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Automatic Region-Based Memory Management for Real-Time Embedded Systems



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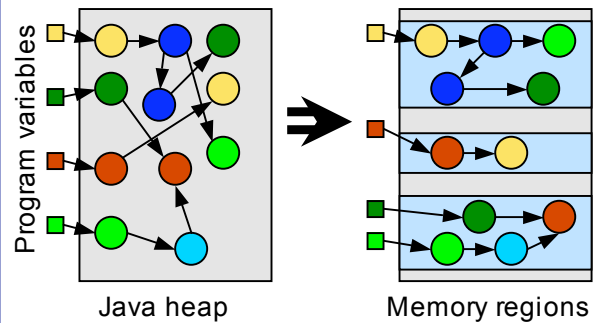
Motivation :

- Java means automatic memory management
- Garbage Collector means problems in a real-time context
 - Unpredictable pause times
 - Fragmentation of the heap
- *How can we provide automatic memory management without using a GC ?*

Our approach :

- Use region-based memory management
- Group data structures in regions
- Use a compile-time analysis to place objects in regions

Memory management with regions



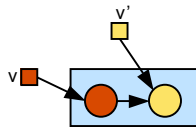
- Objects allocated side by side : no more fragmentation
- Regions destroyed as a whole : predictable times
- Drawback: each object must be placed when allocated

Pointer Interference Analysis :

- Build a partition of local variables
 - $v \sim v'$ means they belong to the same data structure
 - Simple algorithm :
- $$\begin{aligned} v &:= u && \implies v \sim u \\ v &:= u.f && \implies v \sim u \\ v.f &:= u && \\ m() & && \\ \text{call } \begin{cases} p1 \sim v1 \\ p2 \sim v2 \end{cases} &&& \implies v1 \sim v2 \\ m'() & \text{ if } p1 \sim p2 && \end{aligned}$$

Allocation Policy :

Simple allocation policy :
if two variables verify $v \sim v'$,
place their objects in the same region
Data structures will be automatically grouped by region

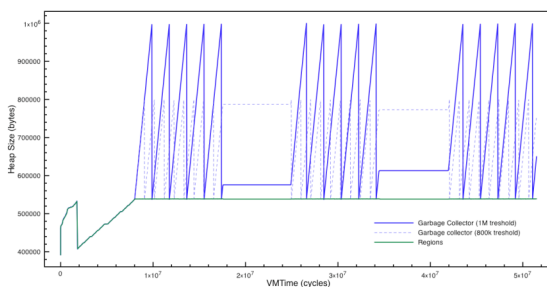


Other kinds of pointer analysis :

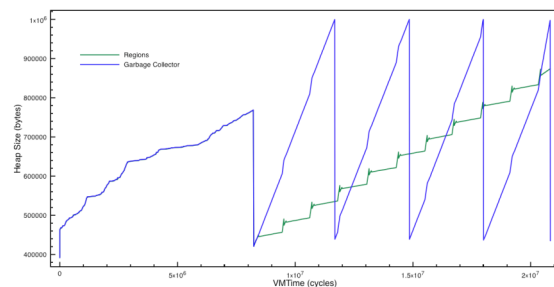
- Escape analysis :
Does my object live longer than its method of origin ?
- Points-to analysis :
Where do the objects of my variable come from ?
- Purity analysis :
Does my method mutate the heap ?

Results :

Memory occupancy for two programs using a Garbage Collector or using Regions



- In this program, most regions are short-lived
- The program runs in nearly constant space
- No more need for a Garbage Collector



- This program uses a large mutating data structure
- Some of the generated garbage stays forever in the long-lived region
- Running this program without a GC may cause a memory leak

How to predict the runtime behaviour ?

Achieved :

- We propose a simple static analysis and allocation policy that groups data structures in regions
- Automatic region-based memory management can allow programs to run without a Garbage Collector

Perspectives :

- This approach has a tendency to place too many objects in the same region
- We need to find an algorithm to predict at compile time the behaviour of the region allocator