

# Software Transaction Roll Back Avoidance

Master Proposal Talk

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## Motivation

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```
type Account = MVar Int

transfer :: Account -> Account -> Int -> IO ()
transfer src dst am = do
  a1 <- takeMVar src
  a2 <- takeMVar dst
  putMVar src (a1 - am)
  putMVar dst (a2 + am)
```

# MVar

---

Thread 1:

```
transfer acc1 acc2 50
```

Thread 2:

```
transfer acc2 acc1 50
```

# MVar

---

Thread 1:

```
a1 <- takeMVar acc1
a2 <- takeMVar acc2
writeMVar acc1 (a1 - 50)
writeMVar acc2 (a2 + 50)
```

Thread 2:

```
a1 <- takeMVar acc2
a2 <- takeMVar acc1
writeMVar acc2 (a1 - 50)
writeMVar acc1 (a2 + 50)
```

# MVar

---

Thread 1:

```
a1 <- takeMVar acc1
a2 <- takeMVar acc2
writeMVar acc1 (a1 - 50)
writeMVar acc2 (a2 + 50)
```

Thread 2:

```
a1 <- takeMVar acc2
a2 <- takeMVar acc1
writeMVar acc2 (a1 - 50)
writeMVar acc1 (a2 + 50)
```

⇒ Deadlock

## Use Transactions

---

```
type Account = TVar Int

transfer :: Account -> Account -> Int -> STM ()
transfer src dst am = do
  a1 <- readTVar src
  a2 <- readTVar dst
  writeTVar src (a1 - am)
  writeTVar dst (a2 + am)
```

# TVar

---

Thread 1:

```
atomically $  
  transfer acc1 acc2 50
```

Thread 2:

```
atomically $  
  transfer acc2 acc1 50
```

# TVar

---

Thread 1:

```
atomically $  
  transfer acc1 acc2 50
```

Thread 2:

```
atomically $  
  transfer acc2 acc1 50
```

⇒ works fine, because transactions provide ACI(D) properties



## Current Implementation (Control.Concurrent.STM)

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- *writeTVar*, *readTVar* and *newTVar* modify TVars
- *retry* and *orElse* alter the control flow
- *atomically* executes a transaction
- composition via bind operator (or do)

# Modify Operations

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- **newTVar**: creates a new, initialized TVar
- **writeTVar**: add the TVar and the value to the write set
- **readTVar**: add the TVar and its version number to the read set
- read set and write set serve as local buffer

atomically :: STM a  $\rightarrow$  IO a

---

1. compute the read set and write set
2. lock TVars
3. validate the read set
4. if valid then commit the write set
5. else roll back

# Validation

---

1. compare version number in read set with actual version number
2. if there is no difference then return valid
3. else return invalid

# Problem

---

Thread 1:

```
a1 <- readTVar acc1  
a2 <- readTVar acc2  
writeTVar acc1 (a1 - 50)  
writeTVar acc2 (a2 + 50)
```

Thread 2:

```
a1 <- readTVar acc2  
a2 <- readTVar acc1  
writeTVar acc2 (a1 - 50)  
writeTVar acc1 (a2 + 50)
```

# Problem

---

Thread 1:

```
a1 <- readTVar acc1
a2 <- readTVar acc2
writeTVar acc1 (a1 - 50)
writeTVar acc2 (a2 + 50)
```

Thread 2:

```
a1 <- readTVar acc2
a2 <- readTVar acc1
writeTVar acc2 (a1 - 50)
writeTVar acc1 (a2 + 50)
```

⇒ either sequential or one transaction is rolled back

# Idea

---

Thread 1:

```
a1 <- readTVar acc1  
writeTVar acc1 (a1 - 50)  
a2 <- readTVar acc2  
writeTVar acc2 (a2 + 50)
```

Thread 2:

```
a1 <- readTVar acc2  
writeTVar acc2 (a1 - 50)  
a2 <- readTVar acc1  
writeTVar acc1 (a2 + 50)
```

# Idea

---

Thread 1:

```
a1 <- readTVar acc1  
writeTVar acc1 (a1 - 50)  
a2 <- readTVar acc2  
writeTVar acc2 (a2 + 50)
```

Thread 2:

```
a1 <- readTVar acc2  
writeTVar acc2 (a1 - 50)  
a2 <- readTVar acc1  
writeTVar acc1 (a2 + 50)
```

⇒ delay the evaluation of readTVar to avoid rollback, but...



## Idea does not work

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```
limitedTransfer src dst am = do
  a1 <- readTVar src
  if a1 < am
    then return ()
    else do a2 <- readTVar dst
             writeTVar src (a1 - am)
             writeTVar dst (a2 + am)
```

... the transaction may need the value

# Problem

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- $(>>=) :: \text{STM } a \rightarrow (a \rightarrow \text{STM } b) \rightarrow \text{STM } b$
- Bind extracts the value from the STM context
- STM no longer controls this value.
- Need another Typeclass than Monad

# Applicative

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- Applicative is less powerfull than Monad
- $(\langle * \rangle) :: \text{STM } (a \rightarrow b) \rightarrow \text{STM } a \rightarrow \text{STM } b$
- The value can be modified without leaving the STM context

# Project

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- Improved a pure Haskell implementation
- Direct notification
- Explicit, ordered locking
- Optimisations

## Master Thesis until now

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- Implementation based on Applicative
- Works without rollbacks...
- ...and without branches
- Constraints on TVars to gain some control
- Still no *retry* or *orElse*

## Master Thesis until now

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- Composition by combination of Monad and Applicative
- $\gg=$  evaluates and enables rollbacks
- $\langle * \rangle$  enables to modify values without rollbacks
- `writeTVar :: TVar a -> STM a -> STM ()`

## New Combinators

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- $(\langle * \rangle) :: \text{STM } (a \rightarrow b) \rightarrow \text{STM } a \rightarrow \text{STM } b$
- $(\langle ** \rangle) :: \text{STM } a \rightarrow \text{STM } (a \rightarrow b) \rightarrow \text{STM } b$
- $(**\rangle) :: \text{STM } a \rightarrow (\text{STM } a \rightarrow \text{STM } b) \rightarrow \text{STM } b$
- $(\rangle \rangle =) :: \text{STM } a \rightarrow (a \rightarrow \text{STM } b) \rightarrow \text{STM } b$
- $(\rangle \rangle) :: \text{STM } a \rightarrow \text{STM } b \rightarrow \text{STM } b$

## New Transfer

---

```
transfer :: Account -> Account -> Int -> STM ()
transfer src dst am = do
    readTVar src <*> pure (- am) *> writeTVar src
    readTVar dst <*> pure (+ am) *> writeTVar dst
```



## Problem solved

---

Thread 1:

```
atomically $  
  transfer acc1 acc2 50
```

Thread 2:

```
atomically $  
  transfer acc2 acc1 50
```

⇒ no more rollback

# Todo

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- Reduce the number of combinators
- Change writeTVars type and use ApplicativeDo
- **But** it extracts the Value from STM context
- investigate other problems:
  - Branch condition is not changed by TVar modification
  - Recomputation of values which did not change

## Unnecessary Recomputation

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```
transaction = do  
  limitedTransfer acc1 acc2 50  
  limitedTransfer acc3 acc4 100
```

If one transfer is invalidated, both are recomputed

## Questions about...

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- ...Control.Concurrent.STM?
- ...rollback avoidance?
- ...unnecessary recomputation?
- ...something else?