EDAN65: Compilers, Exercise set E-14

Problems

Görel Hedin

Revised: 2017-10-16

Problem E14-1

A language L is described by following context-free grammar:

```
p1:   E -> E "+" E
p2:   E -> E "*" E
p3:   E -> ID
```

where E is the start symbol, and ID is a terminal symbol representing an identifier. Prove by writing down a left-most derivation that

```
ID "+" ID "*" ID
```

belongs to L. For each derivation step, show which production was used.

Problem E14-2

Consider the following context-free grammar for a textual representation of a graph with labelled nodes and edges. The start symbol is Graph:

```
Graph -> ElementList
ElementList -> Element ElementList
ElementList -> ε
Element -> Node
Element -> Edge
Node -> ID
Edge -> ID "(" ID "->" ID ")"
```

The terminal ID has the following regular expression definition:

```
ID = [a-z]+
```

Draw the parse tree for the following graph:

```
a e(a->b)
```

Problem E14-3

Consider the following context-free grammar for a textual representation of a graph with labelled nodes and edges. The start symbol is Graph:

```
p1: Graph -> ElementList
p2: ElementList -> Element ElementList
p3: ElementList -> ε
p4: Element -> Node
p5: Element -> Edge
p6: Node -> ID
p7: Edge -> ID "(" ID "->" ID ")"
```

This grammar is not LL(1). Explain why.

Problem E14-4

The following grammar contains a common prefix. Transform the grammar to an equivalent grammar where the common prefix is eliminated.

```
Graph -> ElementList
ElementList -> Element ElementList
ElementList -> ε
Element -> Node
Element -> Edge
Node -> ID
Edge -> ID "(" ID "->" ID ")"
```

Problem E14-5

The following grammar is left-recursive and therefore not LL(1). Transform the grammar to an equivalent grammar that is LL(1). Argue for that your resulting grammar is LL(1).

```
T -> T "*" F
T -> F
F -> ID
F -> "(" T ")"
```

Problem E14-6

Consider the following context-free grammar for a textual representation of a graph with labelled nodes and edges. The start symbol is G:

```
p1: G -> ElemList
p2: ElemList -> Elem ElemList
p3: ElemList -> ε
p4: Elem -> Node
p5: Elem -> Edge
p6: Node -> ID
p7: Edge -> ID "(" ID "->" ID ")"
```

The terminal ID has the following regular expression definition:

```
ID = [a-z]+
```

Show how an LR parser would parsing the following program:

```
a e(a->b)
```

Show the stack contents, the remaining input, and the parsing action taken in each step.

Problem E14-7

Consider the following abstract grammar for a graph of nodes and edges.

```
G ::= Element*;
abstract Element;
Node:Element ::= <ID>;
Edge:Element ::= Src:NodeUse Dst:NodeUse;
NodeUse ::= <ID>;
```

Suppose there is an attribute

```
   Node NodeUse.maybeNode()
```

that refers to the node of the same name as the NodeUse, or to null if there is no such node.

Define a boolean synthesized attribute wellFormed() for Edge nodes, that is true iff both its source and destination nodes exist.

Problem E14-8

Consider the following abstract grammar for a graph of nodes and edges.

```
G ::= Element*;
abstract Element;
Node:Element ::= <ID>;
Edge:Element ::= Src:NodeUse Dst:NodeUse;
NodeUse ::= <ID>;
```

Suppose there is an attribute

```
Node NodeUse.maybeNode()
```

that refers to the node of the same name as the NodeUse, or to null if there is no such node.

To represent missing nodes, introduce a new AST class UnknownNode, and create an object of this class as an NTA of the root.

Define a new attribute

```
Node NodeUse.node()
```

that refers to the UnknownNode object instead of to null.

Problem E14-9

Consider the following abstract grammar for a graph of nodes and edges.

```
G ::= Element*;
abstract Element;
Node:Element ::= <ID>;
Edge:Element ::= Src:NodeUse Dst:NodeUse;
NodeUse ::= <ID>;
```

Implement an attribute

```
Node NodeUse.maybeNode()
```

that refers to the node of the same name as the NodeUse, or to null if there is no such node.

Problem E14-10

Consider the following abstract grammar for a graph of nodes and edges.

```
G ::= Element*;
abstract Element;
Node:Element ::= <ID>;
Edge:Element ::= Src:NodeUse Dst:NodeUse;
NodeUse ::= <ID>;
```

Define an attribute

```
  int G.nbrOfEdges()
```

that counts the number of edges in the graph. Use a collection attribute to compute the attribute. You can use a class Counter with the following implementation:

```
public class Counter {
  private count = 0;
  public void add(int n) {
    count = count + n;
  }
  public int count() {
    return count;
  }
}
```

Problem E14-11

Consider the following abstract grammar for a graph of nodes and edges.

```
G ::= Element*;
abstract Element;
Node:Element ::= <ID>;
Edge:Element ::= Src:NodeUse Dst:NodeUse;
NodeUse ::= <ID>;
```

Suppose there is an attribute

```
Node NodeUse.maybeNode()
```

that refers to the node of the same name as the NodeUse, or to null if there is no such node.

If there is an edge a->b, we say that the node b is a target of a. Implement a collection attribute Node.targets() containing all the target nodes for a given node.

For sets, you may use the Java type HashSet.

Problem E14-12

Consider the following abstract grammar for a graph of nodes and edges.

```
G ::= Element*;
abstract Element;
Node:Element ::= <ID>;
Edge:Element ::= Src:NodeUse Dst:NodeUse;
NodeUse ::= <ID>;
```

If there is an edge a->b, we say that the node b is a *target* of a. Suppose there is a collection attribute

```
Set<Node> Node.targets()
```

containing all the target nodes for a given node.

The *reachable* set of a node is the transitive set of target nodes. Implement the reachable set as a circular attribute. You can use the Java class HashSet with operations add and addAll, for adding one element or a set of elements.

Problem E14-13

```
class Account {
  int balance = 0;
  void deposit(int amount) {
    balance = balance + amount;
  }
  void withdraw(int amount) {
    if (amount > balance)
      overdraft(amount – balance);
    else
      balance = balance – amount;
  }
  void overdraft(int am) {
    /* PC */
    System.out.println
      ("Overdraft with amount "+am);
  }
}
void test() {
  Account a = new Account();
  a.deposit(100);
  a.withdraw(150);
}
```

Suppose that test() is called. Draw the situation on the stack and heap at /* PC */. Your sketch should include dynamic link, fields, local variables, "this" pointer, and arguments including their values. Arguments should be passed on the stack. Explain the contents of the withdraw activation.

Problem E14-14

```
class Figure {
  int area() { return 0; }
}
class Rectangle extends Figure {
  int w;
  int h;
  void set(int w, int h) {
    this.w = w;
    this.h = h;
  }
  int area() {
    return w * h;
  }
  ...
}
```

Suppose this language is implemented using virtual tables. Draw a sketch over the memory showing a Rectangle object, its class descriptor, and its code. Your sketch should include fields, class link, virtual table, and methods.

Problem E14-15

```
class Figure {
  int area() { return 0; }
}
class Rectangle extends Figure {
  int w;
  int h;
  void set(int w, int h) {
    this.w = w;
    this.h = h;
  }
  int area() {
    return w * h;
  }
  ...
}
void m(Figure f) {
  int a;
  a = f.area(); // S
}
```

This language is implemented using virtual tables. Draw the situation on stack and heap at statement S, right before the call to f.area() is made. Assume f is a Rectangle object and include the class descriptor in your sketch. Sketch the code for the statement S. Use x86 instructions according to the assignment 6 cheatsheet. Add comments to the code, explaining what it does.