Database Management Systems

Module 53: Backup & Recovery/3: Recovery/2

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Module Recap

- Failures may be due to variety of sources – each needs a strategy for handling
- A proper mix and management of volatile, non-volatile and stable storage can guarantee recovery from failures and ensure Atomicity, Consistency and Durability
- Log-based recovery is efficient and effective

Module Objectives

- To understand Transactional Logging with Hot Backup
- To focus on concurrent transactions and understand the recovery algorithms

Module Outline

- Transactional Logging
- Recovery Algorithm

Transactional Logging

Hot Backup: Recap

- In systems where high availability is a requirement **Hot backup** is preferable **wherever possible**
- **Hot backup** refers to keeping a database up and running while the backup is performed concurrently
  - Such a system usually has a module or plug-in that allows the database to be backed up while staying available to end users
  - Databases which stores transactions of asset management companies, hedge funds, high frequency trading companies etc. try to implement Hot backups as these data are highly dynamic and the operations run 24x7
  - Real time systems like sensor and actuator data in embedded devices, satellite transmissions etc. also use Hot backup

Transactional Logging as Hot Backup

- In regular database systems, **Hot Backup** is mainly used for *Transaction Log Backup*
- **Cold backup** strategies like **Differential, Incremental** are preferred for *Data backup* The reason is evident from the disadvantages of Hot backup
- **Transactional Logging** is used in circumstances where a possibly inconsistent backup is taken, but another file generated and backed up (after the database file has been fully backed up) can be used to restore consistency
- The information regarding **data backup versions** while recovery at a **given point** can be inferred from the Transactional Log backup set
- Thus they play a vital role in **database recovery**

Transactional Logging with Recovery: Example

To understand how **Transactional Logging** works we consider Figure 1 that represents a chunk of a database just before a backup has been started

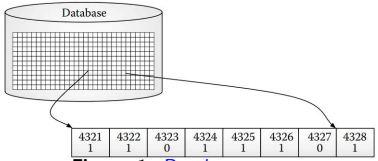


Figure: 1: *Database content*

- While the backup is in progress, modifications may continue to occur to the database. For example, a request to modify the data at location "**4325**" to '**0**' arrives.
- When a request comes through to modify a part of the DB, the modifications will be written in the **given order compulsorily**
  1. Transaction Log
  2. Database (itself)

  This is depicted in Figure 2
- If a crash occurs **before writing to the database** then the **inconsistent backed up file is recovered first**, and then the pending **modifications in the transaction log** (backed up*) are applied to **re-establish consistency**

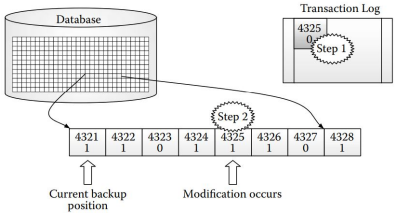


Figure: 2: *Changes to a DB during a hot backup*

***Note**: *The Transactional Log itself is backed up using Hot Backup the Data is backed up incrementally*

Transactional Logging with Recovery: Example (2)

Consider in the previous scenario before the occurrence of crash, another request modifies the content of location "**4321**" to '**0**'. Incidentally, **this change gets written in the database itself** (recall: Immediate Modification). This is indicated in Figure 3

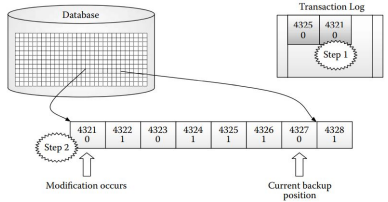


Figure: 3: *Applying Tr. logs during recovery*

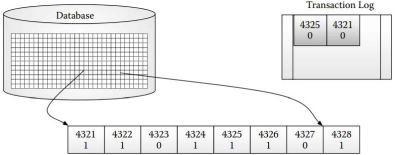


Figure: 4: *Recovered DB files and Tr. logs*

- Figure 3 is the state of the database after which the system crashes. Note that this part has already been backed up, and hence, the backup is inconsistent with the database.
- Recovery Phase:
  - Data recovery is done from the last data back up set (Figure 1)
  - Log recovery is done from the Transaction Log backup set. It will be same as the current transaction log because of Hot backup
  - Figure 4 shows the recovered database and log
- The recovered database is inconsistent. To re-establish consistency all transaction logs generated between the start of the backup and the end of the backup must be **replayed**

Transactional Logging with Recovery: Example (3)

- When using transactional logging we distinguish between *recover* and *restore*:
  - **Recover**: retrieve from the backup media the database files and transaction logs, and
  - **Restore**: reapply database consistency based on the transaction logs
- For our restore process, we recover inconsistent database files and completed transaction logs. The recovered files will resemble the configuration shown in Figure 4
- The final database state after replaying log on the recovered database is displayed in Figure 5
- **The state of database is consistent**

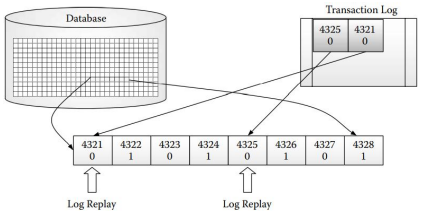


Figure: 5: *Database restore process via log replay*

- Note that an unnecessary log replay is shown occurring for block 4325. Whether such replays will occur is dependent on the database being used. For instance, a database vendor might choose to replay all logs because it would be faster than first determining whether a particular logged activity needs to be replayed
- Once all transaction logs have been replayed, the database is said to have been restored, that is, it is at a point where it can now be opened for user access

Recovery Algorithm

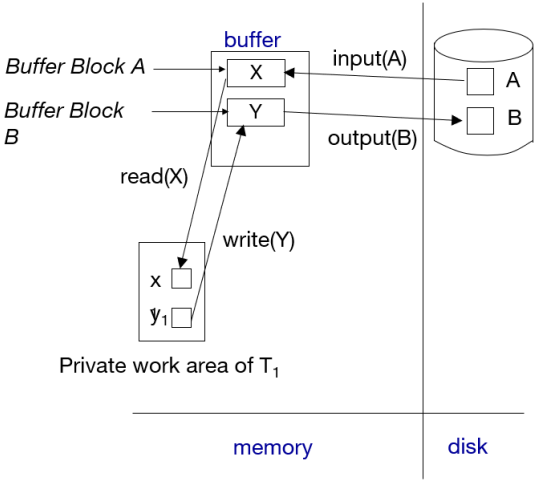
Recovery Schemes

- **So far**:
  - We covered key concepts
  - We assumed serial execution of transactions
- **Now**:
  - We discuss concurrency control issues
  - We present the components of the basic recovery algorithm

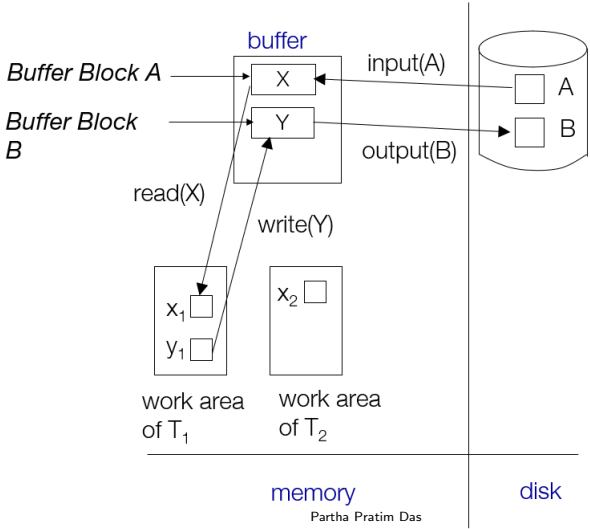
Concurrency Control and Recovery

- With concurrent transactions, all transactions share a single disk buffer and a single log
  - A buffer block can have data items updated by one or more transactions
- We assume that *if a transaction T_i has modified an item, no other transaction can modify the same item until T_i has committed or aborted*
  - That is, the updates of uncommitted transactions should not be visible to other transactions
    - Otherwise how do we perform undo if T_1 updates A, then T_2 updates A and commits, and finally T_1 has to abort?
  - Can be ensured by obtaining exclusive locks on updated items and holding the locks till end of transaction (strict two-phase locking)
- Log records of different transactions may be interspersed in the log

Example of Data Access with Serial Transaction



Example of Data Access with Concurrent Transactions



Recovery Algorithm

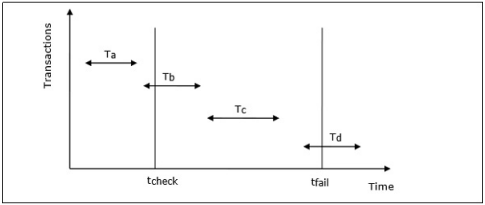
- **Logging** (during normal operation):
  - $< T_i$ **start** $>$ at transaction start
  - $< T_i, X_j, V_1, V_2 >$ for each update, and
  - $< T_i$ **commit**$>$ at transaction end

Recovery Algorithm (2)

- **Transaction rollback (during normal operation)**
  - Let T_i be the transaction to be rolled back
  - Scan log backwards from the end, and for each log record of T_i of the form $< T_i, X_j, V_1, V_2 >$
    - perform the undo by writing V_1 to X_j,
    - write a log record $< T_i, X_j, V_1 >$
      ... such log records are called **Compensation Log Records (CLR)**
  - Once the record $< T_i$ **start**$>$ is found stop the scan and write the log record $< T_i$ **abort**$>$

Recovery Algorithm (3): Checkpoints Recap

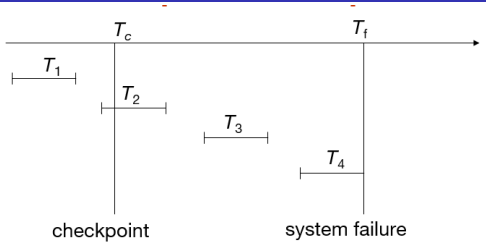
- Let the time of checkpointing is `tcheck` and the time of system crash is `tfail`
- Let there be four transactions T_a, T_b, T_c and T_d such that:
  - T_a commits before checkpoint
  - T_b starts before checkpoint and commits before system crash
  - T_c starts after checkpoint and commits before system crash
  - T_d starts after checkpoint and was active at the time of system crash



- The actions that are taken by the recovery manager are:
  - Nothing is done with T_a
  - Transaction redo is performed for T_b and T_c
  - Transaction undo is performed for T_d

Source: *Distributed DBMS - Database Recovery*

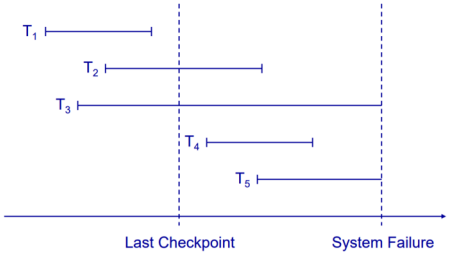
Recovery Algorithm (4): Checkpoints Recap



- Any transactions that committed before the last checkpoint should be ignored
  - T_1 can be ignored (updates already output to disk due to checkpoint)
- Any transactions that committed since the last checkpoint need to be redone
  - T_2 and T_3 redone
- Any transaction that was running at the time of failure needs to be undone and restarted
  - T_4 undone

Recovery Algorithm (5): Redo-Undo Phases

- **Recovery from failure**: Two phases
  - **Redo phase:** Replay updates of all transactions, whether they committed, aborted, or are incomplete
  - **Undo phase:** Undo phase: Undo all incomplete transactions



Requirement:

- Transactions of type T_1 need no recovery
- Transactions of type T_2 or T_4 need to be redone
- Transactions of type T_3 or T_5 need to be undone and restarted

Strategy:

- Ignore T_1
- Redo T_2, T_3, T_4 and T_5
- Undo T_3 and T_5

Recovery Algorithm (6): Redo Phase

- Find last $<$ **checkpoint** $L>$ record, and set undo-list to L
- Scan forward from above $<$ **checkpoint** $L>$ record
  - Whenever a record $< T_i, X_j, V_1, V_2 >$ is found, redo it by writing V_2 to X_j
  - Whenever a log record $< T_i$ **start**$>$ is found, add T_i to undo-list
  - Whenever a log record $< T_i$ **commit**$>$ or $< T_i$ **abort**$>$ is found, remove T_i from undo-list
- Steps for the REDO operation are:
  - If the transaction has done INSERT, the recovery manager generates an insert from the log
  - If the transaction has done DELETE, the recovery manager generates a delete from the log
  - If the transaction has done UPDATE, the recovery manager generates an update from the log.

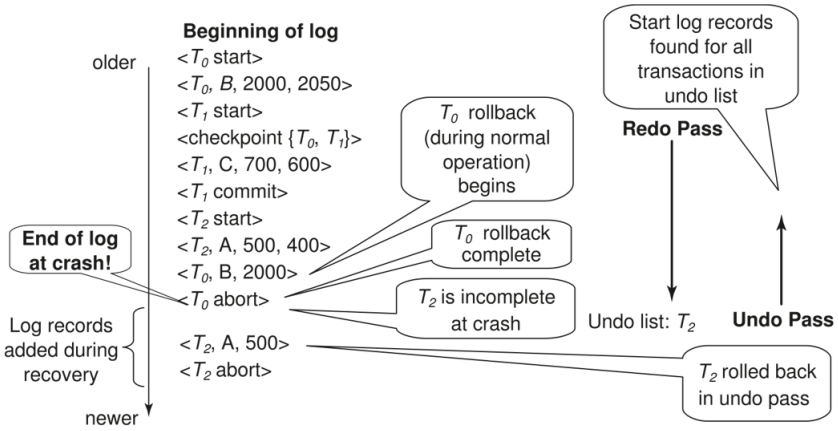
Source: *Distributed DBMS - Database Recovery*

Recovery Algorithm (7): Undo Phase

- Scan log backwards from end
  - Whenever a log record $< T_i, X_j, V_1, V_2 >$ is found where T_i is in undo-list perform same actions as for transaction rollback:
    - ▷ Perform undo by writing V_1 to X_j
    - ▷ Write a log record $< T_i, X_j, V_1 >$
  - Whenever a log record $< T_i$ **start**$>$ is found where Ti is in undo-list
    - ▷ Write a log record $< T_i$ **abort**$>$
    - ▷ Remove T_i from undo-list
  - Stop when undo-list is empty
    That is, $< T_i start >$ has been found for every transaction in undo-list
- Steps for the UNDO operation are:
  - If the faulty transaction has done INSERT, the recovery manager deletes the data item(s) inserted
  - If the faulty transaction has done DELETE, the recovery manager inserts the deleted data item(s) from the log
  - If the faulty transaction has done UPDATE, the recovery manager eliminates the value by writing the before-update value from the log
- After undo phase completes, normal transaction processing can commence

Source: *Distributed DBMS - Database Recovery*

Recovery Algorithm (8): Example



Module Summary

- Learnt how Hot backup of transaction log helps in recovering consistent database.
- Studied the recovery algorithms for concurrent transactions

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