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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

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 \(\rightarrow\) from-space pointer

Mark Phase
- creates empty “shells”

Copy Phase
- copies object bodies

Flip Phase
- flips non-moving space

Mark Phase: from-space and non-moving space

Copy Phase: to-space as well

Flip Phase: 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

\[
\text{copy-object}(X, X') \\
\text{for}(f: \text{fields}(X)) \\
\{ \\
\quad \text{buf.f} = X.f; \\
\quad X'.f = \text{forward}(X.f); \\
\quad \text{fence}; \\
\quad \text{for}(f: \text{fields}(X)) \\
\quad \text{if}(X.f \neq \text{buf.f}) \text{fallback};
\}
\]

- 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