Interpreters

Announcements

Scheme-Syntax Calculator

(Demo)

Calculator Syntax

The Calculator language has primitive expressions and call expressions. (That's it!)

A primitive expression is a number: 2 -4 5.6

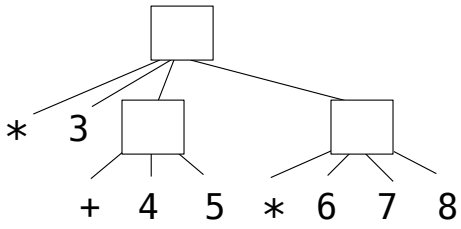
A call expression is a combination that begins with an operator (+, -, *, /) followed by 0 or more expressions: (+ 1 2 3) (/ 3 (+ 4 5))

Expressions are represented as Scheme lists (Pair instances) that encode tree structures.

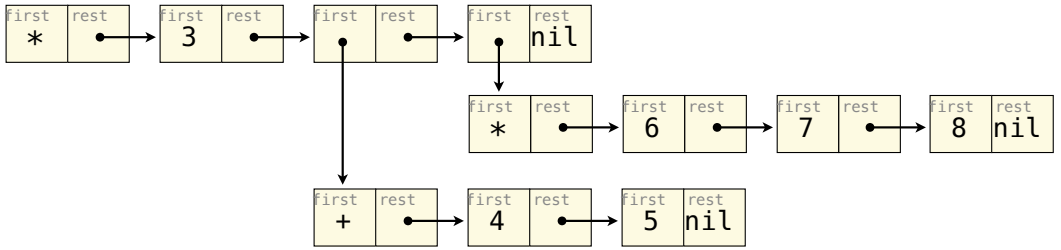
Expression

```
(* 3
   (+ 4 5)
   (* 6 7 8))
```

Expression Tree



Representation as Pairs



Calculator Semantics

The value of a calculator expression is defined recursively.

Primitive: A number evaluates to itself.

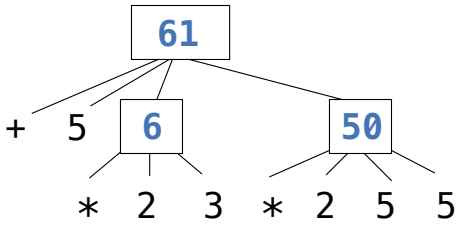
Call: A call expression evaluates to its argument values combined by an operator.

- **+**: Sum of the arguments
- *****: Product of the arguments
- **-**: If one argument, negate it. If more than one, subtract the rest from the first.
- **/**: If one argument, invert it. If more than one, divide the rest from the first.

Expression

```
(+ 5
   (* 2 3)
   (* 2 5 5))
```

Expression Tree



Evaluation

The Eval Function

The eval function computes the value of an expression, which is always a number

It is a generic function that dispatches on the type of the expression (primitive or call)

Implementation

```
def calc_eval(exp):
    if isinstance(exp, (int, float)):
        return exp
    elif isinstance(exp, Pair):
        arguments = exp.rest.map(calc_eval)
        return calc_apply(exp.first, arguments)
    else:
        raise TypeError
```

Recursive call returns a number for each operand

'+', '-', '*', '/'

A Scheme list of numbers

Language Semantics

A number evaluates...

to itself

A call expression evaluates...

to its argument values

combined by an operator

Applying Built-in Operators

The apply function applies some operation to a (Scheme) list of argument values

In calculator, all operations are named by built-in operators: +, -, *, /

Implementation

```
def calc_apply(operator, args):
    if operator == '+':
        return reduce(add, args, 0)
    elif operator == '-':
        ...
    elif operator == '*':
        ...
    elif operator == '/':
        ...
    else:
        raise TypeError
```

Language Semantics

+:
Sum of the arguments
-:
...
...

(Demo)

Interactive Interpreters

Read-Eval-Print Loop

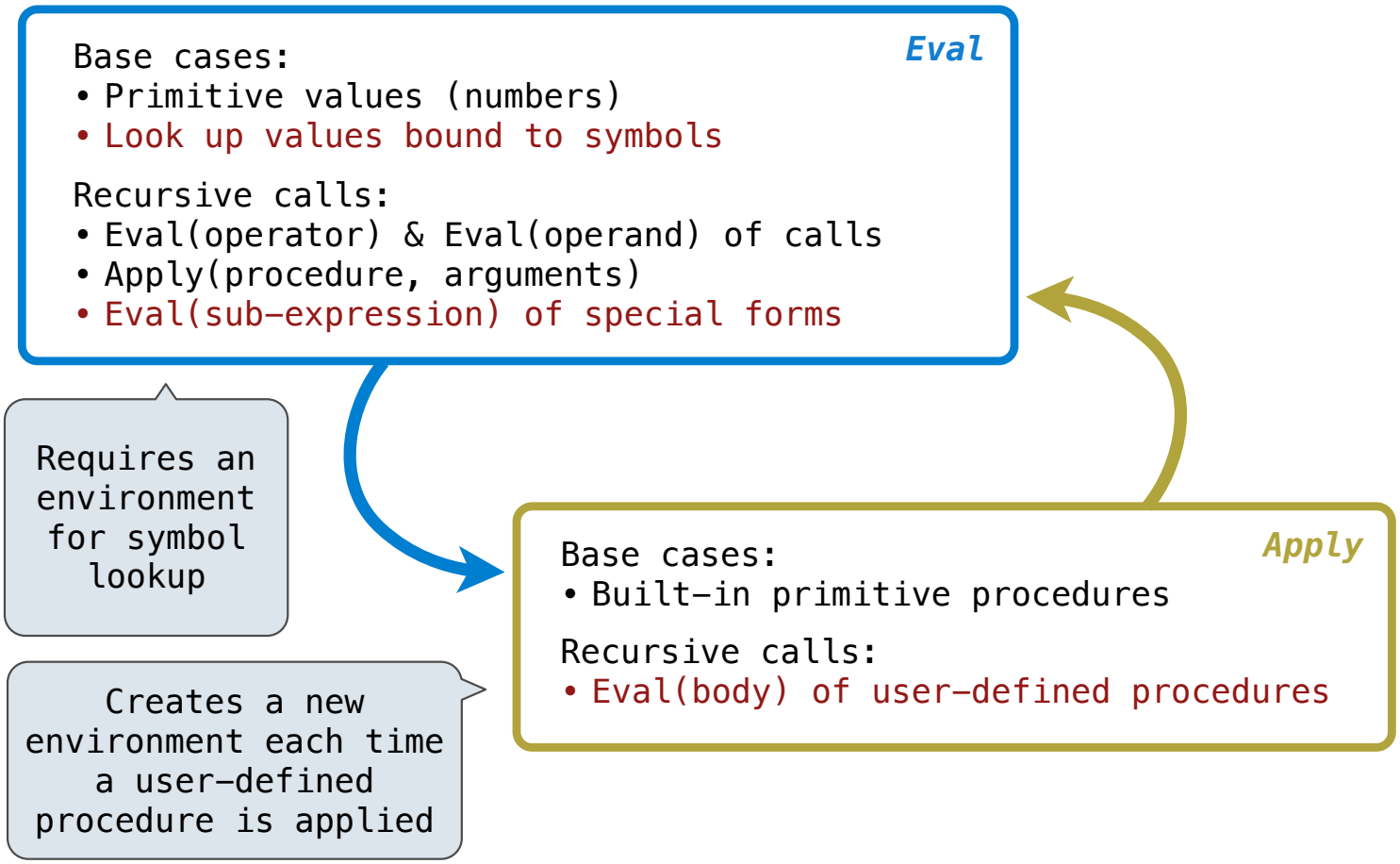
The user interface for many programming languages is an interactive interpreter

1. Print a prompt
2. **Read** text input from the user
3. Parse the text input into an expression
4. **Evaluate** the expression
5. If any errors occur, report those errors, otherwise
6. **Print** the value of the expression and repeat

(Demo)

Interpreting Scheme

The Structure of an Interpreter



Project 4

Pairs in Project 4: Scheme

https://cs61a.org/proj/scheme/

Tokenization/Parsing: Converts text into Python representation of Scheme expressions:

- Numbers are represented as numbers
- Symbols are represented as strings
- Lists are represented as instances of the Pair class

Evaluation: Converts Scheme expressions to values while executing side effects:

- scheme_eval(expr, env) returns the value of an expression in an environment
- scheme_apply(procedure, args) applies a procedure to its arguments
- The Python function scheme_apply returns the return value of the procedure it applies

(Demo)

Discussion Question: The Symbol of a Define Expression

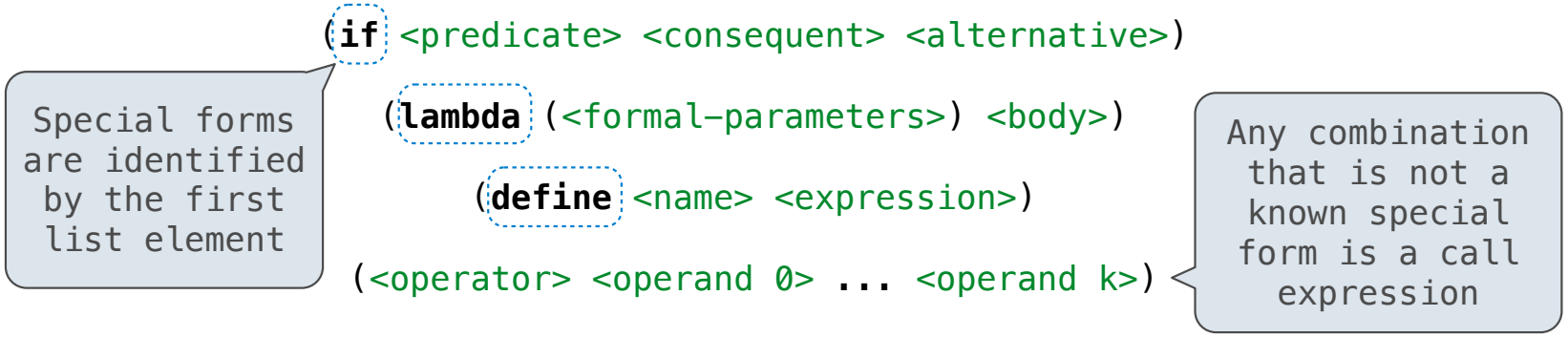
```
Return the symbol of a define expression. There are two formats for define expressions:
(define x (+ 2 3))  or  (define (f x) (+ x 3))
def symbol(exp):
    """Given a define expression exp, return the symbol defined.
    >>> def_x = read_line("(define x (+ 2 3))")
    >>> def_f = read_line("(define (f x) (+ x 3))")
    >>> symbol(def_x)
    'x'
    >>> symbol(def_f)
    'f'
    """
    assert exp.first == 'define' and exp.rest is not nil and exp.rest.rest is not nil
    signature = ____exp.rest.first____
    if scheme_symbolp(signature):
        return signature
    else:
        return ____signature.first____
```

Special Forms

Scheme Evaluation

The scheme_eval function choose behavior based on expression form:

- Symbols are looked up in the current environment
- Self-evaluating expressions are returned as values
- All other legal expressions are represented as Scheme lists, called combinations




```
(define (demo s) (if (null? s) '(3) (cons (car s) (demo (cdr s))) ))

(demo (list 1 2))
```

Lambda Expressions

Lambda Expressions

Lambda expressions evaluate to user-defined procedures

```
(lambda (<formal-parameters>) <body>)
```

```
(lambda (x) (* x x))
```

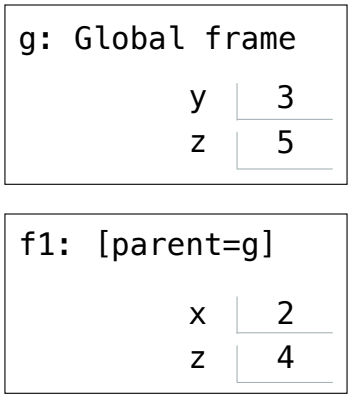
```
class LambdaProcedure:
    def __init__(self, formals, body, env):
        self.formals = formals ..... A scheme list of symbols
        self.body = body ..... A scheme list of expressions
        self.env = env ..... A Frame instance
```

Frames and Environments

A frame represents an environment by having a parent frame

Frames are Python instances with methods **lookup** and **define**

In Project 4, Frames do not hold return values



(Demo)