CS345H: Programming Languages

Lecture 16: Imperative Languages II

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Overview

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- Specifically, we wrote operational semantics for the IMP1 language
- Today: How to give semantics to more feature-rich imperative languages

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- A pointer is a reference to a memory location
- Pointers are naturally supported by hardware through load and store instructions
- In fact, pretty much all code turns into pointer manipulation at the assembly level

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  - Clever and efficient data structures
  - Avoid copying of data if it can be shared
- It is not uncommon for pointers to to be 100x faster than copying data!
- For this reason, pointers are essential for most performance-critical task.

A Simple Pointer Language

- Let us consider the following simple language with pointers we will call IMP2:

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\begin{array}{lcl}
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- Addition: Alloc allocates fresh memory

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- Recall: So far, we only had a environment.
- The environment mapped variables to values
- But how can we look up the value of a pointer?

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  - An environment E mapping variables to addresses
  - A store S mapping addresses to values stored at this address
- The store is emulating memory when executing a program!

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- Statements now both change the environment and the store!

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$$\frac{\begin{array}{c} l_f \text{ fresh} \\ S' = S[l_f \leftarrow 0] \\ S'' = S'[E(v) \leftarrow l_f] \end{array}}{E, S \vdash id = \text{alloc} : E, S''}$$

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- Question: How can we solve this problem?

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- Semantics of `declare id`:

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- This is the solution preferred by most imperative languages

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- This is very bad news for any kind of expressive type system

Run-time errors

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- This is another typical "side effect" of adding pointers to a language

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- Popular because fast
  - Accessing an element only requires adding to the base pointer
  - Can perform in-place updates of values

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- Also, assume that `alloc` allocates arrays of infinite size

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- Pointer store `*id = e` is the same as `id[0] = e`

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- First order of business: Array load

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- Observe how this is a generalization of the earlier rule for pointer load

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- What do we have to do to store a value?
  - Evaluate e_2 to v_i
  - Look up the address l_1 of the variable v in E
  - Look up the value of l_1 in S as l_2
  - Change the value of $l_2 + v_i$ in S to e_1's value

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- Again, this is a direct generalization of the store rule in IMP3

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- You will write semantics for an array language without pointers on the homework

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  - Expressions with side effects (e.g., `i++`)
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- If you think a little, you can now write semantics for any missing feature

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- But your goal is to add them cleanly!