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

Motivation

GC pauses are undesirable for modern enterprise
- Eliminate GC pauses from multi-threaded applications

Mostly Concurrent GC
- need barrier sync. for phase change

On-The-Fly (OTF) GC
- never stop more than one thread at a time

Challenges 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

I. Sapphire [Hudson & Moss, 2001]

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

Mark Phase creates empty “shells”
- mutator works with from-space and non-moving space

Copy Phase copies object bodies
- mutator works with 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 \(\rightarrow\) to-space
- Mutator B in flip phase
  - INV: no new non-moving \(\rightarrow\) 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

```java
for(f : fields(X))
    for(f : fields(X'))
        copy-object(X, X')
    fence;
    
    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

Evaluation Result

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