Nano: Interpreters

CSE 130
Week ???

The plan

1. Interpreters
2. Hw4 concepts

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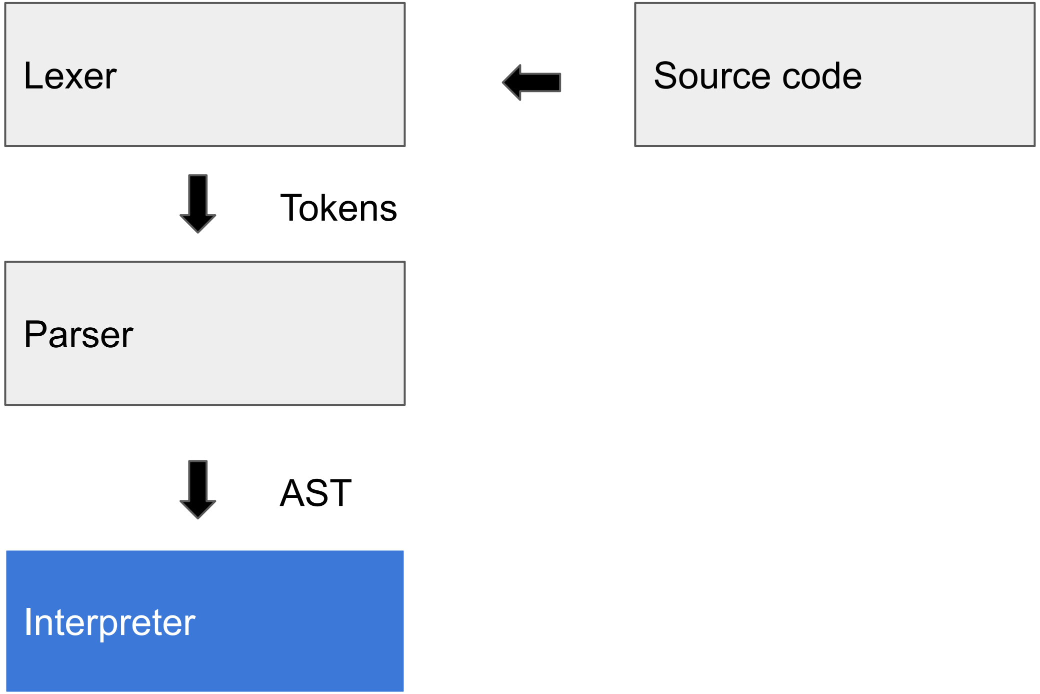
1. Interpreters
2. Hw4 concepts
   a. Environments
   b. Closures
   c. Native ops

Interpreters

Interpreters

An interpreter executes another program in some language without compilation

The big picture



A boring interpreter

```
Expr ::= IntLit Int | Add Expr Expr -- n | e1 + e2

eval :: Expr -> Int
eval e = ??
```

How do we implement `eval`?

A boring interpreter

```
Expr ::= IntLit Int | Add Expr Expr -- n | e1 + e2

eval :: Expr -> Int
eval (IntLit x)  = x
eval (Add e1 e2) = (eval e1) + (eval e2)
```

Nano is not so simple...

```
data Expr
  = EInt Int
  | EBool Bool
  | ENil                    -- []
  | EVar Id                 -- x
  | EBin Binop Expr Expr
  | EIf Expr Expr Expr      -- If e1 then e2 else e3
  | ELet Id Expr Expr       -- let x = e1 in e2
  | EApp Expr Expr          -- e1 e2
  | ELam Id Expr            -- \x. e
```

What does it mean to “evaluate” an Expr?

```
eval :: ??
eval = ??
```

What does it mean to “evaluate” an Expr?

```
eval :: Env -> Expr -> ??
eval = ??
```

Our output type needs to be able to represent any possible result -- a boolean, a list, etc...

What does it mean to “evaluate” an Expr?

```
eval :: Env -> Expr -> Value
eval = ??

data Value
  = VInt  Int
  | VBool Bool
  | VClos Env Id Expr         -- will discuss later
  | VNil                      -- []
  | VCons Value Value         -- x:xs
  | VPrim (Value -> Value)    -- will discuss later
```

Environments

How should we evaluate this:

```
let x = 5 in x + x
```

Environments

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```
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```

We need to know the value of “x” while evaluating “x + x”

```
type Env = [(Id, Value)]
```

Environments

```
eval :: Env -> Expr -> Value
eval env e = ??
```

You might need to update the environment when recursively evaluating subexpressions

Closures

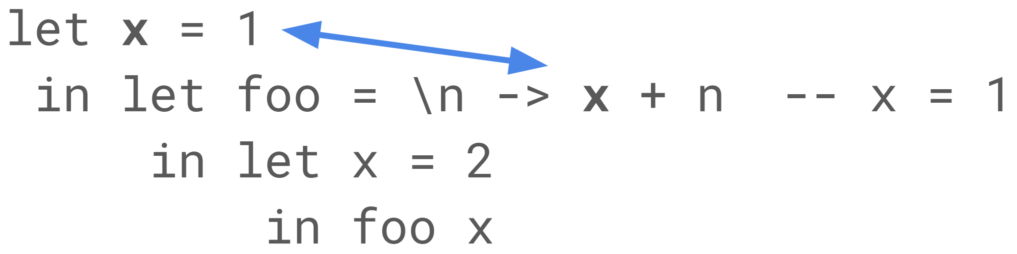
```
data Value
  = VInt  Int
  | VBool Bool
  | VClos Env Id Expr       -- will discuss later
  | VNil                    -- []
  | VCons Value Value       -- x:xs
  | VPrim (Value -> Value)  -- will discuss later
```

Why closures?

```
let x = 1
 in let foo = \n -> x + n
     in let x = 2
         in foo x
```

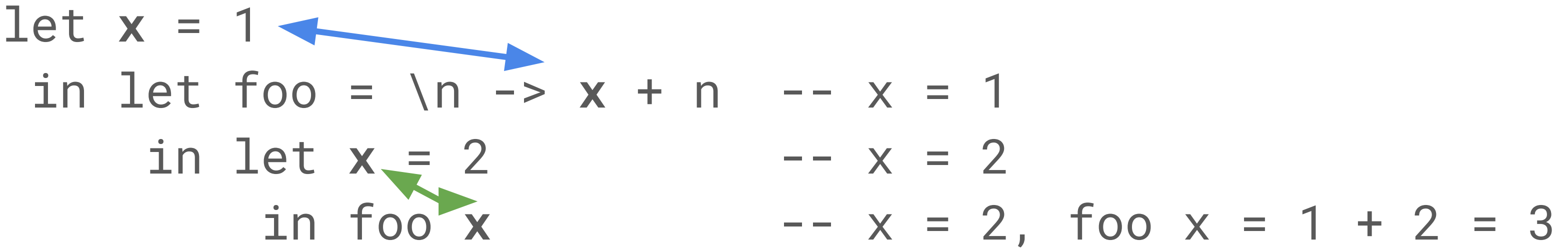
How should we evaluate this?

Why closures?



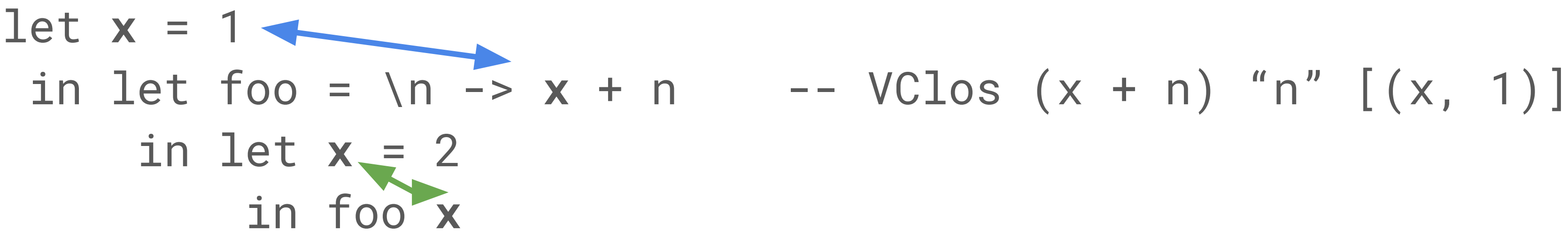
```
let x = 1
 in let foo = \n -> x + n  -- x = 1
   in let x = 2
     in foo x
```

Why closures?



```
let x = 1
 in let foo = \n -> x + n  -- x = 1
     in let x = 2          -- x = 2
         in foo x          -- x = 2, foo x = 1 + 2 = 3
```

When create a closures?



```
let x = 1
 in let foo = \n -> x + n     -- VClos (x + n) “n” [(x, 1)]
     in let x = 2
         in foo x
```

```
data Value
  = …                        -- (VClos e “x” env) is
  | VClos Env Id Expr        -- A function with argument “x”
  | …                        -- and body e that was defined
                             -- in an environment env
```

Native ops

```
data Binop = … | Cons

data ENil = … | ENil

data Value = … | VNil | VCons Value Value
```

Native ops

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Now, add support for “head” and “tail”...

Native ops

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How might we do this?

Native ops

We need to be able to define primitive function -- sort of a standard library

One function constructor:

```
VClos Env Id Expr
```

Native ops

We need to be able to define primitive function -- sort of a standard library

One function constructor:

```
VClos Env Id Expr
```

This won’t let us define “head” or “tail”!

The Expr type doesn’t allow us to pattern match on the list -- no way to represent these functions in our Expr language

Native ops

```
data Value = … | VPrim (Value -> Value)
```

Now you can implement normal Haskell functions over Values and use them

Stuff I haven’t talked about

Function application

```
let f = \x -> x + 1
 in f 3
```

Stuff I haven’t talked about

Function application

```
let f = \x -> x + 1 -- [(“f”, VClos [] “x” (“x” + 1))]
 in f 3
```

How does one evaluate `(f 3)`?

Stuff I haven’t talked about

Function application

```
let f = \x -> x + 1 -- [(“f”, VClos [] “x” (“x” + 1))]
 in f 3
```

Stuff I haven’t talked about

Function application

```
let factorial = \n ->
       if n <= 0
          then 1
          else n * (factorial (n - 1))
 in factorial 3
```