CS 520: Introduction to Artificial Intelligence

Prof. Louis Steinberg

Lecture 8:

Knowledge-based Agents

Propositional Logic

Review - Lisp

Symbol value vs meaning as function

- **Value:**
  - Assign with `(setf var <expression>)`
  - Create local binding with let or let*

```
(let* ((var <expr>)
       (var <expr>) …)
  <expr>  …  )
```

- **Meaning as function**
  - Set global meaning with `defun`
  - Create local scope with `flet` or `labels`

Review

Functions as arguments

- ***Value* of `#'foo` is *function meaning* of `foo`**
- **`(funcall fn-expr argx1` … `argxn)` means treat *value* of fn-expr as a function, call it with values of `argx1` … `argxn` as arguments**

Review - Lexical Scope

- **Scope of a variable is *syntactic* scope of `let`, `defun`, etc.**
- **If a function is created, it carries bindings with it**
  - **Closure: represents function, points to binding & code**

Closures

```
(defun counter (n)
  #'(lambda (i)
      (setf n(+ n i))))
(let((c1 (counter 4))
     (c2 (counter 0)))
  (list
    (funcall c1 10)
    (funcall c2 3)
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=> (14 3 5 74)
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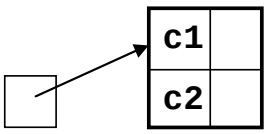

stack

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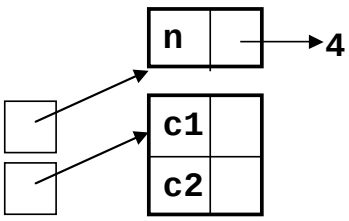

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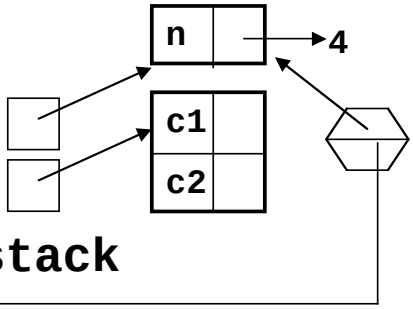

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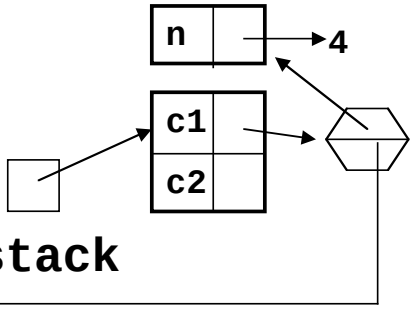

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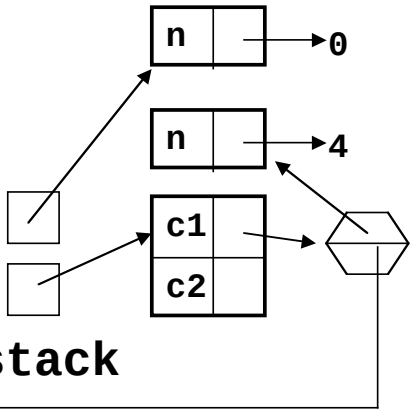

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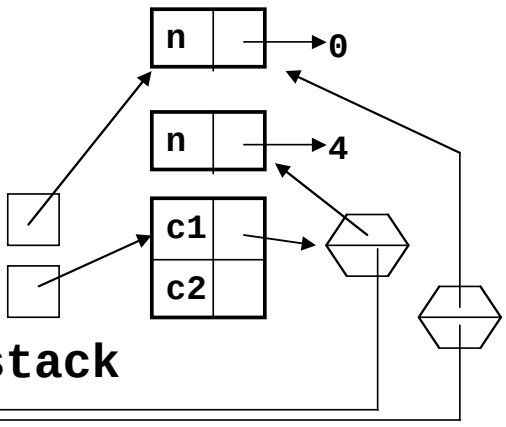

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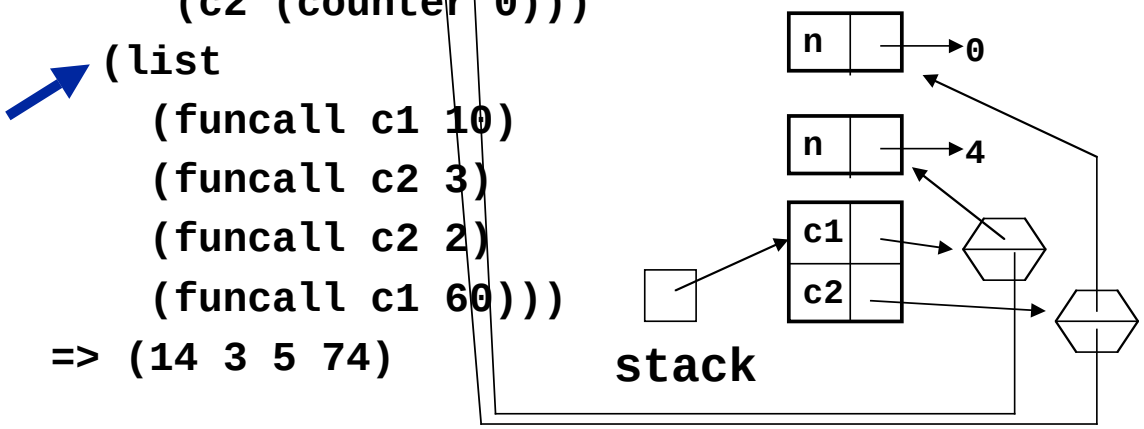

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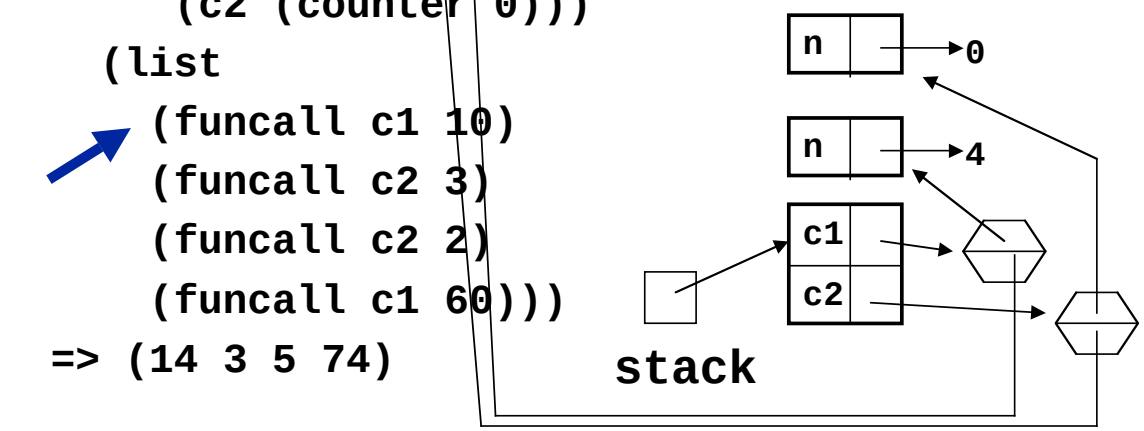

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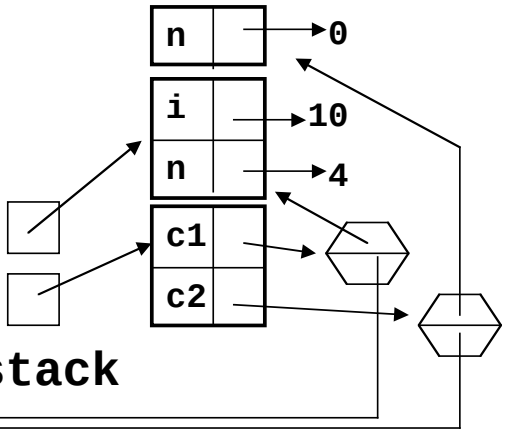

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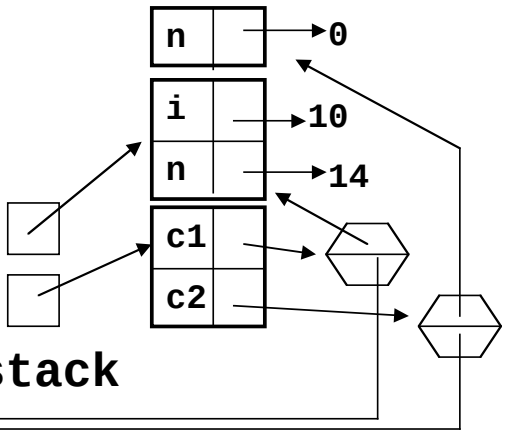

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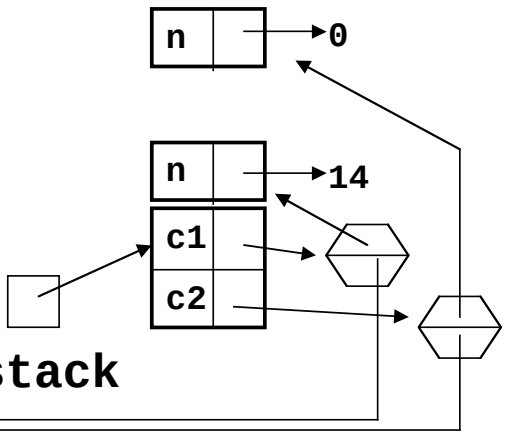


Programming Techniques

- Data-driven programming
- To write a program for X, extend Lisp to be a good language for X

Quiz

- **Write code for some.**

  (some fn list) calls fn on each element of list until a call returns non-nil, then returns that value. If all calls return nil, some returns nil.

  (some #'oddp '(2 4 5)) => t

  (some #'oddp '(2 4 6))=> nil

Mechanisms for Intelligence

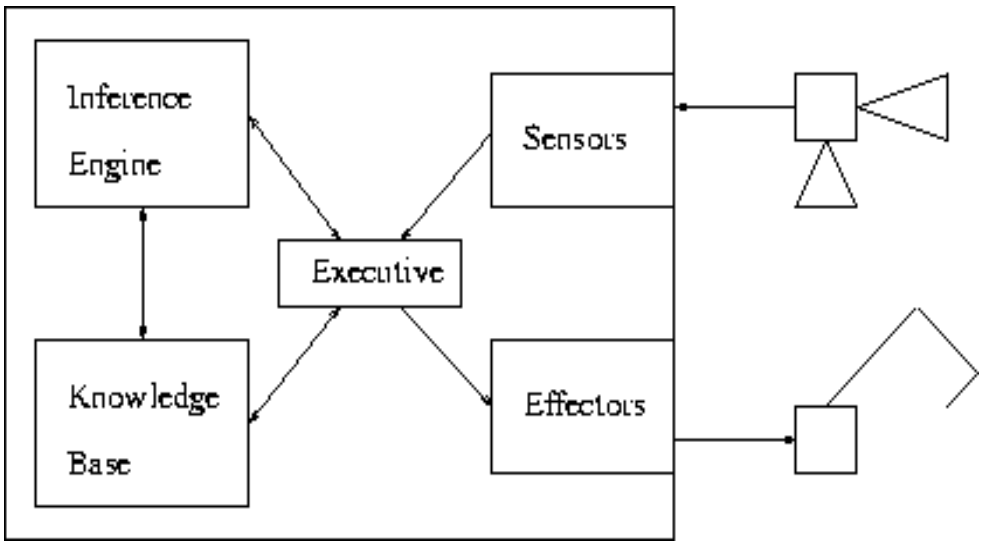
Given a problem, formalize it as an instance of a general class of problems, which you know how to solve

- **Search**
  - **Water jugs => graph search**
  - **N Queens => constraint satisfaction**
  - **Chess => minimax tree**
- **Inference**

Knowledge-Based Agents

- **A knowledge-based agent has knowledge of the world (its environment) and knowledge of its actions.**
- **Using logical reasoning, it maintains a description of the world, and will try to determine an action that will meet its goals.**

Knowledge-based Agent Architecture



Assertions and Queries

- Executive asserts (tells KB) "I sense …."
- Executive queries (asks KB) "What should I do?"
- Internal assertions and queries of KB
  - Sense and Do
  - State of the world
- Eg: (sense obstacle +45 degrees)
  (sense obstacle -45 degrees)
  (sense no obstacle 0 degrees)
  => (facing door)
  => (do move-forward)

Why Inference?

- Ideal:
  - Tell agent *what* is true
    - Fact1, fact2, …
  - Give agent a goal
  - Agent decides for itself *how* to use the facts to attain the goal
- Better than giving agent a program
  - More autonomous
  - For given effort we get agent with more general competence.

Logic

- A logic consists of
  - Formal language: sentences
    - Represent statements about the world
  - Inference mechanism:

    $\{sentence_1, \ldots, sentence_n\} \Rightarrow sentence_{n+1}$
    - Creates new sentences
- Eg, propositional logic

Propositional Logic

- Language:
  - Symbols: a, b, …
  - Operators: ¬, ^, v, =>, ( )
- Semantics:
  - Symbol represents a statement about world that is either true or false
  - Operators combine truth values

a = “it is raining”, b = “the sidewalk is wet”
a^b = “it is raining and the sidewalk is wet”

Models

- **Model:**
  - **An assignment of real-world meaning to the symbols of a logic**
- **A sentence in a logic may be true or false with respect to a model**
- **A sentence may be such that it is *true* in *every* model: "tautology"**
- **A sentence may be such that it is *true* in *some* model: "satisfiable"**
- **A sentence may be such that it is *false* in *every* model: "contradiction"**

Validity of Inference

- **An inference rule**
  {old sentences} -> new-sentence
  is *valid* if for every model it is true that
  - **If meaning(old-sentences) is true**
    then meaning(new-sentence) must be true
- **IE, (old-sentences => new-sentence) is a tautology**
  - **Old-sentences *entail* new sentence**

Soundness and Completeness

- **An inference mechanism is sound or truth-preserving if it generates from the KB only sentences that are entailed by the KB.**
- **Tracing through the steps of deriving a sentence from a KB using a sound inference mechanism is called a proof .**
- **If the inference mechanism can derive any sentence that is entailed by the KB, the mechanism is said to be complete .**

Propositional Inference

- **We can test entailment in propositional logic with a truth table**

  (A ^ B) entails ¬(¬A v ¬B)

A	B	(A ^ B)	¬(¬A v ¬B)
T	T	T	T
T	F	F	F
F	T	F	F
F	F	F	F

Inference by Rules

- **Problem: truth table size is exponential in number of variables**
- **Solution: test entailment by searching for a sequence of inference rule applications**

Rules of Inference for Propositional Logic

Modus Ponens : α; $\alpha \Rightarrow \beta$ / β

And-elimination :$\alpha 1 \wedge \alpha 2 \wedge \ldots \alpha n / \alpha 1$

And-introduction …

Or-elimination . . .

Or-introduction …

Double-negation-elimination

Unit resolution

Resolution

…

Resolution

- **Problem: too many rules -> high branching factor for search**
- **Want single complete rule**
  - **Resolution**