Replicated Concurrency Control and Recovery

Design Document

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December 9, 2019

1 Introduction

This project is to implement a tiny distributed database, complete with multiversion concurrency control, deadlock detection, replication, and failure recovery. The program reads input instructions from a file or standard input, and outputs the results on screen.

2 Design

2.1 Overview

This project is written in Java. The program consists of several data models (`Transaction`, `Operation`, `Variable`, `Lock`), business logic managers (`TransactionManager`, `DataManager`, `LockManager`), and a runner (`Database`).

2.2 Data Models

Below are the data models we have to maintain this distributed database.

```
public class Transaction {
    private int id;
    private int timestamp;
    private TransactionType type;       // Enum, can be READ_ONLY or READ_WRITE
    private boolean isBlocked;
    private boolean isAborted;
    private Set<Integer> accessedSites;
}

public class Operation {
    private int timestamp;
    private int transactionId;
    private int variableId;
    private OperationType type;         // Enum, can be READ or WRITE
    private int value;
}

public class Variable {
    private int id;
    private int valueToCommit;
    private int transactionIdToCommit;
    private int lastCommittedValue;
    private Map<Integer, Integer> committedValues;
                                        // <timestamp, committedValue>
    private boolean isReadable;
}

public class Lock {
    private int transactionId;
    private int variableId;
    private LockType type;              // Enum, can be READ_LOCK or WRITE_LOCK
}
```

Constructors, builders, setters and getters are omitted in this design document.

2.3 Business Logic

`TransactionManager` handles all transactions including read or write on variables and events of different sites. It is able to detect deadlocks.

```
public class TransactionManager {
    private Map<Integer, DataManager> sites;
                                        // <siteId, dataManager>
    private Map<Integer, Transaction> transactions;
                                        // <transactionId, transaction>
    private List<Operation> waitingOperations;
    private Map<Integer, Set<Integer>> waitsForGraph;
                                        // <transactionId, Set<transactionId>>


    public void begin(int transactionId, int timestamp);
    public void beginRO(int transactionId, int timestamp);
    public void end(int transactionId, int timestamp);
    public int read(int transactionId, int variableIndex, int timestamp);
    public void write(int transactionId, int variableIndex, int value, int timestamp);
    public void dump();
    public void fail(int siteId);
    public void recover(int siteId);
}
```

`DataManager` provides the storage of variables and manages their locks for a certain site.

```
public class DataManager {
    private int id;
    private boolean isActive;
    private Map<Integer, Variable> variables;
                                        // <variableId, variable>
    private Map<Integer, LockManager> lockManagers;
                                        // <variableId, lockManager>

    public int getId();
    public boolean isActive();
    public boolean containsVariable(int variableId);
    public boolean canRead(TransactionType transactionType, Operation operation);
    public void read(TransactionType transactionType, int timestamp, Operation
        operation);
    public boolean canWrite(TransactionType transactionType, Operation operation);
    public void write(TransactionType transactionType, Operation operation);
    public List<Integer> getLockHolders(int variableId);
    public void abort(int transactionId);
    public void commit(int timestamp, int transactionId);
    public void dump();
    public void fail();
    public void recover();
}
```

Each `LockManager` maintains locks for a single variable on a certain site.

```
public class LockManager {
    private int siteId;
    private int variableIndex;
    private List<Lock> locks;

    public int getVariableId();
    public boolean canAcquireLock(OperationType operationType, int transactionId);
    public Lock lock(OperationType operationType, int transactionId, int variableId);
    public void unlock(int transactionId);
    public void unlockAll();
    public boolean isWriteLockedBy(int transactionId);
    public List<Integer> getLockHolders();
}
```

Note that private methods in implementation are omitted in this design document.

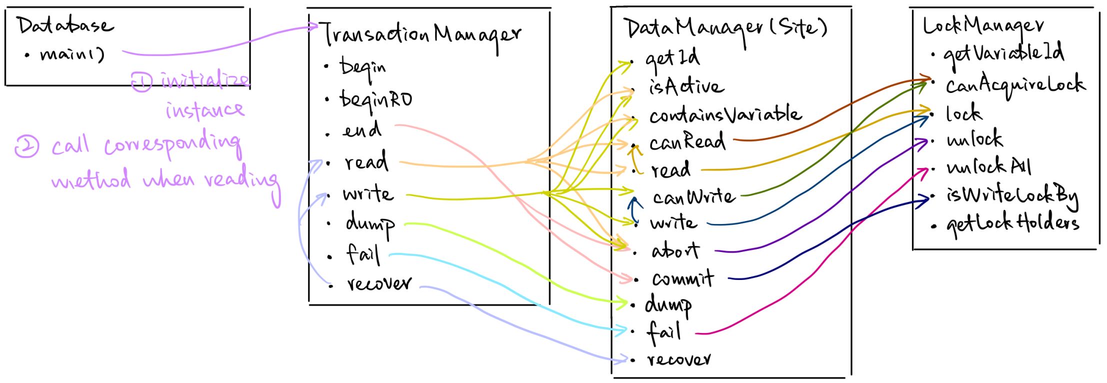
2.4 Runner

A main class is required to initialize `TransactionManager`, read and parse the input, and perform right actions.

```
public class Database {
    public static void main(String[] args);
}
```

2.5 Diagram

Here is a diagram showing how the functions are interacting with each others.



Database
• main()
① initialize instance
② call corresponding method when reading
TransactionManager
• begin
• beginRO
• end
• read
• write
• dump
• fail
• recover
DataManager (Site)
• getId
• isActive
• containsVariable
• canRead
• read
• canWrite
• write
• abort
• commit
• dump
• fail
• recover
LockManager
• getVariableId
• canAcquireLock
• lock
• unlock
• unlockAll
• isWriteLockBy
• getLockHolders