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

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Motivation

The Java programming language

- Attractive language
  - Automatic memory management

Implementation pitfalls

- Garbage Collection $\Rightarrow$ pause times and fragmentation

$\Longrightarrow$ Difficult to use in a real-time embedded context

Our approach

Non-determinism of Garbage Collector pause times:
the problem is in the JVM, not in the language!

Proposition:

- Keep the language
  - no *manual* memory management
- Change the implementation
  - replace the GC by a *predictable* allocator
    - use region-based memory management
  - automatically compute object lifetimes at compilation
    - undecidable problem
    - find a reasonable over-approximation

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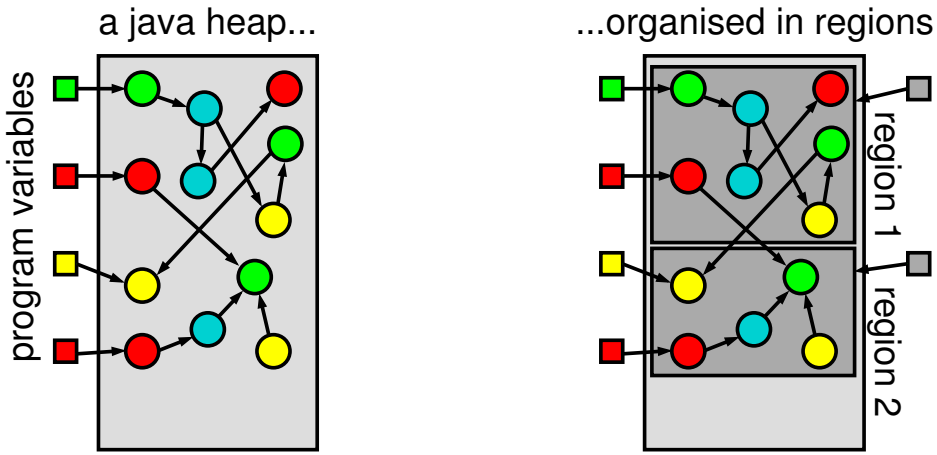
Outline

- Introduction
- Region-Based Memory management
- Pointer Interference Analysis
- Experimental results
- Conclusion

Memory management using regions



Objects in a region will share the same (physical) lifetime

- Benefits: a more *real-time*-compatible behaviour
  - objects allocated side by side
    - no fragmentation, constant time
  - region destroyed as a whole: predictable times
- Drawbacks: more difficult bookkeeping
  - object placement issue: who decides?
  - region destroyed as a whole: space overhead, risk of faults

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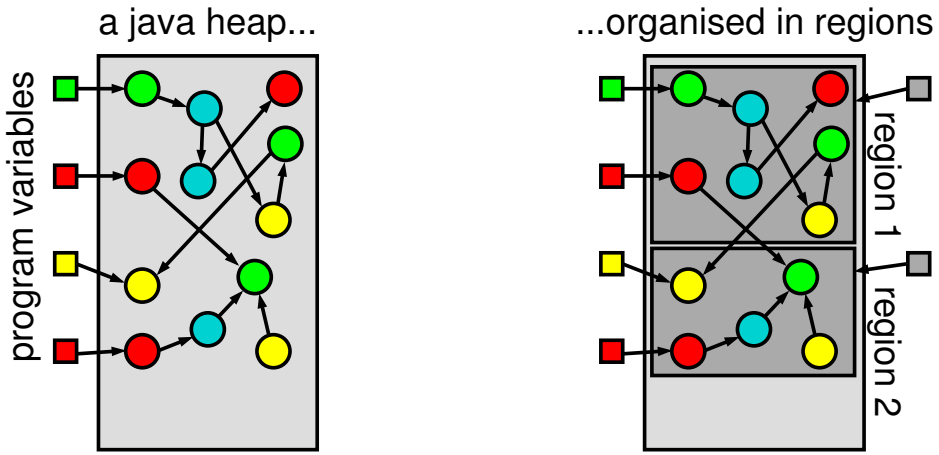

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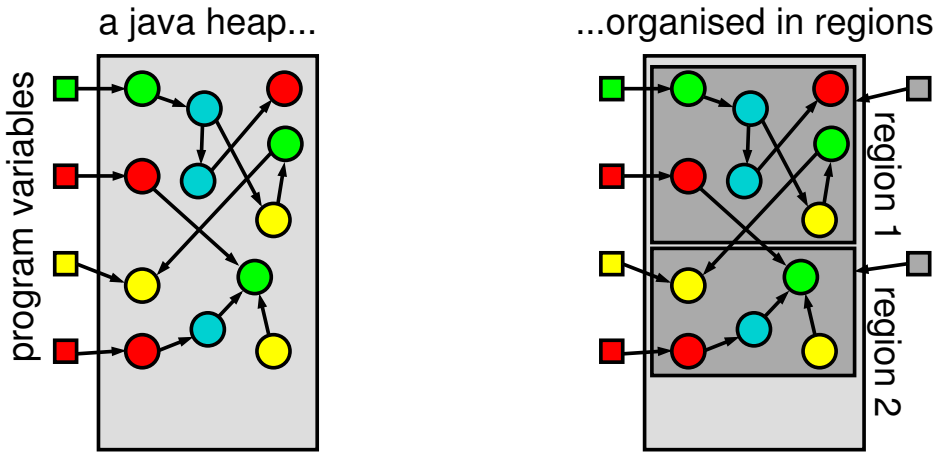

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Region analysis and allocation policy

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$\Longrightarrow$ one region for each data structure

- no inter-region pointer

Static analysis:

- identify variables that may point to connected objects

Allocation Policy:

- place objects so that each structure is grouped in a region

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identify local variables

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$v_1.\mathtt{f}=v_2 \Longrightarrow v_1 \sim v_2$

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interproc. interference:

$p_1 \sim p_2 \implies a_1 \sim a_2$

main()

$list \sim o1 \quad o2$

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$this \sim tmp$

add()

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results:

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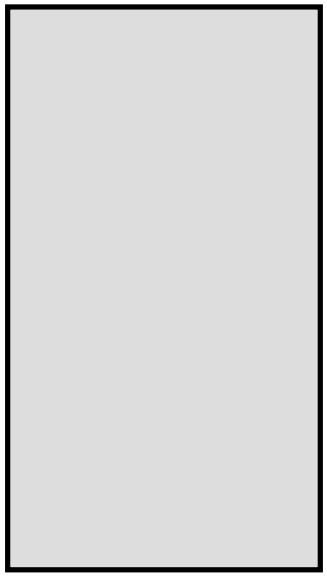

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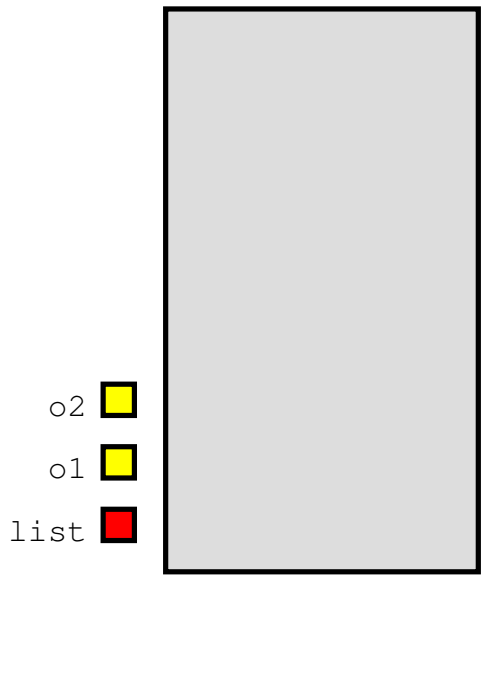

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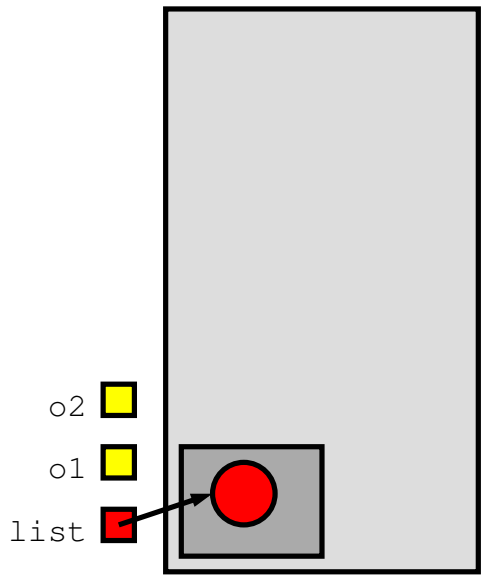

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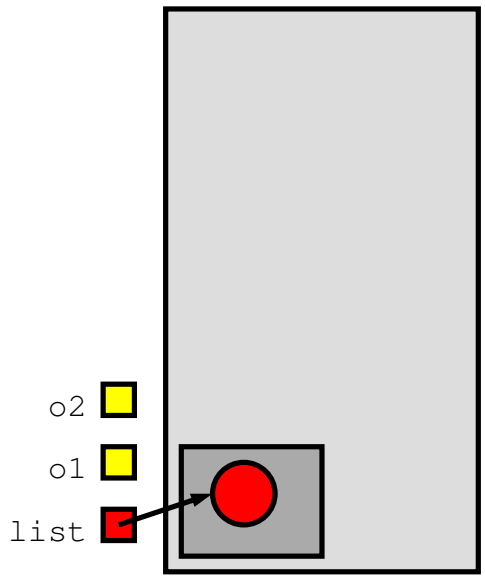

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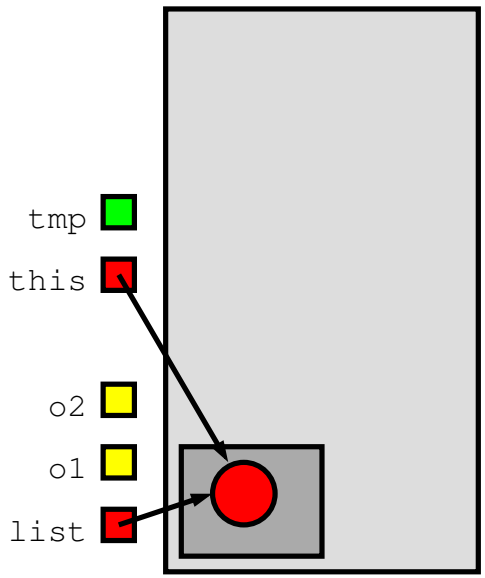

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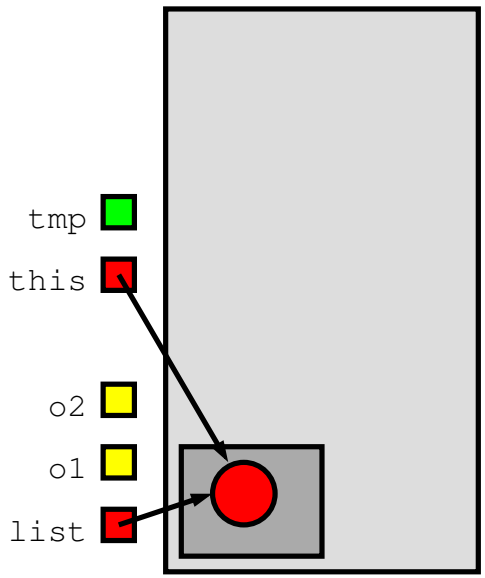

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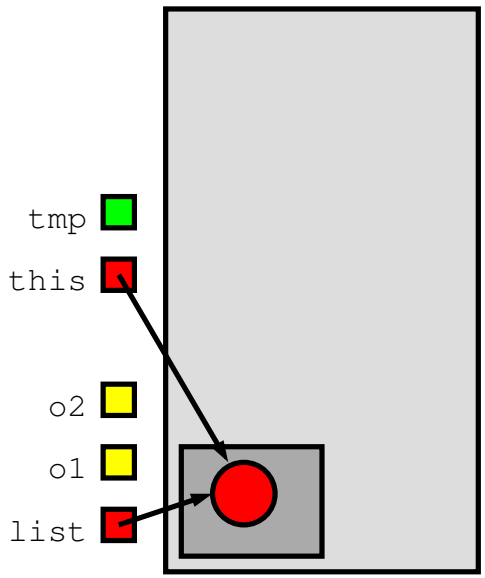

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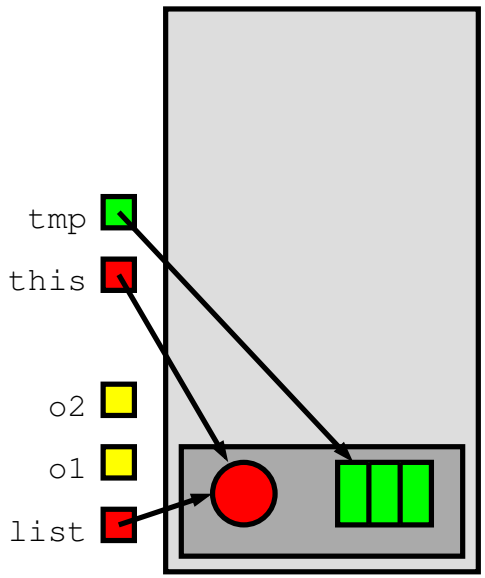

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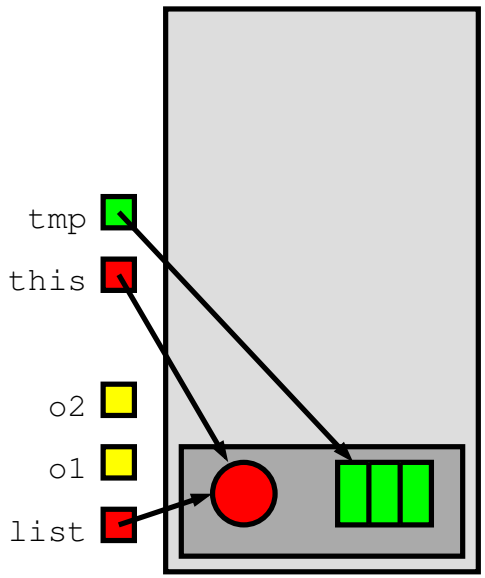

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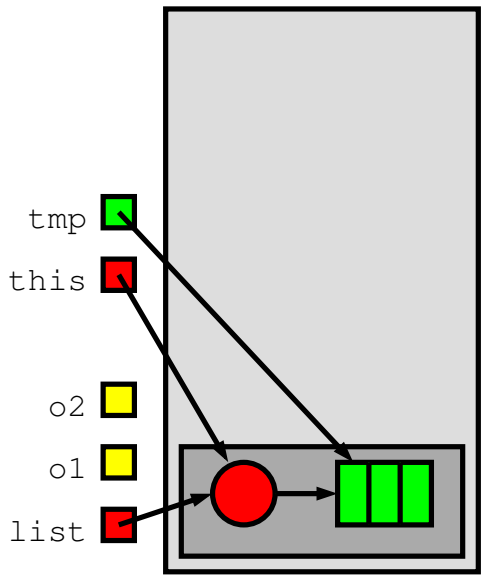

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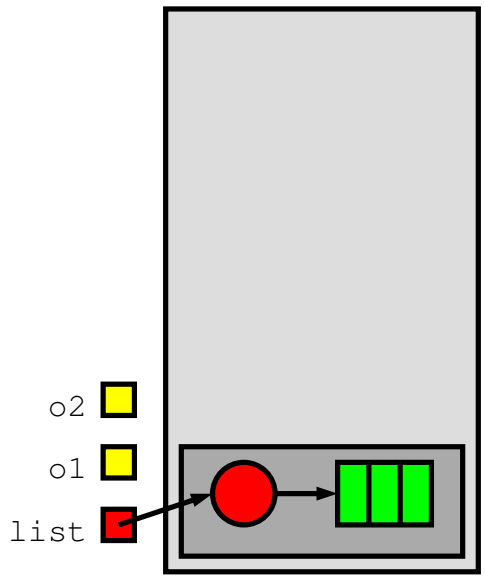

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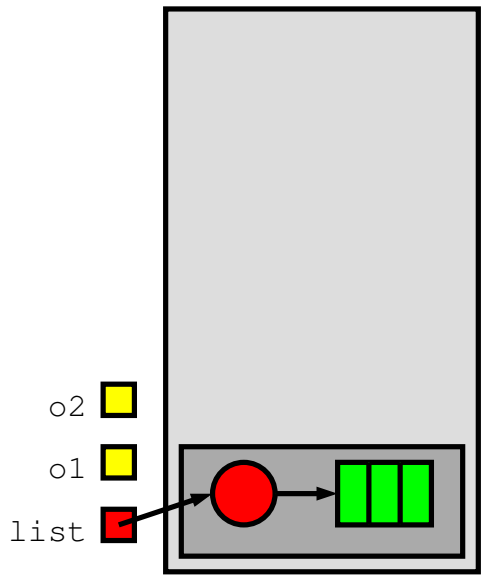

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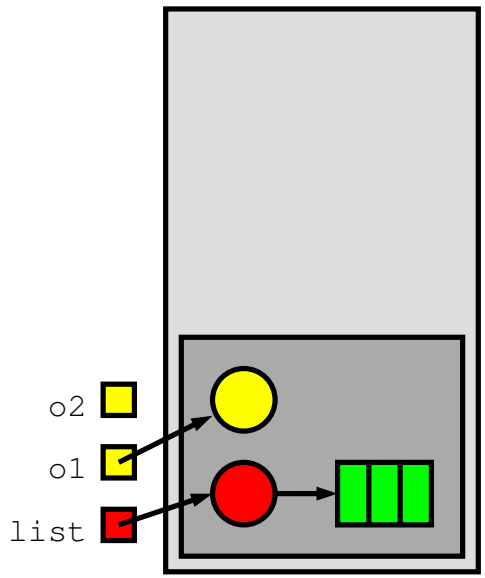

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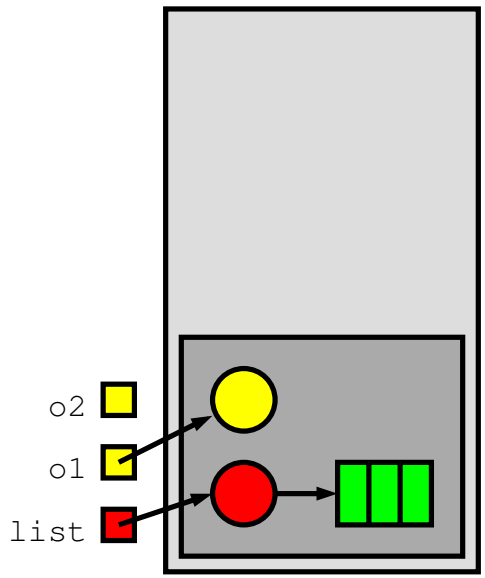

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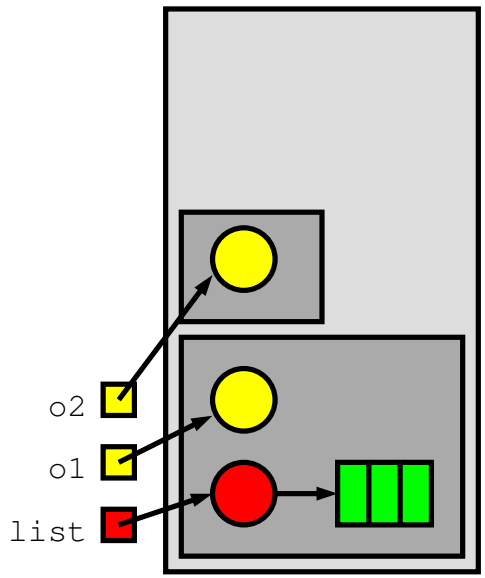

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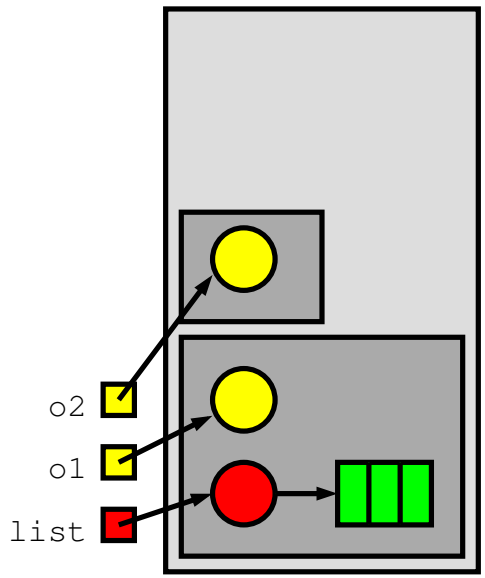

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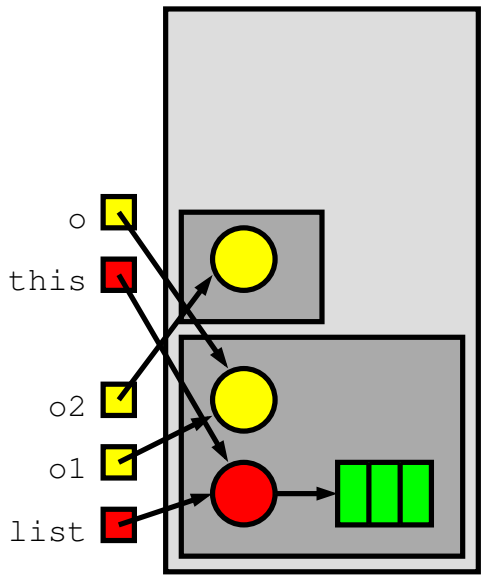

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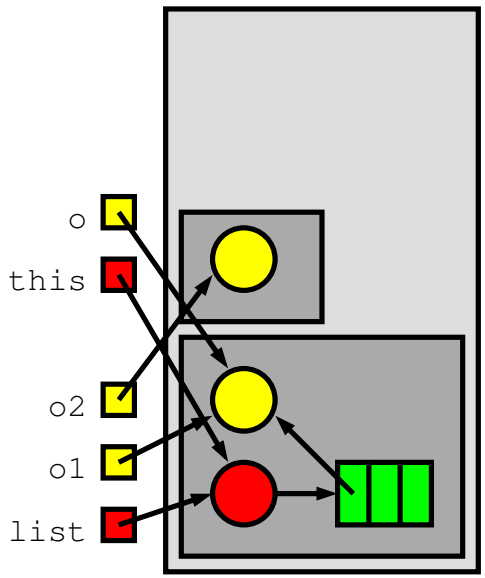

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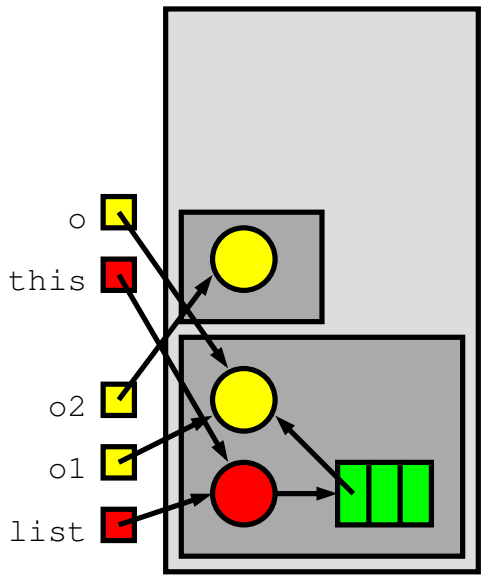

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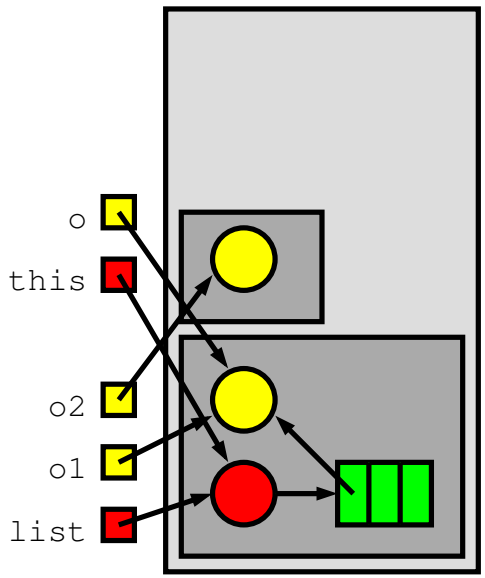

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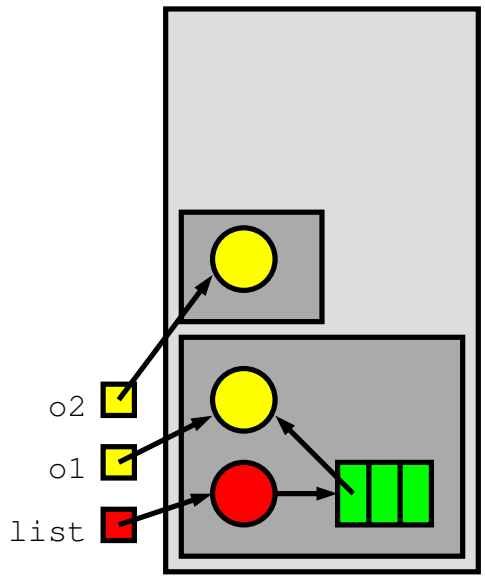

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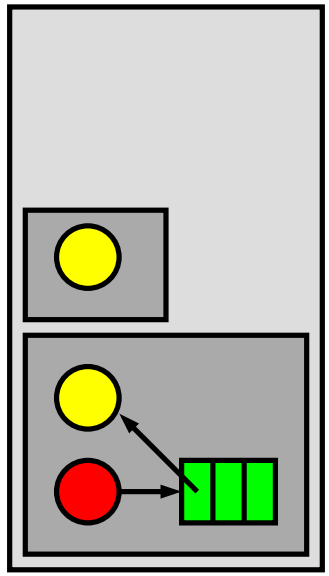

Outline

Experimental setup

Static analysis implemented with the Soot infrastructure

Memory manager implemented in the JITS virtual machine

JITS = *Java In The Small* (LIFL, France)

- a J2SE JavaOS for resource-constrained systems

Comparison of memory occupancy:

- with the default GC (mark & sweep)
- with static analysis + regions

JOlden benchmark suite

- lots of allocations
- different memory usage patterns

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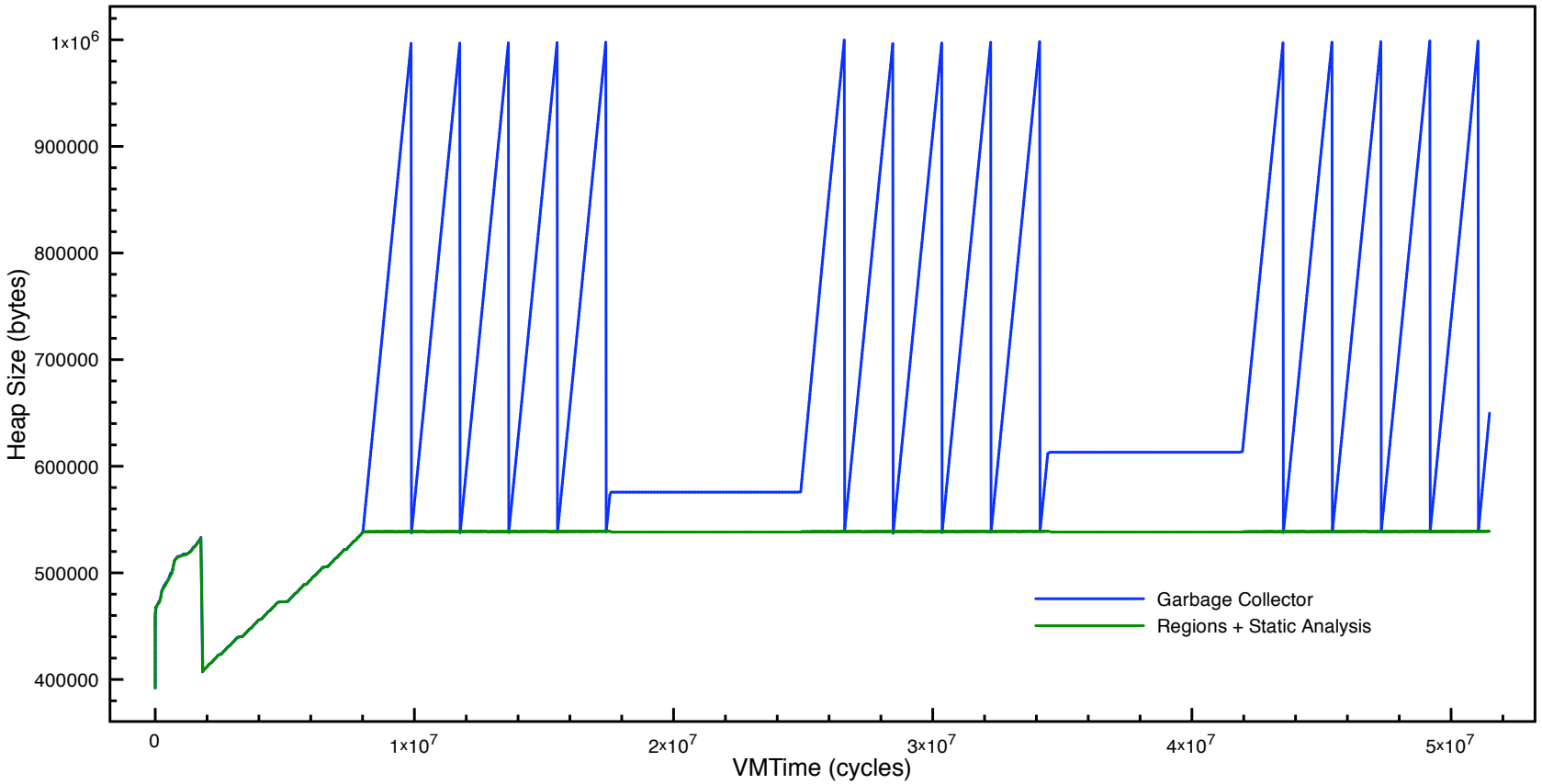

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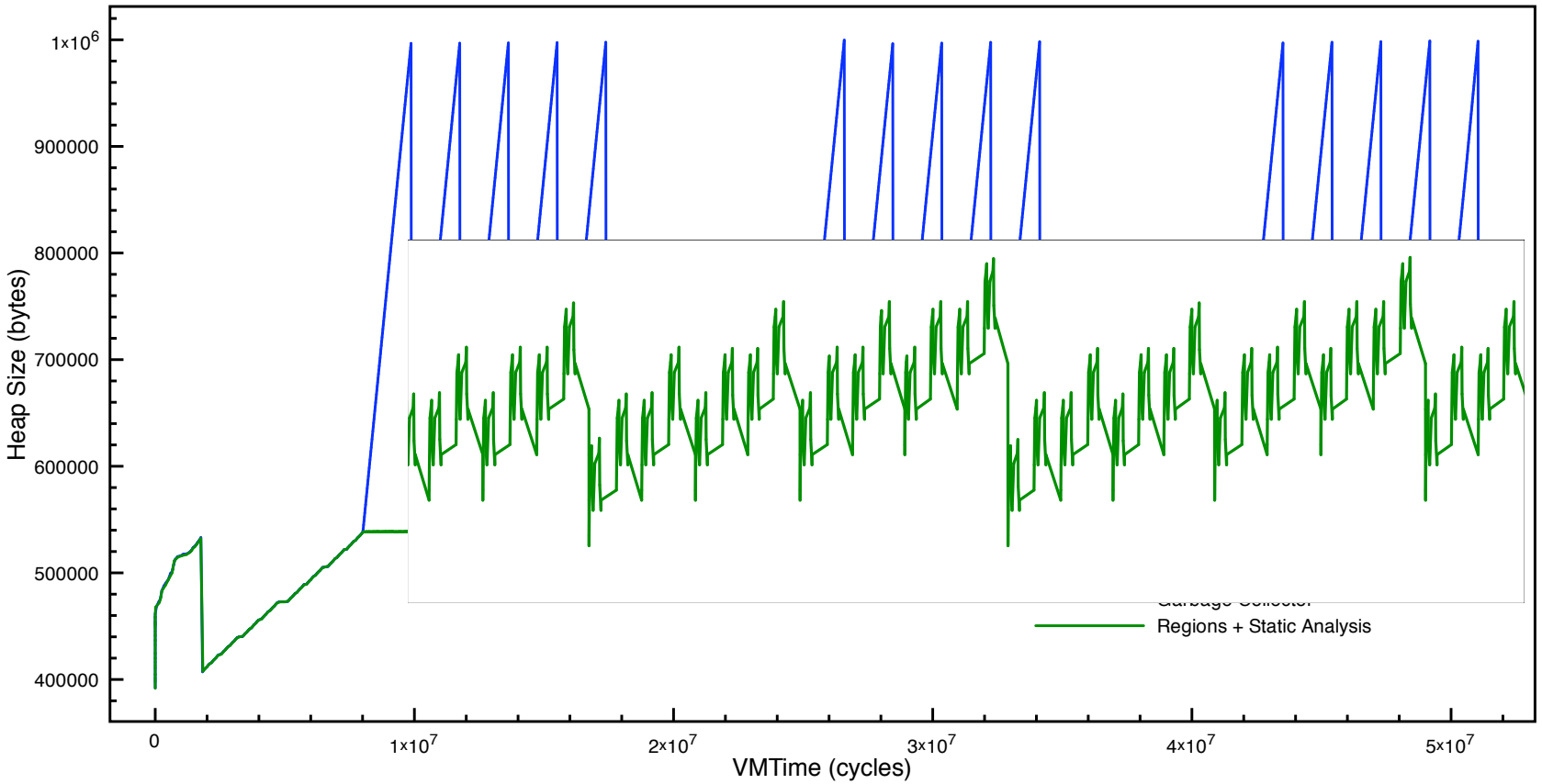

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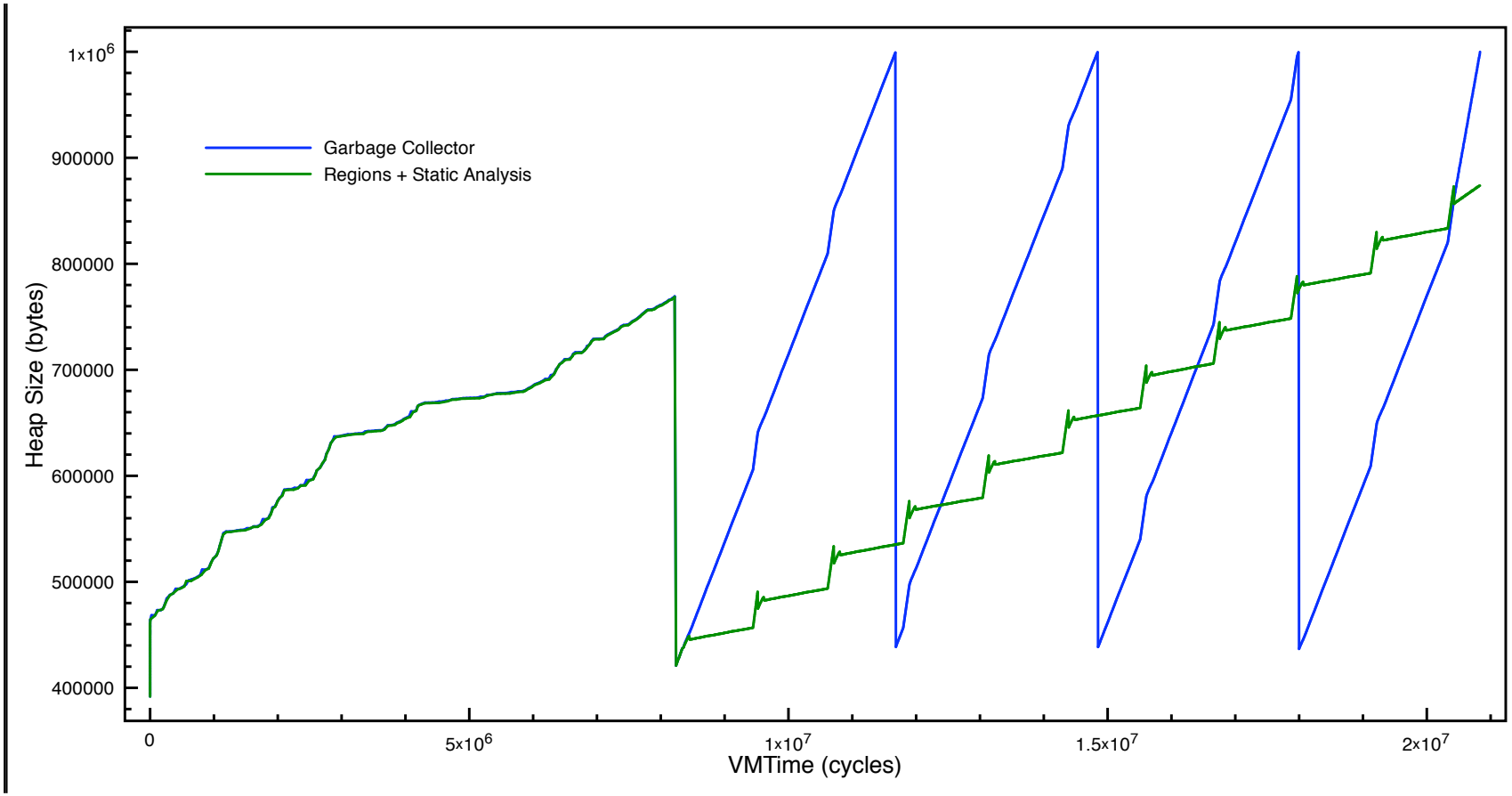

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Pointer interference analysis:

$$foo()$$

$$this \sim bar$$

$$main()$$

$$r$$

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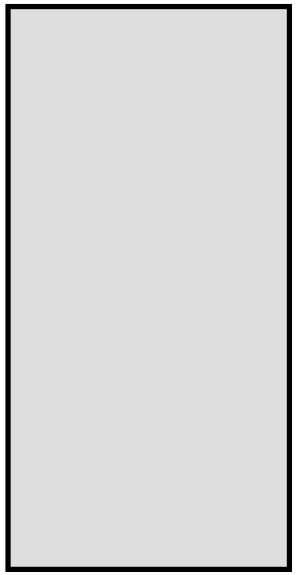

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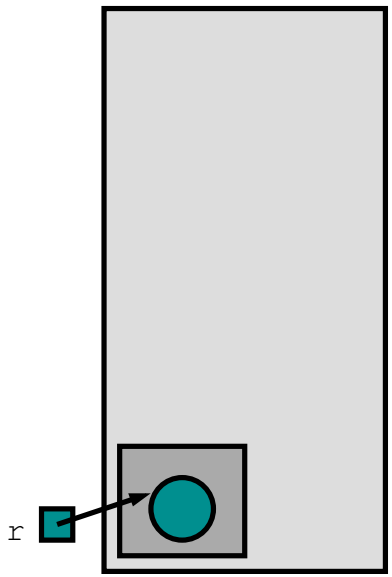

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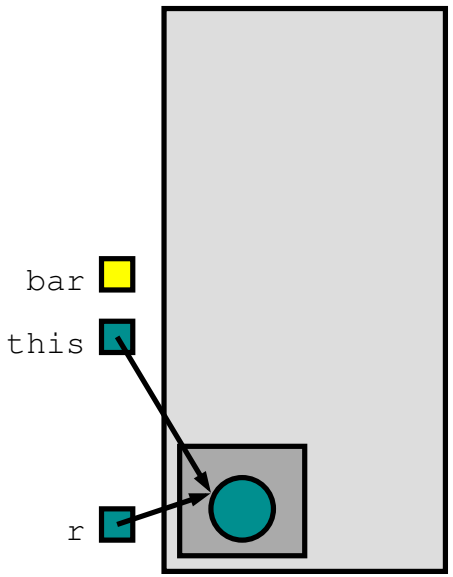

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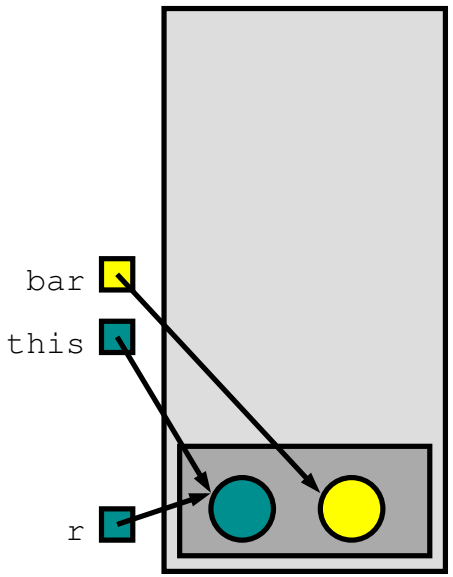

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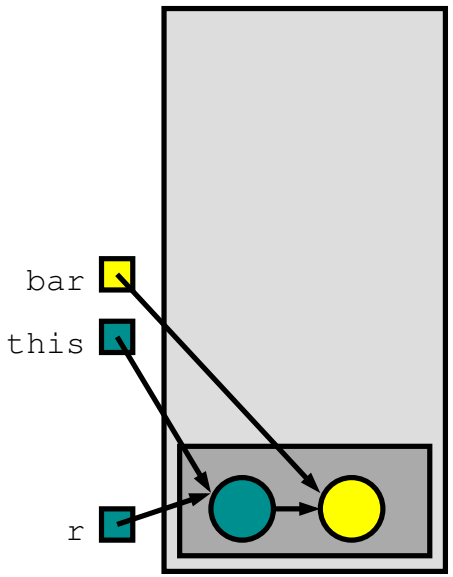

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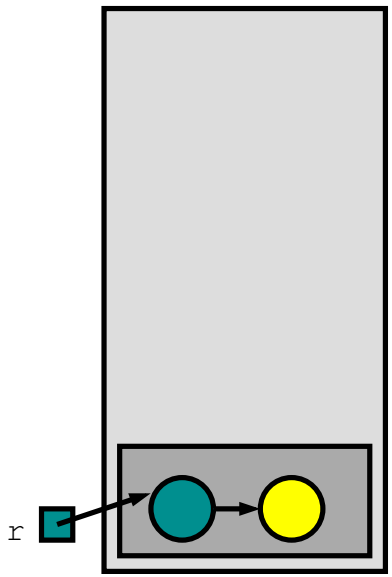

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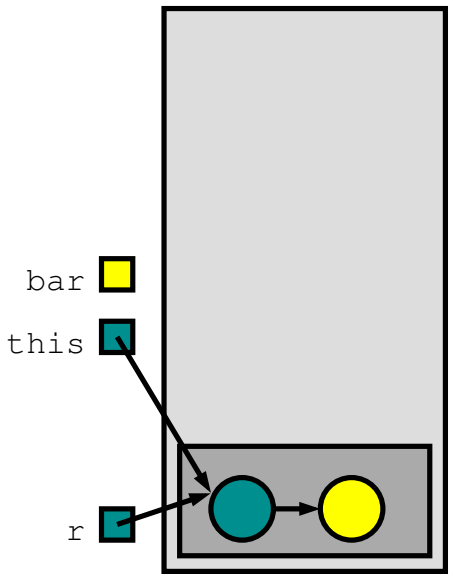

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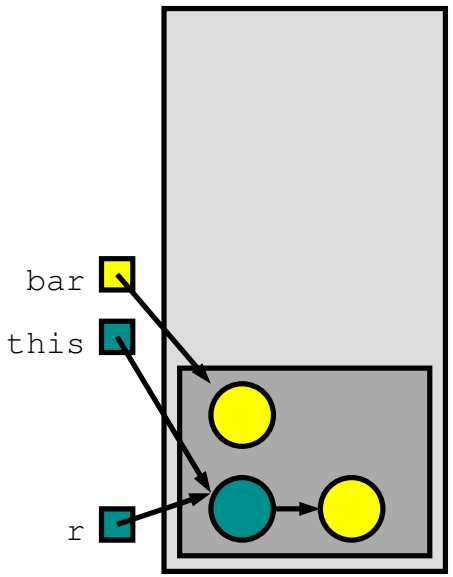

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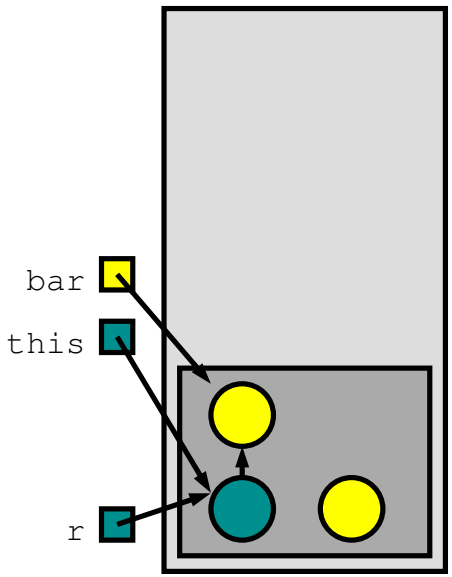

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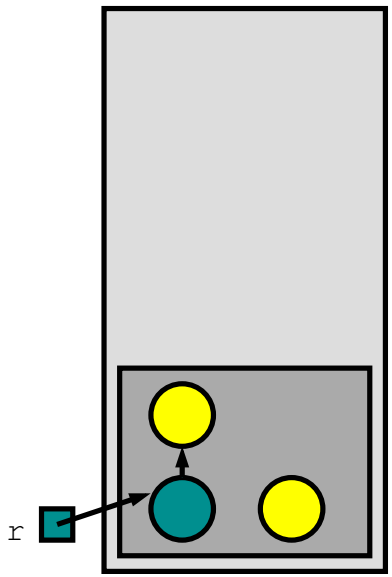

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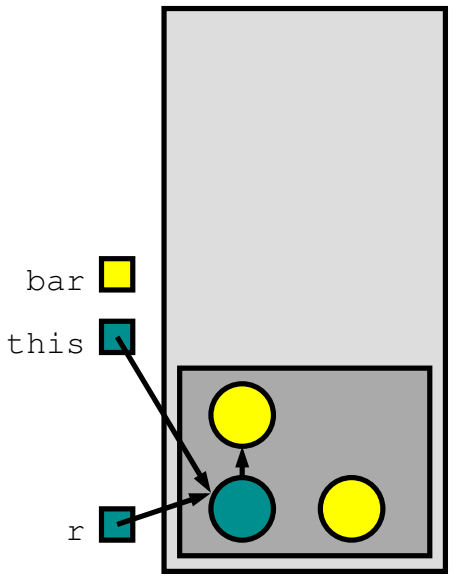

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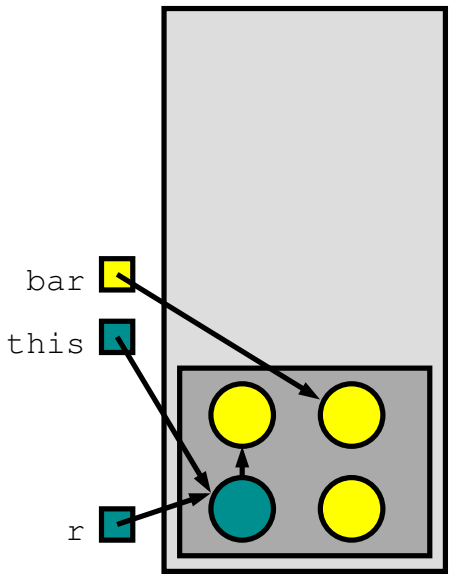

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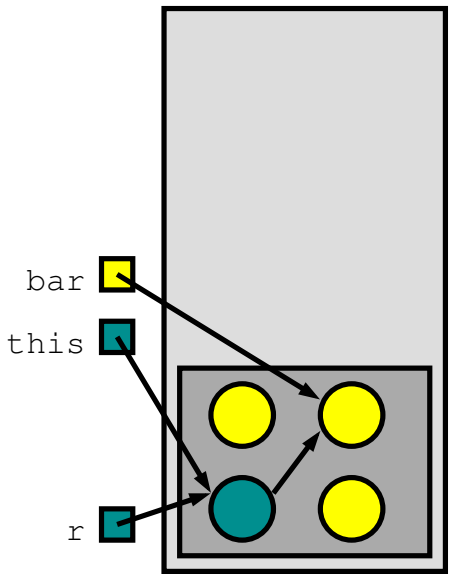

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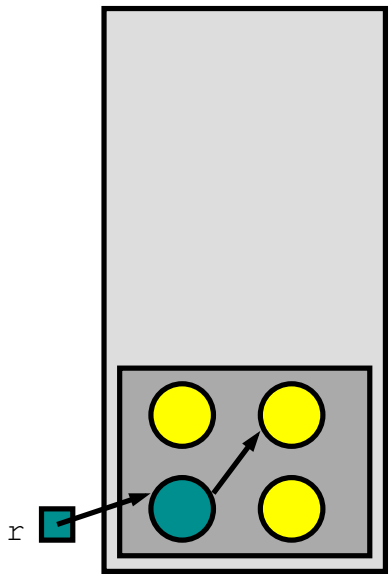

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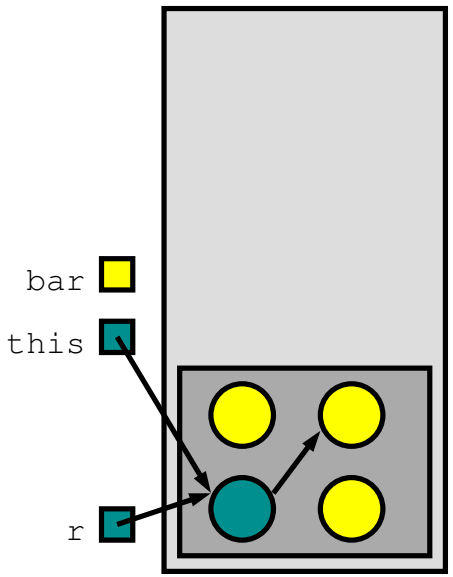

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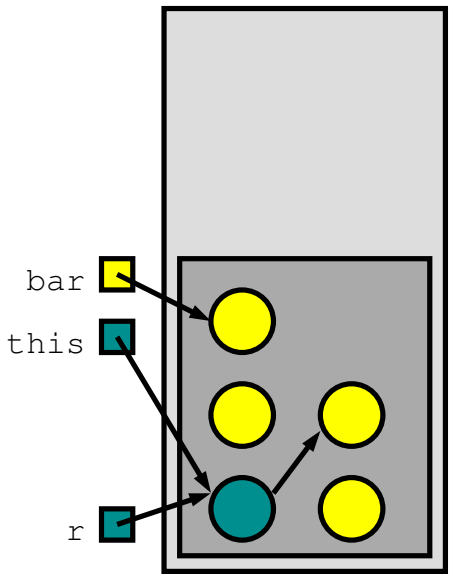

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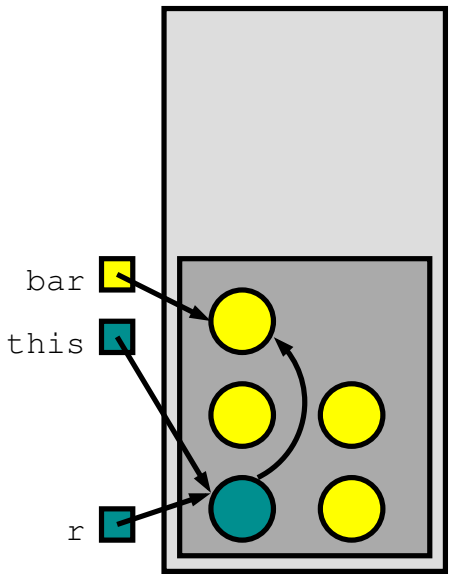

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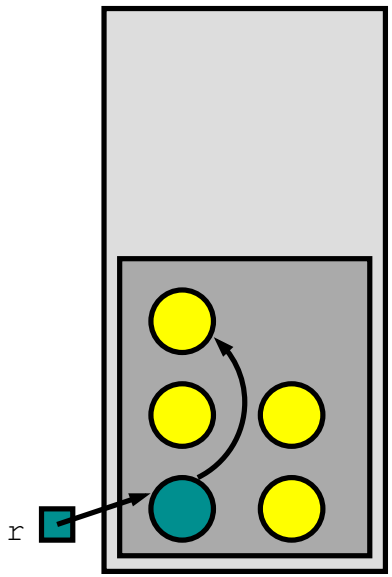

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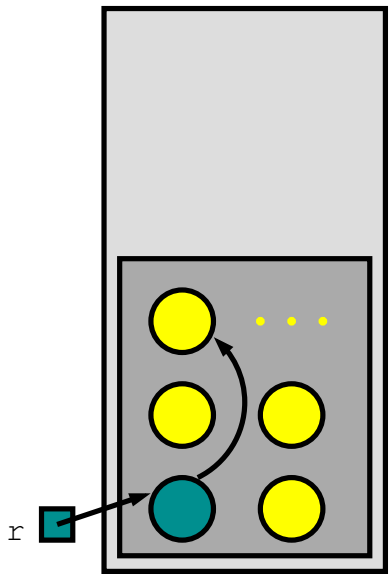

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Region behaviour analysis:

search for bad paths in the call+interference graph...

...and report them to the programmer

Outline

Conclusion and perspectives

Results:

- a new region inference algorithm
- regions work fine for most programming patterns
- compile-time feedback to the programmer otherwise

Work in progress:

- improvement of the allocation policy
  - combination with a reference counting GC

Perspectives:

- extension to concurrency