CSc 520

Principles of Programming Languages

34 : Scheme — Introduction

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Background

- Scheme is based on LISP which was developed by John McCarthy in the mid 50s.
- LISP stands for *LISt Processing*, not *Lots of Irritating Silly Parentheses*.
- Functions and data share the same representation: S-Expressions.
- A basic LISP implementation needs six functions `cons, car, cdr, equal, atom, cond`.
- Scheme was developed by Sussman and Steele in 1975.

[2]

S-Expressions

- An S-Expression is a balanced list of parentheses.

More formally, an S-expression is

1. a literal (i.e., number, boolean, symbol, character, string, or empty list).
2. a list of s-expressions.

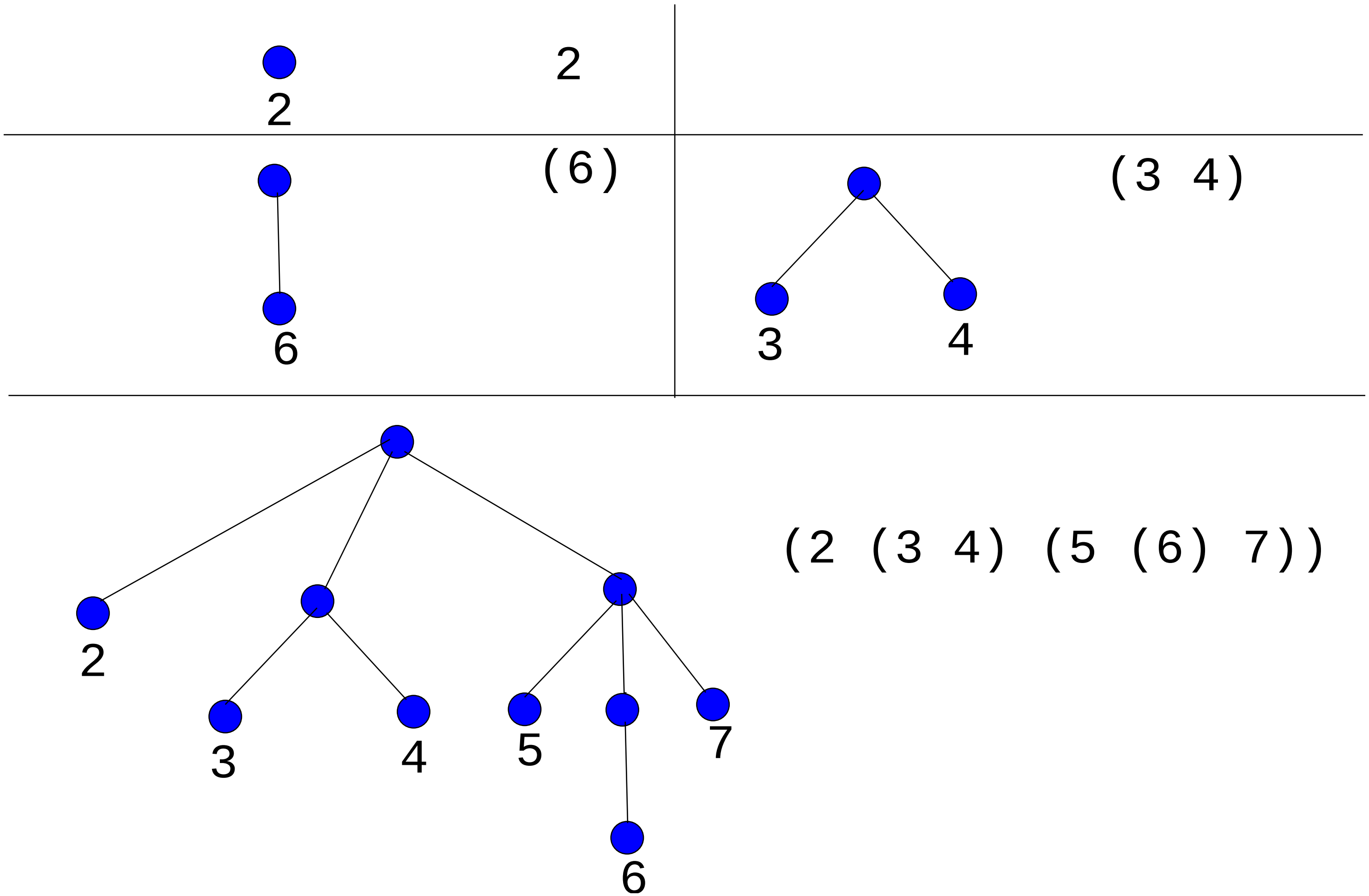
- Literals are sometimes called atoms.

S-Expressions — Examples

Legal	Illegal
`66`	`(`
`()`	`(5))`
`(4 5)`	`()()`
`((5))`	`(4 (5)`
`(()())`	`)(`
`((4 5) (6 (7)))`	

S-Expressions as Trees

- An S-expression can be seen as a linear representation of tree-structure:



S-Expressions as Function Calls

- A special case of an S-expression is when the first element of a list is a function name.
- Such an expression can be evaluated.

```
> (+ 4 5)
9
> (add-five-to-my-argument 20)
25
> (draw-a-circle 20 45)
#t
```

S-Expressions as Functions

- As we will see, function definitions are also S-expressions:

```
(define (farenheit-2-celsius f)
  (* (- f 32) 5/9)
)
```

- So, Scheme really only has one syntactic structure, the S-expression, and that is used as a data-structure (to represent lists, trees, etc), as function definitions, and as function calls.

Function Application

- In general, a function application is written like this:

$$(\texttt{operator}\ \texttt{arg}_1\ \texttt{arg}_2\ \ldots\ \texttt{arg}_n)$$

- The evaluation proceeds as follows:
  1. Evaluate `operator`. The result should be a function $\mathcal{F}$.
  2. Evaluate

     $$\texttt{arg}_1,\ \texttt{arg}_2,\ \ldots\ \texttt{arg}_n$$

     to get

     $$\texttt{val}_1,\ \texttt{val}_2,\ \ldots\ \texttt{val}_n$$

  3. Apply $\mathcal{F}$ to $\texttt{val}_1,\ \texttt{val}_2,\ \ldots\ \texttt{val}_n$.

Function Application — Examples

```
> (+ 4 5)
9
> (+ (+ 5 6) 3)
14
> 7
7
> (4 5 6)
eval:  4 is not a function
> #t
#t
```

Atoms — Numbers

Scheme has

- Fractions (`5/9`)
- Integers (`5435`)
- Complex numbers (`5+2i`)
- Inexact reals (`#i3.14159265`)

```
> (+ 5 4)
9
> (+ (* 5 4) 3)
23
> (+ 5/9 4/6)
1.2
> 5/9
0.5
```

Atoms — Numbers. . .

```
> (+ 5/9 8/18)
1
> 5+2i
5+2i
> (+ 5+2i 3-i)
8+1i
> (* 236542164521634 3746573426573425643)
886222587860913289285513763860662
> pi
#i3.141592653589793
> e
#i2.718281828459045
> (* 2 pi)
#i6.283185307179586
```

Atoms — Numbers. . .

- Scheme tries to do arithmetic exactly, as much as possible.
- Any computations that depend on an inexact value becomes inexact.
- Scheme has many builtin mathematical functions:

```
> (sqrt 16)
4
> (sqrt 2)
#i1.4142135623730951
> (sin 45)
#i0.8509035245341184
> (sin (/ pi 2))
#i1.0
```

Atoms — Strings

- A string is enclosed in double quotes.

```
> (display "hello")
hello
> "hello"
"hello"
> (string-length "hello")
5
> (string-append "hello" " " "world!")
"hello world!"
```

Atoms — Booleans

- `true` is written `#t`.
- `false` is written `#f`.

```
> #t
true
> #f
false
> (display #t)
#t
> (not #t)
false
```

Identifiers

- Unlike languages like C and Java, Scheme allows identifiers to contain special characters, such as `! $ % & * + - . / : < = > ? @ ^ _ ~`. Identifiers should not begin with a character that can begin a number.
- This is a consequence of Scheme's simple syntax.
- You couldn't do this in Java because then there would be many ways to interpret the expression `X-5+Y`.

Legal	Illegal
`h-e-l-l-o`	`3some`
`give-me!`	`-stance`
`WTF?`	

Defining Variables

- define binds an expression to a global name:

  (define name *expression*)

```
(define PI 3.14)

> PI
3.14

(define High-School-PI (/ 22 7))

> High-School-PI
3.142857
```

Defining Functions

- define binds an expression to a global name:

  (define (name $\mathtt{arg}_1$ $\mathtt{arg}_2$ ...) *expression*)

- $\mathtt{arg}_1$ $\mathtt{arg}_2$ ... are formal function parameters.

```
(define (f) 'hello)

> (f)
hello

(define (square x) (* x x))

> (square 3)
9
```

Defining Helper Functions

- A Scheme program consists of a large number of functions.
- A function typically is defined by calling other functions, so called helper or auxiliary functions.

```
(define (square x) (* x x))

(define (cube x) (* x (square x)))

> (cube 3)
27
```

Preventing Evaluation

- Sometimes you don't want an expression to be evaluated.
- For example, you may want to think of (+ 4 5) as a list of three elements +, 4, and 5, rather than as the computed value 9.
- (quote (+ 4 5)) prevents `(+ 4 5)` from being evaluated. You can also write '(+ 4 5).

```
> (display (+ 4 5))
9
> (display (quote (+ 4 5)))
(+ 4 5)
> (display '(+ 4 5))
(+ 4 5)
```

Dr Scheme

- Download DrScheme from here: `http://www.drscheme.org`.
- It has already been installed for you in lectura and the Windows machines in the lab.
- Start DrScheme under unix (on lectura) by saying

```
> drscheme
```

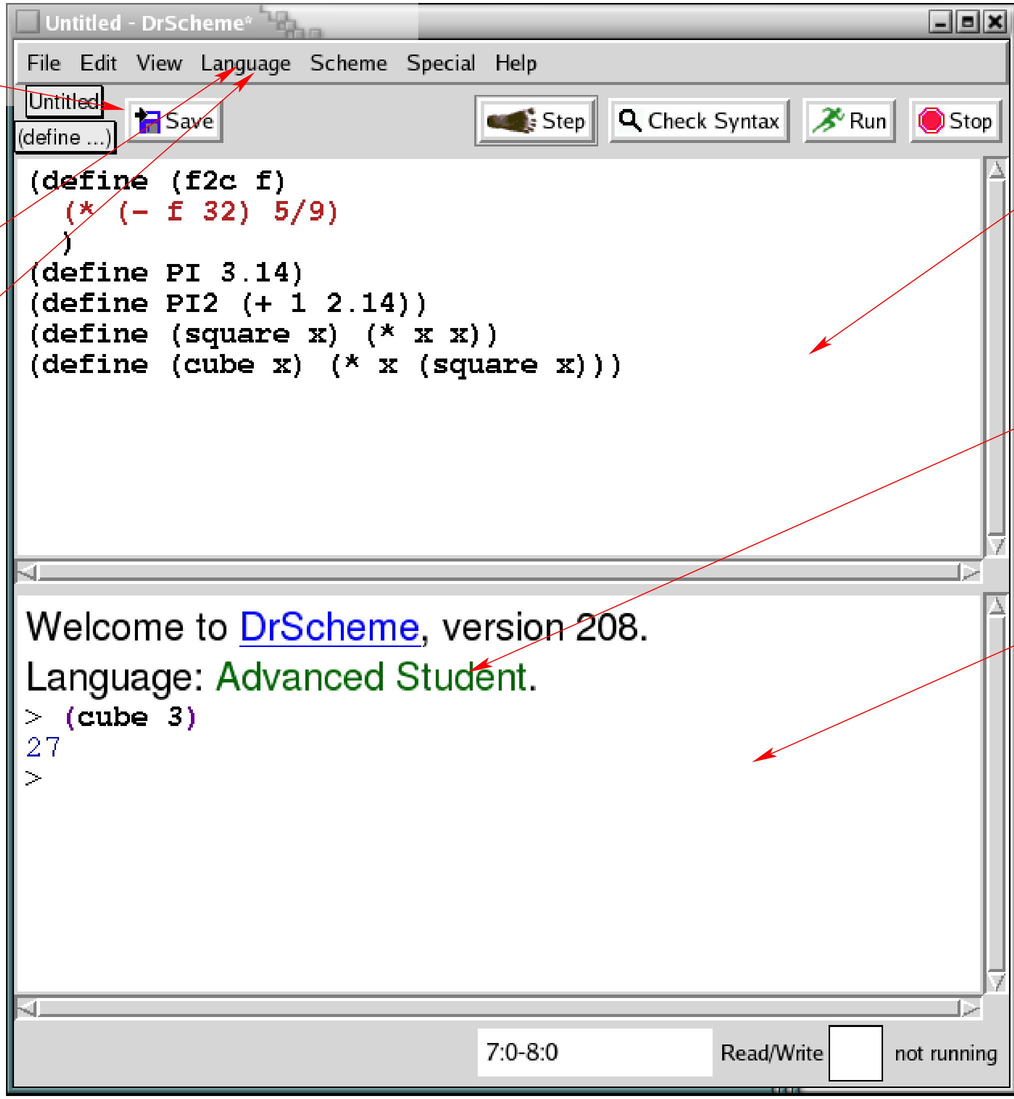
- On Windows and MacOS it may be enough to click on the DrScheme logo to start it up.

Dr Scheme

Save definitions

Select language level

Add teachpacks

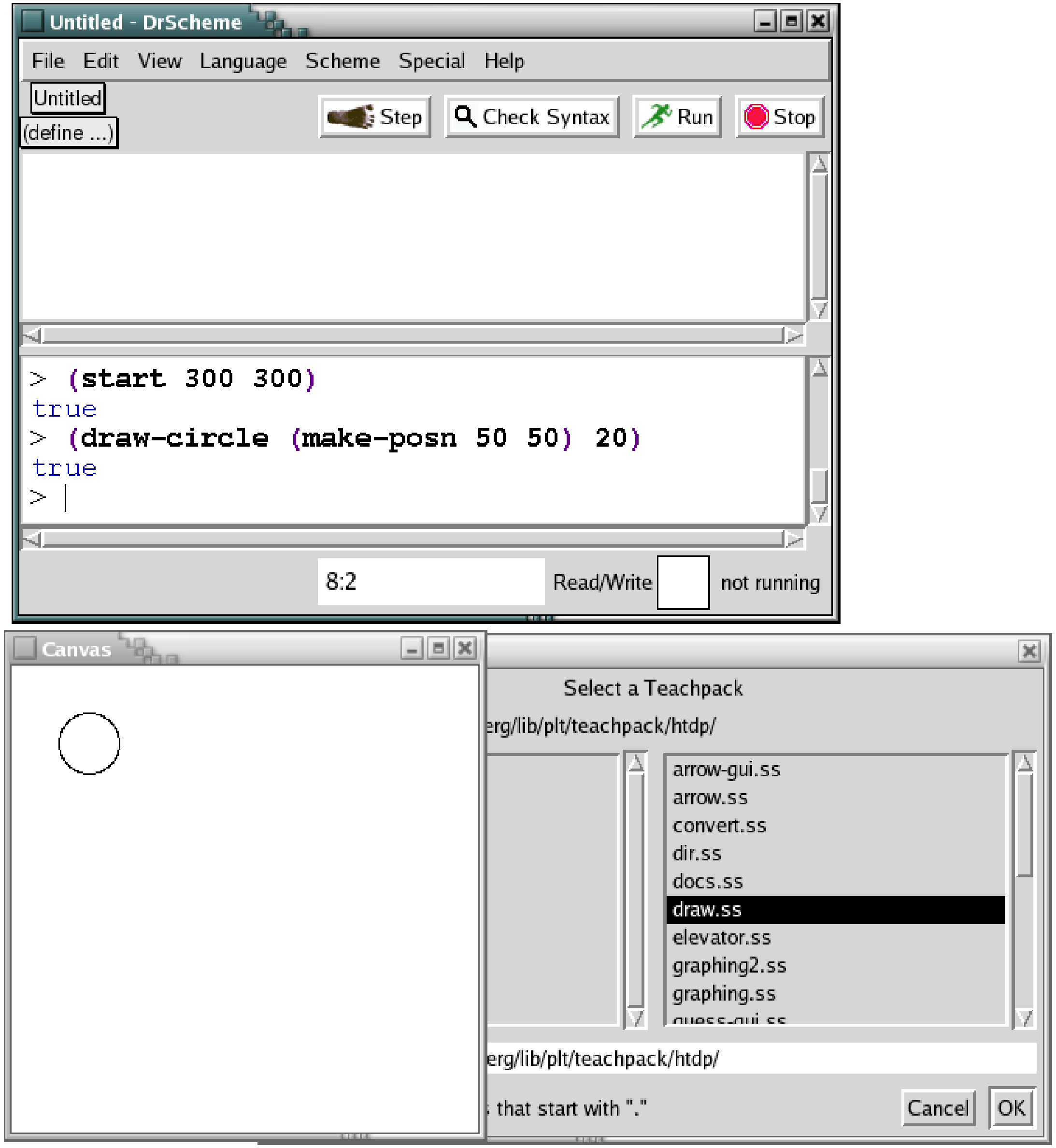


Definitions window

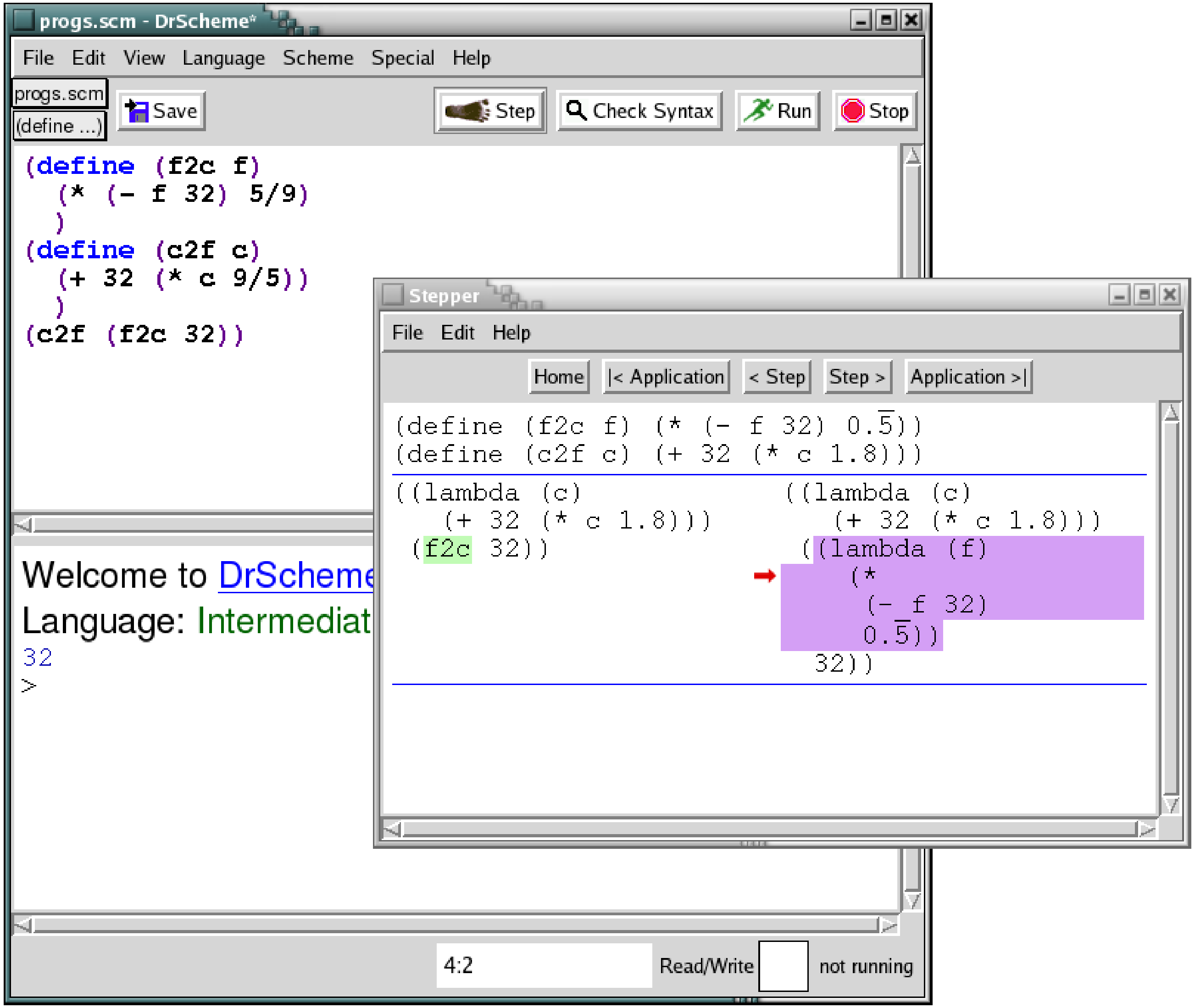
Language level

Interaction window

Dr Scheme — Using TeachPacks



Dr Scheme — Using the Stepper



References

- Read Scott, pp. 523-527, 528-539.
- Free interpreter: http://www.drscheme.org.
- Manual:
  http://www.swiss.ai.mit.edu/projects/scheme/documentation/scheme.html
- Tutorials:
  - http://ai.uwaterloo.ca/~dale/cs486/s99/scheme-tutorial.html
  - http://cs.wwc.edu/%7Ecs_dept/KU/PR/Scheme.html
  - http://www.cis.upenn.edu/%7Eungar/CIS520/scheme-tutorial.html
- http://dmoz.org/Computers/Programming/Languages/Lisp/Scheme

References. . .

- Language reference manual:

  http://www.swiss.ai.mit.edu/ftpdir/scheme-reports/r5rs.ps.

- Some of this material is taken from

  http://www.ecf.utoronto.ca/~gower/CSC326F/slides, ©Diana Inkpen 2002, Suzanne Stevenson 2001.

Scheme so Far

- A function is defined by

```
(define (name arguments) expression)
```

- A variable is defined by

```
(define name expression)
```

- Strings are inclosed in double quotes, like `"this"`. Common operations on strings are
  - (string-length `string`)
  - (string-append `list-of-strings`)
- Numbers can be exact integers, inexact reals, fractions, and complex. Integers can get arbitrarily large.
- Booleans are written `#t` and `#f`.

Scheme so Far...

- An inexact number is written: `#i3.14159265`.
- Common operations on numbers are
  - (+ `arg1 arg2`), (- `arg1 arg2`)
  - (add1 `arg`), (sub1 `arg`)
  - (min `arg1 arg2`), (max `arg1 arg2`)
- A function application is written:

```
> (function-name arguments)
```

- Quoting is used to prevent evaluation

```
(quote argument)
```

or

```
'argument
```