Modern Considerations of Garbage Collection in the Java Hotspot Virtual Machine

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December 3, 2011

Object Oriented Programming Languages

- Objects operate as containers of data
- Objects refer to each other
- Notable object oriented languages:
  - Java
  - C#
  - Ruby

Live Objects versus Dead Objects

- Object reachability with a program
  - Reachable objects are *live*
  - Unreachable objects are *dead*
- The Garbage Problem
  - Memory is finite
  - Dead objects serve no purpose

The Java HotSpot Virtual Machine

The Java Virtual Machine (JVM)

- Runs the Java program
- Manages the object memory space
- Houses Garbage Collection

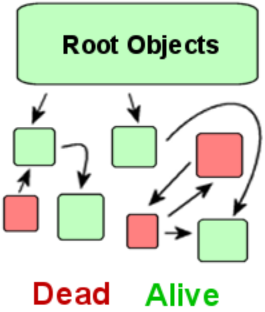
- The HotSpot™ implementation is developed by Oracle, formerly Sun

The Mark-and-Sweep Algorithm

Transitive reachability

If reachable Object A references Object B and Object B references Object C. Then Object C is reachable.

- The *Mark* Phase
  - Begins from root set
  - Traverses object references
- The *Sweep* Phase
  - Traverses all objects
  - Unmarked objects collected

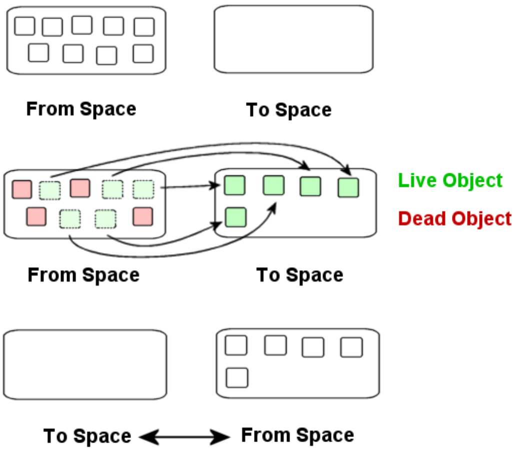


The Stop-and-Copy Algorithm

Initialization

Object Copy

Role Switch



Performance Considerations

- Frequent collection may cause processing overhead
- Infrequent collection may cause memory overhead
- Stop-the-World pauses
- Latency

Generational Garbage Collection

Three object life-time scenarios:

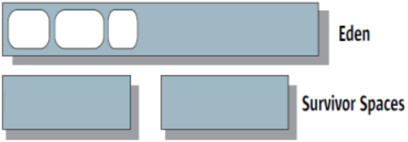
- Object dies soon after allocation
- Objects dies long after allocation
- Object never dies after allocation

Generation: A set of similarly aged objects

- Typically observed that most objects die young
- Java HotSpot generational garbage collection consists of:
  - The Young Generation
  - The Old Generation

The Young Generation

- The Young Generation consists of three spaces:



- Objects initially allocated to the Eden space
- When Eden space fills, *Minor Garbage Collection* occurs

Minor Garbage Collection

Uses Stop-and-Copy collection

- Efficient on small quantities of live objects
- Unaffected by large quantities of dead objects

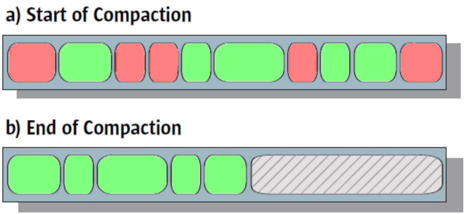
- Eden and one survivor spaces operate as From space
- Surviving objects receive a count
- Objects *tenured* to old generation when count meets threshold

The Old Generation

- Consists of just one space
- Slowly aggregates over time
- When space fills, *Major Garbage Collection* occurs

Major Garbage Collection

- By default uses Mark-Sweep-Compact algorithm
  - Requires less memory to operate
  - Defragments object space for allocation efficiency



Parallel Processing

Thread

A spawned process that is scheduled and functions independently of its parent.

- Single-threaded HotSpot Garbage Collectors:
  - Serial Collector
- Multi-threaded Generational HotSpot Garbage Collectors:
  - Throughput/Parallel Collector (Young Generation only)
  - Parallel Compacting Collector
  - Concurrent Mark-Sweep Collector

Parallel Young Generation Collection

- Uses parallel implementation of Stop-and-Copy

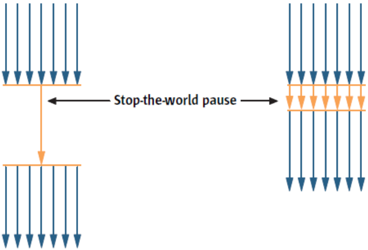


Figure: Single-threaded versus Multi-threaded

Parallel Old Generation Collection

Parallel Compacting Collector

- Uses parallel implementation of Mark-Sweep-Compact
- Incurs lower Stop-the-World pause-times

Concurrent Mark-Sweep Collector

- Uses concurrent implementation of Mark-and-Sweep
- Incurs even lower Stop-the-World pause-times
- Incurs high latency due to program CPU sharing

Real-time Applications

- Real-time applications operate within time-based deadlines:
  - E.g. military command-and-control operations, financial trading systems, on-the-fly audio processing

Three criteria of severity:

Strict	Missing a deadline compromises the entire application
Hard	Missing a deadline compromises that deadline result
Soft	Missing a deadline degrades that deadline result

- Collectors must have very low Stop-the-World pause times
- Only Java Hotspot collector to meet a real-time criteria is the *Garbage First Collector*, which satisfies Soft real-time processing.

Conclusion

- No ideal garbage collector

Main optimization criteria to consider:

- Low Stop-the-World pause times
- Low latency
- Processing power
- Memory capacity

- As computer architecture evolves, more leeway to delegate processing and memory footprints to the underlying computer system

Questions?

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