

Transactions on Mergeable Objects

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10. Nov 2015

Overview

- 1 Software Transactional Memory
- 2 Weakly Consistent Transactions
- 3 Mergeable Data Types
- 4 Evaluation
- 5 Conclusion

Software Transactional Memory

Normal	STM
acquire_lock(x)	atomic
acquire_lock(y)	{
if (x > 0)	if (x > 0)
y++	y++
release_lock(x)	}
release_lock(y)	

Software Transactional Memory

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if (x > 0)	if (x > 0)
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- Composable
- Deadlock freedom
- Semantics (often): serializability

Software Transactional Memory

Pessimistic Approach

- Acquires **exclusive access to data** before processing transaction

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Optimistic Approach

- Execute updates and **buffers writes** (multi-versioning)
- Consistency check during commit
- Abort if check failed

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- Execute updates and **buffers writes** (multi-versioning)
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More Conflicts → Performance degrade

Mechanisms to reduce conflicts

Delayed Operations

- Explicit delaying of some operations to commit time
- Transactional “RMW”

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Transactional Boosting
[Herlihy/Koskinen (PPoPP'11),
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Alternative Programming Models

- RMW [Ruan et al. (TACO'15)]
- Twilight [Bieniusa et al.(PODC'10)]
- Concurrent revisions [Burckhardt et al.(ESOP'12)]

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- Serializability → performance degradation
- Weaken Serializability, but no defined semantics

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Weakly Consistent Transactions

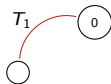
On Shared Memory



- Shared Global Copy

Weakly Consistent Transactions

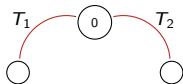
On Shared Memory



- Shared Global Copy
- Read from **Consistent Snapshot**

Weakly Consistent Transactions

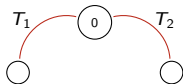
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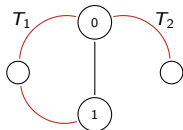
On Shared Memory



- Shared Global Copy
- Read from Consistent Snapshot
- Update thread local copy

Weakly Consistent Transactions

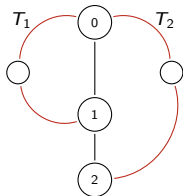
On Shared Memory



- Shared Global Copy
- Read from **Consistent Snapshot**
- Update **thread local copy**
- Commit \rightarrow New Snapshot

Weakly Consistent Transactions

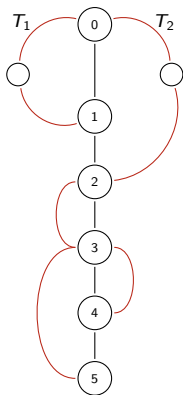
On Shared Memory



- Shared Global Copy
- Read from **Consistent Snapshot**
- Update **thread local copy**
- Commit → New Snapshot
 - **Merge** local to global copy

Weakly Consistent Transactions

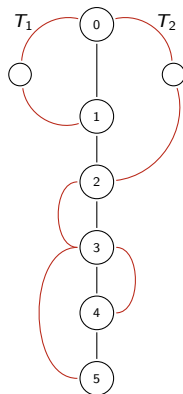
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Weakly Consistent Transactions

On Shared Memory



- Shared Global Copy
 - Read from **Consistent Snapshot**
 - Update **thread local copy**
 - Commit → New Snapshot
 - **Merge** local to global copy
- No aborts
 - Multi-versioning
 - Mergeable objects

Mergeable Data Type

Mergeable Counter

`data Counter = Counter Int Int`

`incrBy :: Int → Counter → Counter`

`incrBy i (Counter g l) = Counter g (l+i)`

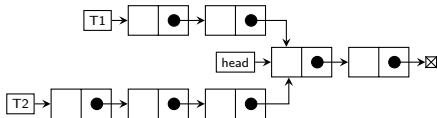
`value :: Counter → Int`

`value (Counter g l) = g+l`

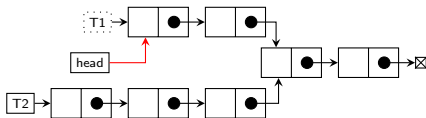
`merge (Counter g _) (Counter _ l) = Counter (g+l) 0`

Mergeable Bag

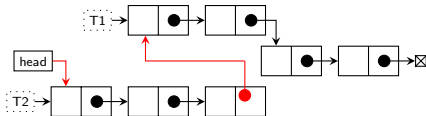
Add only



After $T1$ commits:



After $T2$ commits:



MTM: Transactions on Mergeable Objects

Semantics

```
addToBag(e, bag, size) {  
  add(bag,e)  
  incrBy(size,1)  
}
```

Thread 1	Thread 2
<pre>startTxn { addToBag(1, b, s) addToBag(2, b, s) print b } endTxn</pre>	<pre>startTxn { addToBag(3, b, s) addToBag(4, b, s) print b } endTxn</pre>

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Thread 1	Thread 2
<pre>startTxn { addToBag(1, b, s) addToBag(2, b, s) print b } endTxn 1, 2</pre>	<pre>startTxn { addToBag(3, b, s) addToBag(4, b, s) print b } endTxn 3, 4</pre>

MTM: Transactions on Mergeable Objects

A Haskell Implementation

```
data MTM a = ...
```

```
data CVar a = ...
```

– MTM Functions

```
eventually :: MTM a → IO a
```

```
newCVar :: Mergeable a ⇒ a → MTM (CVar a)
```

```
readCVar :: Mergeable a ⇒ CVar a → MTM a
```

```
modifyCVar :: Mergeable a ⇒ CVar a → (a → a) → MTM a
```

– Mergeable Objects

```
class Mergeable a where
```

```
    merge :: a → a → a
```

MTM: Transactions on Mergeable Objects

Evaluation: Kmeans Clustering

```
function MAIN
  chunks=divide data into N chunks
  In Parallel
  for n in N do
    thread[n].CLUSTER(chunks[n])
  end for
end function
```

Atomic

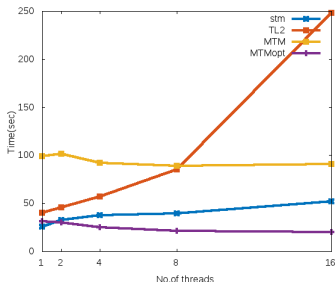
```
function CLUSTER(points)
  for p in points do
    index=findNearestCluster(clusters,p)
    beginTxn
      inc(new_centers_len[index],1)
      add(new_centers[index][0],p[0])
      add(new_centers[index][1],p[1])
    endTxn
  end for
end function
```

MTM-opt

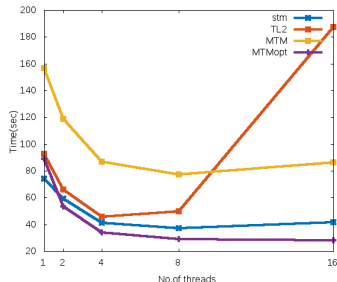
```
function CLUSTER(points)
  beginTxn
    for p in points do
      index=findNearestPoint(clusters,p)
      inc(new_centers_len[index],1)
      inc(new_centers[index][0],p[0])
      inc(new_centers[index][1],p[1])
    end for
  endTxn
end function
```

MTM: Transactions on Mergeable Objects

Evaluation: Kmeans clustering



High contention



Low Contention

MTM: Transactions on Mergeable Objects

Conclusion

- No conflicts → No aborts → More performance
- Longer transactions → Less synchronisation → More parallelism
- Weaker consistency semantics
- Requires efficient merge (space / time complexity)

Thank You!

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```
    merge :: a → a → a
```

MTM: Transactions on Mergeable Objects

Example

```
addToBag :: Int → CVar (Bag Int) → CVar (Counter) → MTM [Int]
addToBag e bag size = do {
  ; b ← modifyCVar bag (add e)
  ; s ← modifyCVar size (incrBy 1)
  ; return (toList b) }
```

Thread 1	Thread 2
b1 ← eventually \$ do addToBag 1 b s addToBag 2 b s print b1	b2 ← eventually \$ do addToBag 3 b s addToBag 4 b s print b2

MTM: Transactions on Mergeable Objects

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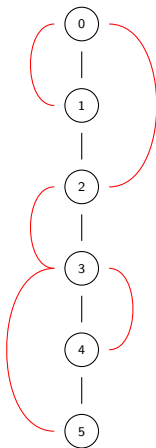
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MTM: Transactions on Mergeable Objects

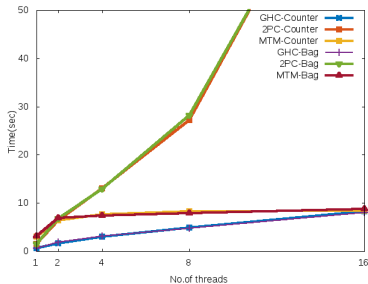
Algorithm

```
txn: {sid, Map writeset, Map readset}  
var: {versions, lock}  
versions: [{val, versionid}]  
function BEGINTRANSACTION(txn)  
  txn.sid  $\leftarrow$  globalclock  
  txn.writeset  $\leftarrow$   $\emptyset$   
  txn.readset  $\leftarrow$   $\emptyset$   
end function  
function COMMIT(txn)  
  lockAll(txn.writeset)  
  versionid  $\leftarrow$  globalclock++  
  for all (var,val)  $\in$  txn.writeset do  
    merge val to the latest version  
  end for  
  unlockAll(txn.writeset)  
end function  
function READVERSION(var, versionid)  
  v  $\leftarrow$  var.versions  
  if v.head.versionid  $\geq$  vid then  
    vr  $\leftarrow$  v.head  
  else  
    waituntil (not locked(var))  
    vr  $\leftarrow$  var.versions.head  
  end if  
  while vr.versionid  $>$  vid do  
    vr  $\leftarrow$  vr.next  
  end while  
  return vr.val  
end function
```

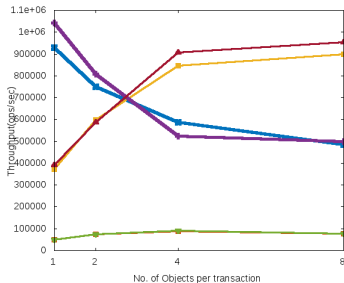


MTM: Transactions on Mergeable Objects

Evaluation: Micro benchmarks



Time vs No. of Threads



Throughput vs. No. of Objects