Compiler construction

Lecture 9: attribute grammars and project summary

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Vårtermin 2017

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Attribute grammars

What are attribute grammars?

- An attribute grammar is a means to associate attributes (semantics) with the productions of a grammar (syntax)
- Describe tree traversals, for example maps, folds
- Attributes:

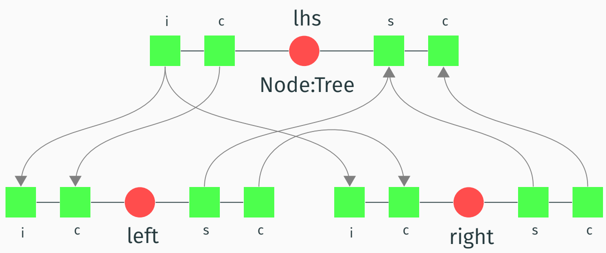
synthesized these 'travel' upward through a syntax tree, from child to parent

inherited these 'travel' downward through a syntax tree, from parent to child

(chained) these are inherited as well as synthesized

Attributes

```
data Tree | Node  left, right  :: Tree
          | Leaf  value        :: Int
```



Why are they useful?

- Allows for modular development, separation of concerns
- Reduces boilerplate code
- Example applications:
  - Scope/type checking
  - AST transformations, for example α-renaming
  - Code generation
  - Pretty printing

UUAGC

- The UU attribute grammar system
- It is implemented as a preprocessor to Haskell
- UHC is developed with UUAGC
- Available on Hackage

Binary trees: `sum`

```
data Tree | Node  left, right  :: Tree
          | Leaf  value        :: Int

attr Tree
  syn sum :: Int

sem Tree
  | Node  lhs.sum  =  @left.sum + @right.sum
  | Leaf  lhs.sum  =  @value

tree :: Tree
tree = Node (Leaf 1) (Node (Leaf 2) (Leaf 3))
```

Binary trees: `sum`

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  | Node left, right :: Tree
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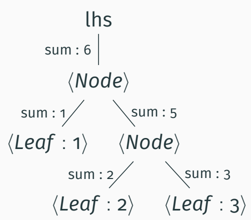

Binary trees: `depth` and `index`

```
attr Tree
  inh depth :: Int
  chn index :: Int

sem Tree
  | Node  loc.depth   = @lhs.depth + 1
          left.depth  = @depth
          right.depth = @depth

sem Tree
  | Node  left.index  = @lhs.index
          right.index = @left.index
          lhs.index   = @right.index
  | Leaf  lhs.index   = @lhs.index + 1
```

Binary trees: `depth` and `index` using copy rules

```
attr Tree
  inh depth :: Int
  chn index :: Int

sem Tree
  | Node  loc.depth   = @lhs.depth + 1

sem Tree
  | Leaf  lhs.index   = @lhs.index + 1
```

The archetypal `repmin` problem

```
data Root
   | Root Tree

attr Tree
  inh gmin :: Int
  syn lmin use {‘min‘} {0} :: Int

attr Root Tree
  syn result :: self

sem Tree
  | Leaf lhs.lmin   = @value
            .result = Leaf @lhs.gmin
sem Root
  | Root tree.gmin = @tree.lmin
```

A small expression language

```
{
data Type  = Int   | Bool
data Value = I Int | B Bool
type Env   = M.Map String Type
}

data Expr
  | Con val  :: {Value}  -- Constants
  | Var name :: String   -- Variables
  | Let name :: String   -- Let binding
        expr :: Expr
        body :: Expr
  | Add x, y :: Expr     -- Add operator
  | And x, y :: Expr     -- Logical and operator

deriving Expr : Ord, Eq, Show
```

Type checking

```
attr Expr
  inh env  :: {Env}
  syn ty   :: {Type}

sem Expr
  | Con lhs.ty   = case @val of I _ -> Int ; _ -> Bool
  | Var lhs.ty   = lookupTy @name @lhs.env
  | Let lhs.ty   = @body.ty
        body.env = M.insert @name @expr.ty @lhs.env
  | Add lhs.ty   = tyCheck Int  @x.ty @y.ty
  | And lhs.ty   = tyCheck Bool @x.ty @y.ty
{
lookupVar v = fromMaybe (error "Unbound var!") . M.lookup v
lookupTy  v = fst . lookupVar v
tyCheck t t1 t2 | t1 == t2 && t == t1 = t1
                | otherwise = error "Type mismatch"
}
```

Free variables

```
attr Expr
  syn free use {++} {[]} :: Strings

-- Free variables
sem Expr
  | Var lhs.free = [@name]
  | Let lhs.free = @body.free \\ [@name]
```

Project summary

Some remarks

- Submit before the deadline!
- Book a time slot on the Doodle, see course website for a link
- Preperare the oral exam
- Good luck!