Immix: A Mark-Region Garbage Collector with Space Efficiency, Fast Collection, and Mutator Performance

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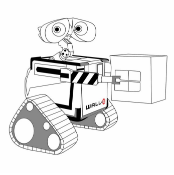

presented by
Michael Lippautz
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WS 2010
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Why do we need GC? Where are we?

2008

- Programmers are more and more choosing managed languages for modern applications (safety)
- Lots of short/medium lived objects

Problem

- $\Rightarrow$ GC has a direct impact on program performance
- Tradeoff between time and space

Goal

Improve existing collection strategies

Immix

(let's figure out what this is about)

Mark-Region Garbage Collector

- Space efficiency - **space**
- Fast collection - **time**
- Mutator performance - **latency**

$\Rightarrow$ 3 dimensions; design space

Immix

(let's figure out what this is about)

How does this work?

Mark-Region Garbage Collector

Which strategies, how, why?

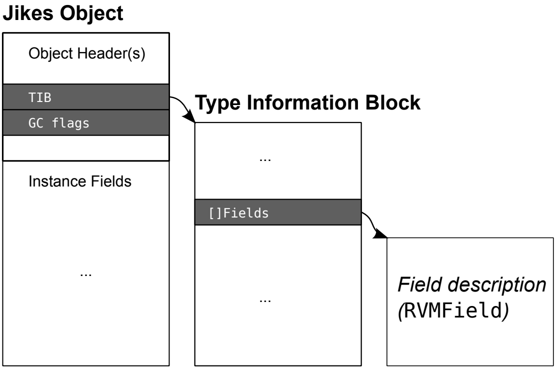
- Space efficiency - **space**
- Fast collection - **time**
- Mutator performance - **latency**

$\Rightarrow$ 3 dimensions; design space

Contents

Environment - the bigger picture

- Java
- Jikes RVM
- GC on object level (not chunks of memory)
  - Object model



A *very brief* overview

Only tracing GCs are discussed, but there do exist others, such as:

- Reference counting GCs
- Mixtures

Memory management utilizing a tracing GC

Basic approach

Determine which objects are reachable, discard the other ones

A *very brief* overview (cont)

Terms

- *Allocation* of new objects
- *Identification* of live objects (reachability analysis)
- *Reclamation* of free memory

Types

- Moving vs non-moving
- Stop-the-world vs incremental
- Precise vs conservative (pointers)

Reclamation strategies

Sweep-to-free-list

1. Allocate from a free list
2. Mark live objects
3. Sweep-to-free-list

Good: Time/space efficient
Bad: Locality
Examples: Mark-sweep (Naïve, tri-color)

Reclamation strategies (cont)

Evacuate

1. Move live objects to new space
2. Reclaim old space

Good: Locality, contiguous allocation
Bad: 2x space, slow (copy)
Example: Semi-space

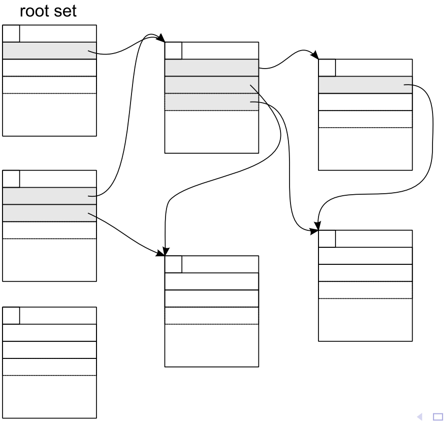
Compact

1. Move live objects to one end of the same space

Good: Locality, contiguous allocation
Bad: Multiple passes over heap, slow (copy)
Example: Mark-compact

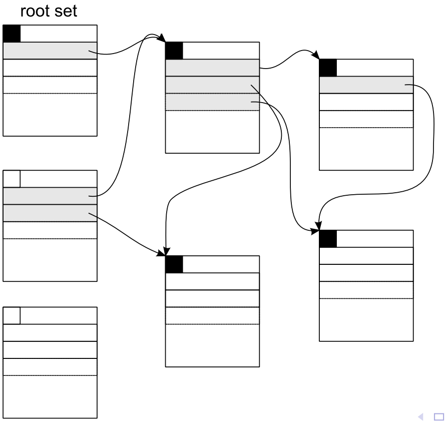
Naïve Mark-Sweep

- Mark phase
- Sweep phase



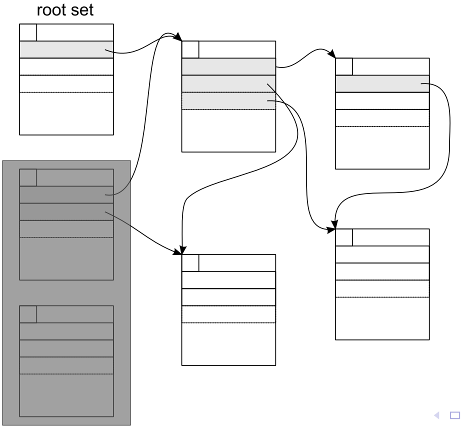
Naïve Mark-Sweep

- **Mark phase**
- Sweep phase



Naïve Mark-Sweep

- Mark phase
- **Sweep phase**



Naïve Mark-Sweep

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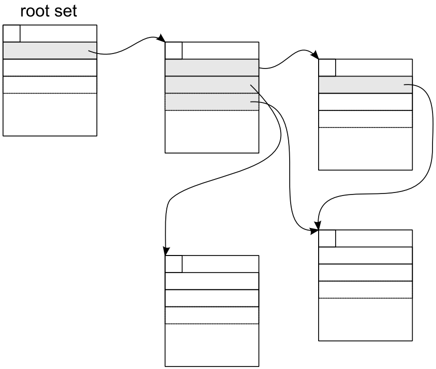
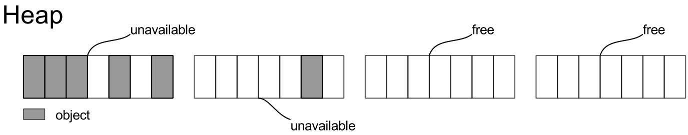
- Sweep phase



Naïve Mark-Region

- Memory is split into regions
- States:
  - *Free*
  - *Unavailable*
- Bump allocator in region
- Collector marks regions with at least one live objects as unavailable



Naïve Mark-Region(cont)

Questions

- How big can/should regions be?
- How does defragmentation work?

Immix

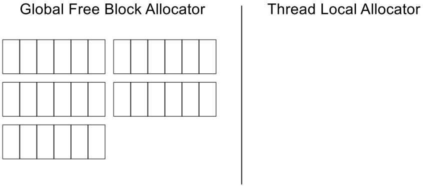
Sneak preview:

- Operates on a *block* (coarse grained) and *line* (fine grained) level
- Recycling of partially used blocks

Immix algorithm

Initial allocation

- **Initially, all blocks are empty**
- Thread-local allocator obtains a block from a global pool
- A full block triggers another request
- A full heap triggers a collection



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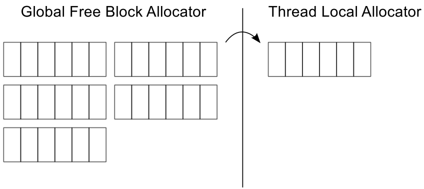

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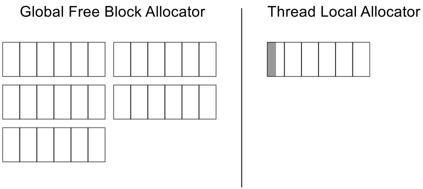

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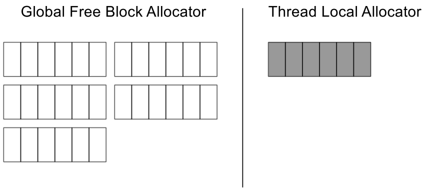

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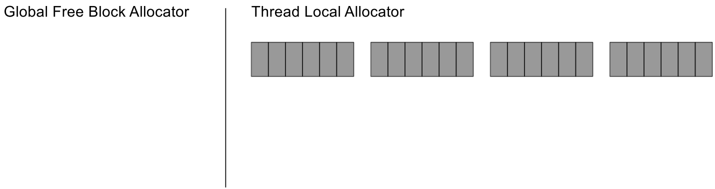
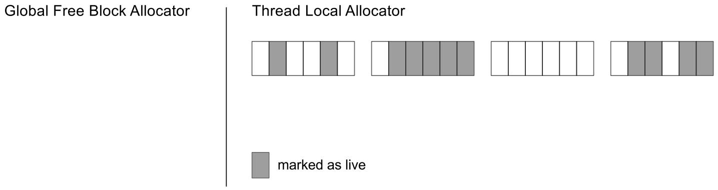


Immix algorithm (cont)

Identification

- Collector traces live objects by performing a transitive closure
- **Marks objects and their lines**

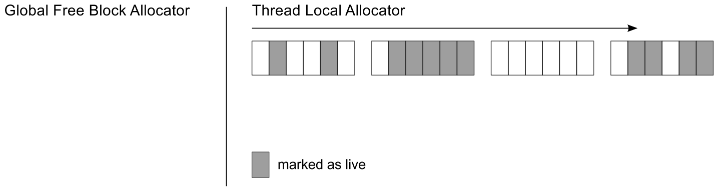


Immix algorithm (cont)

Reclamation

After trace completion the collector performs a *coarse-grained-sweep*.

- **Linearly scans line map to find free blocks and free lines**
- Returns completely free blocks to global allocator
- Recycles (marks) partially free blocks for the next phase



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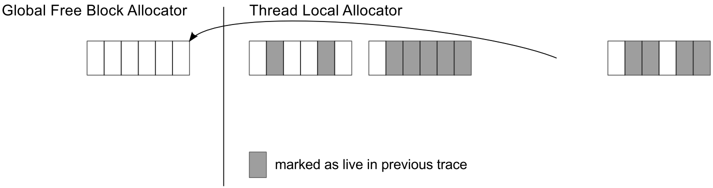

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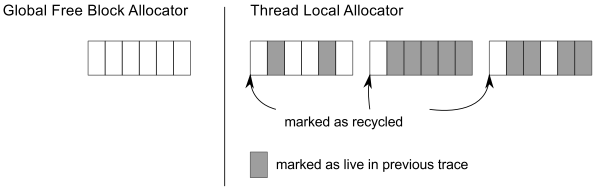
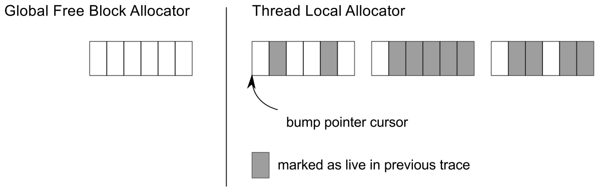


Immix algorithm (cont)

Steady state allocation

- **Thread-local allocator resumes allocation into recycled blocks**
- Bump allocates into free lines in a block
- Once there are no more recycled blocks available, a new one is requested from the global allocator
- Exhausted heap triggers another collection



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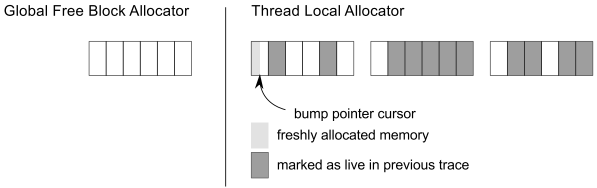

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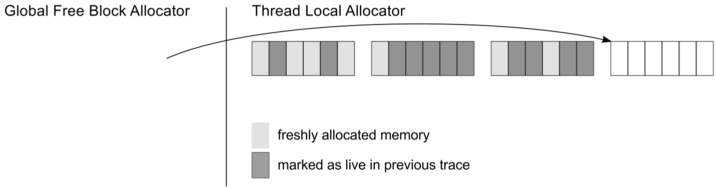

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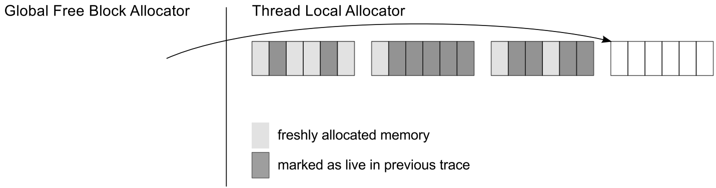


Details and policies

Basic algorithm works, but needs tuning to be competitive with existing GCs

Details and policies (cont)

Recycling policy

The allocator marks partly used blocks with atleast F lines as recyclable. Experimenting shows that $F = 1$ works best on average.

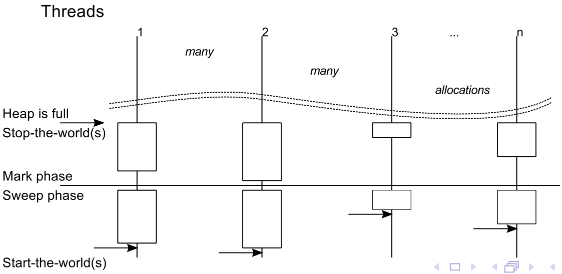
Allocation policy

Immix allocates into recyclable blocks first, before touching any free blocks. This is done to reduce competing for free blocks. I.e. thread-local allocators compete against each other and a large object space allocator for pages (indirectly over blocks).

Details and policies (cont)

Parallelism (detailed study is still open)

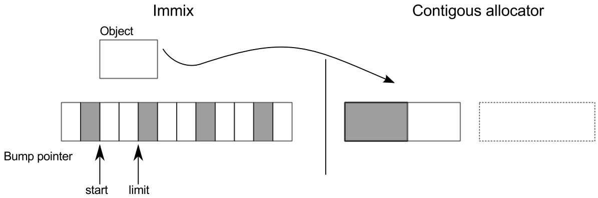
- Synchronization happens only when obtaining/returning a block from the global allocator
- TLAs can work unsychronized
- Transitive closure is performed parallel (worst case: marking an object multiple times)



Details and policies (cont)

Demand driven overflow allocation

- *Definition:* Medium sized objects are greater than one line
- *Problem:* Allocator wastes free space when searching for holes to store medium sized objects
- *Solution:* Each immix allocator is paired with a contigous allocator that uses empty blocks



(This is enough, since there are not that many medium sized objects [1])

Details and policies (cont)

In numbers...

- 128 Byte lines
- 32 KByte blocks

Conservative marking

- Again: Most object are below 128 byte of size (small)
- → Most objects fit in max. 2 lines
- Exact marking of lines is very costly
- Only the first line of an object is marked
- The first line of a hole is skipped upon allocation (implicit marking)
- Flags for small and medium ensure that this is still correct

Defragmentation

Lightweight opportunistic evacuation

- Pure mark-region would be non-moving and suffer from fragmentation
- *Evacuation* and/or *compaction*?

Candidate selection

- Round-robin policy like JRockit
- Defragmentation on demand like Metronome

Defragmentation

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Defragmentation (cont)

Trigger

- If there exists one ore more recyclable blocks that have not been that have not been used by the allocator in the previous run
- If the previous collection did not yield enough free space

Which blocks?

Based on two histograms the collector decides which blocks should be used as source and targets

- Marked, calc. at the end of each run [marked lines/holes]
- Available, calc. on demand [free lines/holes]

Defragmentation (cont)

How?

Immix mixes marking and evacuation

- Candidate blocks have been selected before the collection run
- If an object in a candidate block is mark, it is also evacuated and a forward pointer is set

$\Rightarrow$ Single pass, evacuation based defragmentation

References

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