Overview

- Some more LISP stuff: user input, trace, cons, more setf, etc.
- Symbolic Differentiation:
  $[q]$ does it need intelligence?
- Expression Simplification
- Programming Assignment (due 9/22/02, Sunday).

READ: User Input

READ: keyboard input from user

```
>(read)
hello
HELLO

>(if (equal (read) 'hello)
        'good
        'bad
)
hello
GOOD
```


TRACE/UNTRACE: call tracing

```
>(trace fibo)
(FIBO)
>(fibo 4)
  1> (FIBO 4)
    2> (FIBO 3)
      3> (FIBO 2)
      <3 (FIBO 2)
      3> (FIBO 1)
      <3 (FIBO 1)
    <2 (FIBO 3)
    2> (FIBO 2)
    <2 (FIBO 2)
  <1 (FIBO 5)
5
>
```


List stuff

- CONS: append an atom and a list
  `(cons 'a '(1 2 3)) -> (A 1 2 3)`
  `(cons '(a) '(1 2 3)) -> ((A) 1 2 3)`
- APPEND: append two lists
  `(append '(1 2) '(4 5)) -> (1 2 4 5)`

Fun with SETF

Replace list element with SETF. Note: SETQ will not work!

```
>(setf b '(1 (2 3) 4))
(1 (2 3) 4)

>(caadr b)
2

>(setf (caadr b) 'abcdefg)
ABCDEFG

>b
(1 (ABCDEFG 3) 4)
```


Symbolic Differentiation

Original concept and code borrowed from Gordon Novak's AI course at UTCS.

Symbolic Differentiation

Basics: given variable x, functions $f(x), g(x)$, and constant (i.e. number) a:

1. $$\frac{da}{dx} = 0, \frac{d(a \times x)}{dx} = a$$
2. $$\frac{d(f+g)}{dx} = \frac{df}{dx} + \frac{dg}{dx}$$
3. $$\frac{d(f \times g)}{dx} = \frac{df}{dx} \times g + f \times \frac{dg}{dx}$$

The operators can be extended to: binary minus (e.g. `(- x 1)`), unary minus (e.g. `(- x)`), division (e.g. `(/ x 10)`, etc.

Describing in LISP (I)

`(deriv <expression> <variable>)`

1. $$\frac{da}{dx} = 0, \frac{d(a \times x)}{dx} = a$$

```
(deriv '10 'x) -> 0
(deriv '(* 10 x) 'x) -> 10
```

Describing in LISP (II)

`(deriv <expression> <variable>)`

1. $$\frac{d(f+g)}{dx} = \frac{df}{dx} + \frac{dg}{dx}$$

```
(deriv '(+ (* x 10) (+ 25 x)) 'x)
== (list
       '+
       (deriv '(* x 10) 'x)
       (deriv '(+ 25 x))
   )
```


Describing in LISP (III)

`(deriv <expression> <variable>)`

1. $$\frac{d(f \times g)}{dx} = \frac{df}{dx} \times g + f \times \frac{dg}{dx}$$

```
(deriv '(* (+ 14 x) (* x 17)) 'x)
==(list
     '+
     (list '* (deriv '(* 14 x) 'x) '(* x 17))
     (list '* '(+ 14 x) (deriv '(* x 17)))
  )
```


DERIV: the core function

Pseudo code (basically a recursion):

`(defun deriv (expression var) BODY)`

1. if `expression` is the same as `var` return 1
2. if `expression` is a number return 0
3. if `(first expression)` is `'+`, return

```
'(+ (deriv (second expression) var)
    (deriv (third expression) var)
```

4. and so on.

Main Function: DERIV

You can make separate functions for each operator:

```
(defun deriv (expr var)
  (if (atom expr)
    (if (equal expr var) 1 0)
    (cond
        ((eq '+ (first expr))     ; PLUS
            (derivplus expr var))
        ((eq '* (first expr))     ; MULT
            (derivmult expr var))
        (t    ; Invalid
            (error "Invalid Expression!"))
      )
   )
)
```

Calling DERIV from DERIVPLUS

Then, you can call `deriv` from `derivplus`, etc.

```
(defun derivplus (expr var)
    (list '+
          (deriv (second expr) var)
          (deriv (third expr) var)
    )
)
```


Expression Simplification

Problem: a lot of nested expression containing
`(* 1 x) (* x 1) (+ 0 x) (+ x 0) (+ 3 4) ...`
which are just `x, x, x, x,` and 7.
Use simplification rules:

1. `(+ <number> <number>)`: return the evaluated value
2. `(* <number> <number>)`: return the evaluated value
3. `(+ 0 <expr>) (+ <expr> 0)`: return `<expr>`
4. `(* 1 <expr>) (* <expr> 1)`: return `<expr>`
5. `(- (- <expr>))` : return `<expr>`

HINT: look at the raw result and see what can be reduced.

SPLUS: Simplify `(+ x y)`

```
(defun splus (x y)
    (if (numberp x)
        (if (numberp y)
            (+ x y)
            (if (zerop x)
                y
                (list '+ x y)
            )
        )
        (if (and (numberp y) (zerop y))
            x
            (list '+ x y)
        )
    )
)
```


Programming Assignment 1

1. Implement `deriv` to support:
   addition, subtraction, unary minus, multiplication, and division.
   → HINT: use slide 12 as a skeleton.
2. Implement simplification routines `splus` etc. for all operators and integrate it into `derivplus`, etc.
   → HINT: Integrate code in slide 15 into code in slide 13.
3. Implement a function
   `(deriv-val <expr> <var> <value>)`
   to evaluate the final expression where the number `<value>` replaces the symbol `<var>`.
   → HINT: Use the `eval` function to recursively evaluate.
4. Write a separate `(simplify <expr>)` function using `splus`, etc.

Programming Assignment 1: other conditions

All operators are either binary or unary:
i.e. expressions like `(+ 1 2 3 4 5)` do not need to be supported. Only those in the form of `(+ 1 2)` or `(- 5)` are expected to be used.

Programming Assignment 1: Example Inputs and Outputs

1. `(deriv '(* (+ x 4) (+ x 5)) 'x)`
   `-> (+ (+ X 4) (+ X 5)))`
2. `(deriv '(/ (+ x 1) x) 'x)`
   `-> (/ (- X (+ X 1)) (* X X))`
3. `(deriv-val '(* (+ x 4) (+ x 5)) 'x 10)`
   `-> 29`
4. `(deriv-val '(/ (+ x 1) x) 'x 20)`
   `-> -1/400`

Programming Assignment 1: Required Material

Use the exact filename as shown below (in **bold**).

- Program code (**deriv.lsp**): put it in a single text file.
  – Ample indentation and documentation is required.
- Documentation (**README**): user manual
- Sample inputs and outputs (include in **README**)
  – 10 non-trivial (4 or more terms) examples should be given.
- Grading criteria:
  - README, test cases, comments, readability: 30%
  - deriv (with basic simplification) : 40%
  - deriv-val: 10%
  - simplify: 20%

Programming Assignment 1: Submission

- Use the unix `turnin` command. The folder name is `625-600`. Turn in a single tar file (or tar.gz). Run `man turnin` to find out how to use it.
- Submission deadline is 9/22/02 Sunday midnight (23:59:59).
- Late policy: No late submissions allowed. Submit whatever you have.
- Only send plain text ASCII files. **Do not send MS-Word documents or other formatted text.**

Next Time: Search Methods

- Chapter 3
- Required: sections 3.3–3.7.
- Other sections are optional.