Automatic Memory Management

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Automatic Memory Management

Rationale

Explicit memory management (via, e.g. `malloc()` and `free()`) is prone to errors. All modern languages provide forms of automatic memory management, also called "implicit memory management."

- Manual (explicit) memory management is difficult, many errors are possible
  - Free memory too early, risk use-after-free errors
  - Free too late (or forget to free (*)), risk memory leaks
- Requires principled design that identifies ownership and lifetimes of objects
- Complicates design of APIs

Will study

- Garbage Collection: Principles, Implementation, and Tuning
- Reference-counting approaches
- Related Programming Issues: Leaks, Churn, and Bloat

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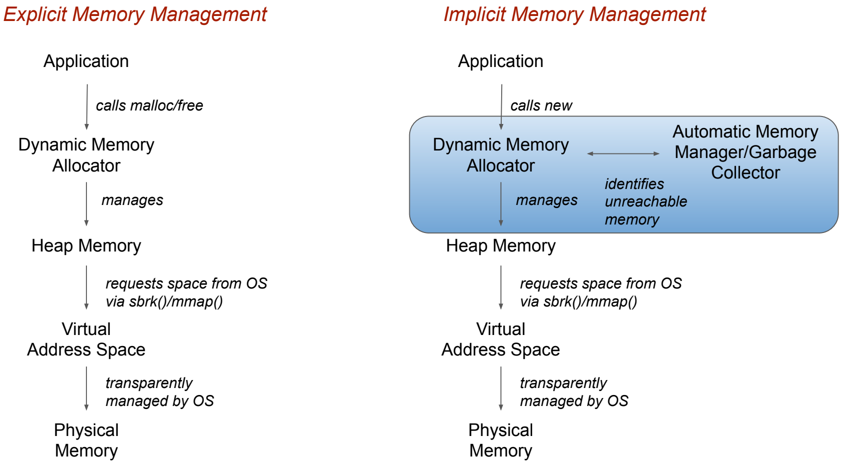
Explicit vs. Implicit Memory Management



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Garbage Collection

Key Idea

Identify those objects that the program may be accessing in the future. Keep them, reclaim the rest.

- Invented in 1960 by McCarthy for LISP [1]
- Assumption: well-defined programs cannot legally access objects to which they do not have pointers/references
  - Assumes no pointer $\leftrightarrow$ integer conversion
- Objects that can be accessed are said to be reachable
- We do not know if program will access any reachable object in the future
  - Those that won't be accessed are said to be leaked
- Essential abstraction: reachability graph

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Reachability Graph: Java Example

```java
class B {
  int x, y;
  B(int x, int y) {
    this.x = x;
    this.y = y;
  }
}

public class A {
    static A S;
    B f;
    public static void main(String[] args) {
      S = new A();
      A local = new A();
      B b = new B(1, 2);
      set(local, b);
      b = null;
      local = null;
    }
    static void set(A t, B b) {
      t.f = b;
    }
}
```

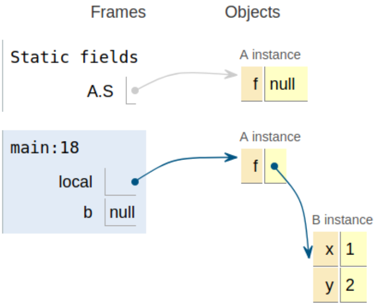

Figure 1: Reachability graph after setting `b = null`. Made with http://pythontutor.com/java.html

Mark and Sweep Garbage Collection

- Identify roots, e.g., in Java
  - Static fields
  - Local variables of in-progress method calls of all threads
  - JVM Internal roots
- Traverse the entire heap via, e.g. DFS, "mark"ing all reachable objects
- Reclaim ("sweep") all objects not marked

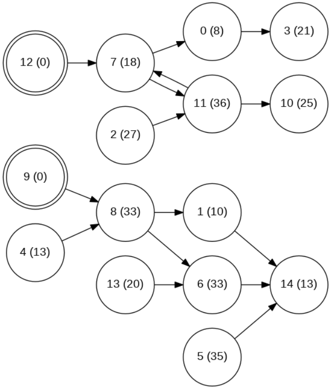

Figure 2: Reachability Graph

References

[1] John McCarthy.
Recursive functions of symbolic expressions and their computation by machine, part I.
Communications of the ACM, 3(4):184–195, 1960.

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