LeakChecker: Practical Static Memory Leak Detection for Managed Languages

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Memory Leaks in Managed Languages

- Languages such as Java still have memory leaks: unnecessary references keep unused objects alive
- Static leak detection
  - Widely used for unmanaged languages such as C
  - Cannot be applied to managed languages: no explicit memory deallocation
- General definition of leaks
  - Precision: difficult to compute object liveness precisely
  - Performance: limited scalability for large programs
- Our approach
  - Shift the focus, and identify common leak patterns

Proposed Leak Detection for Java

- Observation: leaks are often related to frequently occurring events (e.g., loop iterations)
- Solution: focus on a user-specified event loop
- Observation: a leaking object is often
  - created by one loop iteration
  - escapes this iteration
  - never used in later iterations
- Solution: interprocedural tracking of
  - whether an object escapes to a memory location outside of the loop
  - whether an escaping object flows from the outside location back into a later loop iteration

Example

```
“main”:
Transaction t = new Transaction();
for (int i = 0; i < X; ++i) {
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  Order order = new Order(...);
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class Transaction {
  Order prev;
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  void display() {
    Order r = this.prev;
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  void process(Order p) {
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class Customer {
  Order[] orders = new Order[…];
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An example adapted from SPECjbb2000

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outside object

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store_{16}

$$\begin{tikzcd}
\mathrm{Order}_4 \arrow[r, "\mathit{store}_{16}"] \arrow[r, dashed, bend right, "\mathit{escape}"'] & \mathrm{Transaction}_1
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$\boxed{\texttt{Order r = this.prev;}}$ *$load_{11}$*

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(i+1)-th iteration

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i-th iteration

leaking?

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leaking

non-leaking

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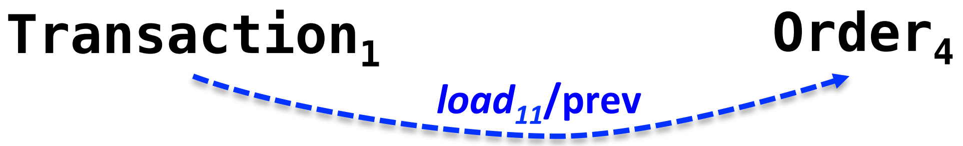
$$\begin{tikzcd}\texttt{Transaction}_1 \arrow[r, dashed, bend right, "load_{11}/\text{prev}"'] & \texttt{Order}_4\end{tikzcd}$$

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outside object

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`Order`$_4$ `Transaction`$_1$

i-th iteration

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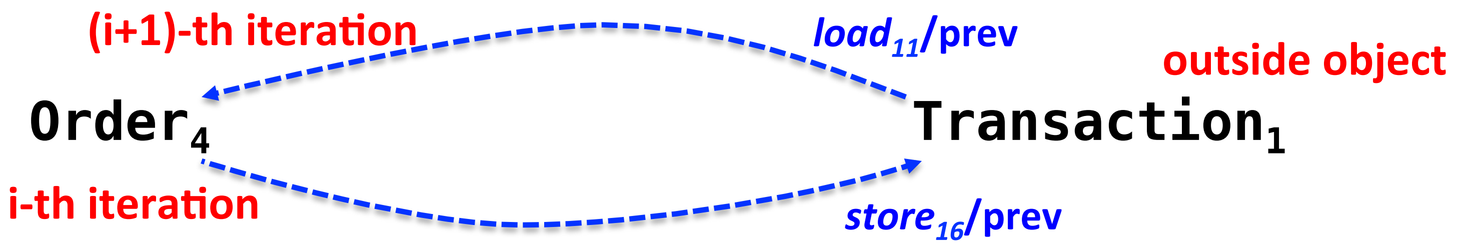
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  - Captured by extended recency abstraction (ERA)

Static Analysis Outline (cont.)

- On-demand analysis
  - Detect leaks only for objects allocated in specified loops
  - Context-free language reachability to match relevant store/load and call/return
- Conservative handling of thread lifetime
  - Assume the lifetime of each thread exceeds the loop lifetime
  - Capture objects leaking to long-running threads

Analysis Implementation

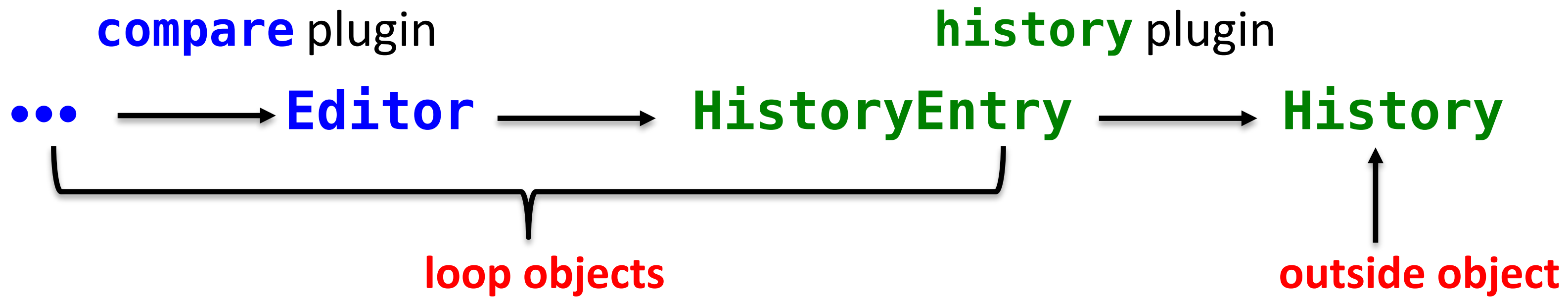
- Memory leak
  - An object leaks if it starts a flows-out path, but does not have a matching flows-in path
- Reporting leaks
  - Leaking object, with calling context of its allocation
  - Outside target object, with calling context of its allocation
  - Escape-causing heap write (store) statement, with its calling context
- LeakChecker: leak detection tool built using Soot

Evaluation

- 8 real-world Java programs
  - Enterprise trading, software tools, databases, logging
  - 3 programs never studied by existing work
- Effective for leak detection?
  - LeakChecker detected both known and new leaks
- Suitable for practical use?
  - Analysis running time (all < 35 mins)
  - Reasonable false positive rate (avg < 50%)
- Case studies
  - Performed to understand quality of leak report
  - For each leak defect, pinpoint root cause and fix the problem in < 2 hours

Eclipse Diff

- Scenario: compare two large JAR files
  - `runCompare` method in **`compare`** plugin
  - An artificial loop to invoke `runCompare` multiple times
- Loop objects
  - `Editor`: display comparison results
  - `HistoryEntry`: represent list of opened editors, and allow users to navigate them backward/forward
- Outside object
  - `History`: managed by another plugin to save `HistoryEntry`



Conclusions

- LeakChecker is both effective and practical
- Key insights
  - Capture common patterns of leaking behavior
  - Focus on user-specified event loops
  - Report leaks with detailed context information

Thank you