Final project

- Reminder: topic + literature review due Friday via email!
  - Min 1 page, max 5 pages, without references
  - Follow format linked on website
- Project proposal due on October 4
  - 1 - 2 pages (without references)
  - Should have problem statement, the technical approach you will take to solve the problem, as well as a plan to evaluate your approach compared to prior work

Transactions, ACID, Concurrency Control

Slides adapted from here, here

Transactions

- A transaction is the execution of a sequence of one or more operations on a database to perform some higher-level function
- A transaction may carry out many operations on the data retrieved from the database
- Example: move $100 from Alice's bank account to Bob's bank account
  - Check whether Alice has $100
  - Deduct $100 from Alice's account
  - Add $100 to Bob's bank account

Defining transaction correctness

- **ACID**
  - **Atomicity:** all actions in a transaction happen, or none happen
  - **Consistency:** if each transaction is consistent, and the database initializes in a consistent state, then it will also end up in a consistent state
  - **Isolation**: execution of a transaction is isolated from that of other transactions
  - **Durability**: if a transaction commits, then its effects persist in spite of failures

Atomicity

- Two possible outcomes of executing a transaction
  - Transaction commits → all of its effects are reflected in the database
  - Transaction aborts → none of its effects are reflected in the database
- Approaches for atomicity
  - Logging: logs all actions of a transaction so that it can undo aborted transactions
  - Shadow paging: DBMS makes copies of data pages and transaction makes changes to these copies; pages made visible once transaction commits

Consistency

- The data representation is logically correct
- Database consistency
    - DB accurately models the real world and follows integrity constraints (e.g., the age of a person cannot be negative)
    - Transactions in the future see the effects of past committed transactions
- Transaction consistency
    - A transaction should only change the database state in allowed ways such that the DB stays consistent after a committed transaction
    - Ensuring transaction consistency is the application's responsibility

Isolation

- DBMS provides transactions with the illusion that they are running alone in the system
- Easy for user to reason about correctness
- How to achieve this?
  - Serialize all transactions by processing one at a time
  - **Interleave transactions efficiently and correctly**

Serializability

- An interleaving is correct if it is equivalent to *some* serial execution

- Serializable schedule: a schedule that does not interleave the actions of different transactions

- Equivalent schedules: given schedules S_1, S_2, and database state D, the effect of executing the S_1 on D is identical to the effect of executing S_2 on D

Conflicting operations

- Two operations conflict if
  - They are by different transactions, and
  - They are on the same object and at least one of them is a write
- Read-Write, Write-Read, Write-Write conflicts
- DBMS support *conflict serializability*:
  - Two schedules are *conflict equivalent* iff
    - They involve the same operations of the same transactions
    - Every pair of conflicting operations is ordered in the same way in both schedules
  - A schedule is *conflict serializable* if it is conflict equivalent to some serial schedule

Concurrency control

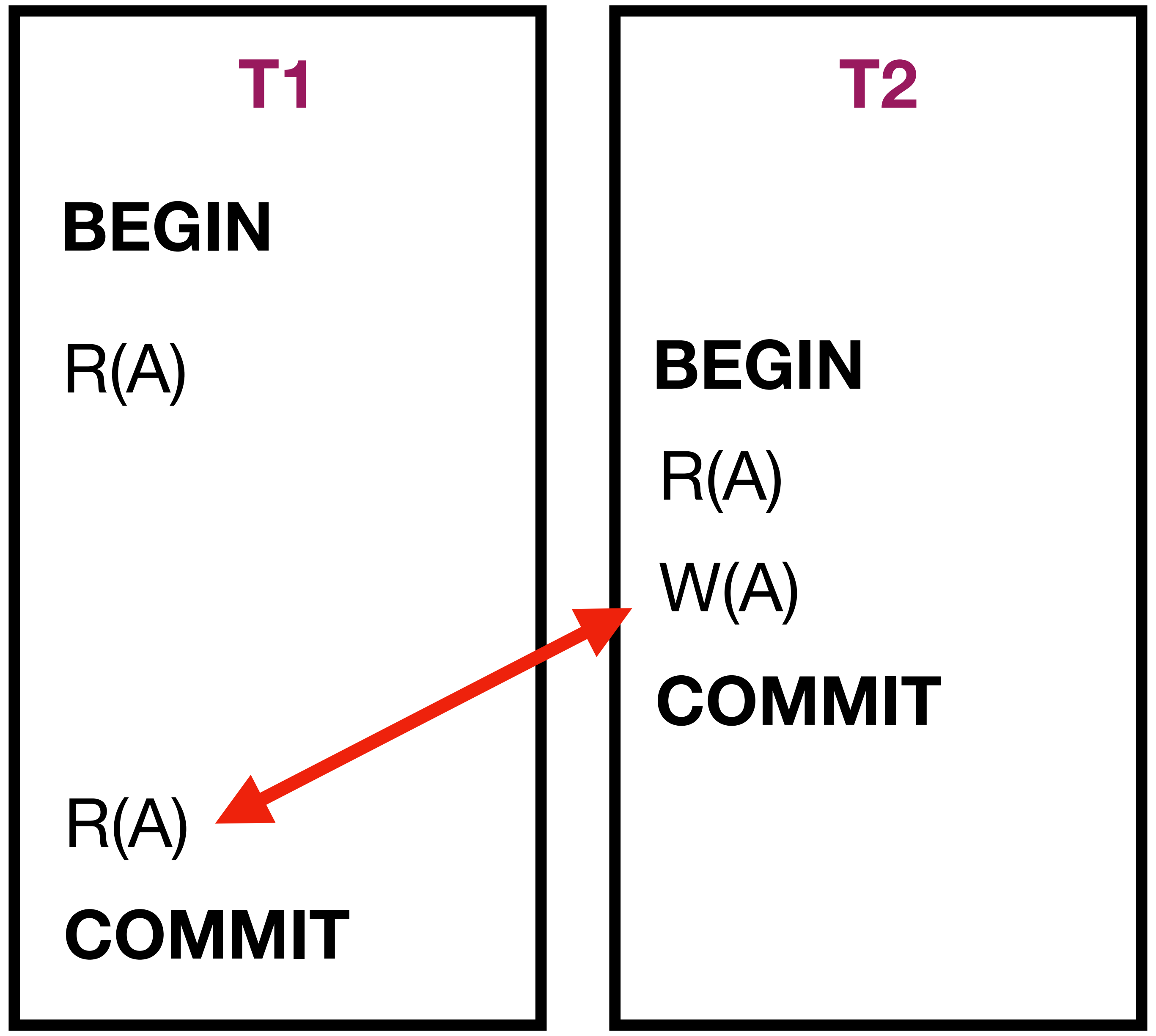
- Mechanism for ensuring isolation
- DBMS uses concurrency control protocol to decide the proper interleaving of operations from multiple transactions
- Two categories
  - Pessimistic: don’t let the problems arise in the first place
  - Optimistic: assume conflicts are rare, deal with them after they happen

Basic timestamp ordering

- Transactions read and write objects without locks
- Every object is tagged with the timestamp of the last transaction that successfully did a read/write
  - $TS_w(X)$ = write timestamp on X
  - $TS_r(X)$ = read timestamp on X
- Check timestamp for every operation; if a transaction tries to access an object with a future timestamp, then abort and retry

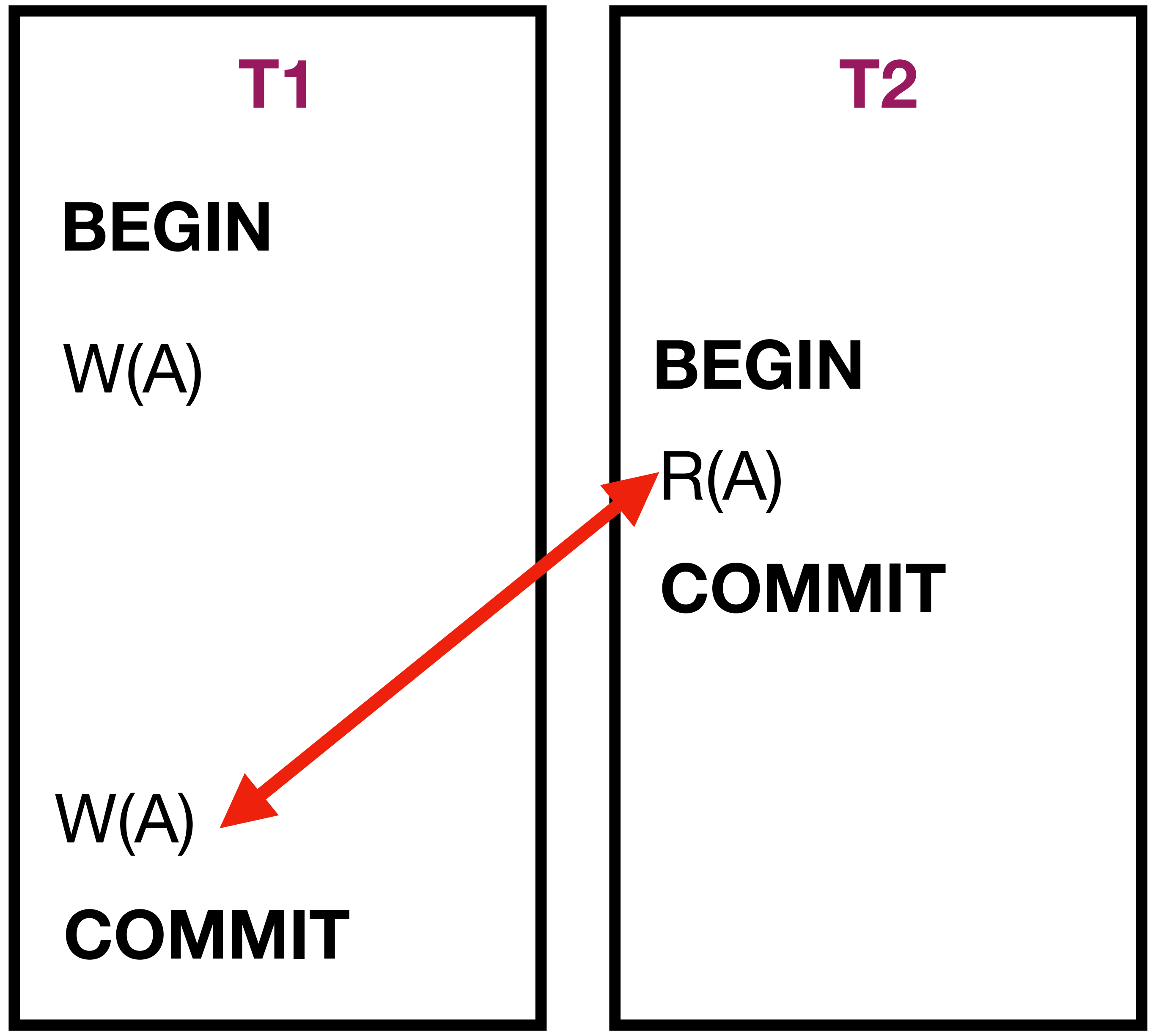
Timestamp ordering

- Reads:
  - If $TS(T_i) < TS_w(X) \rightarrow$ abort T_i and restart with a new timestamp
  - Else: allow T_i to read X, update $TS_r(X) = max(TS_r(X), TS(T_i))$, make a local copy of X to ensure repeatable reads for T_i



Timestamp ordering

- Writes:
  - If $TS(T_i) < TS_r(X)$ or $TS(T_i) < TS_w(X) \rightarrow$ abort T_i and restart with a new timestamp
  - Else: allow T_i to write to X, update $TS_w(X)$, make a local copy of X to ensure repeatable reads for T_i



Weak isolation?

- Serializability is useful but enforcing it may be too expensive
- Anomalies:
    - Dirty read: reading uncommitted data
    - Unrepeatable reads: redoing a read results in a different result
    - Phantom reads: insertions or deletions result in different results for the same range query
- Isolation levels
    - SERIALIZABLE (strongest)
    - REPEATABLE READS: phantoms may happen
    - READ-COMMITTED: phantoms and unrepeatable reads may happen
    - READ-UNCOMMITTED: all anomalies can happen

Durability

- All of the changes of committed transactions should be made persistent after a crash or a restart
- Techniques:
    - Logging, checkpointing
    - Shadow paging

Today’s reading: Obladi