CSE 230: Medium of Instruction

Haskell

What is Haskell?

Programming in Haskell

“Computation by Calculation”

Programming in Haskell

“Substitute Equals by Equals”

Substituting Equals

```
3 * (4 + 5)
```

```
3 * 9
```

```
27
```

That's it!

What is Abstraction?

Pattern Recognition

Pattern Recognition

```
pat x y z  =  x * (y  + z )
```

```
pat 31 42 56 = 31 * (42 + 56)

pat 70 12 95 = 70 * (12 + 95)

pat 90 68 12 = 90 * (68 + 12)
```

Pattern Application: “Fun Call”

```
pat x y z  =  x * (y  + z )
```

```
pat 31 42 56
⇩
31 * (42 + 56)
⇩
31 * 98
⇩
3038
```

Programming in Haskell

"Substitute Equals by Equals"

Really, that's it!

Elements of Haskell

Expressions, Values, Types

Expressions

Values

Types

expression :: Type

⇩

value :: Type

The GHC System

Batch Compiler "ghc"

Compile & Run Large Programs

Interactive Shell "ghci"

Tinker with Small Programs

Interactive Shell: ghci

:load *foo.hs*

:type `expression`

:info `variable`

Basic Types

```
31 * (42 + 56) :: Integer

3 * (4.2 + 5.6) :: Double

          'a' :: Char

         True :: Bool
```

Note: + and * overloaded …

Function Types

A -> B

Function taking input of **A**, yielding output of **B**

```
pos :: Integer -> Bool
pos x = (x > 0)
```

“Multi-Argument” Function Types

```
A1 -> A2 -> A3 -> B
```

Function taking args of **A1**, **A2**, **A3**, giving out **B**

```
pat :: Int -> Int -> Int -> Bool
pat x y z = x * (y + z)
```

Tuples

(A1,…,An)

Bounded Sequence of values of type **A1**,…,**An**

```
('a', 5) :: (Char, Int)
('a', 5.2, 7) :: (Char, Double, Int)
((7, 5.2), True) :: ((Int, Double), Bool)
```

QUIZ

```
pat :: ? -> Int
pat (x, y, z) = x * (y + z)
```

What is input type of pat?

A. Int

B. Int → Int → Int

C. (Int, Int, Int)

D. (Num a, Num a, Num a)

E. None of the above!

Extracting Values From Tuples

(A1,A2,…,An)

Pattern Matching extracts values from tuple

```
pat :: Int -> Int -> Int -> Bool
pat x y z = x * (y + z)

pat’ :: (Int, Int, Int) -> Int
pat’ (x, y, z) = x * (y + z)
```

Lists

[A]

Unbounded Sequence of values of types **A**

```
['a','b','c'] :: [Char]
[1,3,5,7] :: [Int]
[(1,True),(2,False)] :: ?
[[1],[2,3],[4,5,6]] :: ?
```

QUIZ!

What is the type of

[1, 2, 'c'] :: ???

A. [Int]

B. [Char]

C. [a]

D. [Any]

E. [Int+Char]

List's Values Must Have Same Type

`[A]`

Unbounded Sequence of values of types **A**

`[1, 2, 'c']`

What is A ?

List's Values Must Have Same Type

`[A]`

Unbounded Sequence of values of types **A**

`[1, 2, 'c']`

(Mysterious) Type Error!

“Cons”tructing Lists

```
(:) :: a -> [a] -> [a]
```

Input: element (“head”) and list (“tail”)

Output: new list with head followed by tail

```
‘a’:[‘b’,‘c’] ⇨ [‘a’,‘b’,‘c’]
1:[] ⇨ [1]
[]:[] ⇨
```

“Cons”tructing Lists

```
cons2 ::
cons2 x y zs = x:y:zs
```

`cons2 ‘a’ ‘b’ [‘c’]` ⇨ `[‘a’,‘b’,‘c’]`

`cons2 1 2 [3,4,5,6]` ⇨ `[1,2,3,4,5,6]`

QUIZ

$$\text{cons2} :: ???$$

$$\text{cons2}\ x\ y\ zs = x : y : zs$$

A. $Int \to Int \to [Int]$

B. $Int \to Int \to [Int] \to [Int]$

C. $a \to a \to [a]$

D. $a \to a \to [a] \to [a]$

E. $a \to [a] \to [a] \to [a]$

Syntactic Sugar

```
[x1,x2,…,xn]
```

Is actually a pretty way of writing

```
x1:x2:…:xn:[]
```

Function Practice : List Generation

```
clone :: a -> Int -> [a]
clone x n = if n==0
            then []
            else x:(clone x (n-1))
```

```
clone ‘a’ 4  ⇨ [‘a’,‘a’,‘a’,‘a’]
clone 1.1 3  ⇨ [1.1, 1.1,1.1]
```

Function Practice : List Generation

```
clone :: a -> Int -> [a]
clone x 0 = []
clone x n = x:(clone x (n-1))
```

Define with multiple equations

More Readable

Function Practice : List Generation

```
clone :: a -> Int -> [a]
clone x 0 = []
clone x n = x:(clone x (n-1))

clone ‘a’ 3
⇨ ‘a’:(clone ‘a’ 2)
⇨ ‘a’:(‘a’:(clone ‘a’ 1))
⇨ ‘a’:(‘a’:(‘a’:(clone ‘a’ 0)))
⇨ ‘a’:(‘a’:(‘a’:([])))
  [‘a’,‘a’,‘a’]
```

Function Practice : List Generation

```
clone :: a -> Int -> [a]
clone x 0 = []
clone x n = x:(clone x (n-1))
```

Ugly, Complex Expression

Function Practice : List Generation

```
clone :: a -> Int -> [a]
clone x 0 = []
clone x n = let tl = clone x (n-1)
            in x:tl
```

Define with local variables

More Readable

Function Practice : List Generation

```
clone :: a -> Int -> [a]
clone x 0 = []
clone x n = x:tl
            where tl = clone x (n-1)
```

Define with local variables

More Readable

Function Practice : List Generation

```
range :: Int -> Int -> [Int]
range i j = if i<=j
               then []
               else i:(range (i+1) j)
```

```
range 2 8 ⇨ [2,3,4,5,6,7,8]
```

Function Practice : List Generation

```
range :: Int -> Int -> [Int]
range i j | i<=j  = []
          | True  = i:(range (i+1) j)
```

Define with multiple guards

More Readable

Function Practice : List Access

```
listAdd :: [Integer] -> Integer
```

```
listAdd [2,3,4,5,6]  ⇨  20
```

Access elements By Pattern Matching

```
listAdd []     = 0
listAdd (x:xs) = x + listAdd xs
```

Recap

Execution = Substitute Equals

Expressions, Values, Types

Base Vals, Tuples, Lists, Functions

Next: Creating Types

Type Synonyms

Names for Compound Types

```
type XY = (Double, Double)
```

Not a new type, just shorthand

Type Synonyms

Write types to represent:

Circle : x-coord, y-coord, radius

```
type Circle = (Double, Double, Double)
```

Square: x-coord, y-coord, side

```
type Square = (Double, Double, Double)
```

Type Synonyms

Bug Alarm!

Call areaSquare on circle, get back junk

```
type Circle = (Double, Double, Double)
     areaCircle (_,_,r) = pi * r * r

type Square = (Double, Double, Double)
     areaSquare (_,_,d) = d * d
```

Solution: New Data Type

```
data CircleT = Circle (Double,Double,Double)
data SquareT = Square (Double,Double,Double)
```

Creates New Types

`CircleT`

`SquareT`

Solution: New Data Type

```
data CircleT = Circle (Double,Double,Double)
data SquareT = Square (Double,Double,Double)
```

Creates New Constructors

```
Circle :: (Double,Double,Double) -> CircleT
Square :: (Double,Double,Double) -> SquareT
```

Only way to create values of new type

Solution: New Data Type

```
data CircleT = Circle (Double,Double,Double)
data SquareT = Square (Double,Double,Double)
```

Creates New Constructors

```
Circle :: (Double,Double,Double) -> CircleT
Square :: (Double,Double,Double) -> SquareT
```

How to access/deconstruct values?

Deconstructing Data

```
areaSquare :: CircleT -> Double
areaCircle (Circle(_,_,r)) = pi * r * r

areaSquare :: SquareT -> Double
areaSquare (Square(_,_,d)) = d * d
```

How to access/deconstruct values?

Pattern Match…!

Deconstructing Data

```
areaSquare :: CircleT -> Double
areaCircle (Circle(_,_,r)) = pi * r * r

areaSquare :: SquareT -> Double
areaSquare (Square(_,_,d)) = d * d
```

Call `areaSquare` on `CircleT` ?

Different Types: GHC catches bug!

How to build a list with squares & circles?

Restriction: List elements have same type!

How to build a list with squares & circles?

Solution: Create a type to represent both!

Variant (aka Union) Types

Create a type to represent both!

```
data CorS =
    | Circle (Double,Double,Double)
    | Square (Double,Double,Double)

                  Circle(1,1,1) :: CorS
                  Square(2,3,4) :: CorS
[Circle(1,1,1),Square(2,3,4)] :: [CorS]
```

QUIZ

```
data CoS = Circle (Double, Double, Double)
         | Square (Double, Double, Double)
```

What is type of Circle?

A. CoS

B. (Double, Double, Double)

C. (Double, Double, Double) → CoS

D. Double → Double → Double → CoS

E. None of the above!

Variant (aka Union) Types

Access/Deconstruct by Pattern Match

```
data CorS =
    | Circle (Double,Double,Double)
    | Square (Double,Double,Double)

area :: CorS -> Double
area (Circle(_,_,r)) = pi*r*r
area (Square(_,_,d)) = d*d
```

A Richer Shape

```
data Shape =
    | Rectangle (Double, Double)
    | Ellipse   (Double, Double)
    | RtTriangle(Double, Double)
    | Polygon  [(Double, Double)]
```

Lets drop the parens...

A Richer Shape

```
data Shape =
    | Rectangle  Double Double
    | Ellipse    Double Double
    | RtTriangle Double Double
    | Polygon  [(Double, Double)]
```

Lets drop the parens...

A Richer Shape

```
data Shape =
    | Rectangle  Double Double
    | Ellipse    Double Double
    | RtTriangle Double Double
    | Polygon  [(Double, Double)]
```

Why can’t we drop last case’s parens?

Making Shape Readable

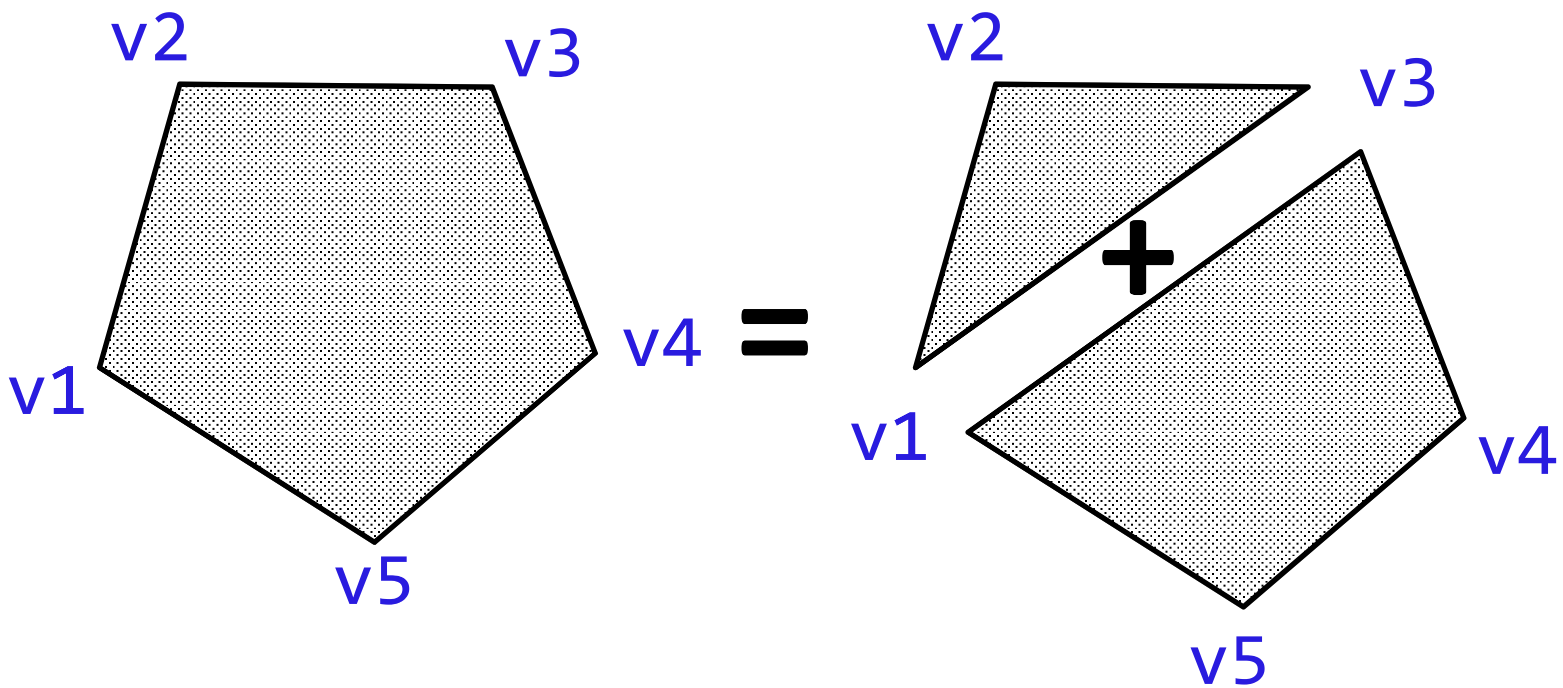
```haskell
data Shape =
    | Rectangle  Side Side
    | Ellipse    Radius Radius
    | RtTriangle Side Side
    | Polygon    [Vertex]

type Side   = Double
type Radius = Double
type Vertex = (Double, Double)
```

Calculating The Area

```
area :: Shape -> Double
area (Rectangle l b)  = l*b
area (RtTriangle b h) = b*h/2
area (Ellipse r1 r2)  = pi*r1*r2
```

GHC warns about missing case!

Calculating Area of Polygon




```
area (Polygon (v1:v2:v3:vs))
  = triArea v1 v2 v3 + area (Polygon (v1:v3:vs))
area (Polygon _)
  = 0
```

“Hello World”

Input/Output in Haskell

Programs Interact With The World

(Don’t just compute values!)

Programs Interact With The World

Read files,

Display graphics,

Broadcast packets, …

Programs Interact With The World

How to fit w/ values & calculation ?

I/O via an "Action" Value

Action

Value describing an effect on world

`IO a`

Type of an action that returns an a

Example: Output Action

Just do something, return nothing

```
putStr :: String -> IO ()
```

takes input string, returns action

that writes string to stdout

Example: Output Action

Only one way to “execute” action

make it the value of name `main`

```
main :: IO ()
main = putStr “Hello World! \n”
```

Example: Output Action

Compile and Run

```
ghc -o hello helloworld.hs
```

```
main :: IO ()
main = putStr “Hello World! \n”
```

Example: Output Action

“Execute” in ghci

```
:load helloworld.hs
```

```
main :: IO ()
main = putStr “Hello World! \n”
```

Actions Just Describe Effects

Writing does not trigger Execution

```
act2 :: (IO (), IO ())
act2 = (putStr “Hello”, putStr “World”)
```

Just creates a pair of actions…

```haskell
main :: IO ()
```

How to do many actions?

```
main :: IO ()
```

By composing small actions

Just “do” it

```
do putStr “Hello”
   putStr “World”
   putStr “\n”
```

Single Action

“Sequence” of sub-actions

Just “do” it

```
do act1
   act2
   …
   actn
```

Single Action

“Sequence” of sub-actions

Just “do” it

```
do act1
   act2
   …
   actn
```

Block Begin/End via Indentation

“Offside Rule” (Ch3. RWH)

Example: Input Action

Action that returns a value

```
getLine :: IO String
```

Read and Return Line from StdIn

Example: Input Action

Name result via "assignment"

```
x <- act
```

`x` **refers to result in later code**

Example: Input Action

Name result via “assignment”

```
main :: IO ()
main = do putStr “What is your name?”
          n <- getLine
          putStrLn (“Happy New Year ” ++ n)
```