CIS (4|5)61

Winter 2017 Final Exam

1. Consider the following grammar. (I use λ as a place-holder for an empty production.)

$\langle S \rangle$ ::= $\langle Tree \rangle$ \$

$\langle Tree \rangle$ ::= $\langle Leaf \rangle$

$\langle Tree \rangle$ ::= $\langle Head \rangle$ $\boxed{:}$ $\langle Children \rangle$ $\boxed{;}$

$\langle Head \rangle$ ::= v

$\langle Children \rangle$ ::= $\langle Children \rangle$ $\langle Tree \rangle$

$\langle Children \rangle$ ::= λ

$\langle Leaf \rangle$ ::= v

Part 1 [5 points]: Assuming the strings a, b, c, ... all match the lexical pattern for the token v, which of these sentences are accepted by the grammar? (Circle accepted sentences.)

- `a: ;`
- `a b c`
- `a: b c;`
- `a: b c d: e f ; g h;`
- `a: b: c: ; ; ;`

Part 2 [10 points]: Here's that grammar again. Show a parsing state in which LALR(1) lookahead resolves an LR(0) conflict.

$\langle S \rangle$ ::= $\langle Tree \rangle$ \$

$\langle Tree \rangle$ ::= $\langle Leaf \rangle$

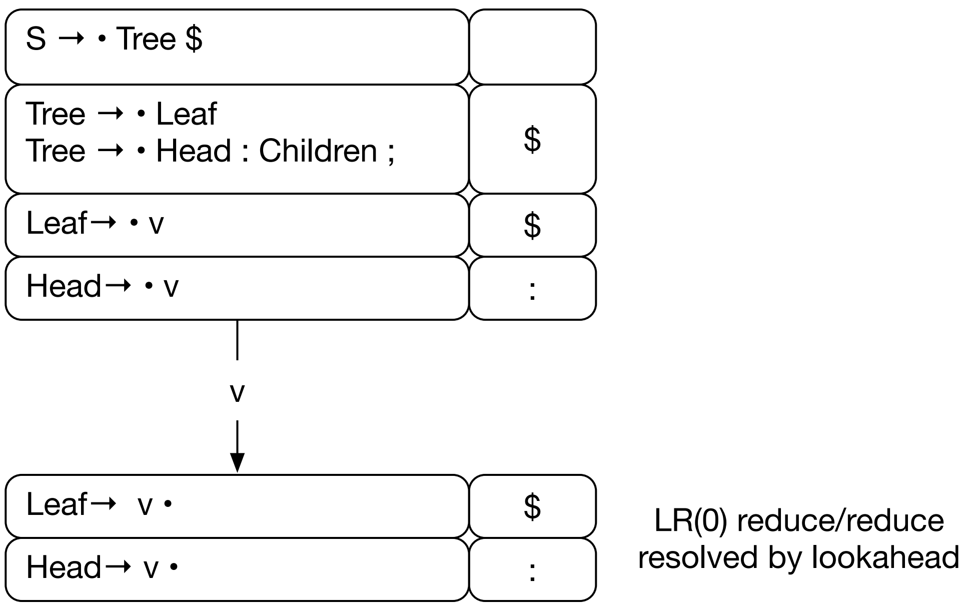
$\langle Tree \rangle$ ::= $\langle Head \rangle$ $\boxed{:}$ $\langle Children \rangle$ $\boxed{;}$

$\langle Head \rangle$ ::= v

$\langle Children \rangle$ ::= $\langle Children \rangle$ $\langle Tree \rangle$

$\langle Children \rangle$ ::= λ

$\langle Leaf \rangle$ ::= v



(score)

2. [5 points] Consider the following Quack program.

```
class Weight(w: Int) {
  this.w = w;
  def inc(delta: Int): Weight {
     return Weight(this.w + delta);
  }
}

class Height(h: Int) {
  this.h = h;
  def inc(delta: Int): Height {
     return Height(this.h + delta);
  }
}

x = 42;
if x > 13 {
   measure = Weight(x);
} else {
   measure = Height(x);
}
size = measure.inc(13);
```

Will this program pass the type checker? If not, why not? If so, what value will be computed for `size`?

It will fail because inferred type Obj (the least common ancestor of Height and Weight) does not have a method inc.

(score)

3. [5 points] Consider the following Quack program.

```
class RGB(r: Int, g: Int, b: Int) {
   this.r = r; this.g = g; this.b = b;
   def STR(): String {
        return "rgb(" + this.r.STR() +
                ", " + this.g.STR() +
                 "," + this.b.STR() +
              ")";
   }
}

class Red() extends RGB {
     this.r = 255; this.g = 0; this.b = 0;
     def STR(): String { return "RED"; }
}

class Purple() extends RGB {
       this.r = 150; this.g = 0; this.b = 150;
       def STR(): String { return "PURPLE"; }
}

color = RGB(0,0,0);
color.PRINT();
"\n".PRINT();
color = Red();
color.PRINT();
"\n".PRINT();
```

What will this Quack program print?

rgb(0,0,0)
RED

I was a little surprised how many students had trouble with this, and with subsequent questions that required you to understand dynamic method dispatch. Regardless of the static type of variable 'color,' the PRINT and STR methods will be accessed through the method table (vtable) in the class referenced by the actual object, i.e., the dynamic type determines which method is called.

(score)

4. [5 points] While the Quack type system enforces contravariance for most arguments to methods that override a superclass method, the implicit "this" argument (also known as the "receiver" object) is not contravariant. Why is it ok for the implicit "this" argument to be a subtype of the "this" argument of the method from the superclass?

Dynamic method dispatch prevents the method from ever being called with a supertype of the expected 'this' argument, because we use the method table of the variable to find the method code.

5. [5 points] Our compiled programs use three areas of program storage:

- *text* area: Program code goes here.
- *stack* area: Local variables and some other dynamic information such as method return addresses go here.
- *heap* area: We put objects here. Class method tables can go here or in the *text* area.

Allocating storage in the *stack* area is more efficient than allocating storage in the *heap* area. Why don't we put objects in the *stack*? What could go wrong if we did?

Stack frames are reclaimed and reused when a method returns. If a reference to an object lives beyond the return of a function (e.g., because we returned an object created in the method), then our object reference will be a pointer to an area of memory that has been recused for something else.

(score)

6. [10 points] I made a mistake in the design of the Quack language. I intended that the == operation as syntactic sugar would make it easy to create user-defined EQUALS methods for each class, or to inherit the EQUALS method of the Obj class. But the following program is rejected by the Quack compiler:

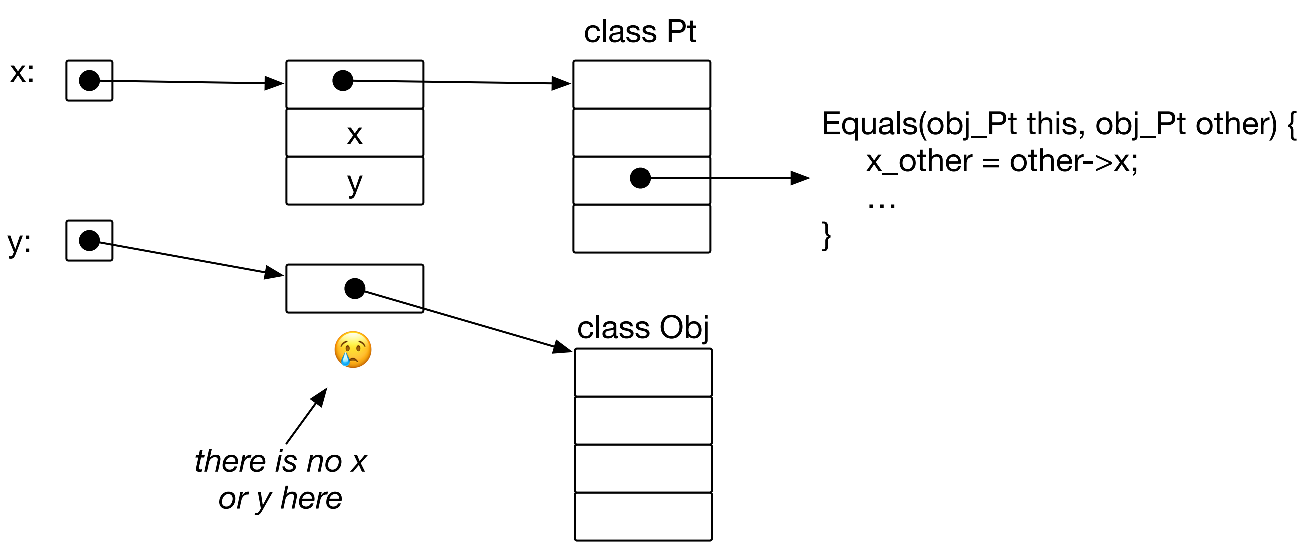
```
class Pt(x: Int, y: Int) {
   this.x = x;
   this.y = y;

   /* Override Obj.EQUALS */
   def EQUALS(other: Pt): Boolean {
       return this.x == other.x and
              this.y == other.y;
   }
}
```

Explain why this class, which overrides the EQUALS method of the Obj class, must be rejected. Be as explicit and concrete as possible. Don't just tell me that it breaks the covariance/contravariance rule of the Quack type system; explain how the object code created for this class could crash if we compiled it the way we compile other Quack classes. If possible, illustrate with a little bit of Quack code that will result in an invalid pointer dereference (typically a 'segfault'), or draw a picture to illustrate the issue.

Example code:

```
x = "Doop doop de woop";
x = Pt(1,1);
y = Obj();
if x == y {
   "We'll crash before we get here".PRINT();
}
```



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