Diagnosing Memory Leaks using Graph Mining on Heap Dumps

Evan K. Maxwell, Godmar Back, Naren Ramakrishnan

Virginia Tech, Department of Computer Science

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Memory Leaks

Exception in thread "main": java.lang.OutOfMemoryError

Effects:
- Exhaustion of heap memory
- Application slowdowns and crashes

Detection difficulties:
- Leak source ≠ observed failure
- Heap reachability graph
- Large heap size
Memory Leaks

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Existing methods:
- Tools:
  - Eclipse MAT\(^1\)
  - IBM’s LeakBot\(^2\)
- Static (post-mortem)\(^1\) vs. dynamic (runtime)\(^2\) heap analysis
- Object size
public class HiddenLeak
{
    static HashMap legitimateMap;

    static class Legitimate
    {
        HashMap leakyMap = new HashMap();

        static class Leak
        {
            // This object is leaked
        }

        void leak()
        {
            // insert Leak instances
            // into leakyMap
        }
    }

    public static void main(String []av)
    {
        // insert Legitimate instances
        // into legitimateMap
    }

    HiddenLeak.java
Compute Dominator Tree

- Edges indicate object ownership/liveness
- 44-61% edge reduction

(i) An example graph and (ii) its dominator tree.
Our Approach

1. Leaks manifest as frequent subgraphs.
2. Dominator tree shows object liveness.
3. Frequent subgraphs equivalent from graph to dominator tree.
4. Root path summarization shows objects’ location.
Graph Grammar Mining

- Recursive constructs → data structure usage.
- Variable labels → inexact pattern matching.
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Root Path Analysis

- Summarization of object ownership
- Provides context
HiddenLeak.java

```java
java.lang.Class | (legitimateMap) 
++---> java.util.HashMap | (table) 
++---> [Ljava.util.HashMap$Entry; | ($array$)
++---> java.util.HashMap$Entry | (value)
++---> HiddenLeak$Legitimate | (leakyMap)
++---> java.util.HashMap | (table)
++---> [Ljava.util.HashMap$Entry; | ($array$)
++---> java.util.HashMap$Entry
```

E.K. Maxwell
Virginia Tech, Department of Computer Science
MVEL Parser Leak

- ~1.7 million objects.
- ~4 million references.
- Manual inspection is impractical.
Contributions

Graph Mining:
- Dominator tree for graph reduction.

Memory Leak Detection:
- First static analysis method using graph mining.
- Graph grammars indicate data structures.
- Subgraph frequency + root path summarization = context.
Thank You