10.5 Laboratory: A Stack-Based Language

Objective. To implement a PostScript-based calculator.

Discussion. In this lab we will investigate a small portion of a stack-based language called PostScript. You will probably recognize that PostScript is a file format often used with printers. In fact, the file you send to your printer is a program that instructs your printer to draw the appropriate output. PostScript is stack-based: integral to the language is an operand stack. Each operation that is executed pops its operands from the stack and pushes on a result. There are other notable examples of stack-based languages, including `forth`, a language commonly used by astronomers to program telescopes. If you have an older Hewlett-Packard calculator, it likely uses a stack-based input mechanism to perform calculations.

We will implement a few of the math operators available in PostScript.

To see how PostScript works, you can run a PostScript simulator. (A good simulator for PostScript is the freely available `ghostscript` utility. It is available from `www.gnu.org`.) If you have a simulator handy, you might try the following example inputs. (To exit a PostScript simulator, type `quit`.)

1. The following program computes $1 + 1$:

   ```
   1 1 add pstack
   ```

   Every item you type in is a *token*. Tokens include numbers, booleans, or symbols. Here, we've typed in two numeric tokens, followed by two symbolic tokens. Each number is pushed on the internal stack of operands. When the `add` token is encountered, it causes PostScript to pop off two values and add them together. The result is pushed back on the stack. (Other mathematical operations include `sub`, `mul`, and `div`.) The `pstack` command causes the entire stack to be printed to the console.

2. Provided the stack contains at least one value, the `pop` operator can be used to remove it. Thus, the following computes 2 and prints nothing:

   ```
   1 1 add pop pstack
   ```

3. The following "program" computes $1 + 3 * 4$:

   ```
   1 3 4 mul add pstack
   ```

   The result computed here, 13, is different than what is computed by the following program:

   ```
   1 3 add 4 mul pstack
   ```

   In the latter case the addition is performed first, computing 16.

4. Some operations simply move values about. You can duplicate values—the following squares the number 10.1:

   ```
   10.1 dup mul pstack pop
   ```

   The `exch` operator to exchange two values, computing $1 - 3$:

   ```
   3 1 exch sub pstack pop
   ```

5. Comparison operations compute logical values:

   ```
   1 2 eq pstack pop
   ```

   tests for equality of 1 and 2, and leaves `false` on the stack. The program

   ```
   1 1 eq pstack pop
   ```

   yields a value of `true`.

6. Symbols are defined using the `def` operation. To define a symbolic value we specify a "quoted" symbol (preceded by a slash) and the value, all followed by the operator `def`:

   ```
   /pi 3.141592653 def
   ```

   Once we define a symbol, we can use it in computations:

   ```
   /radius 1.6 def
   pi radius dup mul mul pstack pop
   ```

   computes and prints the area of a circle with radius 1.6. After the pop, the stack is empty.

Procedure. Write a program that simulates the behavior of this small subset of PostScript. To help you accomplish this, we've created three classes that you will find useful:

Token

Reader

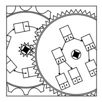
- `Token`. An immutable (constant) object that contains a double, boolean, or symbol. Different constructors allow you to construct different `Token` values. The class also provides methods to determine the type and value of a token.
- `Reader`. A class that allows you to read `Token`s from an input stream. The typical use of a reader is as follows:

  ```
  Reader r = new Reader();
  Token t;
  while (r.hasNext())
  {
      t = (Token)r.next();
      if (t.isSymbol() && // only if symbol:
          t.getSymbol().equals("quit")) break;
      // process token
  }
  ```

This is actually our first use of an `Iterator`. It always returns an `Object` of type `Token`.

- `SymbolTable`. An object that allows you to keep track of `String`–`Token` associations. Here is an example of how to save and recall the value of π:

```
SymbolTable table = new SymbolTable();
// sometime later:
table.add("pi",new Token(3.141592653));
// sometime even later:
if (table.contains("pi"))
{
    Token token = table.get("pi");
    System.out.println(token.getNumber());
}
```


SymbolTable

You should familiarize yourself with these classes before you launch into writing your interpreter.

To complete your project, you should implement the PostScript commands `pstack`, `add`, `sub`, `mul`, `div`, `dup`, `exch`, `eq`, `ne`, `def`, `pop`, `quit`. Also implement the nonstandard PostScript command `ptable` that prints the symbol table.

Thought Questions. Consider the following questions as you complete the lab:

1. If we are performing an `eq` operation, is it necessary to assume that the values on the top of the stack are, say, numbers?

2. The `pstack` operation should print the contents of the operand stack without destroying it. What is the most elegant way of doing this? (There are many choices.)

3. PostScript also has a notion of a *procedure*. A procedure is a series of `Token`s surrounded by braces (e.g., `{ 2 add }`). The `Token` class reads procedures and stores the procedure's `Token`s in a `List`. The `Reader` class has a constructor that takes a `List` as a parameter and returns a `Reader` that iteratively returns `Token`s from its list. Can you augment your PostScript interpreter to handle the definition of functions like `area`, below?

```
/pi 3.141592653 def
/area { dup mul pi mul } def
1.6 area
9 area pstack
quit
```

   Such a PostScript program defines a new procedure called `area` that computes πr^2 where r is the value found on the top of the stack when the procedure is called. The result of running this code would be

```
254.469004893
8.042477191680002
```

4. How might you implement the `if` operator? The `if` operator takes a boolean and a token (usually a procedure) and executes the token if the boolean is true. This would allow the definition of the absolute value function (given a less than operator, `lt`):

   ```
   /abs { dup 0 lt { -1 mul } if } def
   3 abs
   -3 abs
   eq pstack
   ```

   The result is `true`.

5. What does the following do?

   ```
   /count { dup 1 ne { dup 1 sub count } if } def
   10 count pstack
   ```

Notes: