Locks Do Not Compose!

Example Code

```
class Account {
  float balance;
  void deposit(float amt) {
    this.lock();
    balance += amt;
    this.unlock();
  }
  void withdraw(float amt) {
    this.lock();
    balance -= amt;
    this.unlock();
  }
}
…
void transfer(Account from, Account to, float amt) {
  from.lock(); to.lock();
  from.withdraw(amt);
  to.deposit(amt);
  to.unlock(); from.unlock();
}
```

Thread 1

```
transfer(A, B, 10);
-> call A.lock() ①
-> call B.lock() ③
```

Thread 2

```
transfer(B, A, 10);
-> call B.lock() ②
-> call A.lock() ④
```

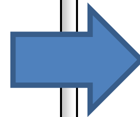
- Deadlock!!!
- Changing order of *from.lock()* and *to.lock()* inside *transfer(…)* will not solve problem
- Need elaborate scheme to ensure uniform lock ordering among Acount objects for each new type of transaction

⇒ Not Composable!

Converting to a TM Paradigm

Example Code

```
class Account {
  float balance;
  void deposit(float amt) {
    this.lock();
    balance += amt;
    this.unlock();
  }
  void withdraw(float amt) {
    this.lock();
    balance -= amt;
    this.unlock();
  }
}
…
void transfer(Account from, Account to, float amt) {
  from.lock(); to.lock();
  from.withdraw(amt);
  to.deposit(amt);
  to.unlock(); from.unlock();
}
```



TM Code

```
class Account {
  float balance;
  void deposit(float amt) {
    begin_atomic;
    balance += amt;
    end_atomic;
  }
  void withdraw(float amt) {
    begin_atomic;
    balance -= amt;
    end_atomic;
  }
}
…
void transfer(Account from, Account to, float amt) {
  begin_atomic;
  from.withdraw(amt);
  to.deposit(amt);
  end_atomic;
}
```

⇒ Now no Deadlocks! (Roll back on atomicity violation)

Open vs. Closed Nesting

Example Code

```
class List {
  void insert(Object o) {
    begin_atomic;
    …
    end_atomic;
  }
  …
}
void foo(List list, Object o) {
  …
  list.insert(o);
  …
}
void bar(List list, Object x, Object y) {
  /* nested transaction */
  begin_atomic;
  …
  list.insert(x);
  list.insert(y);
  …
  end_atomic;
}
```

Thread 1

```
foo(list, x, y);
-> call list.insert(x); ①
-> call list.insert(y); ③
```

Thread 2

```
bar(list, z);
-> call list.insert(z) ②
```

- Can *list* ordering *x, z, y* happen?
  - No: Closed Nesting
  - Yes: Open Nesting
- Closed Nesting
  - Inner transaction state merged to outer transaction on commit
  - Preserves atomicity of outer transaction
  - Most intuitive to programmers
- Open Nesting
  - Inner transaction state merged to main memory on commit
  - Breaks atomicity of outer transaction
  - Needs compensating code
  - Allows interleaving w/o squashing (e.g. malloc)