Announcements

1. Midterm coming – Dec 5
2. Midterm during lecture time
3. Most of the code used in the class at the EOPL web site: https://eopl3.com

Lecture 9
Representation Strategies for Data Types

T. METIN SEZGIN

The general form of **define-datatype**

```
(define-datatype environment environment?
  (empty-env)
  (extend-env
    (bvar symbol?)
    (bval expval?)
    (saved-env environment?))
  (extend-env-rec
    (id symbol?)
    (bvar symbol?)
    (body expression?)
    (saved-env environment?)))
```

$$(\texttt{define-datatype}\ \textit{type-name}\ \ \textit{type-predicate-name}$$
$$\{(\textit{variant-name}\ \ \{(\textit{field-name}\ \ \textit{predicate})\}^{*})\}^{+})$$

Example uses of `define-datatype`

$$
\begin{aligned}
\mathit{S\text{-}list} &::= (\{\mathit{S\text{-}exp}\}^*) \\
\mathit{S\text{-}exp} &::= \mathit{Symbol} \mid \mathit{S\text{-}list}
\end{aligned}
$$

```
(define-datatype s-list s-list?
  (empty-s-list)
  (non-empty-s-list
    (first s-exp?)
    (rest s-list?)))

(define-datatype s-exp s-exp?
  (symbol-s-exp
    (sym symbol?))
  (s-list-s-exp
    (slst s-list?)))
```

Lecture 10
Abstract Syntax, Representation, Interpretation

T. METIN SEZGIN

Nuggets of the lecture

- Syntax is all about structure
- Semantics is all about meaning
- We can use abstract syntax to represent programs as trees
- Parsing takes a program builds a syntax tree
- Unparsing converts abstract tree to a text file
- Big picture of compilers and interpreters

Human vs. the computer

- Lambda calculus

$$\begin{aligned} \mathit{LcExp} &::= \mathit{Identifier} \\ &::= (\texttt{lambda}\ (\mathit{Identifier})\ \mathit{LcExp}) \\ &::= (\mathit{LcExp}\ \mathit{LcExp}) \end{aligned}$$

- Alternative syntax

$$\begin{aligned} \mathit{Lc\text{-}exp} &::= \mathit{Identifier} \\ &::= \texttt{proc}\ \mathit{Identifier}\ \texttt{=>}\ \mathit{Lc\text{-}exp} \\ &::= \mathit{Lc\text{-}exp}\ (\mathit{Lc\text{-}exp}) \end{aligned}$$

- The computer

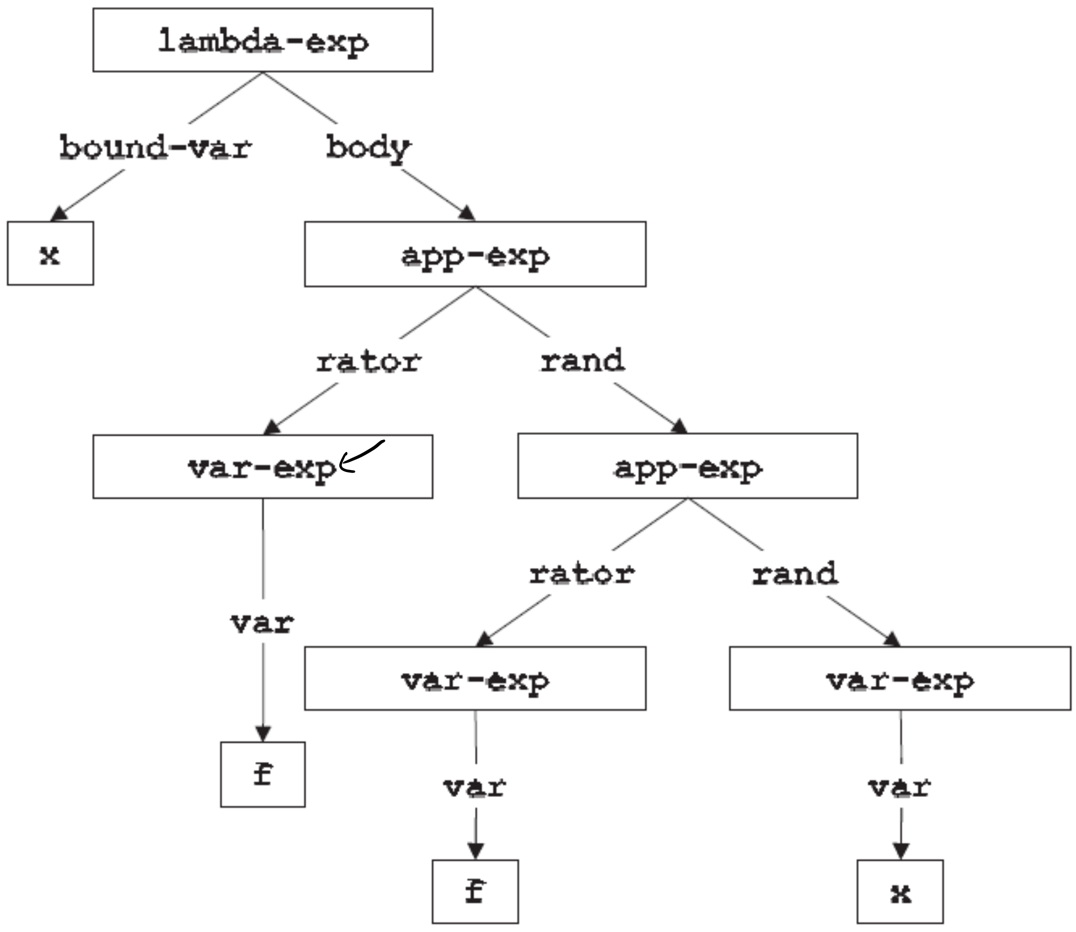
```
(define-datatype lc-exp lc-exp?
  (var-exp
    (var identifier?))
  (lambda-exp
    (bound-var identifier?)
    (body lc-exp?))
  (app-exp
    (rator lc-exp?)
    (rand lc-exp?)))
```

$$\begin{aligned} \mathit{Lc\text{-}exp} &::= \mathit{Identifier} \\ &\quad \boxed{\texttt{var-exp (var)}} \\ &::= (\texttt{lambda}\ (\mathit{Identifier})\ \mathit{Lc\text{-}exp}) \\ &\quad \boxed{\texttt{lambda-exp (bound-var body)}} \\ &::= (\mathit{Lc\text{-}exp}\ \mathit{Lc\text{-}exp}) \\ &\quad \boxed{\texttt{app-exp (rator rand)}} \end{aligned}$$

Nugget

We can use abstract syntax to represent programs as trees

A specific example



Abstract syntax tree for `(lambda (x) (f (f x)))`

Nugget

Parsing takes a program builds a syntax tree

Parsing expressions

parse-expression : $\mathit{SchemeVal} \rightarrow \mathit{LcExp}$

```
(define parse-expression
  (lambda (datum)
    (cond
      ((symbol? datum) (var-exp datum))
      ((pair? datum)
       (if (eqv? (car datum) 'lambda)
         (lambda-exp
           (car (cadr datum))
           (parse-expression (caddr datum)))
         (app-exp
           (parse-expression (car datum))
           (parse-expression (cadr datum)))))
      (else (report-invalid-concrete-syntax datum)))))
```

Nugget

Unparsing goes in the reverse direction

"Unparsing"

unparse-lc-exp : *LcExp* → *SchemeVal*

```
(define unparse-lc-exp
  (lambda (exp)
    (cases lc-exp exp
      (var-exp (var) var)
      (lambda-exp (bound-var body)
        (list 'lambda (list bound-var)
          (unparse-lc-exp body)))
      (app-exp (rator rand)
        (list
```

The next few weeks

- Expressions
- Binding of variables
- Scoping of variables
- Environment
- Interpreters

Nugget

Semantics is all about evaluating programs, finding their "value"

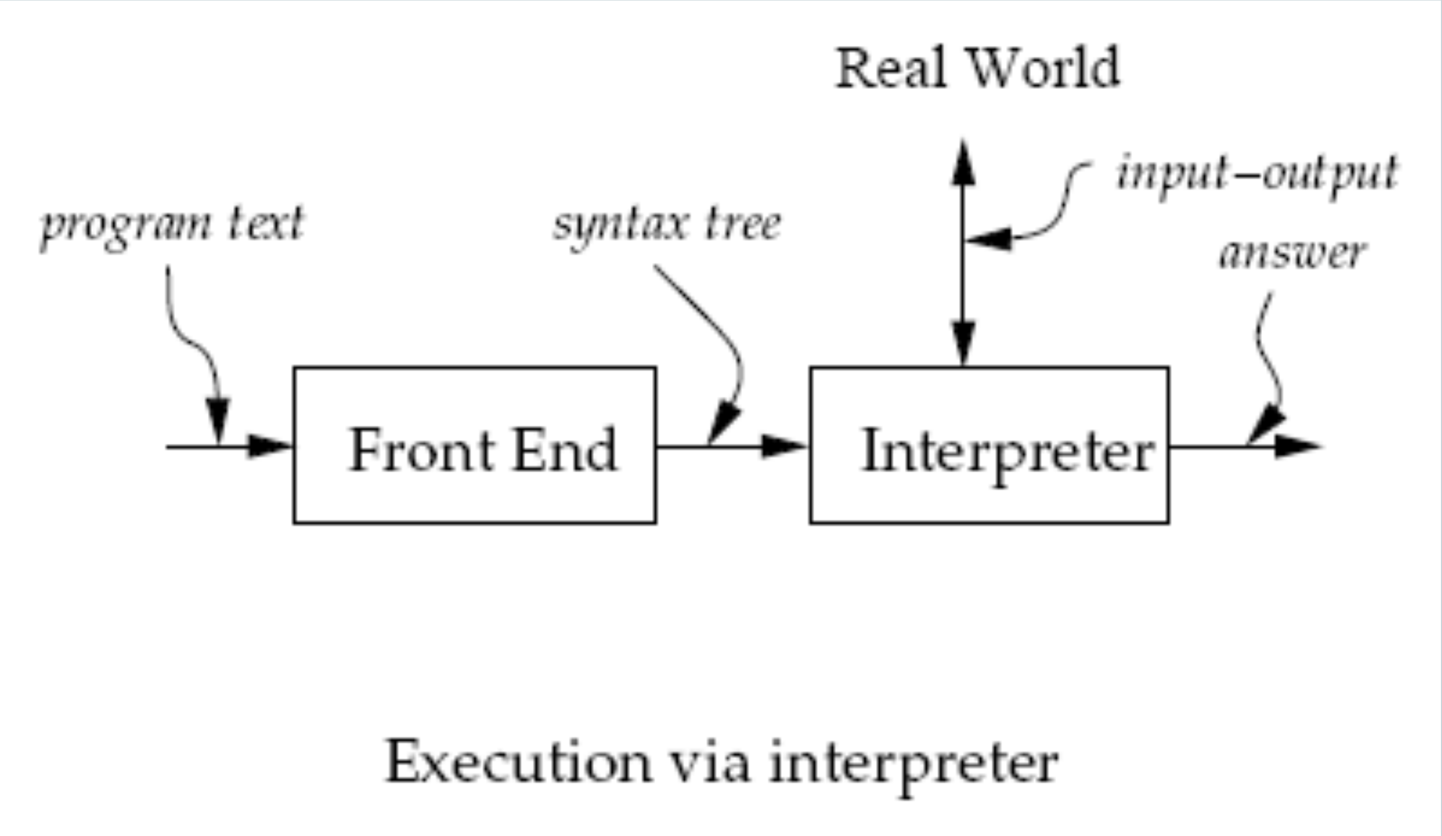
Notation

- Assertions for specification

$$(\texttt{value-of}\ exp\ \ \rho) = val$$

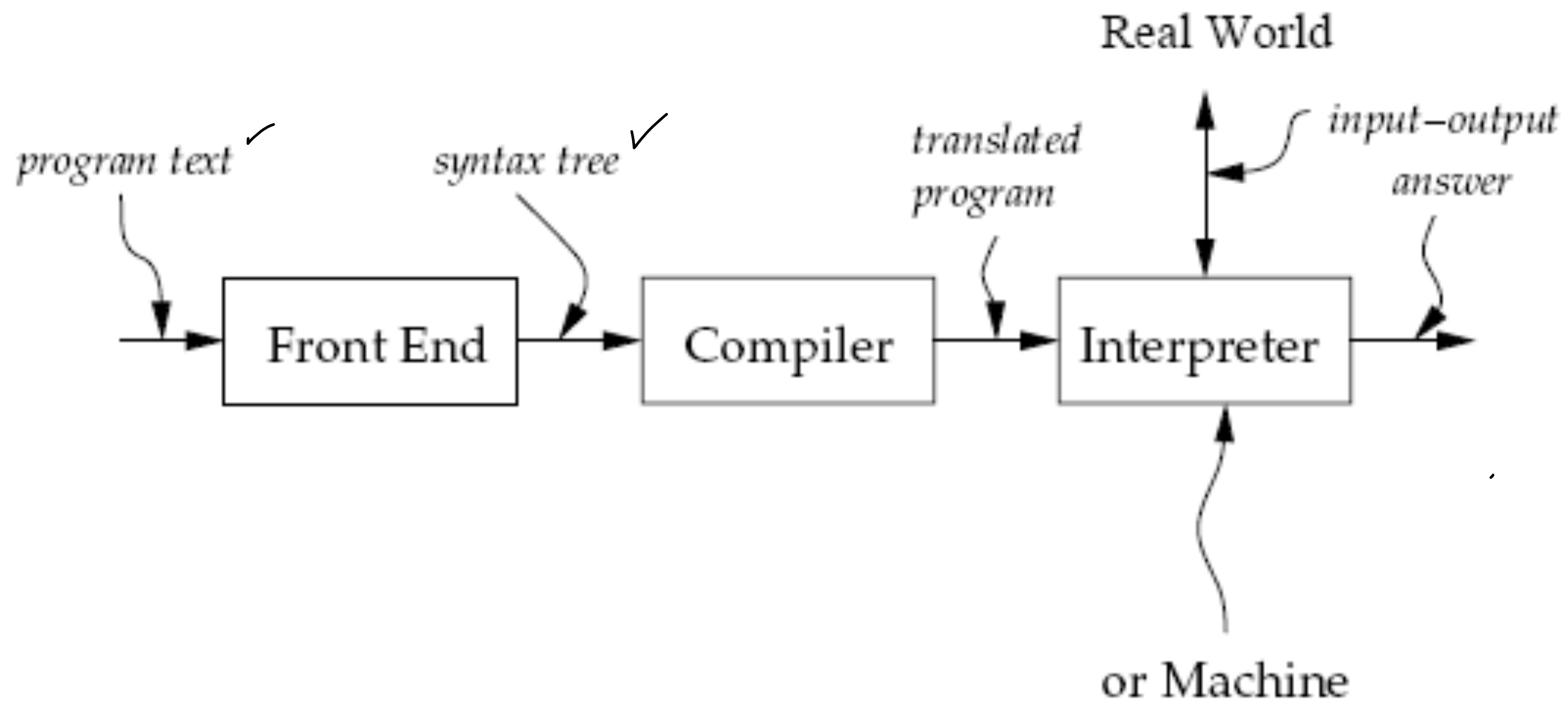
- Use rules from earlier chapters and specifications to compute values

The big picture – interpreter



Source language (defined language), implementation language (defining language), target language,

The big picture – compiler



Execution via Compiler

Source language (defined language), implementation language (defining language), target language, bytecode, virtual machine

About compilation

- Compilation
  - Analyzer
    - Scanning (lexical scanning)
      - Generates
        - Lexemes
        - Lexical items
        - Tokens
    - Parsing
      - Generates
        - AST
        - Syntactic structure
        - Grammatical structure
  - Translator
- All this work simplified
  - Lexical analyzers (lex)
  - Parser generators (yacc)
  - Use scheme ☺

```
int main()
{
        printf("hello, world");
        return 0;
}
```

Nugget

Evaluating programs, requires understanding the expressions of the language

LET: our pet language

$$
\begin{array}{lcl}
\textit{Program} & ::= & \textit{Expression} \\
 & & \boxed{\texttt{a-program (exp1)}} \\[1em]
\textit{Expression} & ::= & \textit{Number} \\
 & & \boxed{\texttt{const-exp (num)}} \\[1em]
\textit{Expression} & ::= & \texttt{-}\,(\textit{Expression}\ \texttt{,}\ \textit{Expression}) \\
 & & \boxed{\texttt{diff-exp (exp1 exp2)}} \\[1em]
\textit{Expression} & ::= & \texttt{zero?}\ (\textit{Expression}) \\
 & & \boxed{\texttt{zero?-exp (exp1)}} \\[1em]
\textit{Expression} & ::= & \texttt{if}\ \textit{Expression}\ \texttt{then}\ \textit{Expression}\ \texttt{else}\ \textit{Expression} \\
 & & \boxed{\texttt{if-exp (exp1 exp2 exp3)}} \\[1em]
\textit{Expression} & ::= & \textit{Identifier} \\
 & & \boxed{\texttt{var-exp (var)}} \\[1em]
\textit{Expression} & ::= & \texttt{let}\ \textit{Identifier}\ \texttt{=}\ \textit{Expression}\ \texttt{in}\ \textit{Expression} \\
 & & \boxed{\texttt{let-exp (var exp1 body)}}
\end{array}
$$

An example program

- Input

```
"-(55, -(x,11))"
```

- Scanning & parsing

```
(scan&parse "-(55, -(x,11))")
```

- The AST

```
#(struct:a-program
   #(struct:diff-exp
      #(struct:const-exp 55)
      #(struct:diff-exp
         #(struct:var-exp x)
         #(struct:const-exp 11))))
```

Program ::= *Expression*
$\boxed{\texttt{a-program (exp1)}}$

Expression ::= *Number*
$\boxed{\texttt{const-exp (num)}}$

Expression ::= `-(`*Expression* `,` *Expression*`)`
$\boxed{\texttt{diff-exp (exp1 exp2)}}$

Expression ::= `zero?` `(`*Expression*`)`
$\boxed{\texttt{zero?-exp (exp1)}}$

Expression ::= `if` *Expression* `then` *Expression* `else` *Expression*
$\boxed{\texttt{if-exp (exp1 exp2 exp3)}}$

Expression ::= *Identifier*
$\boxed{\texttt{var-exp (var)}}$

Expression ::= `let` *Identifier* `=` *Expression* `in` *Expression*
$\boxed{\texttt{let-exp (var exp1 body)}}$