Implementing Type Checking with Classes

We used to have two records for each class:

- *Class declarations* = abstract syntax
- *Class* = run-time class information
  - flattened field and method lists

Now we'll have three:

- *Class declarations* = abstract syntax
- *Static class* = check-time class information
  - flattened lists with types
- *Class* = run-time class information
  - flattened lists

Static Class Elaboration

```
;; type-of-program : program -> type
(define (type-of-program pgm)
 (cases program pgm
   (a-program (c-decls exp)
     (statically-elaborate-class-decls! c-decls)
     (type-of-expression exp (empty-tenv)))))
```

Checking Class Declarations

Check:

- Superclass exists, and no cyclic inheritance
- Methods bodies ok
  - Use host class for type of **self**
- Overriding method signatures are the same as in superclass
  - Except for **initialize**

```
class c2 extends c1
 method void m(int x, bool y)
  if y then +(2, x) else send self w()
```

Checking Class Declarations

- Cyclic inheritance covered by requirement that classes are ordered

```
(define statically-elaborate-class-decls!
  (lambda (c-decls)
    (for-each statically-elaborate-class-decl!
              c-decls)
    (for-each check-class-method-bodies!
              c-decls)))
```

Checking Class Declarations: Methods

```
(define (check-class-method-bodies! c-decl)
   ...
   (for-each
     (lambda (m-decl)
       (typecheck-method-decl!
         m-decl
         class-name super-name
         field-ids field-tys))
     m-decls))
```

Checking Class Declarations: Methods

```
(define (typecheck-method-decl! m-decl self-name
                 super-name field-ids field-types)
 (cases method-decl m-decl
  (a-methd-decl (res-texp name id-texps ids body)
   (let* ((id-tys (expand-ty-exprs id-texps))
          (tenv
            (extend-tenv
             (cons '%super (cons 'self ids))
             (cons (class-type super-name)
                   (cons (class-type self-name)
                         id-tys))
             (extend-tenv
              field-ids field-tys (empty-tenv))))
          (body-ty (type-of-expr body tenv)))
     (check-is-subtype!
      body-ty (expand-ty-expr res-texp) m-decl)))
  (an-abstract-method-decl (...) #t)))
```

Checking Object Creation

Check:

- Class exists, and is not abstract
- Class has an **initialize** method
- **initialize**'s argument types match the operand types

class c1 extends object
method void initialize(**int x**, **bool y**)
...

new c1(1, **false**)

Checking Object Creation

```
(define (type-of-new-obj-exp rand-types)
 (cases static-class (static-lookup class-name)
  (a-static-class (...)
    (cases abstraction-specifier specifier
      (abstract-specifier ()
        (eopl:error ...))
      (concrete-specifier ()
        (type-of-method-app-exp
         #t ;; means from 'new'
         (class-type class-name)
         'initialize
         rand-types)
        ;; Result:
        (class-type class-name))))))
```

Checking Method Calls

Check:

- Receiver expression is an object
- Method is in the object-type's class
  - Except **initialize**...
- Method's argument types match the operand types

```
class c1 extends object
  method void initialize() ...
  method void m(int x, bool y)
    ...
let o1 = new c1()
in send o1 m(1, false)
```

Checking Method Calls

```
(define (type-of-method-app-exp for-new? obj-type
                                 msg rand-types)
  (if (and (eq? msg 'initialize) (not for-new?))
    (eopl:error ...))
  (cases type obj-type
    (class-type (class-name)
      (type-of-method-app-or-super-call
        #f class-name msg rand-types))
    (else
      (eopl:error ...))))
```

Checking Super Calls

Check:

Same as method calls, but simpler:

- No check for **initialize**
- No possibility of a non-object type

```
(define (type-of-super-call-exp super-name
                                msg rand-types)
    (type-of-method-app-or-super-call
      #t super-name msg rand-types)
```

Checking Method Application

```
(define (type-of-method-app-or-super-call
             super-call? host-name msg rand-tys)
 (let ((method (statically-lookup-method msg
                (static-class->methods
                  (static-lookup host-name)))))
   (if (static-method? method)
     (cases static-method method
       (a-static-method (method-name spec
                         method-ty super-name)
         (let ((result-ty (type-of-app
                           method-ty rand-tys)))
           (if super-call?
               (cases abstraction-specifier spec
                 (concrete-spec () result-ty)
                 (abstract-spec () (error ...)))
               result-ty))))
     (eopl:error ...))))
```

Checking Casts

Check:

- Operand has an object type (for any class)
- Target class exists
- Class for operand and target must be comparable
  - Otherwise, cast cannot possibly succeed

class c1 extends object ...
class c2 extends object ...
cast new c1() c2

Checking Casts

```
(define (type-of-cast-exp ty name2 exp)
 (cases type ty
  (class-type (name1)
    (if (or (statically-is-subclass? name1 name2)
            (statically-is-subclass? name2 name1))
        (class-type name2)
        (eopl:error ...)))
  (else
    (eopl:error ...)))))
```

Checking Other Expressions

- Other expression forms checked as before
- **`check-is-subtype!`** often used instead of **`check-equal-type!`**

Compiling with Classes (Optionally)

- Recall that a ***compiler*** takes a program in language *A* and produces a program in language *B*
- To make compilation optional, a common trick is to set *B* = *A*, with the expectation that source programs use only a subset of *A*

Grammar with Compiler-target Cases

<expr> ::= <num>
::= <id>
::= <prim>(<expr>*(,))
...
::= **send** <expr> <id>(<expr>*(,))
...
::= <<num>,<num>>
::= **send** <expr> <<num>>(<expr>*(,))

Grammar with Compiler-target Cases

```
(define the-grammar
  '((program ((arbno class-decl) expression)
             a-program)

    (expression (number) lit-exp)
    (expression ("true") true-exp)
    ...
    (expression ("lexvar" number number)
      lexvar-exp)
    (expression
      ("imethod" expression number
       (separated-list expression ","))
      apply-method-indexed-exp)))
```

Interpreter with Compiler-target Cases

```
(define (eval-expression exp env)
  (cases expression exp
    (lit-exp (datum) datum)
    (var-exp (id) (apply-env env id))
    ...
    (lexvar-exp (depth pos)
         (apply-env-lexvar env depth pos))
    (apply-method-indexed-exp (obj-exp pos rands)
      (let ((obj (eval-expression obj-exp env))
            (args (eval-rands rands env))
            (c-name (object->class-name obj)))
        (apply-method
          (list-ref
           (class->methods (lookup-class c-name))
           pos)
          ...)))))
```

HW 10

Homework 10:

- Replace variables with lexical addresses
- Attach field count to **new**
- Index for **initialize** for **new**
- Index for class, instead of finding by name
- Change **super** to use class and method index
- ... and more, if you'd like