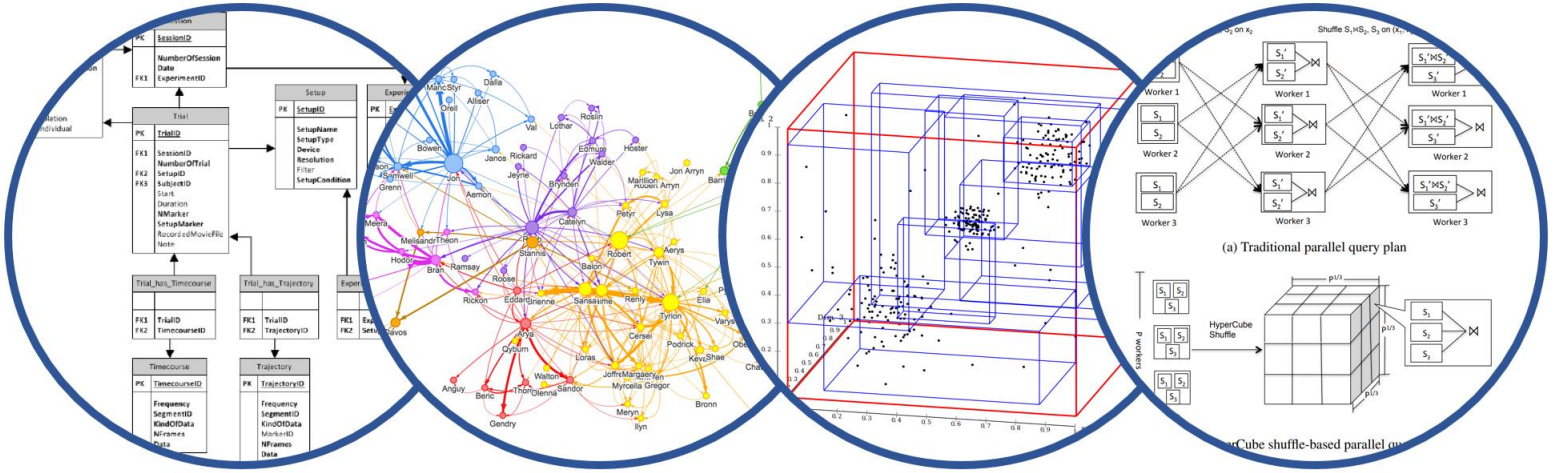


Introduction to Data Management

Transactions

Paul G. Allen School of Computer Science and Engineering
University of Washington, Seattle

Announcement

- Midterm is graded and will be released shortly
- Final exam will be comprehensive:
  - Includes this material plus what we cover in 2nd half
- HW4 dues on Friday

Terminology

Two types of query workloads:

- Online Analytical Processing (OLAP)
  - SELECT-FROM-WHERE are complex
  - No INSERT/UPDATE/DELTE, or very few
  - For data visualization (eg Tableau), or interactive SQL

We focused on these

- Online Transaction Processing (OLTP):
  - Lots of INSERT/UPDATE/DELETE
  - SELECT-FROM-WHERE are very simple
  - Used in Java/Python apps

Next few lectures

Applications and Databases

Almost every app uses some database

- General purpose language (Java, Python)
- App issues SQL commands to RDBMS
- Usually, multiple apps (users) access same DB

Simple Banking App in Python

- Manage user accounts:
  - Names
  - Balances
  - …
- Allow users to:
  - Inquire balance
  - Deposit cash/check
  - Withdraw cash
  - Transfer money

Simple Banking App in Python

SQL

```
CREATE TABLE Acc (
    Usr TEXT PRIMARY KEY,
    Balance INT);
```

Acc

Usr	Balance
Alice	300
Bob	600
Carol	400

Simple Banking App in Python

SQL

```
CREATE TABLE Acc (
    Usr TEXT PRIMARY KEY,
    Balance INT);
```

Acc

Usr	Balance
Alice	300
Bob	600
Carol	400

Python*

```
import sqlite3
con = sqlite3.connect("/Users/suciu/temp/bank.db",
                      autocommit=True)

cur = con.cursor()
res = cur.execute("SELECT * FROM acc")
answ = res.fetchall()
print("The answer is: ", answ)
```

* Documentation here https://docs.python.org/3/library/sqlite3.html

Simple Banking App in Python

SQL

```
CREATE TABLE Acc (
    Usr TEXT PRIMARY KEY,
    Balance INT);
```

Acc

Usr	Balance
Alice	300
Bob	600
Carol	400

Python*

```
import sqlite3
con = sqlite3.connect("/Users/suciu/temp/bank.db",
                      autocommit=True)

cur = con.cursor()
res = cur.execute("SELECT * FROM acc")
answ = res.fetchall()
print("The answer is: ", answ)
```

SQL query sent to DBMS

* Documentation here https://docs.python.org/3/library/sqlite3.html

DEMO:

lec16_txn_demo_create_table.sql

lec16_txn_demo_simple_1.py

Terminology: Client/Server

- Client:
  - The program running the application
  - In our example: a python program running on laptop
  - In general: a big program on laptop or in the cloud

- Server:
  - The database management system
  - In our example it is Sqlite on laptop
  - In general: any RDBMS, on remote server or in cloud

Parameterized Query

Give every user a 4% interest

```
res = cur.execute("SELECT * FROM acc")
answ = res.fetchall()
for row in answ:
    usr = row[0]
    bal = row[1]
    b = int(bal)
    i = b*0.04
    cur.execute("UPDATE acc
                 SET balance=?
                 WHERE usr=?",
                 [b+i, usr])
```

Parameterized Query

Give every user a 4% interest

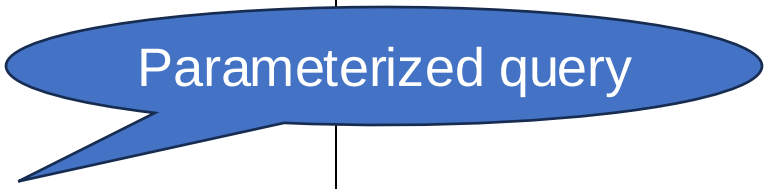
Read data

```
res = cur.execute("SELECT * FROM acc")
answ = res.fetchall()
for row in answ:
    usr = row[0]
    bal = row[1]
    b = int(bal)
    i = b*0.04
    cur.execute("UPDATE acc
                 SET balance=?
                 WHERE usr=?",
                 [b+i, usr])
```

Parameterized Query

Give every user a 4% interest

```
res = cur.execute("SELECT * FROM acc")
answ = res.fetchall()
for row in answ:
    usr = row[0]
    bal = row[1]
    b = int(bal)
    i = b*0.04
    cur.execute("UPDATE acc
                 SET balance=?
                 WHERE usr=?",
                 [b+i, usr])
```



DEMO:

lec16_txn_demo_simple_2.py

Simple Banking App in Python

Read a username

Repeat:

- Read a command
- Execute that command
  - Check the balance
  - Deposit money
  - Withdraw money
  - Transfer between accounts

Simple Banking App in Python

Read a username, check if exists:

```
usr = input("Enter the user name: ")

res = cur.execute("SELECT *
                   FROM acc
                   WHERE usr=?",
                  [usr])
if res.fetchone() is None:
    print("Wrong user. Exit")
    exit()
```

We check that the user exists

Simple Banking App in Python

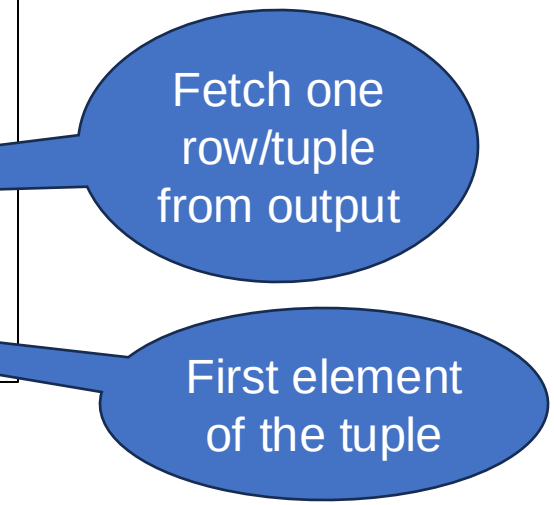
A simple loop for executing commants:

```
while True:
    cmd = input()
    if cmd == “b”:     ... check balance
    elif cmd == “d”:   ... deposit
    elif cmd == “w”:   ... withdraw
    elif cmd == “t”:   ... transfer
    elif cmd == “q”:   exit()
```

Simple Banking App in Python

Check balance

```
res = cur.execute("SELECT balance
                   FROM acc
                   WHERE usr=?",
                  [usr])
row = res.fetchone()
b = row[0]
print(“Balance is”, b)
```



Simple Banking App in Python

Deposit

```
... Read the balance b as before
amount = input()  # amount to be deposited
a = int(amount)
b1 = b+a          # the new balance
cur.execute("UPDATE acc
             SET balance = ?
             WHERE usr=?",
             [b1,usr])
```

Simple Banking App in Python

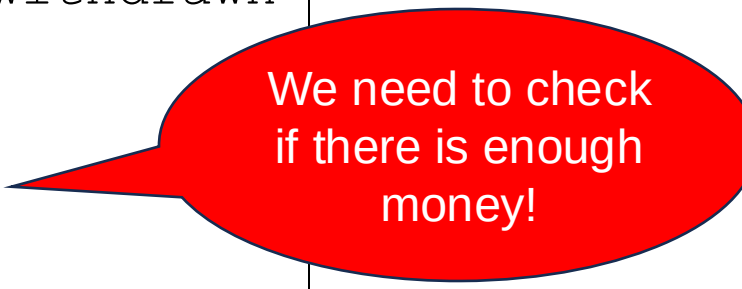
Withdraw

```
... Read the balance b as before
amount = input()  # amount to be withdrawn
a = int(amount)
#
# THE BANK DISPENSES MONEY HERE!
#
b1 = b-a            # the new balance
cur.execute("UPDATE acc
             SET balance = ?
             WHERE usr=?",
             [b1,usr])
```

Simple Banking App in Python

Withdraw

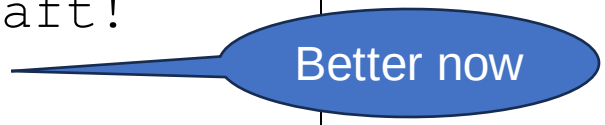
```
... Read the balance b as before
amount = input()  # amount to be withdrawn
a = int(amount)
#
# THE BANK DISPENSES MONEY HERE!
#
b1 = b-a              # the new balance
cur.execute("UPDATE acc
             SET balance = ?
             WHERE usr=?",
             [b1,usr])
```



Simple Banking App in Python

Withdraw

```
... Read the balance b as before
amount = input()   # amount to be withdrawn
a = int(amount)
if a>b:            # error: overdraft!
   exit()
#
# THE BANK DISPENSES MONEY HERE!
#
b1 = b-a           # the new balance
cur.execute("UPDATE acc
             SET balance = ?
             WHERE user=?",
             [b1,usr])
```



Simple Banking App in Python

Transfer

```
... Read the balance b as before
amount = input()   # amount to be transferred
a = int(amount)
if a>b:            # error: overdraft!
   exit()
usrt = input()     # to whom to transfer
... Read the balance bt of usrt
b1 = b-a
bt1 = bt+a
cur.execute("UPDATE acc
             SET balance = ?
             WHERE user=?",
             [b1,usr])
cur.execute("UPDATE acc
             SET balance = ?
             WHERE user=?",
             [bt1,usrt])
```

DEMO:

lec16_txn_demo.py

single user

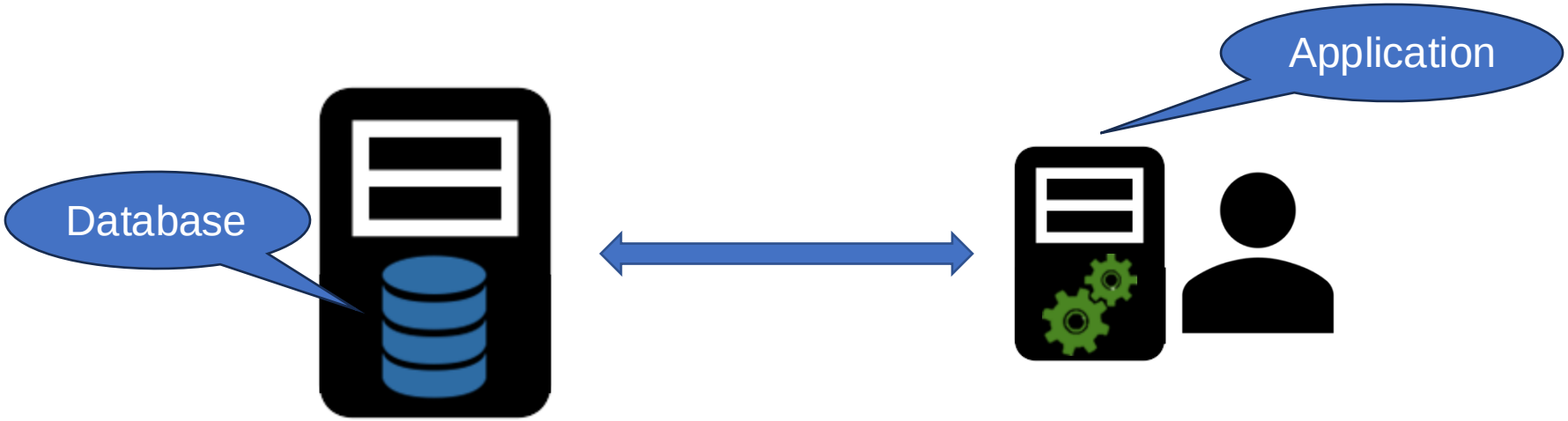
Discussion so Far

- The users Alice, Bob, … don’t need to know SQL, but interact with the app;
- The app usually has a nice User Interface (UI)
- The database is persistent: it retains the data for a long period of time

Concurrency

Single-Server

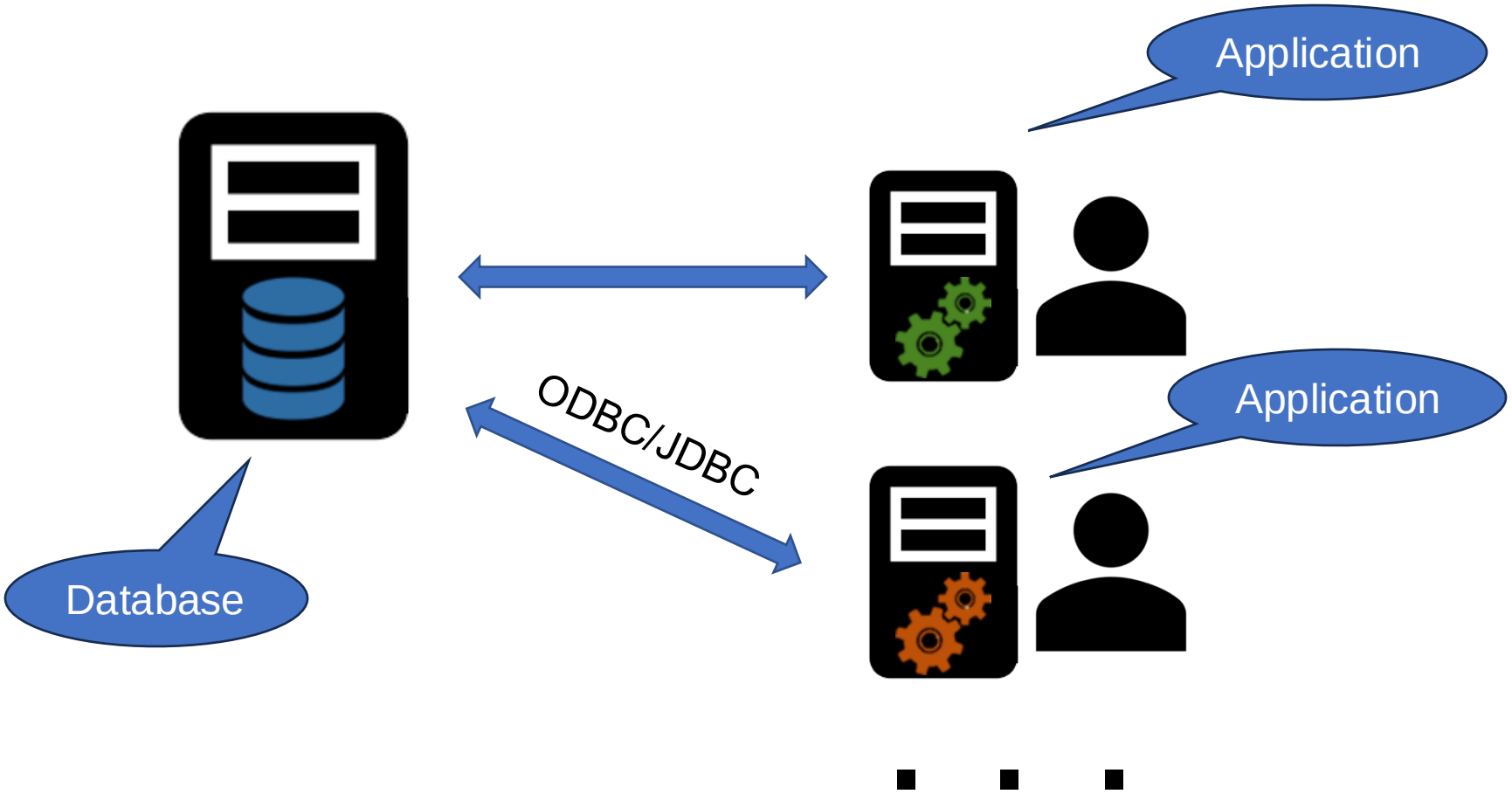
- The database is accessed by a single user:



- RDBMS on same laptop, or a server, or the cloud

Client-Server or Two-Tier Architecture

- Multiple users access the database concurrently



DEMO:

lec16_txn_demo.py

multiple users

lec16_txn_demo_txn_no.sql

What We Have Seen

How Alice and Bob colluded to steal $100 (simplified, using only SQL)
Current balance of Alice is $100:

```
-- Alice withdraws $100
b = SELECT balance
    FROM acc
    WHERE user = 'Alice';
-- Is b >= 100?  Yes:
-- Dispense money




UPDATE acc SET balance=b-100
WHERE user = 'Alice'
```


```
-- Bob impersonates Alice
-- and also withdraws $100
b = SELECT balance
    FROM acc
    WHERE user = 'Alice';
-- Is b >= 100?  Yes:
-- Dispense money
UPDATE acc SET balance=b-100
WHERE user = 'Alice'
```

Discussion

- Users Alice, Bob, … can access the same database concurrently

- This may lead to the database being inconsistent, which is a big problem

Consistency

Database Consistency

- Consistency: a property that should always hold
  - Every account balance is ≥ 0
  - The sum of all balances is constant,
    or changes exactly by the amount deposited/withdrawn
- If we write the application correctly, we expect the database to remain consistent
- But (without transactions!) things can go wrong during concurrency. Next.

Conflicts Between Concurrent Operations

We will return to these in a later lectrue

Common Concurrency Conflicts

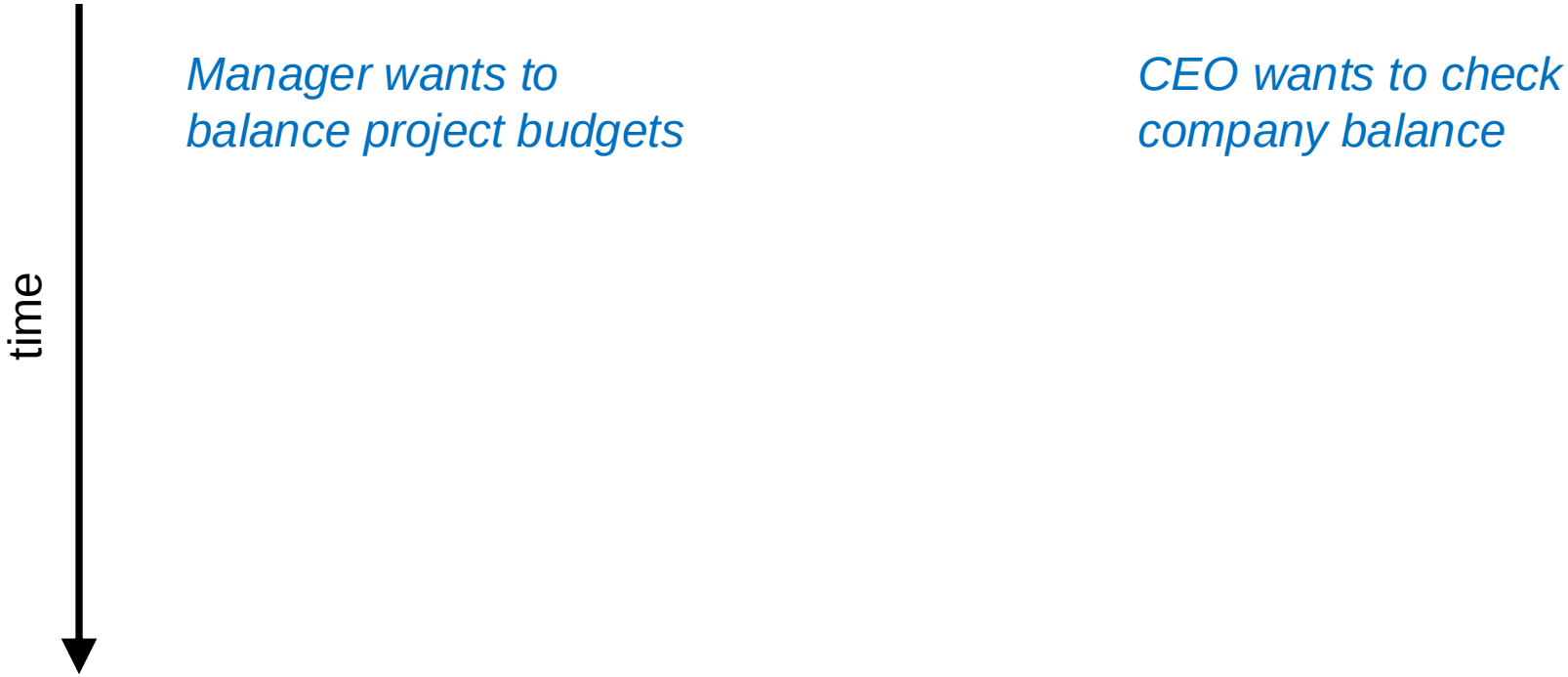
- Dirty/Inconsistent Read
- Unrepeatable Read
- Phantom Read
- Lost Update

These have popular names, but all sorts of other conflicts can happen. Let's see these.

Dirty/Inconsistent Read

- **Dirty/Inconsistent Read**
- Unrepeatable Read
- Phantom Read
- Lost Update

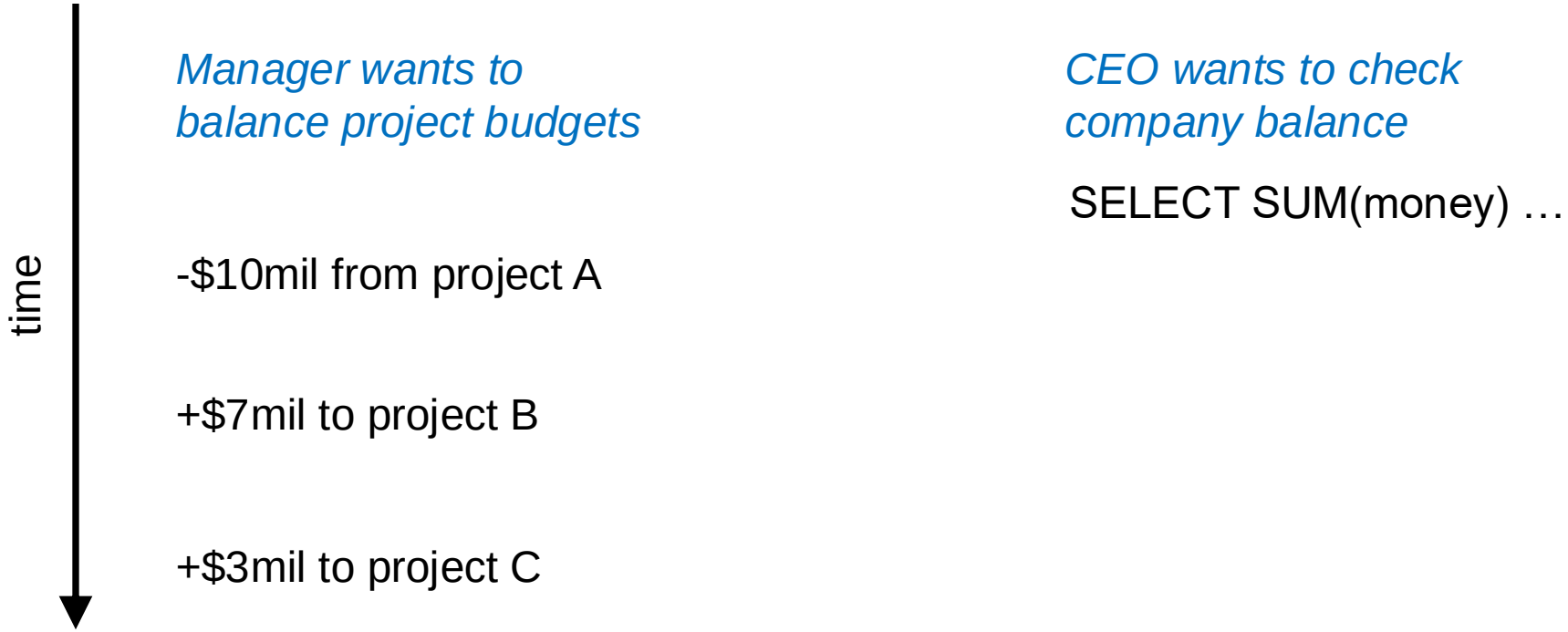
A **inconsistent read** happens when data is read "during" a write



Dirty/Inconsistent Read

- **Dirty/Inconsistent Read**
- Unrepeatable Read
- Phantom Read
- Lost Update

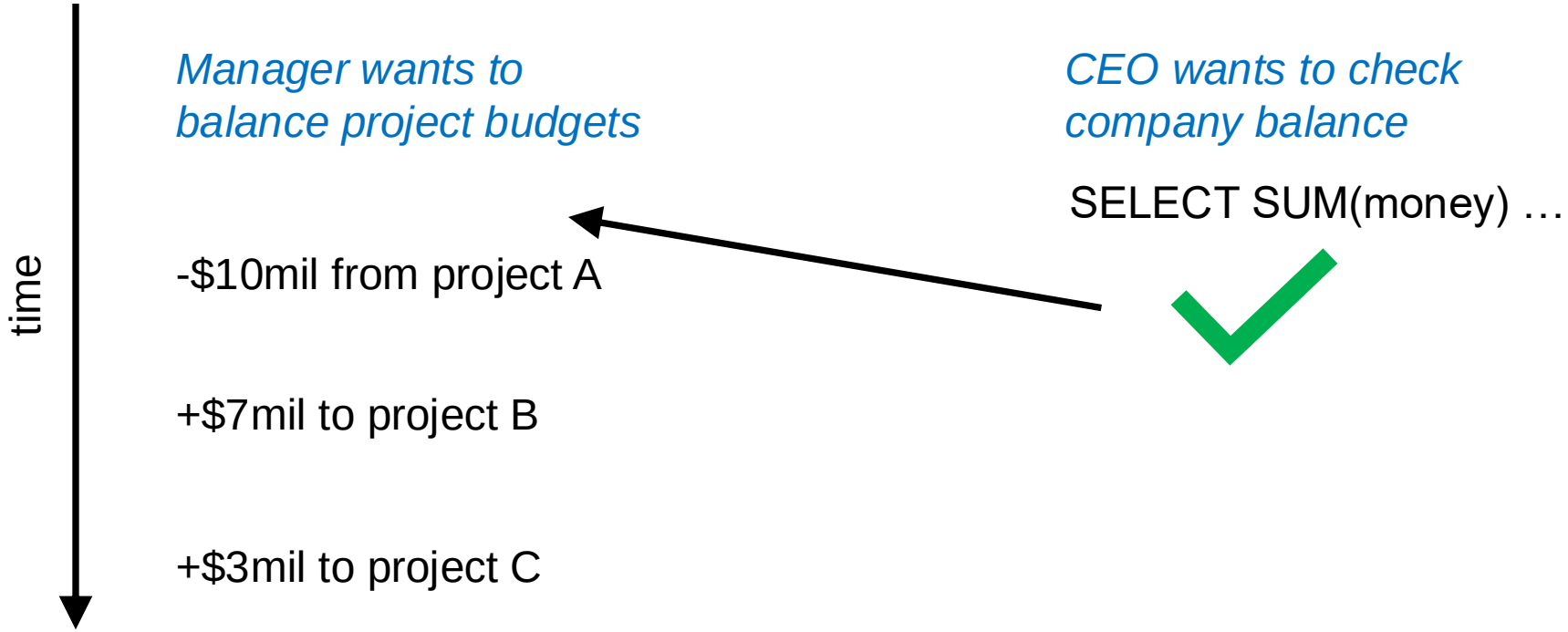
A **inconsistent read** happens when data is read "during" a write



Dirty/Inconsistent Read

- **Dirty/Inconsistent Read**
- Unrepeatable Read
- Phantom Read
- Lost Update

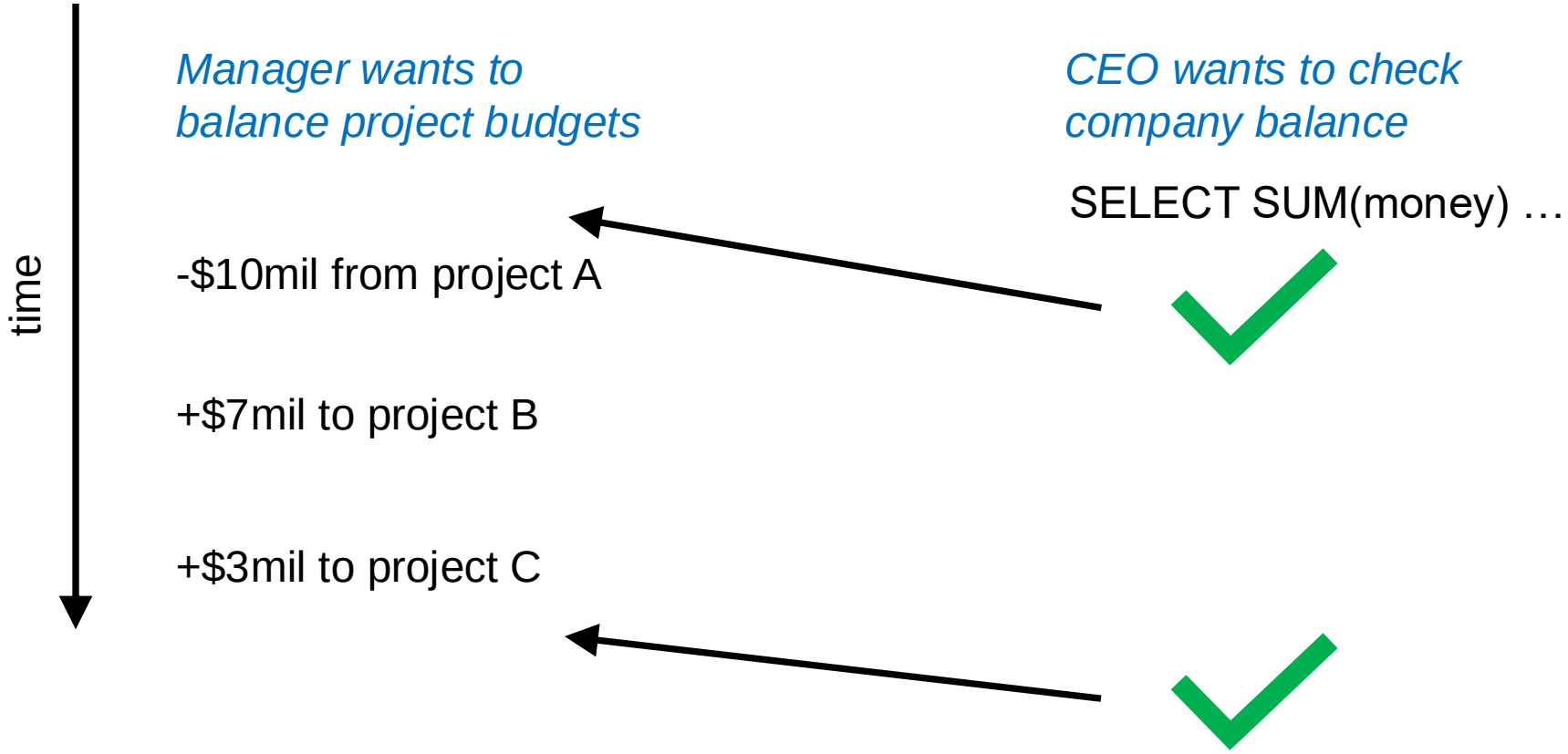
A **inconsistent read** happens when data is read "during" a write



Dirty/Inconsistent Read

- **Dirty/Inconsistent Read**
- Unrepeatable Read
- Phantom Read
- Lost Update

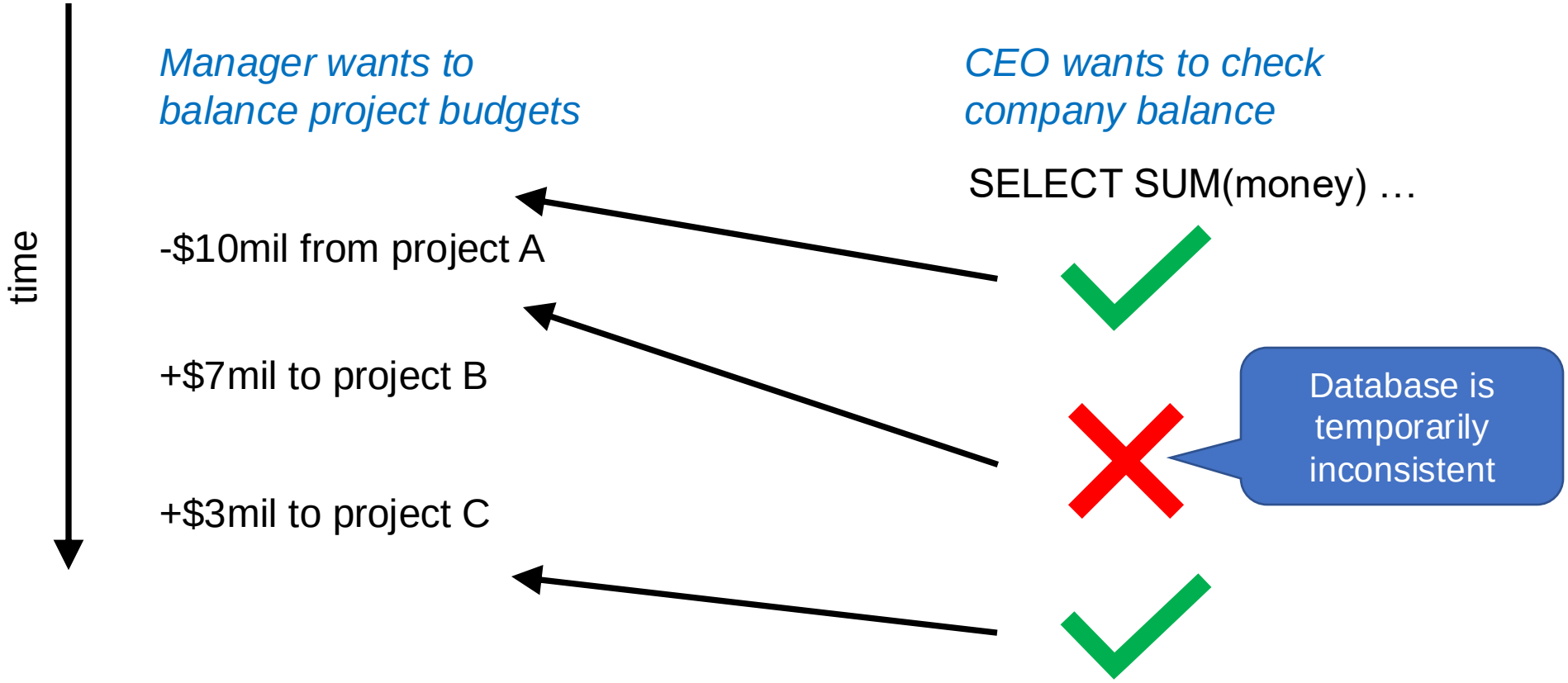
A **inconsistent read** happens when data is read "during" a write



Dirty/Inconsistent Read

- **Dirty/Inconsistent Read**
- Unrepeatable Read
- Phantom Read
- Lost Update

A **inconsistent read** happens when data is read "during" a write



Unrepeatable Read

- Dirty/Inconsistent Read
- **Unrepeatable Read**
- Phantom Read
- Lost Update

An **unrepeatable read** happens when data read twice differs

Accountant wants to check company assets

```
SELECT inventory
FROM Products
WHERE pid = 1
```

Warehouse updates inventory levels

```
UPDATE Products
SET inventory = 0
WHERE pid = 1
```

```
SELECT inventory*price
FROM Products
WHERE pid = 1
```

Might get a value that doesn't correspond to previous read!

Phantom Read

- Dirty/Inconsistent Read
- Unrepeatable Read
- **Phantom Read**
- Lost Update

A **phantom read** happens when
a record is inserted/delete during reads

time

Accountant wants to check company assets

```
SELECT *
FROM products
WHERE price < 20.00
```

Warehouse receives new products

```
INSERT INTO Products
VALUES ('nuts', 10, 8.99)
```

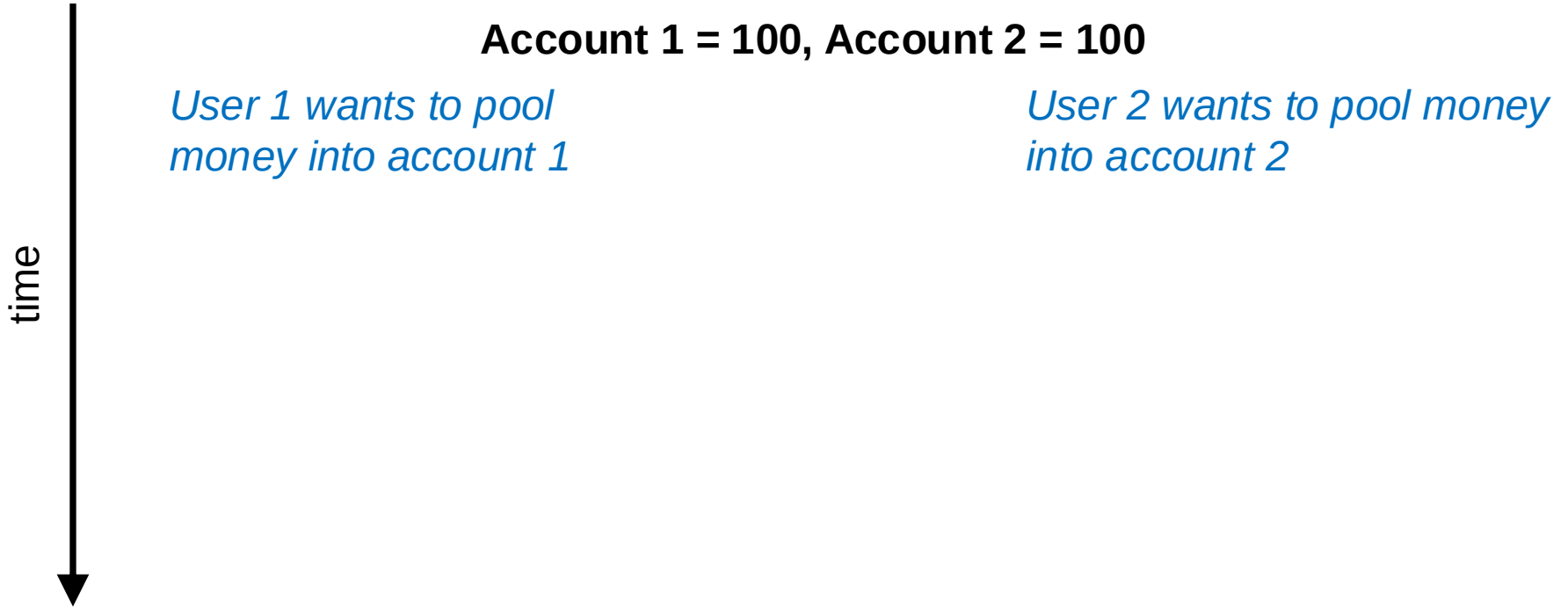
```
SELECT *
FROM products
WHERE price < 10.00
```

Returns a "new" row that should have been in the last read!

Lost Update

- Dirty/Inconsistent Read
- Unrepeatable Read
- Phantom Read
- **Lost Update**

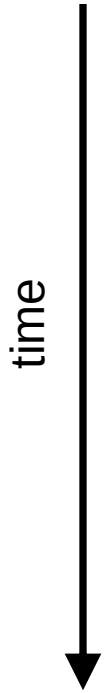
A **lost update** happens when a write "disappears"



Lost Update

- Dirty/Inconsistent Read
- Unrepeatable Read
- Phantom Read
- **Lost Update**

A **lost update** happens when a write "disappears"



Account 1 = 100, Account 2 = 100

User 1 wants to pool money into account 1

User 2 wants to pool money into account 2

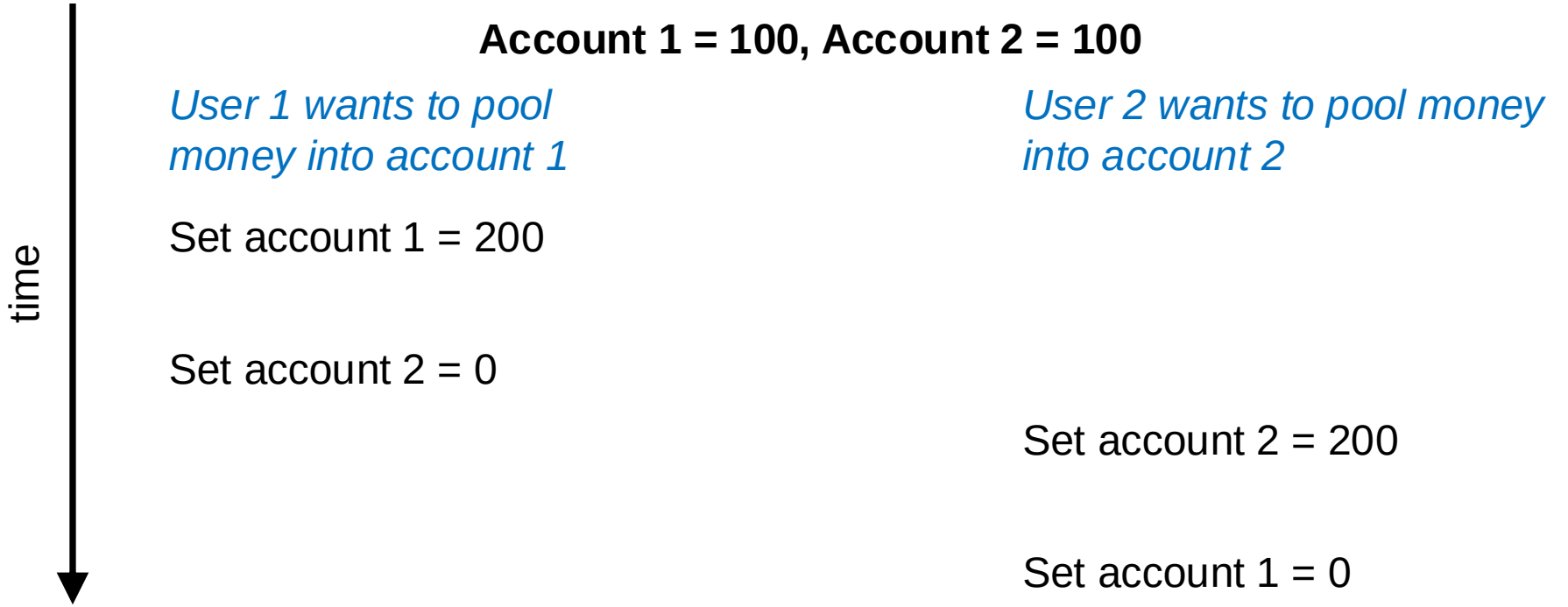
Set account 1 = 200

Set account 2 = 0

Lost Update

A **lost update** happens when a write "disappears"

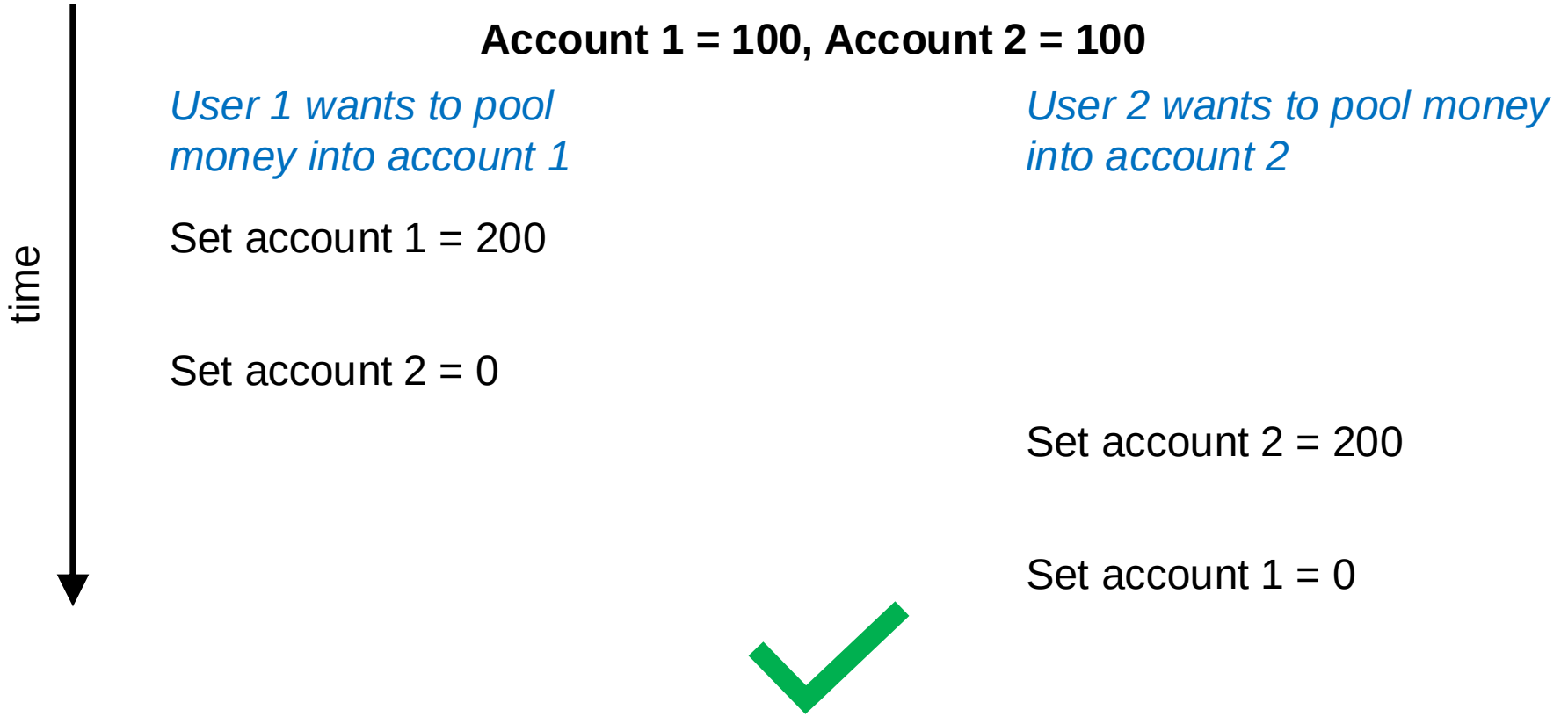
- Dirty/Inconsistent Read
- Unrepeatable Read
- Phantom Read
- **Lost Update**



Lost Update

- Dirty/Inconsistent Read
- Unrepeatable Read
- Phantom Read
- **Lost Update**

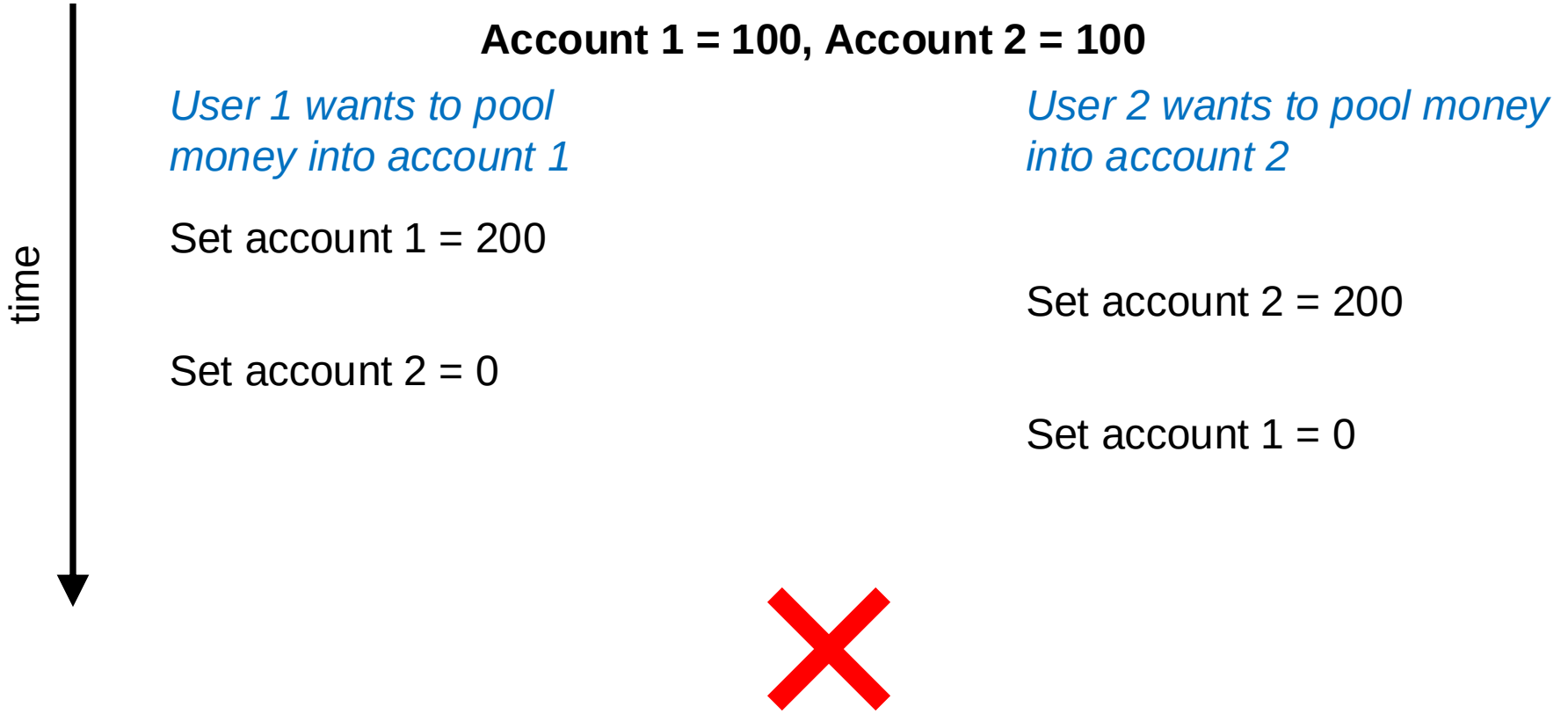
A **lost update** happens when a write "disappears"



Lost Update

A **lost update** happens when a write "disappears"

- Dirty/Inconsistent Read
- Unrepeatable Read
- Phantom Read
- **Lost Update**



Transactions

Transactions

- A transaction is a set of read and writes to the database that execute all or nothing

```
BEGIN TRANSACTION
   ...SQL Statements
COMMIT
```

Entire txn is executed

```
BEGIN TRANSACTION
   ...SQL Statements
ROLLBACK
```

No part of txn is executed

Transactions

- Prevent all concurrency control conflicts
- Easy to use in app: group statements in txns
- Let’s see how they work

DEMO:
lec16_txn_demo_txn_yes.sql