An On-The-Fly Copying Garbage Collection Framework for Jikes RVM

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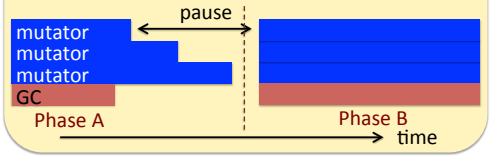
Motivation

GC pauses are undesirable for modern enterprise

➡ Eliminate GC pauses from multi-threaded applications

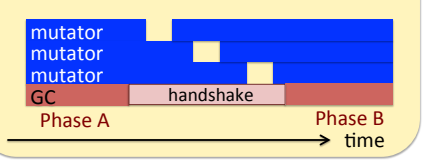
Mostly Concurrent GC (widely used)

need barrier sync. for phase change



On-The-Fly (OTF) GC (we develop)

never stop more than one thread at a time



Challenge on OTF GC: designing correct and efficient write barrier

Contributions

1. Implemented Sapphire OTF GC on widely-used Java VM (Jikes RVM)
2. Developed general framework for OTF, parallel GC
3. Identified a pattern of lagged phase change and fixed a bug in Sapphire
4. Developed efficient concurrent copying method using transactions
5. Support subtleties such as `Object.hashCode()` and weak references

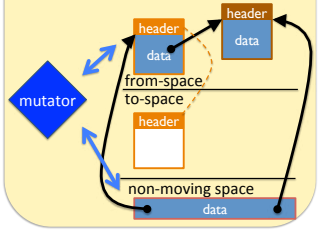
1. Sapphire [Hudson & Moss, 2001]

The only known on-the-fly copying GC, but no full-scale implementation exists

Replication: create semantically equivalent replica behind mutators

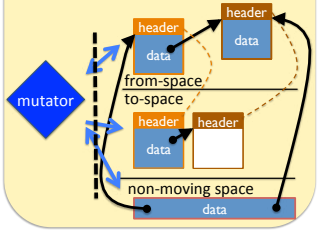
write barrier enforces invariant: no to-space ⟵ from-space pointer

Mark Phase
creates empty "shells"



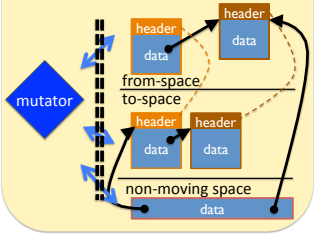
mutator works with from-space and non-moving space

Copy Phase
copies object bodies



write to to-space as well

Flip Phase
flips non-moving space



mutator works with all spaces
flip before writing from-space ptr

2. Lagged Phase Change

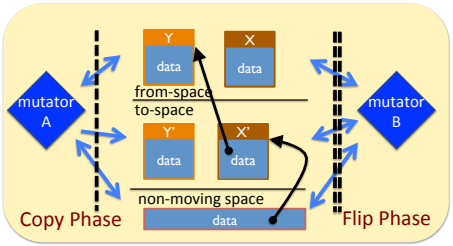
Different phases require different invariants

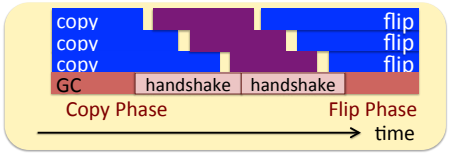
Sapphire's bug

Mutator A in copy phase
INV: no non-moving⟶ to-space
Mutator B in flip phase
INV: no new non-moving⟶ from-space

1. B stores pointer to to-space object X' to non-moving space
2. A loads X' from non-moving space
3. A stores pointer to from-space object Y to a slot of X'

We introduce intermediate states to prevent conflicts between invariants of adjacent phases





3. Concurrent Copy

Sapphire: compare-and-swap per word

Our solution: copy-fence-verify per object

```
copy-object(X, X')
  for(f : fields(X))
    { buf.f = X.f;  X'.f = forward(X.f); }
  fence;
  for (f : fields(X))
    if (X.f != buf.f) fallback;
```

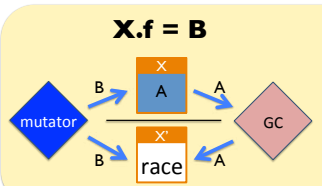
- fewer synchronisation
- sequential memory access

Can use HW transaction for race detection

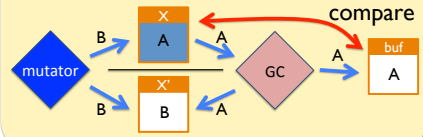
- transaction setup was heavier than fence

  ➡ similar throughput to SW transaction

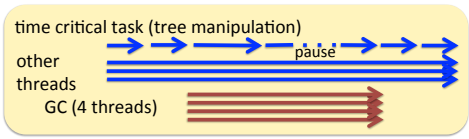
X.f = B



Race detection



Evaluation Result



- Long pauses were very rare (observed regardless of GC)
- Write barrier slowed down mutators to roughly half speed