Lecture 32: Truthiness

"It would appear that we have reached the limits of what it is possible to achieve with computer technology, although one should be careful with such statements, as they tend to sound pretty silly in five years."

John Von Neumann, 1949

CS150: Computer Science
University of Virginia
Computer Science

David Evans
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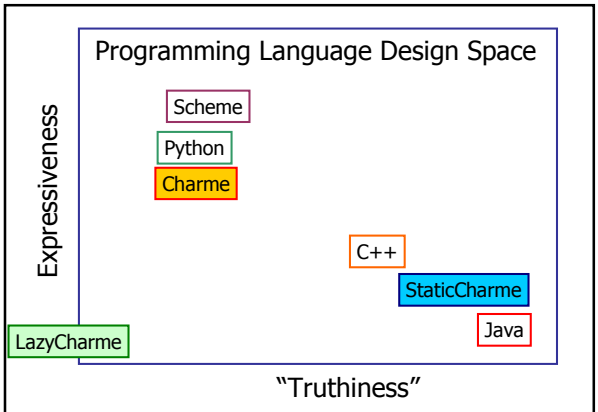
Problem Set 8

- Understand and modify a dynamic web application
- Will be posted on the web site before midnight tonight
- Due next Friday (April 13)

Problem Set 9

- Team requests and ideas due Monday (email me before midnight)

Programming Language Design Space



Types of Types

Charme StaticCharme

Latent ⇨ Manifest
change grammar, represent types

Dynamically Checked ⇨ Statically Checked
typecheck expressions before eval

Manifest Types

Need to change the grammar rules to include types in definitions and parameter lists

Definition ::= **(define** *Name* **:** *Type Expression*)
Parameters ::= ε | *Parameter Parameters*
Parameter ::= *Name* **:** *Type*

Type ::= ??

Types in Charme

CType ::= *CPrimitiveType*
CType ::= *CProcedureType*
CType ::= *CProductType*

CPrimitiveType ::= **Number** | **Boolean**
CProcedureType ::= **(***CProductType* **->** *Type***)**
CProductType ::= **(***CTypeList***)**
CTypeList ::= *CType CTypeList*
CTypeList ::=

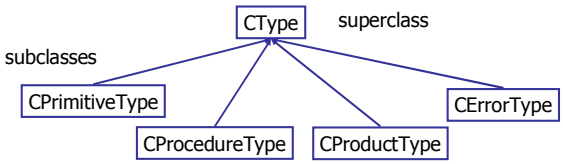
CType ::= *CPrimitiveType* | *CProcedureType* | *CProductType*
CPrimitiveType ::= **Number** | **Boolean**
CProcedureType ::= **(***CProductType* **->** *Type***)**
CProductType ::= **(***CTypeList***)**
CTypeList ::= *CType CTypeList*
CTypeList ::=

3
Number
+
((Number Number) -> Number)
(+ 3 3)
Number
(lambda (x:Number y:Number) (> x y))
((Number Number) -> Boolean)

Changed parameters grammar rule:
Parameter ::= *Name* **:** *Type*

Representing Types

CType ::= *CPrimitiveType* | *CProcedureType* | *CProductType*
CPrimitiveType ::= **Number** | **Boolean**
CProcedureType ::= **(***CProductType* **->** *Type***)**
CProductType ::= **(***CTypeList***)**
CTypeList ::= *CType CTypeList*
CTypeList ::=




```
class CType:
  @staticmethod
  def fromString(s):
     # create type from string
     tparse = parse(s)
     return CType.fromParsed(tparse[0])

  @staticmethod
  def fromParsed(typ):
     ... # create type from parsed type
  # These methods are overridden by subclasses
  def isPrimitiveType(self): return False
  def isProcedureType(self): return False
  def isProductType(self): return False
  def isError(self): return False
```

No self object

CPrimitiveType

```
class CPrimitiveType(CType):
  def __init__(self, s):
     self._name = s
  def __str__(self):
     return self._name
  def isPrimitiveType(self):
     return True
  def matches(self, other):
```

class X(Y):
means **X** is a subclass of **Y**

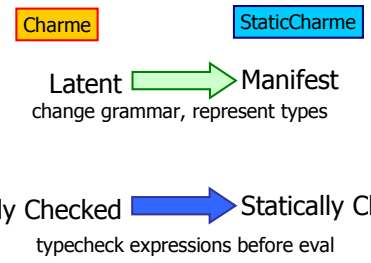
CProcedureType

```
class CProcedureType(CType):
  def __init__(self, args, rettype):
     self._args = args
     self._rettype = rettype
  def __str__(self):
     return "(" + str(self._args) + " -> " \
            + str(self._rettype) + ")"
  def isProcedureType(self): return True
  def getReturnType(self): return self._rettype
  def getParameters(self): return self._args
  def matches(self, other):
```


CProductType

```
class CProductType(CType):
  def __init__(self, types): self._types = types
  def __str__(self): ...
  def isProductType(self): return True
  def matches(self, other):
```

Types of Types



Adding Type Checking

```
def evalLoop():
    initializeGlobalEnvironment()
    while True:
        ...
            for expr in exprs:
                typ = typecheck(expr, globalEnvironment)
                if typ and typ.isError():
                    print "Type error:" + typ.getMessage()
                else:
                    res = meval(expr, globalEnvironment)
                    if res != None:
                        print str(res)
```


Static Type Checking

```
def typecheck(expr, env):
  if isPrimitive(expr):
    return typePrimitive(expr)
  elif isConditional(expr):
    return typeConditional(expr, env)
  elif isLambda(expr):
    return typeLambda(expr, env)
  elif isDefinition(expr):
    typeDefinition(expr, env)
  elif isName(expr):
    return typeName(expr, env)
  elif isApplication(expr):
    return typeApplication(expr, env)
  else: evalError ("Unknown expression: " + str(expr))
```



```
class Environment:
  # Store a [type, value] pair for each variable.
  ...
  def addVariable(self, name, typ, value):
    self._frame[name] = (typ, value)
  def lookupPlace(self, name):
    if self._frame.has_key(name): return self._frame[name]
    elif (self._parent): return self._parent.lookupPlace(name)
    else: return None
  def lookupVariableType(self, name):
    place = self.lookupPlace(name)
    if place: return place[0]
    else: return CErrorType("Name not found")
  def lookupVariable(self, name):
    return self.lookupPlace(name)[1]
   ...
```


Typing Names

```
def typeName(expr, env):
    return env.lookupVariableType(expr)


def evalDefinition(expr, env):
    name = expr[1]
    value = meval(expr[4], env)
    typ = CType.fromParsed(expr[3])
    env.addVariable(name, typ, value)
```


Static Type Checking

```
def typecheck(expr, env):
  if isPrimitive(expr):
    return typePrimitive(expr)
  elif isConditional(expr):
    return typeConditional(expr, env)
  elif isLambda(expr):
    return typeLambda(expr, env)
  elif isDefinition(expr):
    typeDefinition(expr, env)
  elif isName(expr):
    return typeName(expr, env)
  elif isApplication(expr):
    return typeApplication(expr, env)
  else: evalError ("Unknown expression: " + str(expr))
```

```
def typeDefinition(expr, env):
    assert isDefinition(expr)
    if len(expr) != 5:
        evalError ("Bad definition: %s" % str(expr))
    name = expr[1]
    if isinstance(name, str):
        if expr[2] != ':':
            evalError ("Definition missing type: %s" % str(expr))
        typ = CType.fromParsed(expr[3])
        etyp = typecheck(expr[4], env)
        if not typ.matches(etyp):
            evalError("Mistyped definition: ..." % (name, typ, etyp))
    elif isinstance(name, list):
        evalError ("Procedure definition syntax not implemented")
    else: evalError ("Bad definition: %s" % str(expr))
```


Static Type Checking

```
def typecheck(expr, env):
    if isPrimitive(expr):
        return typePrimitive(expr)
    elif isConditional(expr):
        return typeConditional(expr, env)
    elif isLambda(expr):
        return typeLambda(expr, env)
    elif isDefinition(expr):
        typeDefinition(expr, env)
    elif isName(expr):
        return typeName(expr, env)
    elif isApplication(expr):
        return typeApplication(expr, env)
    else: evalError ("Unknown expression: " + str(expr))
```



```
class Procedure:
    def __init__(self, params, typ, body, env):
        self._params = params
        self._body = body
        self._typ = typ
        self._env = env
    def getParams(self):
        return self._params
    def getParamTypes(self):
        return self._typ
    def getBody(self): return self._body
    def getEnvironment(self): return self._env
    def __str__(self):
        return "<Procedure %s / %s>" \
          % (str(self._params), str(self._body))
```

Add type to Procedure


```
def evalLambda(expr, env):
    assert isLambda(expr)
    if len(expr) != 3:
        evalError ("Bad lambda expression: %s" % (str(expr)))
    params = expr[1]
    paramtypes = []
    paramnames = []
    assert len(params) % 3 == 0
    for i in range(0, len(params) / 3):
        name = params[i*3]
        assert params[(i*3)+1] == ':'
        paramnames.append(name)
        typ = CType.fromParsed(params[(i*3)+2])
        paramtypes.append(typ)
    return Procedure(paramnames, paramtypes, expr[2], env)
```



```
def typeLambda(expr, env):
    assert isLambda(expr)
    if len(expr) != 3: evalError ("Bad lambda expression: %s" % str(expr))
    # this is a bit tricky - we need to "partially" apply it
    # to find the type of the body
    newenv = Environment(env)
    params = expr[1]
    paramnames = []
    paramtypes = []
    assert len(params) % 3 == 0
    for i in range(0, len(params) / 3):
        name = params[i*3]
        assert params[(i*3)+1] == ':'
        typ = CType.fromParsed(params[(i*3)+2])
        paramnames.append(name)
        paramtypes.append(typ)
        newenv.addVariable(name, typ, None)
    resulttype = typecheck(expr[2], newenv)
    return CProcedureType(CProductType(paramtypes), resulttype)
```


Static Type Checking

```
def typecheck(expr, env):
    if isPrimitive(expr):
        return typePrimitive(expr)
    elif isConditional(expr):
        return typeConditional(expr, env)
    elif isLambda(expr):
        return typeLambda(expr, env)
    elif isDefinition(expr):
        typeDefinition(expr, env)
    elif isName(expr):
        return typeName(expr, env)
    elif isApplication(expr):
        return typeApplication(expr, env)
    else: evalError ("Unknown expression: " + str(expr))
```

Type Application

```
def typeApplication(expr, env):
    proctype = typecheck(expr[0], env)
    if not proctype.isProcedureType():
        evalError("Application of non-procedure: " + str(expr[0]))
    optypes = map (lambda op: typecheck(op, env), expr[1:])
    optype = CProductType(optypes)
    if not optype.matches(proctype.getParameters()):
        evalError("Parameter type mismatch: ..." \
                  % (proctype.getParameters(), optype))
    return proctype.getReturnType()
```


Static Type Checking

```
def typecheck(expr, env):
  if isPrimitive(expr):
    return typePrimitive(expr)
  elif isConditional(expr):
    return typeConditional(expr, env)
  elif isLambda(expr):
    return typeLambda(expr, env)
  elif isDefinition(expr):
    typeDefinition(expr, env)
  elif isName(expr):
    return typeName(expr, env)
  elif isApplication(expr):
    return typeApplication(expr, env)
  else: evalError ("Unknown expression: " + str(expr))
```


Type Primitives

```
def typePrimitive(expr):
    if isNumber(expr):
        return CPrimitiveType('Number')
    elif isinstance(expr, bool):
        return CPrimitiveType('Boolean')
    elif callable(expr):
        return findPrimitiveProcedureType(expr)
    else:
        assert False
```

This is a kludgey procedure that looks through the global environment to find the matching procedure, and returns its type

Static Type Checking

```
def typecheck(expr, env):
  if isPrimitive(expr):
    return typePrimitive(expr)
  elif isConditional(expr):
    return typeConditional(expr, env)
  elif isLambda(expr):
    return typeLambda(expr, env)
  elif isDefinition(expr):
    typeDefinition(expr, env)
  elif isName(expr):
    return typeName(expr, env)
  elif isApplication(expr):
    return typeApplication(expr, env)
  else: evalError ("Unknown expression: " + str(expr))
```

Left as possible Exam 2 question!

StaticCharme

```
StaticCharme> (+ 1 #t)
Error: Parameter type mismatch:
expected (Number Number), given (Number Boolean)
StaticCharme> (define square:((Number) -> Number)
  (lambda (x:Number) (* x x)))
StaticCharme> (square #t)
Type error: Parameter type mismatch:
expected (Number), given (Boolean)
StaticCharme> (define badret:((Number) -> Number)
                (lambda (x: Number) (> x 3)))
Error: Mistyped definition:
badret declared type ((Number) -> Number),
actual type ((Number) -> Boolean)
```


Define Compose

Is it possible to define compose in StaticCharme?

```
(define compose:((((Number) -> Number)
                  ((Number) -> Number))
                 -> ((Number) -> Number))
  (lambda (f:((Number) -> Number)
           g:((Number) -> Number))
    (lambda (x:Number)
      (f (g x)))))
```

But, no way to define a compose that works for any functions.

Charge

- PS9 project team requests and ideas due by midnight Monday
- PS8 will be posted soon