Announcements

- HW5 due Thu Oct 22 at 11:55pm
- How was Project 1?
- How are recitations?

Finish Unions

Unions

- What are they for?
  - same type
  - different possibilities (float, int)
- Kinds of unions?
  - dominated vs. non-dominated
  - know which, else we're done
  - do not know

Exercise

- Define types and code for evaluating an expression language in C (and in SML):
  
  $e ::= n | -e | e + e | e * e$

  ```c
  int eval (struct Expr e) {
    ...
    struct Expr s {
      ...
      struct Union {
        ...}
      ...
    }
    ...
  }
  ```
Pointers

• A pointer type include values that range over memory addresses
• ... and often an additional distinguished value null.
  - “The Billion Dollar Mistake”

Problem: Dangling Pointer

• What is it?
  1. Pointing to a caller’s stack variable deallocation \( \rightarrow \) at return
  2. Heap
    - delete \( p_i \)
    - \( p = \text{null} \)
    - \( n_i \)
Problem: Dangling Pointer
• What is it?

Problem: Dangling Pointer
• What problems can it cause?

Problem: Dangling Pointer
• Possible solutions?
  • Avoid leaks = be a good programmer
  • Tackling
    • lost or unchecked
    • forced memory leak
  • Garbage Collection
    • takes memory management out of the control of programmers

Problem: Memory Leak
• What is it?

Problem: Memory Leak
• What is it?
Problem: Memory Leak

• What problems can it cause?
  - Run out of memory at some point

Problem: Memory Leak

• What problems can it cause?

Problem: Memory Leak

• Possible solutions?
  - Garbage collection (partially)

Garbage Collection

Garbage Collection: Reference Counting

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Garbage Collection: Reference Counting

For Next Time
- Reading
- Online discussion forum
  - ≥1 substantive question, comment, or answer each week
- Work on HW3

Garbage Collection: Mark-and-Sweep