Logging and conflict-serializability

CSE 444 section

October 28, 2010

Today

- Logging and recovery review
- Identifying conflict-serializable schedules

Why use logs to recover from crashes?

Helps satisfy 2 of the ACID constraints:

- Atomicity
  - How does log-based recovery keep TXen atomic?
  - How is this done in an undo log?
  - In a redo log?
- Durability
  - How does logging ensure that TXen persist?

Our undo log notation

- <START T>
  - Transaction T has begun
- <COMMIT T>
  - T has committed
- <ABORT T>
  - T has aborted
- <T, X, v> - Update record
  - T has updated element X, and its *old* value was v

An undo logging problem

Given this undo log, when can each data item be output to disk?

- A: after 2
- B: after 3
- C: after 5, before 12
- D: after 7
- E: after 8, before 12
- F: after 10
- G: after 11

1	**<START T1>**
2	**<T1, A, a>**
3	**<T1, B, b>**
4	**<START T2>**
5	**<T2, C, c>**
6	**<START T3>**
7	**<T3, D, d>**
8	**<T2, E, e>**
9	**<START T4>**
10	**<T4, F, f>**
11	**<T3, G, g>**
12	**<COMMIT T2>**

Undo logging problem, continued

After writing these log entries, the DBMS crashes. What does it do when it restarts?

- Scan for transactions to undo: T1, T3, T4
- G, F, D, B, A reverted (in that order)
- <ABORT> written for T1, T3, T4

1	**<START T1>**
2	**<T1, A, a>**
3	**<T1, B, b>**
4	**<START T2>**
5	**<T2, C, c>**
6	**<START T3>**
7	**<T3, D, d>**
8	**<T2, E, e>**
9	**<START T4>**
10	**<T4, F, f>**
11	**<T3, G, g>**
12	**<COMMIT T2>**

What if it was a redo log?

Now, <T,X,v> means X's *new* value is v!

… so *now* when can we output each item?

- C, E: after 12
- Others: never

(given log available)

1	**<START T1>**
2	**<T1, A, a>**
3	**<T1, B, b>**
4	**<START T2>**
5	**<T2, C, c>**
6	**<START T3>**
7	**<T3, D, d>**
8	**<T2, E, e>**
9	**<START T4>**
10	**<T4, F, f>**
11	**<T3, G, g>**
12	**<COMMIT T2>**

Redo log problem, continued

How do we recover from this redo log?

- Scan for transactions to redo: only T2
- C and E rewritten

1	**<START T1>**
2	**<T1, A, a>**
3	**<T1, B, b>**
4	**<START T2>**
5	**<T2, C, c>**
6	**<START T3>**
7	**<T3, D, d>**
8	**<T2, E, e>**
9	**<START T4>**
10	**<T4, F, f>**
11	**<T3, G, g>**
12	**<COMMIT T2>**

Why add (non-quiescent) checkpoints?

Undo log recovery with checkpoints

The DBMS crashes with this undo log.

What do we do to recover?

- Which log entries are read?

  From end to 9: <START CKPT>

- Which transactions are undone?

  None; all have committed

- Which data do we change?

  None; no transactions to undo

1	**<START T1>**
2	**<T1, A, a>**
3	**<T1, B, b>**
4	**<START T2>**
5	**<T2, C, c>**
6	**<START T3>**
7	**<T3, D, d>**
8	**<COMMIT T1>**
9	**<START CKPT (T2, T3)>**
10	**<T2, E, e>**
11	**<START T4>**
12	**<T4, F, f>**
13	**<T3, G, g>**
14	**<COMMIT T3>**
15	**<COMMIT T2>**
16	**<END CKPT>**
17	**<COMMIT T4>**

Redo log recovery with checkpoints

This similar log is a REDO log.

How do we recover this one?

- Which log entries are read?

  From end to 9: <START CKPT>

  Then from 4: <START T2> down to end

- Which transactions are redone?

  T2, T3, T4

- Which data do we change?

  C ← c, D ← d, E ← e, F ← f, G ← g

Lines 15, 16 swapped

1	**<START T1>**
2	**<T1, A, a>**
3	**<T1, B, b>**
4	**<START T2>**
5	**<T2, C, c>**
6	**<START T3>**
7	**<T3, D, d>**
8	**<COMMIT T1>**
9	**<START CKPT (T2, T3)>**
10	**<T2, E, e>**
11	**<START T4>**
12	**<T4, F, f>**
13	**<T3, G, g>**
14	**<COMMIT T3>**
15	**<END CKPT>**
16	**<COMMIT T2>**
17	**<COMMIT T4>**

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Schedules and conflicts

For some transaction T_1:

- $r_1(X)$ means "T_1 reads the data element X"
- $w_1(X)$ means "T_1 writes the data element X"

Two actions from T_1, T_2 *conflict* iff:

- one or both is a write, and
- they act on the same element

Two actions both from T_1 also conflict

Example 1: find all conflicts

$w_3(A)$

$r_1(A)$

$w_1(B)$

$r_2(B)$

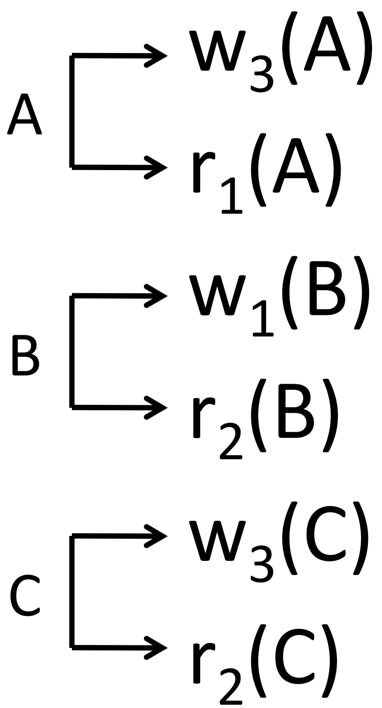
$w_3(C)$

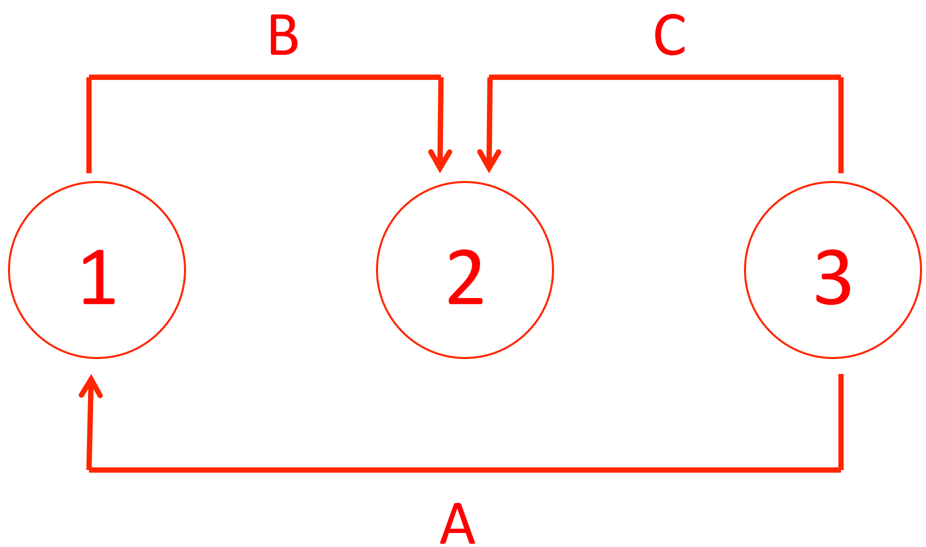
$r_2(C)$

The precedence graph

- Recall: T_1 must *precede* T_2 iff an action from T_1 conflicts with a later action from T_2
  - Ignore conflicting actions from the same transaction
- Precedence graph shows the precedence relations

Example 1: precedence graph





Is it conflict serializable?

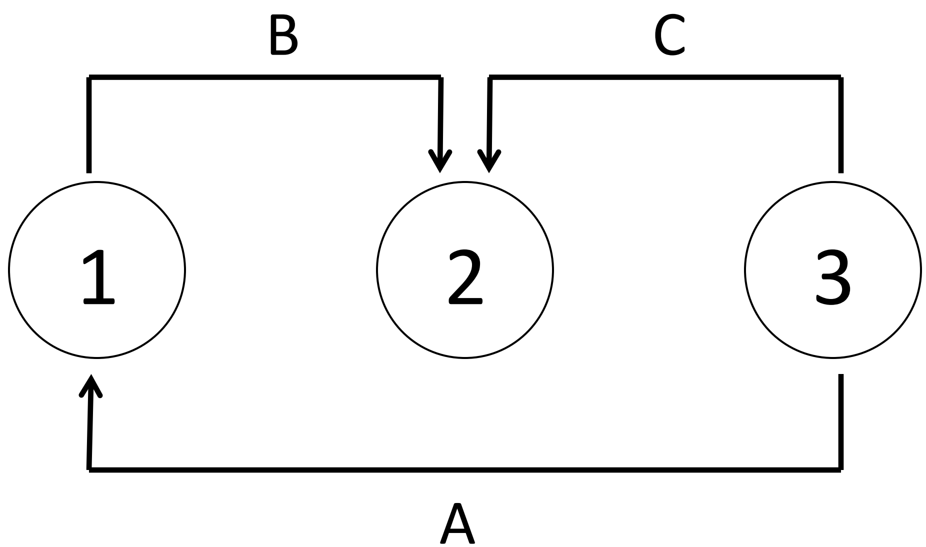
- **YES:** if no cycles in the precedence graph
  - Any transaction order which follows the precedences shown is an equivalent serial schedule
- **NO:** if there are cycles in the precedence graph

Example 1: conflict serializable?

A: $w_3(A)$, $r_1(A)$

B: $w_1(B)$, $r_2(B)$

C: $w_3(C)$, $r_2(C)$



No cycles: **YES,** conflict serializable

Only serial equivalent schedule: T_3, T_1, T_2

Example 1: serial equivalent

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

Only serial equivalent schedule: T_3, T_1, T_2

Example 2: find non-self conflicts

$r_1(A)$

$r_2(A)$

$r_1(B)$

$r_2(B)$

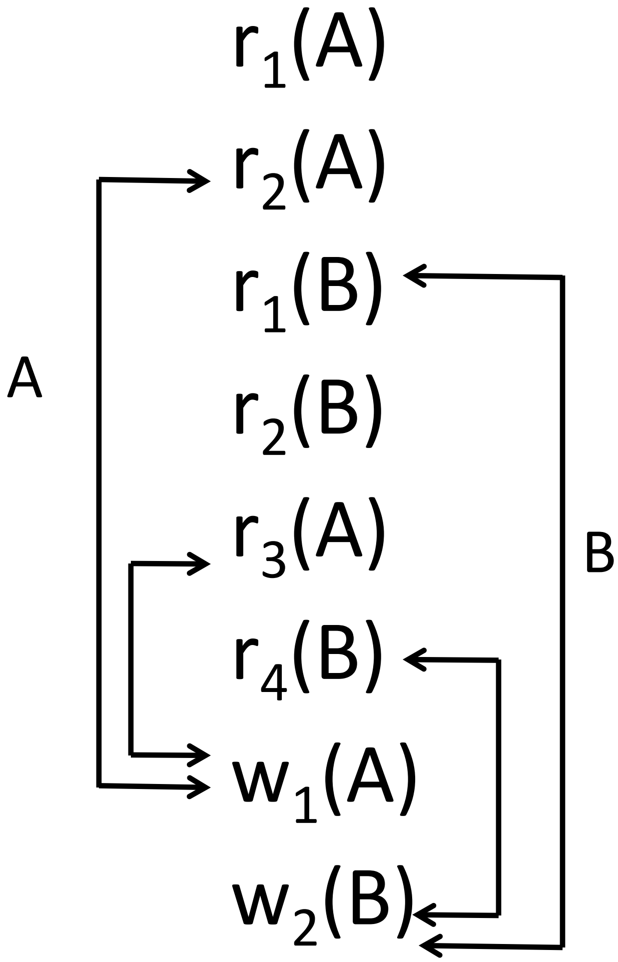
$r_3(A)$

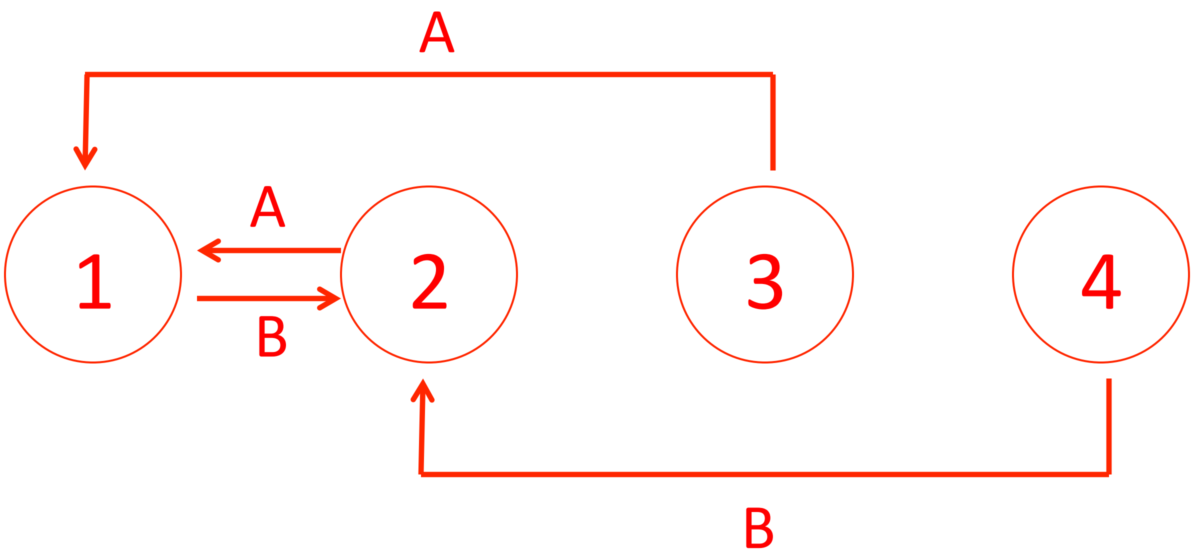
$r_4(B)$

$w_1(A)$

$w_2(B)$

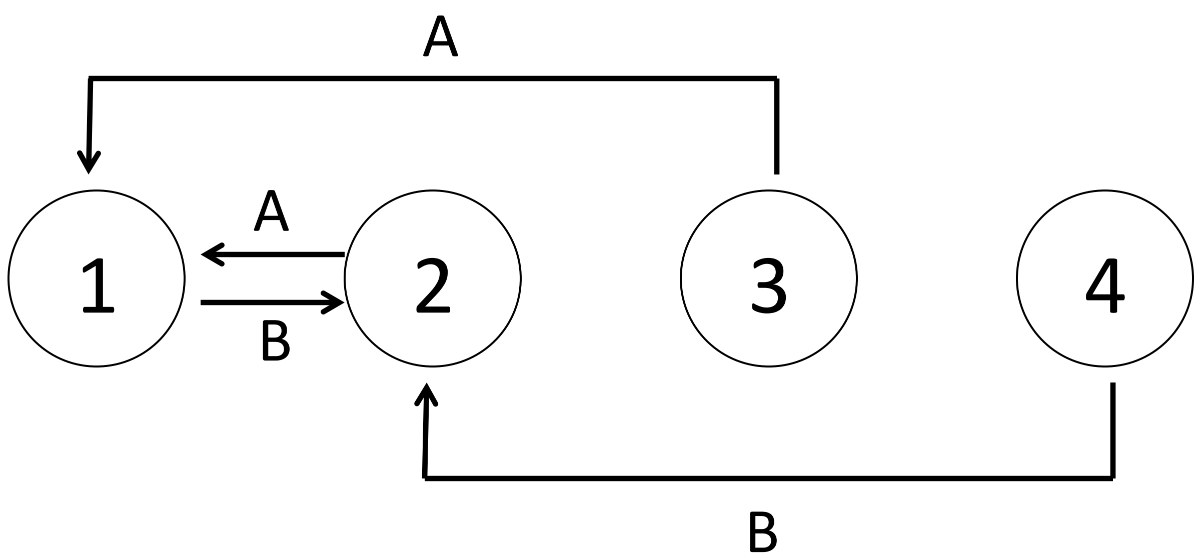
Example 2: precedence graph





Example 2: conflict serializable?

$r_1(A)$
$r_2(A)$
$r_1(B)$
$r_2(B)$
$r_3(A)$
$r_4(B)$
$w_1(A)$
$w_2(B)$



Cycle between T_1 and T_2:
NO, not conflict serializable