CS4613 Lecture 1

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Online resources

- https://www.cs.unb.ca/~bremner/teaching/cs4613/

- D2L will only be used for handing in online SMoL tutorials
- Homework and (some) tests will be handed via a custom handin server
- Marked work will be returned via the same server.

Syllabus

- https://www.cs.unb.ca/~bremner/teaching/cs4613/printable/
- https://www.cs.unb.ca/~bremner/teaching/cs6905/printable/

Getting started

Install racket
https://download.racket-lang.org

Customize https://www.cs.unb.ca/~bremner/teaching/cs4613/racket/setup

Documentation https://docs.racket-lang.org

SMoL: Standard Model of Languages

SMoL Core language containing features used to build many common languages.

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tutor https://www.cs.unb.ca/~bremner/teaching/cs4613/smol-tutorials

reference `raco doc smol` or https://www.cs.unb.ca/~bremner/teaching/cs4613/docs

```
1 #lang smol/fun
  (defvar x 10)
  (deffun (f y) (+ x y))
  (f 3)
```

Plait: statically typed racket

reference `raco doc plait` or https://www.cs.unb.ca/~bremner/teaching/cs4613/docs

tutorials https://www.cs.unb.ca/~bremner/teaching/cs4613/tutorials

tour https://www.cs.unb.ca/~bremner/teaching/cs4613/racket/plait-demo.rkt/

Interpreters

- An interpreter maps programs to values (+ side effects).
- A compiler translates programs to other programs, typically lower level.
- Most modern languages use a mix of the two evaluation strategies

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Substitution

- The simplest model of evaluation is substitution
- Consider the following SMoL program

```
(deffun (f x) (+ x 1))
(f 3)
```

stacker

- We can evaluate it by substituting the argument in the function body

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```
  (f 3)
→ (+ x 1)[3/x]
→ (+ 3 1)
→ 4
```

Substitution continued

Building on the previous example

smol3

```
;; f is the same as before
(deffun (g z)
  (f (+ z 4)))
(g 5)
```

We can evaluate in the same way:

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```
  (g 5)
→ (f (+ z 4))[5/z]
→ (f (+ 5 4)) → (f 9)
→ (+ x 1)[9/x]
→ (+ 9 1) → 10
```

Design choices 1: lazy vs. eager

Eager

```
→ (f (+ 5 4))
→ (f 9)
→ (+ x 1)[9/x]
→ (+ 9 1)
```

Lazy

```
  (f (+ 5 4))
→ (+ x 1)[(+ 5 4)/x]
→ (+ (+ 5 4) 1)
```

Design choices 2: sequential versus parallel

Sequential

```
  (+ (f 3) (f 4))
→ (+ (+ x 1)[3/x] (f 3))
→ (+ (+ x 1)[3/x] (+ x 1)[4/x])
```

Parallel

```
  (+ (f 3) (f 4))
→ (+ (+ x 1)[3/x] (+ x 1)[4/x])
```

Surface Syntax: Arithmetic Expressions

Consider a grammar (EBNF) for arithmetic with addition and multiplication

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grammar

```
ae: fac "+" ae
  | fac

fac: atom "*" fac
   | atom

atom: NUMBER | "(" ae ")"
```

Concrete syntax

driver

```
(parse-string "1 + 2 * 3")
(parse-string "1 * 2 + 3")
(parse-string "(1 + 2) * (3 + 4)")

⋮
'(ae
  (fac
   (atom "(" (ae (fac (atom 1)) "+" (ae (fac (atom
      2)))) ")")
   "*"
   (fac (atom "(" (ae (fac (atom 3)) "+" (ae (fac
      (atom 4)))) ")"))))
```

Abstract Syntax

- `define-type` provides Algebraic Data Types for `plait`
- We use them as programs encoding programs

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exp

```
(define-type Exp
  [num (n : Number)]
  [plus (left : Exp) (right : Exp)]
  [times (left : Exp) (right : Exp)])
```

Parsing S-Expressions

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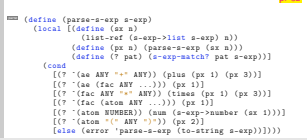
parse

```
(define (parse-s-exp s-exp)
  (local [(define (sx n)
            (list-ref (s-exp->list s-exp) n))
          (define (px n) (parse-s-exp (sx n)))
          (define (? pat) (s-exp-match? pat s-exp))]
    (cond
      [(? `(ae ANY "+" ANY)) (plus (px 1) (px 3))]
      [(? `(ae (fac ANY ...))) (px 1)]
      [(? `(fac ANY "*" ANY)) (times (px 1) (px 3))]
      [(? `(fac (atom ANY ...))) (px 1)]
      [(? `(atom NUMBER)) (num (s-exp->number (sx 1)))]
      [(? `(atom "(" ANY ")")) (px 2)]
      [else (error 'parse-s-exp (to-string s-exp))])))
```



1. In a sense this is a *compiler*: it translates one representation of a program to another
2. There is one case per grammar rule here, because the output from the `brag` parser has the same structure for each rule
3. See the text for a more direct way of parsing s-expressions; here we rely on `s-exp-match?` to replace those tests.
4. The local functions are used just to reduce boilerplate (and fit the parser on the page). '?' looks exotic, but it just an identifier for Racket

Testing our parser

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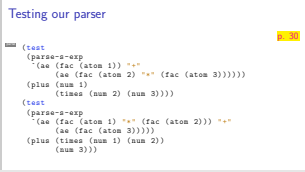
parse

```
(test
 (parse-s-exp
  `(ae (fac (atom 1)) "+"
       (ae (fac (atom 2) "*" (fac (atom 3))))))
 (plus (num 1)
       (times (num 2) (num 3))))
(test
 (parse-s-exp
  `(ae (fac (atom 1) "*" (fac (atom 2))) "+"
       (ae (fac (atom 3)))))
 (plus (times (num 1) (num 2))
       (num 3)))
```



1. `test` is going to be very important in this course
2. `test` uses `equal?` for equality testing

Recursive Evaluation

The important part

In this course we want to focus on the back end of interpreters: processing (abstract) representations of programs.

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calc

```
(define (calc e)
  (type-case Exp e
    [(num n) n]
    [(plus l r) (+ (calc l) (calc r))]
    [(times l r) (* (calc l) (calc r))]))
```

Testing our evaluator

calc

```
(test (calc (num 1)) 1)
(test (calc (num 2.3)) 2.3)
(test (calc (plus (num 1) (num 2))) 3)
(test (calc (plus (plus (num 1) (num 2))
                  (num 3)))
      6)
```