Interpreters

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Objectives

You should be able to …

- Enumerate and explain the different parts of an interpreter.
- Explain what an abstract syntax tree is.
- Explain the difference between an interpreter and a compiler.
- Explain what REPL means and what it does.
- Show how to define types in HASKELL to represent expressions, values, and statements.

What Is an Interpreter?

- There are two ways to execute code on a computer:
  - Convert the code to machine code and run it directly.
  - Have another program read the code and "do what it says."
- The second method is what we will do in this course.

Parts of an Interpreter

- The *parser*
  - Converts your ASCII input into an *abstract syntax tree*
- The *evaluator*
  - Processes the abstract syntax tree to yield a result
  - A type to represent values
  - A function to evaluate the expressions into values (`eval`),
- An *environment* to keep track of the values of variables
- A top-level function to tie all this together: the *REPL*
  - Read
  - Eval
  - Print
  - Loop

Our Language

Let's write an interpreter for a simple functional language. We want the language to have:

- Integers
- Variables
- Arithmetic (+,-,*,/)
- Comparisons ($<$,$<=$,$>$,$>=$,$=$,$\neq$)
- Booleans (`true`, `false`, `and`, `or`, `not`)
- Local variables (`let`)
- Conditionals
- Functions

File Structure

- A reference version has been provided for you.
- `stack build` will compile them for you.
- `stack exec i1` will run the first interpreter.
- `stack repl i1/Main.hs` will load the interpreter but give you a HASKELL prompt.

```
first/
 |---- i1/
 |       |--- Main.hs
 |       |--- Types.hs
 |       |--- Parser.hs
 |---- i2/
 |       |--- Main.hs
 |       |--- Types.hs
 |       |--- Parser.hs
 |---- ...
```

Define the Types – Types.hs

```
1 data Exp = IntExp Integer
2    deriving (Show,Eq)
3
4 data Val = IntVal Integer
5    deriving (Show,Eq)
6
7 type Env = [(String,Val)]
```

Eval – I1.hs

```
1 eval :: Exp -> Env -> Val
2 eval (IntExp i) _ = IntVal i
```

```
% stack repl i1/Main.hs
*Main Lib Parser Types> :t eval
eval :: Exp -> Env -> Val
*Main Lib Parser Types> eval (IntExp 123) []
IntVal 123
*Main Lib Parser Types> main
Welcome to your interpreter!
i1> 23
IntVal 23
i1> quit
```

- Or use `stack exec i1` to run it directly.

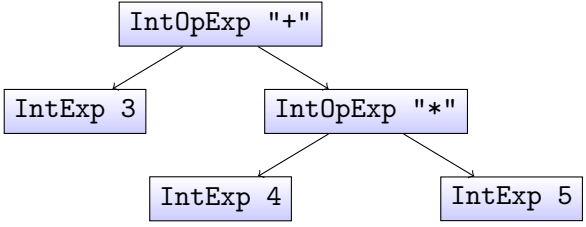
Adding Arithmetic and Abstract Syntax Trees

- Add the following to the Exp type.

```
1 data Exp = IntOpExp String Exp Exp
2          | ...
```

- Represent 3 + 4 * 5 with HASKELL code.

```
1 IntOpExp "+" (IntExp 3)
2          (IntOpExp "*" (IntExp 4) (IntExp 5))
```



- Note that this is a tree!

Eval – i2.hs

```
1  eval (IntOpExp "+" e1 e2) env =
2    let v1 = eval e1 env
3        v2 = eval e2 env
4    in IntVal (getInt v1 + getInt v2)
5  eval (IntOpExp "*" e1 e2) env =
6    let v1 = eval e1 env
7        v2 = eval e2 env
8    in IntVal (getInt v1 * getInt v2)
9  eval (IntOpExp "-" e1 e2) env =
10   let v1 = eval e1 env
11       v2 = eval e2 env
12   in IntVal (getInt v1 - getInt v2)
13 getInt (IntVal i) = i
14 getInt _          = 0
```

Making a Dictionary

```
1 intOps = [ ("+",(+))
2          , ("-",(-))
3          , ("*",(*))
4          , ("/",div)]
5
6 liftIntOp f (IntVal i1) (IntVal i2) = IntVal (f i1 i2)
7 liftIntOp f _           _           = IntVal 0
```

The compiler will give you a warning about `liftIntOp`.

```
Main> liftIntOp (*) (IntVal 10) (IntVal 20)
IntVal 200
```

Our New Eval – I2

```
Main> let Just f = lookup "*" intOps
Main> f 10 20
200
```

```
1 eval (IntOpExp op e1 e2) env =
2   let v1 = eval e1 env
3       v2 = eval e2 env
4       Just f = lookup op intOps
5   in liftIntOp f v1 v2
```

You try!

- The interpreter `i3` is a copy of `i2` with some extra constructors added:
  - `RelOpExp` – for integer comparisons like $\geq$
  - `BoolOpExp` – for `&&` and `||`
  - `BoolExp` – for `True` and `False`
  - `BoolVal` – the corresponding value
- The parser has also been updated to return these expressions.
- See if you can update `eval` to work with these new things.
- The next video will go over the solutions, plus show you how to add variables to the language. (Or you can peek at `i4` ...)