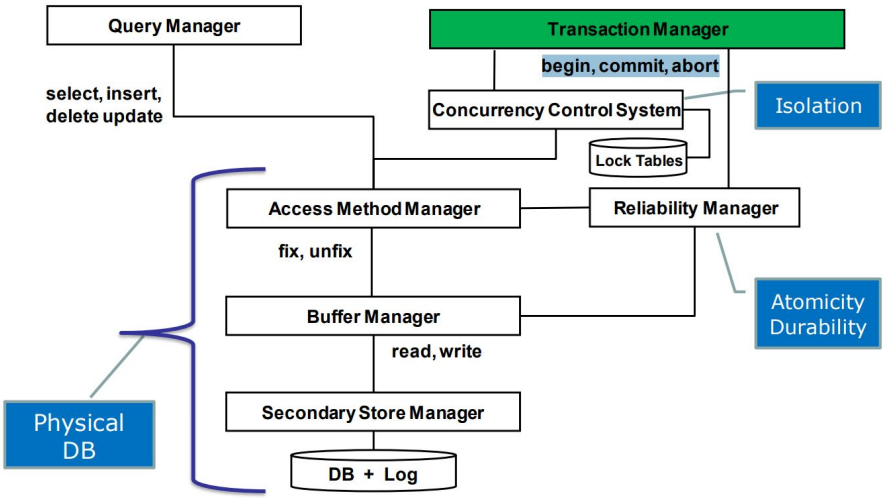
- **commit**;
- **rollback**.

Transactional System (OLTP) is a system that supports the execution of transactions on behalf of concurrent applications.

A transaction is a unit of work enjoying the **ACID** properties:

- **Atomicity** (abort-rollback-restart, commit protocols): either all the operations in the transaction are executed or none is executed;
- **Consistency** (integrity checking of the DBMS): a transaction must satisfy the DB integrity constraints, if the initial state is consistent then the final state is also consistent, but this is not necessarily true for the intermediate states of the transaction;
- **Isolation** (concurrency control): the concurrent execution of a number of transaction must produce the same result as the execution of the same transactions in a sequence;
- **Durability** (recovery management): the effect of a transaction that has successfully committed will last "forever".

Lets take a look at where are the ACID properties managed in the DBMS architecture:



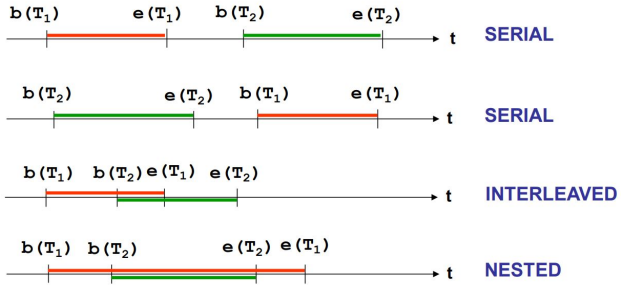
3 Concurrency Control

`../other/professor'sslides/2-ConcurrencyControl.pdf`

The **concurrency control system**:

- manage the simultaneous execution of transactions;
- avoids the insurgence of anomalies;
- ensure performance: exploit parallelism to maximise transactions per second.

Two transaction can have a **serial** execution, an **interleaved** execution or a **neasted** execution.



3.1 Anomalies

An anomalie happens when two transaction are executed interleaved or nested and the result is different if they were executed serially.

3.1.1 Lost Update

$$r_1(x) \rightarrow r_2(x) \rightarrow w_1(x) \rightarrow w_2(x)$$

An update is applied from a state that ignores a preceding update, wich is lost.

3.1.2 Dirty Read

$$r_1(x) \rightarrow w_1(x) \rightarrow r_2(x) \rightarrow abort_1 \rightarrow w_(2)$$

An uncommitted value is used to update the data.

3.1.3 Nonrepeatable Read

$$r_1(x) \rightarrow r_2(x) \rightarrow w_2(x) \rightarrow r_1(x)$$

Someone else updates a previously read value.

3.1.4 Phantom Update

$$r_1(x) \rightarrow r_2(x) \rightarrow w_2(x) \rightarrow r_1(x)$$

Someone else updates data that contributes to a previously read datum.

Lets see an example: given the costraint $A+B+C = 100$ and the initial values $A = 50, B = 30, C = 20$
$T_1 : r(A), r(B)$
$T_2 : r(B), r(C)$
T_2 : subtract 10 from C and add 10 to B.
$T_2 : w(B), w(C)$
$T_1 : r(C)$ (T_1 reads that the sum is 90).
So for T_1 it is as if "somebody else" had updated the value o the sum, but for T_2 the update is perfectly legal (does not change the value of the sum).

3.1.5 Phantom Insert

$$r_1(x) \rightarrow w_2(new\ tuple) \rightarrow r_1(x)$$

Someone else inserts dataa that contributes to a previously read datum.

This anomaly does not depend on data already present in the DB when T_1 executes, but on a "phantom" tuple that is inserted by "someone else" and satisfies the conditions of a previous query of T_1.

3.2 Principles of Concurrency Control

Operations: a read or write of a specific datum by a specific transaction.

Schedule: a sequence of operations performed by concurrent transactions that respects the order of operations of each transaction.
How many distinct schedules exist for n transaction each with k_i operations?

$$N_D = \frac{(\sum_{i=1}^{n} k_i)!}{\Pi_{i=1}^{n}(k_i!)}$$

How many of them are serial?

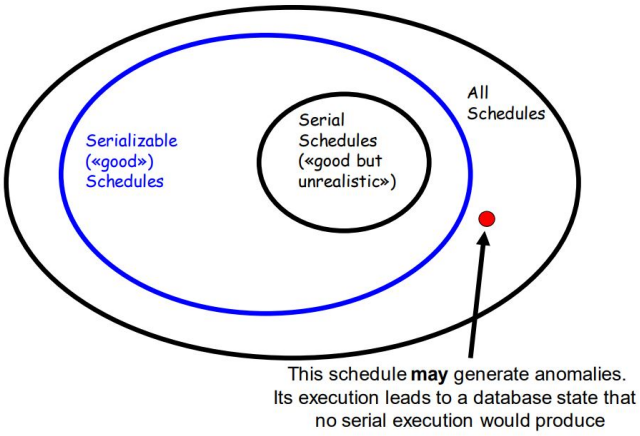
$$N_S = n!$$

Scheduler: a component that accepts or rejects the operations requested by the transactions.

Serial schedule: a schedule in which the actions of each transaction occur in a contiguos sequence.

3.2.1 Serializable schedule

A **serializable schedule** is a schedule that leaves the database in the **same state** as **some** serial schedule of the same transactions.



3.2.2 View-serializability

$r_i(x)$ **reads-from** $w_j(x)$ in a schedule S when $w_j(x)$ precedes $r_i(x)$ and there is no $w_k(x)$ in S between $r_i(x)$ and $w_j(x)$.

$w_i(x)$ in a schedule S is a **final write** if it is the last write on x that occurs in S.

Two schedules are **view-equivalent** if they have the same operations, the same reads-from relation, and the same final writes.

A schedule is **view-serializable** if it is view-equivalent to a serial schedule of the same transactions.
The class of view-serializable schedules is named **VSR**.
S is **view-serializable** if:

1. every read operation sees the same values;

2. the final value of each object is written by the same transaction as if the transactions were executed serially in some order.

Deciding if a generic schedule is in VSR is an **NP-complete problem** but is an heavy task, so we look for a stricter definition that is easier to check, even if we reject sosme schedule that would be acceptable: VSR schedules are "too many".

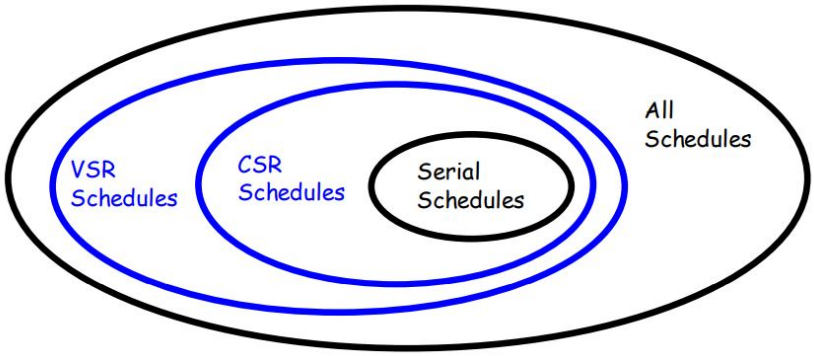
3.2.3 Conflict-serializability

Two operations o_i and o_j are in **conflict** if they address the same resource and at least one of them is a write: **read-write** conflicts (r-w or w-r) and **write-write** conflicts (w-w).

Two schedules are **conflict-equivalent** if contain the same operations and in all conflicting pairs transactions occur in the same order.

A schedule is **conflict-serializable** if it is conflict-equivalent to a serial schedule of the same transactions.
The class of conflict-serializable schedules is named **CSR**.

All conflict-serializable schedules are also view-serializable, but the inverse is not necessarily true: $CSR \rightarrow VSR$.



3.2.4 Testing conflict-serializability

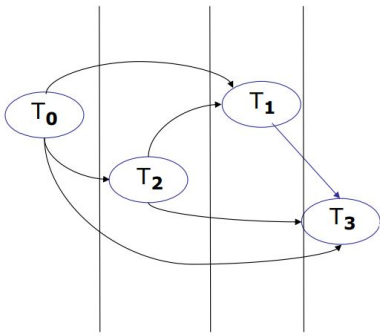
To check if a schedule is conflict-serializable we use a **conflict graph**:

- one node for each transaction T_i;
- one arc from T_i to T_j if there exists at least one conflict between an operation o_i of T_i and an operations o_j of T_j such that o_i precedes o_j;
- a schedule is in CSR if and only if its conflict graph is **acyclic**.

To check if a graph is acyclic we use this algorithm:

- if a graph is acyclic, then it must have at least one node with no targets, called leaf (with no arrows going away from the node).
- if we "peel off" a leaf in an acyclic graph, then we are always left with an acyclic graph, and if we keep peeling off leaf nodes, one of two things will happen: we will eventually peel off al node and so the graph is acyclic, or we will get to a point where there is no leaf, yet the graph is not empty and so the graph is cyclic.

If S's graph is acyclic then it induces a **topological (partial) ordering** on its nodes, that is easier to understand graphically with an example:



In general, there can be many compatible serial schedules.

3.3 Concurrency control approaches: locking

Everything we have seen untill now is based on study of schedules after they have been executed. In real life we need a system that can assure cocnurrency control in "live".
There are two main families of techniques:

- Pessimistic: based on locks, resource access control.
- Optimistic: based on timestamps and versions, serve as many requests as possible, possibly using out-of-date versions of the data.

3.3.1 Locking

A transaction is **well-formed w.r.t. locking** if

- read operations are preceded by **r_lock** (shared lock) and followed by **unlock**;
- write operations are preceded by **w_lock** (exclusice lock) and followed by **unlock**.

Transactions that first read and then write an object may:

- acquire a w_lock already when reading or
- acquire a r_lock first and then upgrade it into a w_lock (lock escalation).

Possible states of an object:

- free;
- r-locked (locked by one or more readers);
- w-locked (locked by a writer);

When a lock request is granted, the resource is acquired; when an unlock is executed, the resource becomes available.
The lock manager grants access to resources according to the **conflict table**:

	FREE	R_LOCKED	W_LOCKED
r_lock	OK (R_LOCKED)	OK (R_LOCKED n++)	NO (W_LOCKED)
w_lock	OK (W_LOCKED)	NO (R_LOCKED)	NO (W_LOCKED)
unlock	ERROR	OK (DEPENDS n- -)	OK (FREE)

where n is the counter of the current readers.

Is respecting locks enough for serializability? No. For example non repeatable read anomalies can still occur and to prevent it we use the **Two-Phase Locking (2PL)**: the requirement (two-phase rule) is that a transaction cannot acquire any other lock after releasing a lock. Doing so we avoid non repeatable reads.