Data Bases II
Exercises

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Abstract

The course aims to prepare software designers on the effective development of database applications.

First, the course presents the fundamental features of current database architectures, with a specific emphasis on the concept of transaction and its realization in centralized and distributed systems.

Then, the course illustrates the main directions in the evolution of database systems, presenting approaches that go beyond the relational model, like active databases, object systems and XML data management solutions.

Contents

Chapter 1

Exercise session I

Exercise 1

Can the following schedules produce anomalies? c_i and a_i indicate the transactional decision (commit/abort).

1. $r_1(x)w_1(x)r_2(x)w_2(y)\ a_1\ c_2$
2. $r_1(x)w_1(x)r_2(y)w_2(y)\ a_1\ c_2$
3. $r_1(x)r_2(x)r_2(y)w_2(y)r_1(z)\ a_1\ c_2$
4. $r_1(x)r_2(x)w_2(x)w_1(x)\ c_1\ c_2$
5. $r_1(x)r_2(x)w_2(x)r_1(y)\ c_1\ c_2$
6. $r_1(x)w_1(x)r_2(x)w_2(x)\ c_1\ c_2$

Answer of exercise 1

1. We have a serial execution, but with the abort of the first transaction. Since the second transaction reads the modified value of x before the abort, we have a dirty read.
2. We have a serial execution and the two transactions require different resources, so there are no anomalies.
3. There are no anomalies because the last operation of the first transaction works on a different resource.
4. Both transactions first reads in sequence the resource x and then updates it without considering the updated value, so we have a lost update.

5. There are no anomalies because the last operation of the first transaction works on a different resource.

6. We have a serial execution, so the schedule is correct.

Exercise 2

The following schedule may produce 2 anomalies: a lost update and a phantom update. Identify them.

$$r_1(x)r_2(x)r_3(x)w_1(x)r_4(y)w_2(x)r_4(x)w_4(y)r_3(y)w_4(x)r_5(y)w_6(y)w_5(y)w_7(y)$$

Answer of exercise 2

We can write the schedule in the following way:

$$\begin{array}{cccccccccccccc}
r_1(x) & & & w_1(x) & & & & & & & & & & \\
 & r_2(x) & & & & w_2(x) & & & & & & & & \\
 & & r_3(x) & & & & & & r_3(y) & & & & & \\
 & & & & r_4(y) & & r_4(x) & w_4(y) & & w_4(x) & & & & \\
 & & & & & & & & & & r_5(y) & & w_5(y) & \\
 & & & & & & & & & & & w_6(y) & & \\
 & & & & & & & & & & & & & w_7(y)
\end{array}$$

And we can see that there is a lost update with transactions T_1 and T_2 and a phantom update with T_3 and T_4.

Exercise 3

Classify the following schedule with respect to CRT and VRT classes:

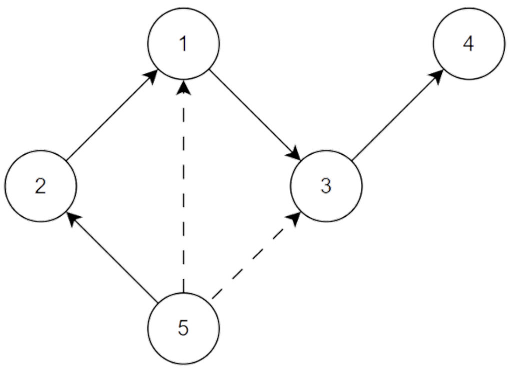
$$r_1(x)r_2(y)w_3(y)r_5(x)w_5(u)w_3(s)w_2(u)w_3(x)w_1(u)r_4(y)w_5(z)r_5(z)$$

Answer of exercise 3

Since CSR contains VSR we check with the conflict graph. To do so we first divide the schedule based on the resources:

- $x : r_1\ r_5\ w_3$
- $y : r_2\ w_3\ r_4$
- $z : w_5\ r_5$
- $s : w_3$
- $u : w_5\ w_2\ w_1$

The nodes are $\{1, 2, 3, 4, 5\}$ and the arcs are found with the write-write or write-read relations found in the previous groups. So we have the following graph:



Some arcs can be omitted if the nodes are connected in another way (in this case we can remove arcs $\{\{5, 1\}, \{5, 3\}\}$).

There are no cycles: the schedule is CSR (and also VSR).

Exercise 4

Classify the following schedule with respect to CRT and VRT classes:

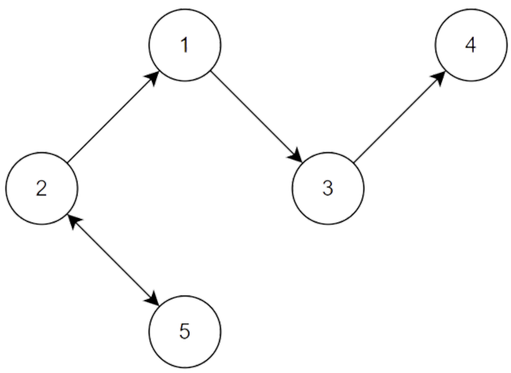
$$r_2(u)w_2(s)r_1(x)r_2(y)w_3(y)r_5(x)w_5(u)w_3(s)w_2(u)w_3(x)w_1(u)r_4(y)w_5(z)r_5(z)$$

Answer of exercise 4

Since CSR contains VSR we check with the conflict graph. To do so we first divide the schedule based on the resources:

- $x : r_1\, r_5\, w_3$
- $y : r_2\, w_3\, r_4$
- $z : w_5\, r_5$
- $s : w_2\, w_3$
- $u : r_2\, w_5\, w_2\, w_1$

The nodes are $\{1, 2, 3, 4, 5\}$ and the arcs are found with the write-write or write-read relations found in the previous groups. So we have the following graph:



It is possible to see that there is a cycle between two and five. The definition of VSR states that we need to have the same reads-from relations and final writes. So, we try to find a view-equivalent schedule that is also CSR. One possible solution is simply to swap the two writes on the resource u and that is sufficient to eliminate the cycle. So, the schedule:

$$r_2(u)w_2(s)r_1(x)r_2(y)w_3(y)r_5(x)w_5(u)w_2(u)w_3(s)w_3(x)w_1(u)r_4(y)w_5(z)r_5(z)$$

is CSR and also VSR.

Exercise 5

Classify the following schedule with respect to CRT and VRT classes:

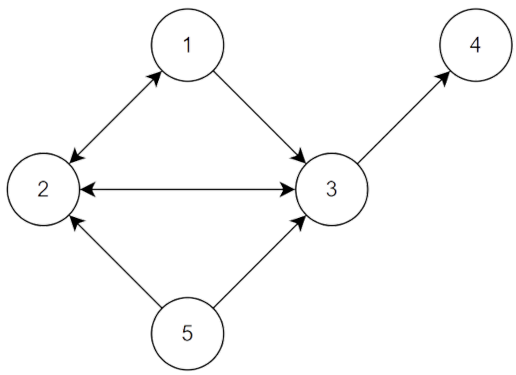
$$r_1(x)r_2(y)w_3(y)r_5(x)w_5(u)w_3(s)w_2(u)w_3(x)w_1(u)r_4(y)w_5(z)r_5(z)r_2(u)w_2(s)$$

Answer of exercise 5

Since CSR contains VSR we check with the conflict graph. To do so we first divide the schedule based on the resources:

- $x : r_1\ r_5\ w_3$
- $y : r_2\ w_3\ r_4$
- $z : w_5\ r_5$
- $s : w_3\ w_2$
- $u : w_5\ w_2\ w_1\ r_2$

The nodes are $\{1, 2, 3, 4, 5\}$ and the arcs are found with the write-write or write-read relations found in the previous groups. So we have the following graph:



In this case it is not possible to find a VSR schedule because it is impossible to do so without changing the final write on s.

Exercise 6

Classify the following schedule with respect to CRT and VRT classes:

$$r_5(x)r_3(y)w_3(y)r_6(t)r_5(t)w_5(z)w_4(x)r_3(z)w_1(y)\dots$$

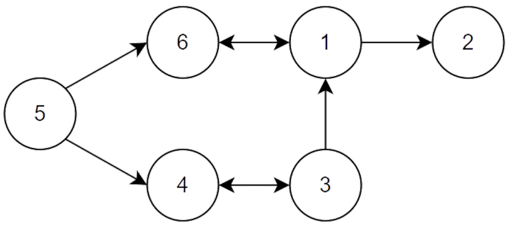
$$\dots r_6(y)w_6(t)w_4(z)w_1(t)w_3(x)w_1(x)r_1(z)w_2(t)w_2(z)$$

Answer of exercise 6

Since CSR contains VSR we check with the conflict graph. To do so we first divide the schedule based on the resources:

- $t:\ r_6\,r_5\,w_6\,w_1\,w_2$
- $x:\ r_5\,w_4\,w_3\,w_1$
- $y:\ r_3\,w_3\,w_1\,r_6$
- $z:\ w_5\,r_3\,w_4\,r_1\,w_2$

The nodes are $\{1,2,3,4,5,6\}$ and the arcs are found with the write-write or write-read relations found in the previous groups. So we have the following graph:



We have two cycles. It is impossible to find a VSR schedule because only the conflict between four and three can be eliminated (the other one changes a read-write relation).

Chapter 2

Exercise session II

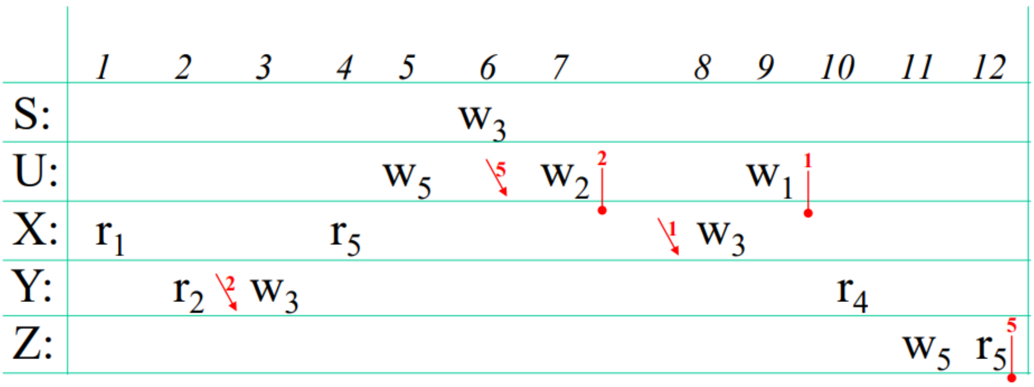
Exercise 7

Classify the following schedule with respect to $2PL$ and strict $2PL$ classes:

$$r_1(x)r_2(y)w_3(y)r_5(x)w_5(u)w_3(s)w_2(u)w_3(x)w_1(u)r_4(y)w_5(z)r_5(z)$$

Answer of exercise 7

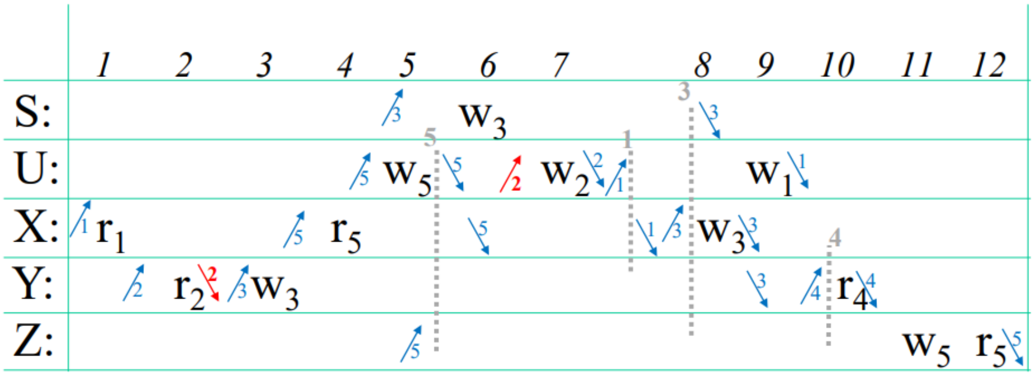
For strict $2PL$ we assume that all transactions commit and release all locks immediately after their last operation, and check if releases can be executed at commit time.



S clearly cannot be in strict $2PL$. The contradictions are:

- T_1 must release X before 8.
- T_2 must release Y before 7.
- T_5 must release U before 12.

For $2PL$ we have:



It is also not in $2PL$: an assignment is not possible for T_2 (which must release Y before locking U).

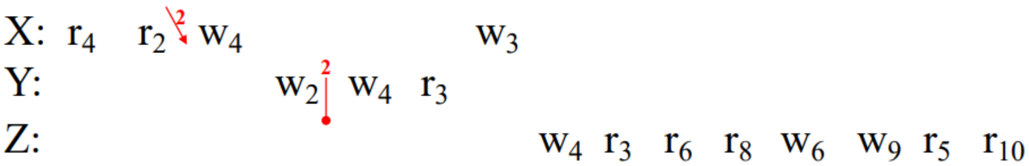
Exercise 8

Classify the following schedule with respect to $2PL$ and strict $2PL$ classes:

$$r_4(x)r_2(x)w_4(x)w_2(y)w_4(y)r_3(y)w_3(x)w_4(z)r_3(z)r_6(z)r_8(z)w_6(z)w_9(z)r_5(z)r_10(z)$$

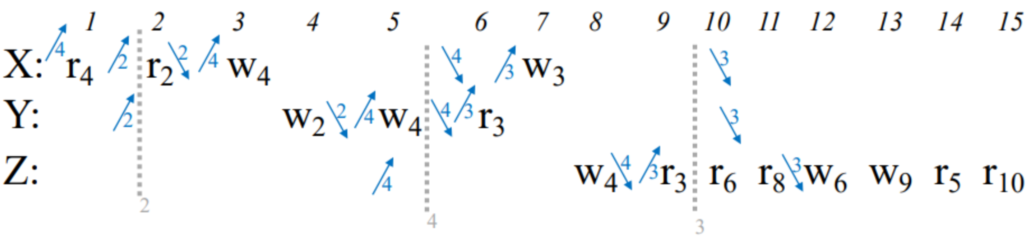
Answer of exercise 8

For strict $2PL$ we assume that all transactions commit and release all locks immediately after their last operation, and check if releases can be executed at commit time.



It is therefore clear that the schedule cannot be in $2PL$-strict, due to T_2 and T_4: T_2 ends after 4, but T_4 wants to write X at 3, and T_2 would thus be required to release X earlier, which is impossible if T_2 has to keep all locks until after 4.

For $2PL$ we have:



We need to look at those acquisitions that must be anticipated and to those releases that must be delayed to not violate the $2PL$ rules. T_4 can only get the XL on X only after 2 and on Y after 4 and has to release Y before 6 and X before 7. Thus, the lock on Z must be acquired before 6. T_2 can get all the locks at the beginning and release them immediately after each use. T_3 can acquire X, Y and Z just before using them and release them all before 12. All other transactions (T_6, T_9, T_5, T_10) clearly pose no problems.

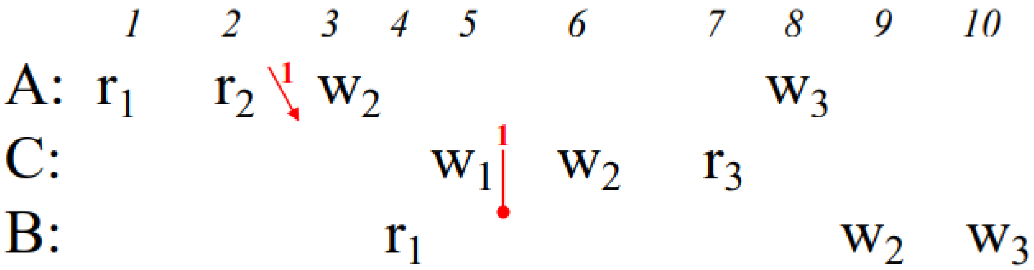
Exercise 9

Classify the following schedule with respect to $2PL$ and strict $2PL$ classes:

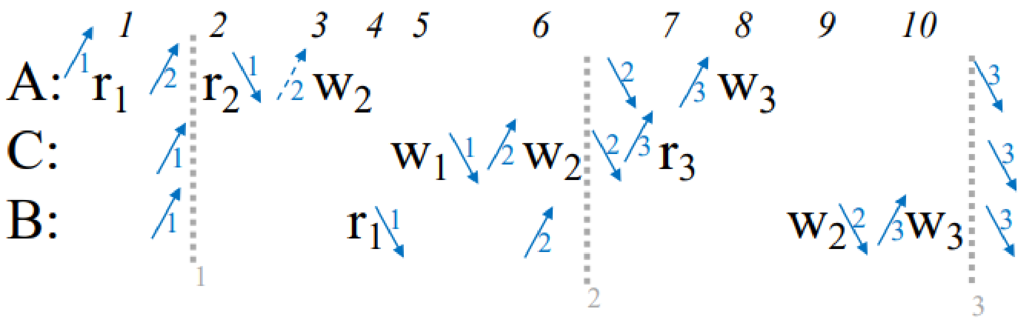
$$r_1(A)r_2(A)w_2(A)r_1(B)w_1(C)w_2(C)r_3(C)w_3(A)w_2(B)w_3(B)$$

Answer of exercise 9

For strict $2PL$ we assume that all transactions commit and release all locks immediately after their last operation, and check if releases can be executed at commit time.



The schedule is not strict $2PL$.
For $2PL$ we have:



The schedule is $2PL$.

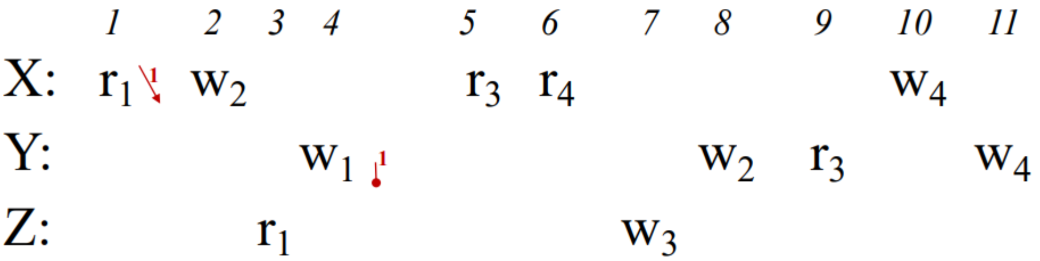
Exercise 10

Classify the following schedule with respect to $2PL$ and strict $2PL$ classes:

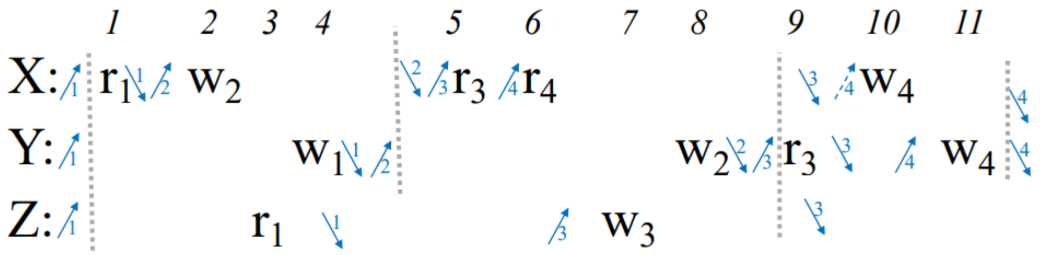
$$r_1(x)w_2(x)r_1(z)w_1(y)r_3(x)r_4(x)w_3(z)w_2(y)r_3(y)w_4(x)w_4(y)$$

Answer of exercise 10

For strict $2PL$ we assume that all transactions commit and release all locks immediately after their last operation, and check if releases can be executed at commit time.



The schedule is not strict $2PL$.
For $2PL$ we have:



The schedule is $2PL$.

Exercise 11

Given the schedule:

$$r1(x)r2(x)r3(y)w3(y)w1(x)w2(y)$$

show the sequence of lock and unlock requests produced by the transactions in a $2PL$ execution, in a system with update lock (available locks: SL, UL, XL).

Answer of exercise 11

The locking phases with update locks are the following:

X	Y
$\mathrm{UL}_1(x)$	
$r_1(x)$	
$\mathrm{SL}_2(x)$	
$r_2(x)$	
	$\mathrm{UL}_3(y)$
	$r_3(y)$
	$\mathrm{XL}_3(y)$[upgrade]
	$w_3(y)$
	$\mathrm{rel}(\mathrm{XL}_3(y))$
	$\mathrm{XL}_2(y)$
$\mathrm{rel}(\mathrm{SL}_2(x))$	
$\mathrm{XL}_1(x)$[upgrade]	
$w_1(x)$	
$\mathrm{rel}(\mathrm{XL}_1(x))$	
	$w_2(y)$
	$\mathrm{rel}(\mathrm{XL}_2(y))$

Exercise 12

Update lock was introduced to contrast deadlocks. Can we state that deadlocks are impossible in the presence of update locks?

1. If so, concisely explain why.
2. If not, provide a counter-example.

Answer of exercise 12

1. Clearly deadlocks are possible in the presence of UL. Indeed, UL only makes deadlock less likely, by preventing one type of (very frequent) deadlock, due to update patterns, when two transactions compete for the same resource ($r_1(x)r_2(x)w_1(x)w_2(x)$).
2. Consider two distinct resources X and Y, and two transactions that want to access them in this order: $r_1(X)r_2(Y)w_1(Y)w_2(X)$. It is likely that they end up in deadlock, especially if the system on which they run applies $2PL$. UL is totally irrelevant here, because there is no update pattern.