Recovery

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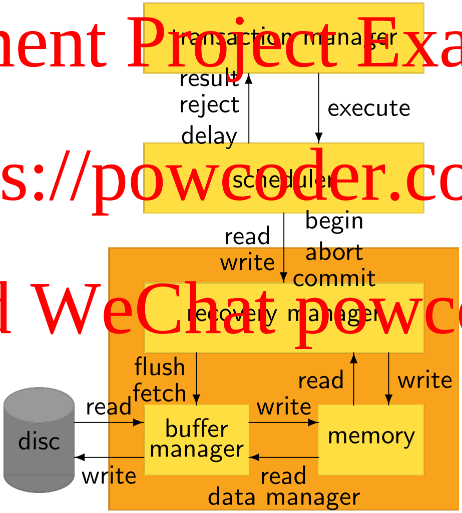
DBMS Architecture



Recovery Manager (RM)

protect the DBMS against failures

- **system failures** loss of volatile storage

  1. committed transactions written to disc

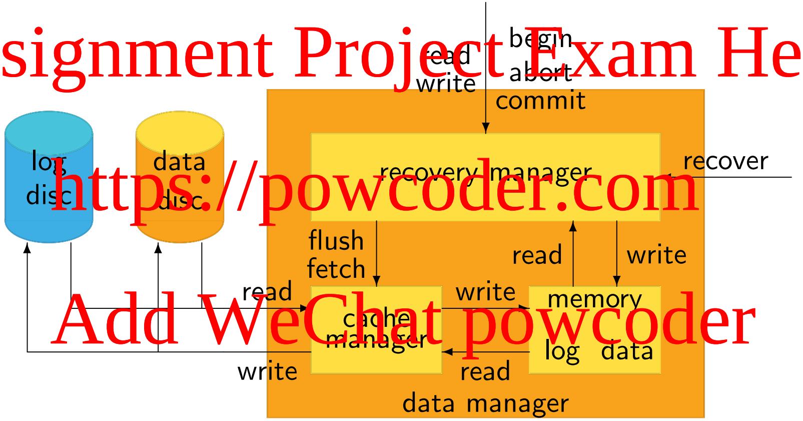
  2. uncommitted transactions not written to disc

     OR

  3. sufficient information such that (1) and (2) may be met by a *recovery*

- **media failures** loss of stable storage

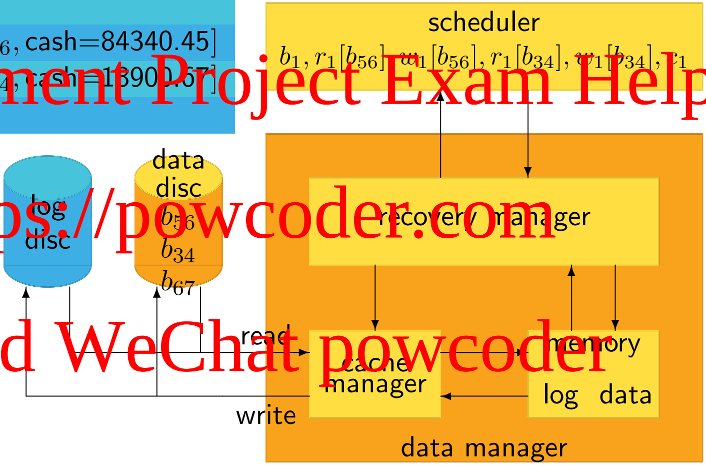
Enhanced Data Manager Architecture



- Need to cache log as well

Need to REDO

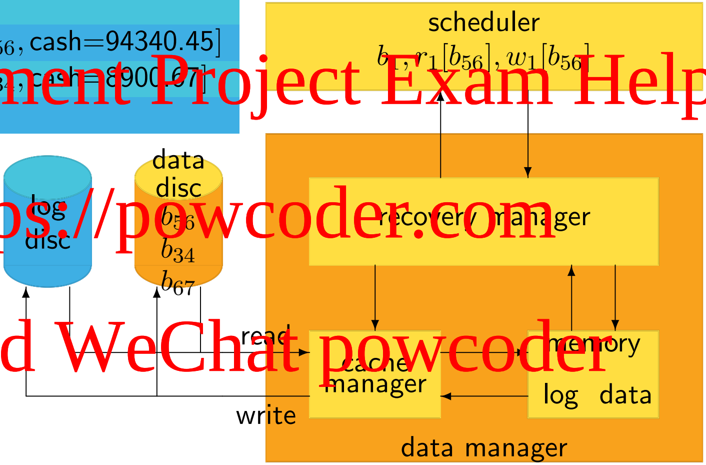
LOG	b_1
REDO	$w_1[b_{56}, \text{cash}=84340.45]$
REDO	$w_1[b_{34}, \text{cash}=13900.67]$
LOG	c_1



- REDO required if committed transactions not in stable storage
- must write all REDO to log before commit of transaction

Need to UNDO

LOG	b_1
UNDO	$w_1[b_{56}, \text{cash}=94340.45]$
UNDO	$w_1[b_{34}, \text{cash}=8900.67]$
LOG	c_1



- UNDO required if non-committed transactions in stable storage
- Must flush UNDO to log before corresponding write to data

Quiz 1: Contents of Data Disc After a Transaction

branch		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

```
BEGIN TRANSACTION T1
      UPDATE branch
      SET cash=cash-10000.00
      WHERE sortcode=56

      UPDATE branch
      SET cash=cash+10000.00
      WHERE sortcode=34
COMMIT TRANSACTION T1
```

branch ①		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

branch ③		
sortcode	bname	cash
56	'Wimbledon'	84340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

branch ②		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	18900.67
67	'Strand'	34005.00

branch ④		
sortcode	bname	cash
56	'Wimbledon'	84340.45
34	'Goodge St'	18900.67
67	'Strand'	34005.00

What must the contents of the branch table on the data disc be after the transaction commits?

A
④

B
① or ④

C
①,③ or ④

D
①,②,③ or ④

Quiz 2: Contents of Log Disc After a Transaction

Data Disc Before Transaction

branch		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

```
BEGIN TRANSACTION T1
      UPDATE branch
      SET cash=cash-10000.00
      WHERE sortcode=56

      UPDATE branch
      SET cash=cash+10000.00
      WHERE sortcode=34
COMMIT TRANSACTION T1
```

Data Disc At Commit Time

branch		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	18900.67
67	'Strand'	34005.00

What must be on the log disc after commit time?

A

REDO r_{56}
REDO r_{34}
UNDO r_{56}
UNDO r_{34}

B

REDO r_{56}
UNDO r_{34}

C

UNDO r_{34}

D

REDO r_{56}

Before and after images

before image

branch		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

$\Downarrow$

$w_1[b_{56}]$

$\Downarrow$

branch		
sortcode	bname	cash
56	'Wimbledon'	84340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

after image

- before image allows RM to **undo** $w_1[b_{56}]$
- after image allows RM to **redo** $w_1[b_{56}]$

Database Logs

LOG	b_1
REDO	$w_1[b_{56}, \text{cash}{=}84340.45]$
REDO	$w_1[b_{34}, \text{cash}{=}18900.67]$
LOG	c_1

LOG	b_1
UNDO	$w_1[b_{56}, \text{cash}{=}94340.45]$
UNDO	$w_1[b_{34}, \text{cash}{=}8900.67]$
LOG	c_1

LOG	b_1
UNDO	$w_1[b_{56}, \text{cash}{=}94340.45]$
REDO	$w_1[b_{56}, \text{cash}{=}84340.45]$
UNDO	$w_1[b_{34}, \text{cash}{=}8900.67]$
REDO	$w_1[b_{34}, \text{cash}{=}18900.67]$
LOG	c_1

What must a complete REDO/UNDO log contain?

Must contain

- REDO information for each update
- UNDO information for each update
- commit of each transaction

Might contain

- begin of each transaction
  - can be inferred from first REDO/UNDO
  - presence useful to stop search of UNDO records
- abort of each transaction
  - can be inferred from lack of commit
  - presence useful to indicate UNDO already done

Rules for log and data updates

write ahead logging (WAL)

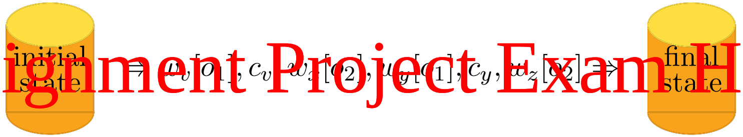
Redo rule

- commit $\rightarrow$ flush log of transaction to disc
- never respond to scheduler before log written

Undo rule:

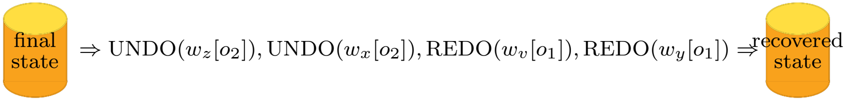
- flushing uncommitted data $\rightarrow$ flush log of operations

Basic Recovery Procedure



$\Rightarrow w_v[o_1], c_v, w_x[o_2], w_y[o_1], c_y, w_z[o_2] \Rightarrow$

1. UNDO $\rightarrow$ *Scan back through the log*
   - Collect set of committed transactions $C = \{v, y\}$
   - Collect set of incomplete transactions $I = \{x, z\}$
   - Perform UNDO for any transaction in $I = w_z[o_2], w_x[o_2]$
2. REDO $\rightarrow$ *Scan forward through the log*
   - Perform REDO for any transaction in $C = w_v[o_1], w_y[o_1]$



$\Rightarrow \text{UNDO}(w_z[o_2]), \text{UNDO}(w_x[o_2]), \text{REDO}(w_v[o_1]), \text{REDO}(w_y[o_1]) \Rightarrow$

Example of Recovery

Log

LOG	b_4
LOG	b_1
UNDO	$w_1[b_{56}, \text{cash}{=}94340.45]$
REDO	$w_1[b_{56}, \text{cash}{=}84340.45]$
LOG	b_2
UNDO	$w_2[b_{34}, \text{cash}{=}10900.67]$
REDO	$w_2[b_{34}, \text{cash}{=}8900.67]$
UNDO	$w_2[b_{67}, \text{cash}{=}34005.00]$
REDO	$w_2[b_{67}, \text{cash}{=}36005.25]$
LOG	b_7
LOG	c_2
UNDO	$w_1[b_{34}, \text{cash}{=}8900.67]$
REDO	$w_1[b_{34}, \text{cash}{=}18900.67]$
UNDO	$w_7[b_{67}, \text{cash}{=}36005.25]$
REDO	$w_7[b_{67}, \text{cash}{=}37005.25]$
LOG	c_7
LOG	c_4

Disc Before Recovery

branch		
sortcode	bname	cash
56	'Wimbledon'	84340.45
34	'Goodge St'	18900.67
67	'Strand'	34005.00

Disc After Recovery

branch		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	37005.25

Omitting the REDO Log

If no REDO records kept

must flush committed transactions to data disc

1. $C = \emptyset, D = \emptyset$
2. Scan the log backwards from the end.
3. commit entry $\rightarrow$ add to C
4. undo entry for member of $C \rightarrow$ add object to D *without* making changes to the data.
5. perform undo entry for object not of member D

Omitting the Undo Log

If no UNDO records kept

transaction must never write uncommitted data

- add **fix** command between RM and CM to stop CM flushing data
- commit is followed by flush or **unfix** of fixed objects

Omitting UNDO and REDO

atomic commit → out of place updating

Quiz 3: Contents of Disc Before Commit if no UNDO log

branch

sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

```
BEGIN TRANSACTION T1
    UPDATE branch
    SET cash=cash-10000.00
    WHERE sortcode=56

    UPDATE branch
    SET cash=cash+10000.00
    WHERE sortcode=34
COMMIT TRANSACTION T1
```

branch ①

sortcode	bname	cash
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34	'Goodge St'	8900.67
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branch ③

sortcode	bname	cash
56	'Wimbledon'	84340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

branch ②

sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	18900.67
67	'Strand'	34005.00

branch ④

sortcode	bname	cash
56	'Wimbledon'	84340.45
34	'Goodge St'	18900.67
67	'Strand'	34005.00

What must the contents of the branch table on disc be before the transaction commits?

A
①

B
① or ④

C
④

D
①,②,③ or ④

Quiz 4: Contents of Disc After Commit if no REDO log

branch		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

```
BEGIN TRANSACTION T1
      UPDATE branch
      SET cash=cash-10000.00
      WHERE sortcode=56

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      WHERE sortcode=34
COMMIT TRANSACTION T1
```

branch ①		
sortcode	bname	cash
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67	'Strand'	34005.00

branch ③		
sortcode	bname	cash
56	'Wimbledon'	84340.45
34	'Goodge St'	8900.67
67	'Strand'	34005.00

branch ②		
sortcode	bname	cash
56	'Wimbledon'	94340.45
34	'Goodge St'	18900.67
67	'Strand'	34005.00

branch ④		
sortcode	bname	cash
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What must the contents of the branch table on disc be after the transaction commits?

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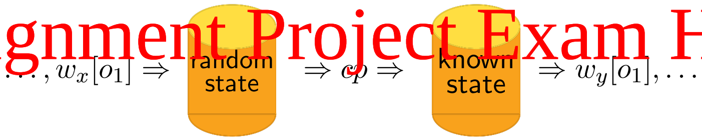
①

B
① or ④

C
④

D
①,②,③ or ④

Checkpointing


$\ldots, w_x[o_1] \Rightarrow$
random state
$\Rightarrow cp \Rightarrow$
known state
$\Rightarrow w_y[o_1], \ldots$

- Forces the database into some known state
- Recovery limited to only look back to checkpoint (or a ‘bit’ before!)
    - speeds the recovery operation
    - limits the size of log

- The more consistent this known state
    - the easier it is to recover
    - the longer it takes to perform the checkpoint

Commit Consistent Checkpoint

Generating a Commit Consistent Checkpoint

1. Stop accepting new transactions
2. Finish existing transactions.
3. Flush all dirty data cache objects to disc.
4. Write a checkpoint to stable log.

- recovery now only needs to scan back to cp in log ✓
- possible long hold-up at checkpoint ✖

Cache Consistent Checkpoint

Generating a Cache Consistent Checkpoint

1. Suspend all transactions
2. Flush all dirty cache objects to disc
3. Write a checkpoint + active transactions to stable log

Recovery from Cache Consistent Checkpoint records

1. perform UNDOs of non-committed transactions back to *cp*
2. perform UNDO of non-committed transactions before *cp* if they were active at *cp*
3. perform REDOs of committed transactions after *cp*

- could still have delay whilst flushing cached objects

Worksheet: Cache Consistent Checkpoint

LOG	b_7
UNDO	$w_7[b_{67},\text{cash}=34005.25]$
REDO	$w_7[b_{67},\text{cash}=37005.25]$
LOG	b_2
UNDO	$w_2[b_{34},\text{cash}=10900.67]$
REDO	$w_2[b_{34},\text{cash}=8900.67]$
LOG	b_6
UNDO	$w_6[a_{101},\text{rate}=5.25]$
REDO	$w_6[a_{101},\text{rate}=6.00]$
LOG	b_1
UNDO	$w_1[b_{56},\text{cash}=94340.45]$
REDO	$w_1[b_{56},\text{cash}=84340.45]$
LOG	a_7
LOG	$cp\{1,2,6\}$
	⋮

	⋮
UNDO	$w_6[a_{119},\text{rate}=5.50]$
REDO	$w_6[a_{119},\text{rate}=6.00]$
LOG	c_6
UNDO	$w_2[b_{67},\text{cash}=34005.00]$
REDO	$w_2[b_{67},\text{cash}=36005.25]$
LOG	b_8
LOG	c_2
UNDO	$w_1[b_{34},\text{cash}=8900.67]$
REDO	$w_1[b_{34},\text{cash}=18900.67]$
LOG	b_9
UNDO	$w_9[b_{67},\text{cash}=36005.00]$
REDO	$w_9[b_{67},\text{cash}=20000.00]$
LOG	c_9

Fuzzy Checkpointing

Generating a Fuzzy Checkpoint

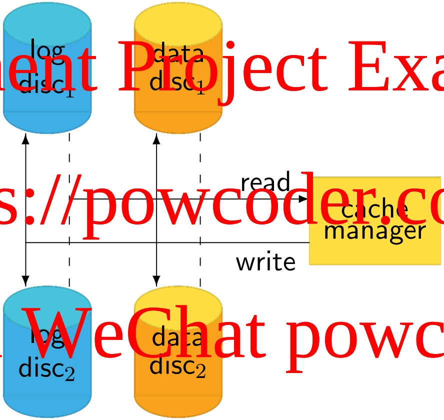
1. Suspend all transactions
2. Flush any dirty cache objects to disc not flushed in previous *cp*
3. Write a checkpoint + active transactions to stable log

Recovery from Fuzzy Checkpoint records

Recovery works like cache consistent checkpoint, but working with penultimate *cp*

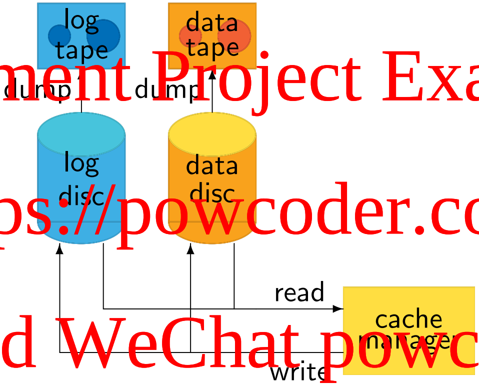
1. perform UNDOs of non-committed transactions back to penultimate *cp*
2. perform UNDO of non-committed transactions before penultimate *cp* if they were active at *cp*
3. perform REDOs of committed transactions after penultimate *cp*

Media Failures: Mirroring (RAID-1)



- Keep more than one active copy of data and log
- Writes sent to both
- Read from either

Media Failures: Dumping

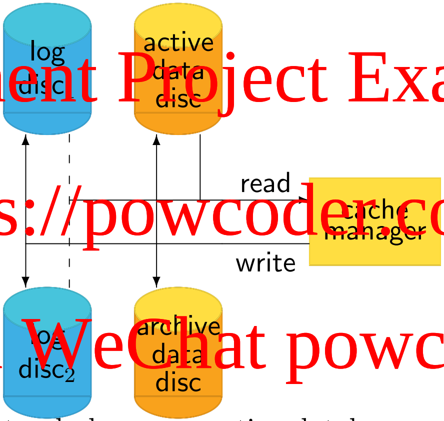


- ‘tape’ might also be a external file server, removable HD, *etc.*
- To use normal OS backup procedure
  - DBMS must not be still running
  - raw partition must not be used

Checkpoints and Dumps

- Dump must do a checkpoint
- Restore involves:
  1. copy tape to disc
  2. undo transactions active at the archive time
  3. redo transactions that committed after the archive
- commit consistent checkpoint obvious choice

Media Failures: Archive Database



- mirror log, but only have one active database
- periodically archive updates onto archive database
- failure of active database disc involves restore of archive database using logs

THE END

- Content of the course is what has been presented in the lectures
- Revise by reviewing worksheets and courseworks
- 2011 exam papers onwards set to current syllabus
- Older exam questions mostly apply, but there is more emphasis on RA and SQL, less on concurrency.