CPSC-354 Report

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October 16, 2022

Abstract

Updated throughout Fall 2022 for 354 Programming Languages at Chapman Univ.

Contents

1 Introduction

Tylers introduction. Yeah, this will get some work before final submission.

2 Homework

2.1 Week 1

Euclid's Algorithm

Input: Two whole numbers (integers) called a and b, both greater than 0.
(1) if a < b then replace a by (a - b).
(2) if b > a then replace b by (b - a).

(3) Repeat from (1) if a $\neq b$

Output: a.

Code (Golang)

```
package main
import ( "fmt"; "strconv"; "os")
// Calculate GCD of a & b using Euclid's algorithm
func Euclid-GCD( a int, b int ) int {
    if a > b { return Euclid_GCD( a-b, b ) } // recursive GCD function
    if a < b { return Euclid_GCD( a, b-a ) } // Subtract lesser from greater
   return a // a == b End recursive function
} func main() {
    // Args(str) int conversion
   a, err1 := strconv.Atoi(os.Args[1]); b, err2 := strconv.Atoi(os.Args[2])
    // If no errors:
   if err1 == nil && err2 == nil {
      gcd := Euclid_GCD( a, b ) // Evaluate GCD of args(int) => a, b
      fmt.Println(gcd) // Print divisor to console
      return // End script
    } fmt.Println("Error", err1, err2) // Errors happened
}
```

Explaination

Following the steps of Euclids algorithm detailed in section **Euclid's Algorithm**, the GCD between any two numbers is determined. The Golang function, **Euclid-GCD**, detailed step-by-step in section **Code (Golang)**, determines the GCD by recursively subtracting one non-zero integer by the other.

How to run:

1–3 need only be done once:

(1) Install Golang
(2) Init Golang project: `go mod init`
(3) Compile: `go build gcd.go`
(4) Run: `./gcd.go [int arg1] [int arg2]`

2.2 Week 2

Task 1

```
select_evens :: [a] -> [a]
select_evens [] = []
select_evens (x:xs) = select_odds(xs)

select_odds :: [a] -> [a]
select_odds [] = []
select_odds (x:xs) = [x] ++ select_evens(xs)

revert :: [a] -> [a]
revert [] = []
```

```
revert (x:xs) = revert xs ++ [x]

append :: [a] -> [a] -> [a]
append [] x = x
append (x:xs) b = x : append xs b
```

Task 2
append [2,5,4,3] 5
-> [2]:[5]:[4]:[3]: 5
-> [2,5,4,3,5]

2.3 Week 3

Completed 'fill in the dot' execution:

```
hanoi 5 0 2
   hanoi 4 0 1
      hanoi 3 0 2
         hanoi 2 0 1
            hanoi 1 0 2 = move 0 2
            move  0 1
            hanoi 1 2 1 = move 2 1
         move 0 2
         hanoi 2 1 2
            hanoi 1 1 0 = move 1 0
            move  1 2
            hanoi 1 0 2 = move 0 2
      move 0 1
      hanoi 3 2 1
         hanoi 2 2 0
            hanoi 1 2 1 = move 2 1
            move 2 0
            hanoi 1 1 0 = move 1 0
         move 2 1
         hanoi 2 0 1
            hanoi 1 0 2 = move 0 2
            move 0 1
            hanoi 1 2 1 = move 2 1
   move 0 2
   hanoi 4 1 2
      hanoi 3 1 0
         hanoi 2 1 2
            hanoi 1 1 0 = move 1 0
            move 1 2
            hanoi 1 0 2 = move 0 2
         move 1 0
         hanoi 2 2 0
            hanoi 1 2 1 = move 2 1
            move 2 0
            hanoi 1 1 0 = move 1 0
      move 1 2
      hanoi 3 0 2
         hanoi 2 0 1
            hanoi 1 0 2 = move 0 2
```

```
         move  0 1
         hanoi 1 2 1 = move 2 1
      move 0 2
      hanoi 2 1 2
         hanoi 1 1 0 = move 1 0
         move  1 2
         hanoi 1 0 2 = move 0 2
      |
   |
|
|
```

```
The word 'hanoi' appears 31 times for a tower of height 5. Hanoi will execute {2^n - 1}  times

Javascript-ish formula to solve Tower of Hanoi with n discs:
```

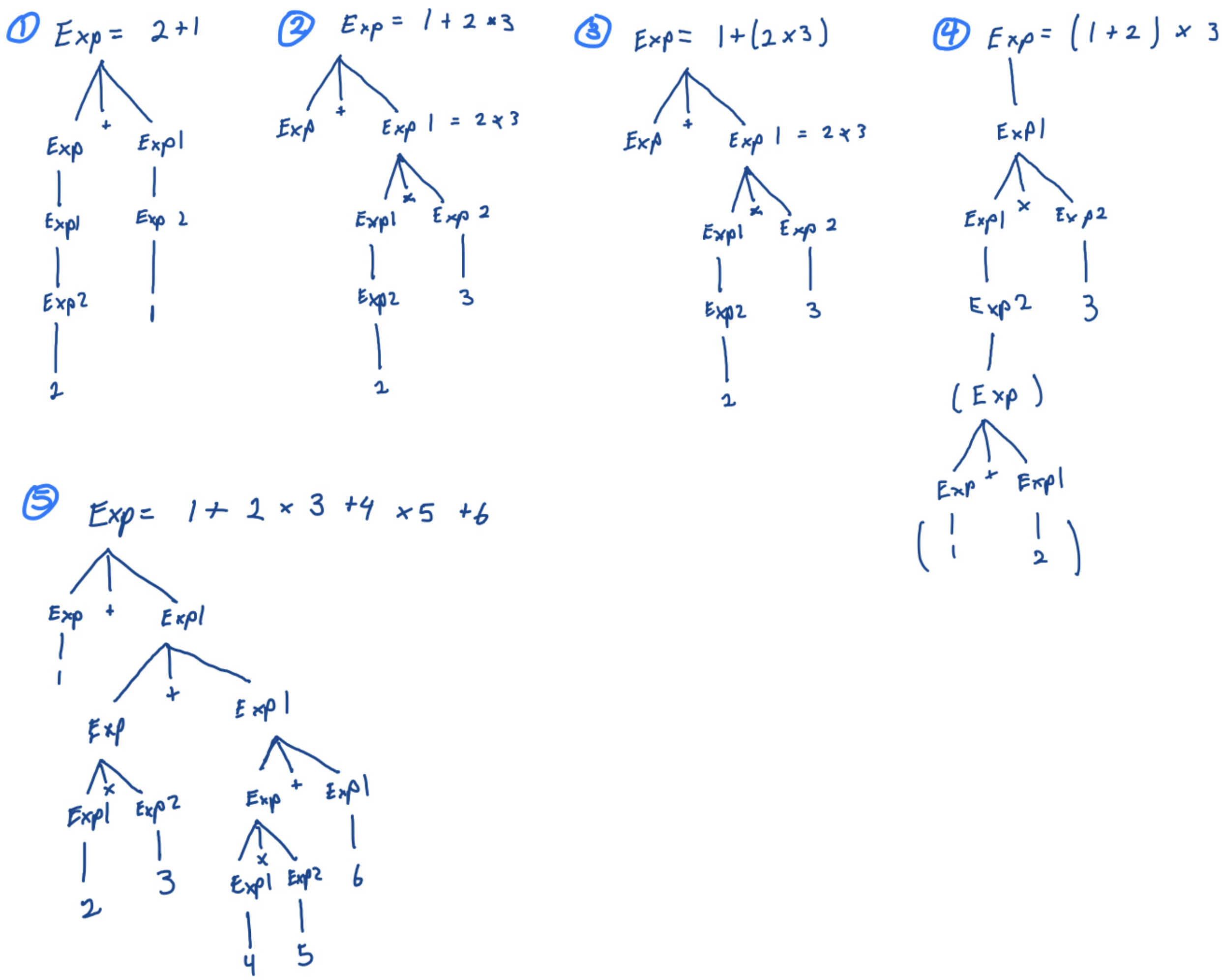
```
func hanoi( n, x, y ) {
   switch( n ) {
      case 1:
         move( x, y );
         break;
      default:
         hanoi ( n-1, x, other( x, y ) );
         move( x, y );
         hanoi ( n-1, other( x, y ), y );
         break;
   }
}

func move( x, y ) {
    // move top disk of position x to position y
}

func other( x, y ) {
   return (2 * ( x + y )) % 3;
}
```

2.4 Week 4

derivation trees



= 1 + (2 ×3) + (4× 5) +6

"More exercises"

Why do the following strings not have parse trees (given the context-free grammar above)?

```
2-1: No rule for subtraction
1.0+2: Only rules for integers
6/3: No specification for division
8 mod 6: No specification for modulus
```

Can you change the grammar, so that the strings in the previous exercise become parsable?

```
yes you can, I would assume for modulus as well
```

write out the abstract syntax trees for the following strings:

```
2+1: Plus (Num 2) (Num 1)
1+2*3: Plus (Num 1) (Times (Num 2) (Num 3))
1+(2*3): Plus (Num 1) (Times (Num 2) (Num 3))
(1+2)*3: Times (Plus (Num 1) (Num 2)) (Num 3)
```

Is the abstract syntax tree of 1+2+3 identical to the one of (1+2)+3 or the one of 1+(2+3)?

```
No particular right answer.
```

2.5 Week 5 (line 300)

Use the parser to generate linearized abstract syntax trees for the following expressions:
x

```
Prog (EVar (Id "x"))
```

x x

```
Prog (EApp (EVar (Id "x")) (EVar (Id "x")))
```

x y

```
Prog (EApp (EVar (Id "x")) (EVar (Id "y")))
```

x y z

```
Prog (EApp (EApp (EVar (Id "x")) (EVar (Id "y"))) (EVar (Id "z")))
```

\x.x

```
Prog (EAbs (Id "x") (EVar (Id "x")))
```

\x.x x

```
Prog (EAbs (Id "x") (EApp (EVar (Id "x")) (EVar (Id "x"))))
```

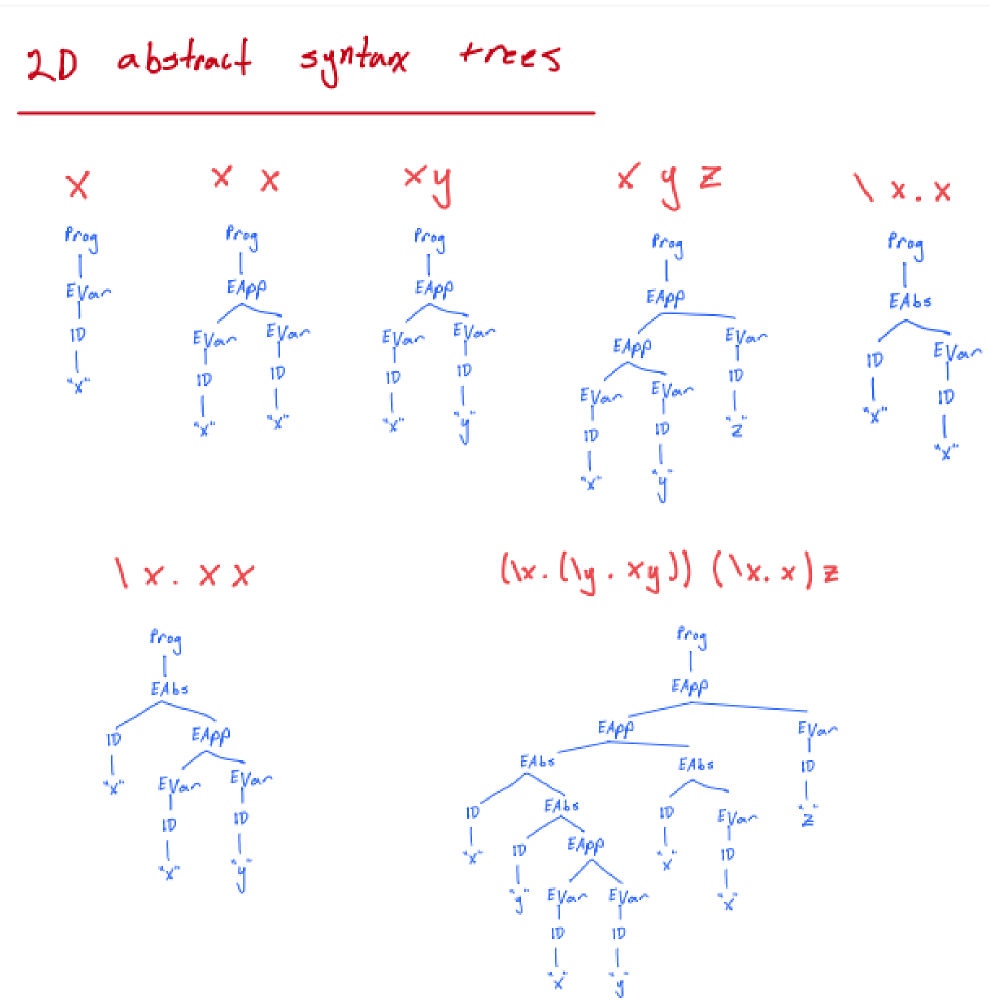
(\x . (\y . x y)) (\x.x) z

```
Prog (EApp (EApp (EAbs (Id "x") (EAbs (Id "y") (EApp (EVar (Id "x")) (EVar (Id "y"))))) (EAbs (Id "x")
(EVar (Id "x")))) (EVar (Id "z")))
```

(\x . \y . x y z) a b c

```
Prog (EApp (EApp (EApp (EAbs (Id "x") (EAbs (Id "y") (EApp (EApp (EVar (Id "x"))
(EVar (Id "y"))) (EVar (Id "z"))))) (EVar (Id "a"))) (EVar (Id "b"))) (EVar (Id "c")))
```

Write out the abstract syntax trees in 2-dimensional notation using pen and paper.



Evaluate using pen-and-paper [2] the following expressions:

Lambda Calculus Semantics

```
(\x. x) a ⟶ a
\x.x a ⟶ \y.y a
(\x. \y. x) a b ⟶ (\y. a) b
                  ↳ a
(\x. \y. y) a b ⟶ (\y.y) b
                  ↳ b
(\x.\y. x) a b c ⟶ (\y. a) b c
                   ↳ a
(\x.\y. y) a b c ⟶ (\y. y) b c
                   ↳ b
(\x.\y. x) a (b c) ⟶ (\y. a) (bc)
                   ↳ a
(\x.\y. y) a (b c) ⟶ (\y. y) (bc)
                     ↳ (bc)
(\x.\y. x) (a b) c ⟶ (\y. (ab)) c
                     ↳ (a b)
(\x.\y. y) (a b) c ⟶ (\y. y) c
                     ↳ c
(\x.\y. x) (a b c) ⟶ \y (abc)
                     ↳ (abc)
(\x.\y. y) (a b c) ⟶ (\y. y)
                       ↳
```

Evaluate (.x)((.y)a) by executing the function evalCBN defined on line 26-28 in Interpreter.hs pen-and-paper. The function subst is doing capture avoiding substitution and you can reduce subst in one step in your pen and paper computation

2.6 Week 6 (line 350)

```
Reduce the following lambda calculus expression:

    (\exp . \two . \three . exp two three)
    (\m.\n. m n)
    (\f.\x. f (f x))
    (\f.\x. f (f (f x)))


    ( (\m.\n. m n) (\f.\x. f (f x)) (\f.\x. f (f (f x))) )  -- Substitution

    ( (\m.\n. m n) (\f.\x. f (f x)) (\x0.\x1. x0 (x0 (x0 x1))) )  -- conversion

    ( (\n.  (\f.(\x. f (f x))) n) (\x0.(\x1. x0 (x0 (x0 x1)))) )  -- Substitution
```

```
( (\f.(\x. f (f x))) (\x0.(\x1. x0 (x0 (x0 x1)))) )  -- Substitution

( ((\x. (\x0.(\x1. x0 (x0 (x0 x1)))) ((\x0.(\x1. x0 (x0 (x0 x1)))) x))) )  -- Substitution

( ((\x. (\x0.(\x1. x0 (x0 (x0 x1)))) ((\x2.(\x3. x2 (x2 (x2 x3)))) x))) )  -- conversion

( ((\x. ((\x1. ((\x2.(\x3. x2 (x2 (x2 x3)))) x) (((\x2.(\x3. x2 (x2 (x2 x3)))) x)
(((\x2.(\x3. x2 (x2 (x2 x3)))) x) x1)))) )) )  -- Substitution

( ((\x. ((\x1. ((\x2.(\x3. x2 (x2 (x2 x3)))) x) (((\x4.(\x5. x4 (x4 (x4 x5)))) x)
(((\x6.(\x7. x6 (x6 (x6 x7)))) x) x1)))) )) )  -- conversion

( ((\x. ((\x1. (\x3. x (x (x x3))) (((\x4.(\x5. x4 (x4 (x4 x5)))) x)
(((\x6.(\x7. x6 (x6 (x6 x7)))) x) x1)) )))))  -- Substitution

(\x. (\x1. (x (x (x (((\x4.(\x5. x4 (x4 (x4 x5)))) x) (((\x6.(\x7. x6 (x6 (x6 x7)))) x)
x1)) )))))  -- Substitution

(\x. (\x1. (x (x (x (((\x5. x (x (x x5)))) (((\x6.(\x7. x6 (x6 (x6 x7)))) x)
x1)) )))))  -- Substitution

(\x. (\x1. (x (x (x (x (x (x (((\x6.(\x7. x6 (x6 (x6 x7)))) x) x1)))) )))))  -- Substitution

(\x. (\x1. (x (x (x (x (x (x ((\x7. x (x (x x7))) x1)))) )))))  -- Substitution

(\x. (\x1. (x (x (x (x (x (x (x (x (x x1)))))))) )))  -- Substitution, final
```

Algrbra formula:

```
f(m,n) = n^m
```

2.7 Week 7 (line 400)

1. REFERENCE, in lines 5-7 and also in lines 18-22 explain for each variable

- Whether it is bound or free
- If it is bound say what the binder and the scope of the variable are

lines 5-7:
evalCBN, and subst are function names declared outside our scope and thus are **free**.
EApp, and EAbs are type variables declared elsewhere and thus are **free** within our scope.
e1, e2, e3, i, and x are placeholders and can be interchanged with another fresh variable at will making them **bound**.
lines 18-22:
subst, and fresh are function names declared outside our scope and thus are **free**.
id, EAbs, and EVar are type variables declared elsewhere and thus are **free** within our scope.
s, id1, e1, f, and e2 are placeholders and can be interchanged with another fresh variable at will making them **bound**.
2. evalCBN part of hw5 using equal sign

```
evalCBN( EApp (\x.x) ((\y.y) a) )
```

```
= EAbs x x → evalCBN( subst x ((\y.y) a) x )

= evalCBN( subst x ((\y.y) a) x )

= evalCBN( EApp (\y. y) a )

= EAbs y y → evalCBN(subst y a y)

= evalCBN(a)

= a
```

3. This item is as the previous one, but for a different lambda term, namely ‘(..x) y z‘

```
(\x.\y. x) y z

= (\x.\y'. x) y z

= (\y'. y) z

= y
```

4. https://hackmd.io/@alexhkurz/BJ7AoGcVK
Consider the listed ARSs

1. $A = \{\ \}$

✓ Terminating
✓ Confluent
✓ UNF's

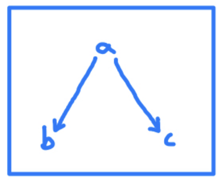
2. $A = \{a\}$, $R = \{\ \}$

✓ Terminating
✓ Confluent
✓ UNF's

3. $A = \{a\}$, $R = \{(a,a)\}$

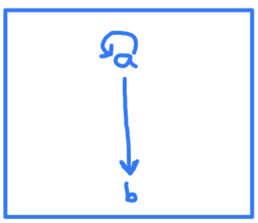
✗ Terminating
✓ Confluent
✗ UNF's

4. $A = \{a, b, c\}$, $R = \{(a,b), (a,c)\}$



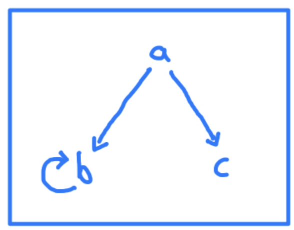
✓ Terminating
✗ Confluent
✗ UNF's

5. $A = \{a, b\}$, $R = \{(a,a), (a,b)\}$



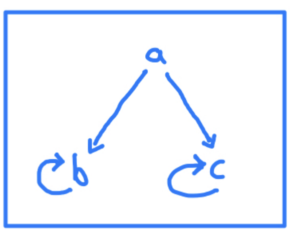
✗ Terminating
✓ Confluent
✗ UNF's

6. $A = \{a, b, c\}$, $R = \{(a,b), (b,b), (a,c)\}$



✗ Terminating
✗ Confluent
✗ UNF's

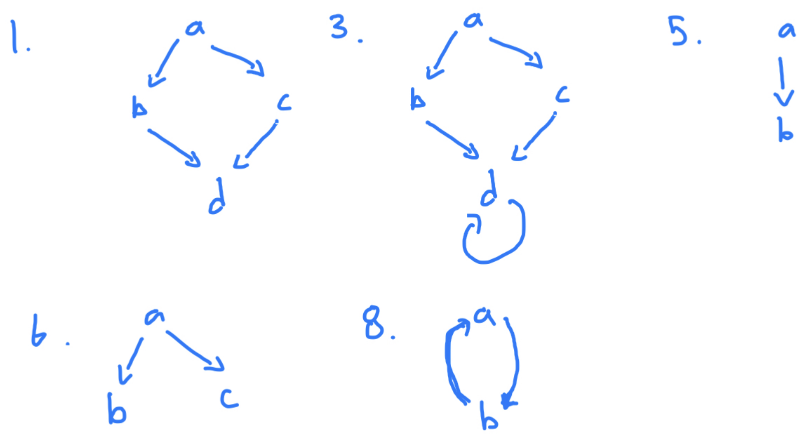
7. $A = \{a, b, c\}$, $R = \{(a,b), (b,b), (a,c), (c,c)\}$



✗ Terminating
✗ Confluent
✗ UNF's

Try to find an example of an ARS for each of the possible 8 combinations.

Conf.	Term	UNF's	example
T	T	T	$A = \{a, b, c, d\}$, $R = \{(a,b), (a,c), (b,d), (c,d)\}$
T	T	F	$\emptyset$
T	F	T	$A = \{a, b, c, d\}$, $R = \{(a,b), (a,c), (b,d), (c,d), (d,d)\}$
T	F	F	$\emptyset$
F	T	T	$A = \{a, b\}$, $R = \{(a, b)\}$
F	T	F	$A = \{a, b, c\}$, $R = \{(a, b), (a, c)\}$
F	F	T	$\emptyset$
F	F	F	$A = \{a, b\}$, $R = \{(a, b), (b, a)\}$



3 Project

Introductory remarks ...
The following structure should be suitable for most practical projects.

3.1 Specification

For my project I wish to design an interpreter for a programming language of my own design.
Possible launch point

3.2 Prototype

3.3 Documentation

3.4 Critical Appraisal

...

4 Conclusions

Thanks, goodbye.

References

[PL] Programming Languages 2022, Chapman University, 2022.