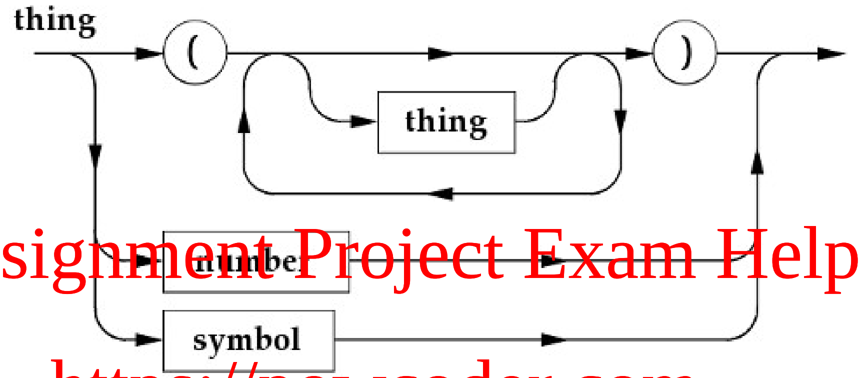
Programming Project 2
CSci 2041 Advanced Programming Principles
November 14, 2022

0. Introduction.

In this programming project, you will write an OCaml module whose functions read Lisp *thing*'s from a file. If we have a function that reads Lisp *thing*'s, a function that evaluates Lisp *thing*'s, and a function that prints Lisp *thing*'s, then we could put them all together to make a complete Lisp system.

1. Theory.

In formal language theory, a *language* is a set of strings; a *string* is a sequence of characters. A *grammar* is a mathematical description of a language that tells which strings are in the set, and which strings are not. One way to specify a grammar is to use mathematical rules, but we won't do that here. Instead, we'll use a directed graph called a *syntax diagram.* A syntax diagram for Lisp *thing*'s is shown below.



Every syntax diagram has a *name:* the name of this diagram is **thing**. It has exactly one arrow that lets you enter the diagram on the left, and exactly one arrow that lets you exit the diagram on the right. By following arrows from left to right, going all the way through the diagram, you can tell what sequences of tokens can be *thing*'s.

- The box labeled **thing** stands for a Lisp *thing*. The diagram is recursive, because it is defined in terms of itself: there is a box labeled **thing** inside the diagram labeled **thing**.

- The box labeled **number** is a Lisp number token. It's a sequence of one or more digits, '`0`' through '`9`', preceded by an optional minus sign '`-`'.

- The box labeled **symbol** is a Lisp symbol token. It's a sequence of one or more characters other than blanks, newlines, and parentheses.

- There is no box labeled **nil**, because it's simpler to pretend that `nil` is a **symbol**, although it really isn't (see below).

Here are some examples of *thing*'s that are described by the diagram.

- A number, like `100`, is a *thing,* because we can start on the left, follow arrows to the box labeled **number**, and then follow arrows out of the diagram again.

- A symbol, like `hello`, is also a *thing,* because we can start on the left, follow arrows to the box labeled **symbol**, and then follow arrows out of the diagram.

- An empty list, like `()`, is a *thing,* because we can follow an arrow to the circle labeled '**(**', follow an arrow to the circle labeled '**)**', and then follow an arrow out of the diagram. In Lisp, `()` is another notation for nil (see below).

- A list, like (a b c), is a *thing*, because we can follow an arrow to the circle labeled ‘**(**’, and then to the box labeled **thing**. We imagine that a copy of the diagram **thing** appears in place of that box. If we follow arrows through that copy, then we find that a is also a *thing*. If we go around the loop, back to the box labeled **thing**, we find that b is another *thing* in the same way, and if we go around the loop again, we find that c is a *thing* as well. When we exit the loop, we follow an arrow through a circle labeled ‘**)**’, and then follow yet another arrow out of the diagram.

We could show that nested lists like ((a) b c) and (a (b c)) are *thing*’s too, by following arrows through the diagram in the same way. And we could show that something like ‘)x(()5(’ is not a *thing*, because there is no way to follow arrows through the diagram given its characters.

2. Implementation.

For this project, you must write an OCaml module called Parser, whose type is the OCaml signature Parsers. (A *parser* is a procedure that reads a series of tokens and constructs a representation of what the tokens stand for.) The module Parser will use functions defined in the module Scanner from the lectures. Although Parser may contain many functions, only two OCaml objects must be visible outside it: the exception Can'tParse, and the function makeParser, both of which are described below.

Parsers

(5 points.) Signature. This signature must describe the function makeParser and the exception Can'tParse, but nothing else.

Can'tParse message

(5 points.) Exception, where message is a string. This must be raised by the functions described below if they can’t read a *thing*.

Parser

(10 points.) Module, with the type Parsers (see above). It must contain definitions for the exception Can'tParse, along with the functions makeParser, nextThing, and nextThings. It may also contain definitions of other objects, but only makeParser and Can'tParse must be visible outside Parser.

makeParser path

(10 points.) Return a parser: a new function that takes the OCaml unit object () as its only argument. (Do not confuse the OCaml unit object () with the Lisp empty list ()!) Each time it is called, the parser reads the next Lisp *thing* from the file whose pathname is the string path, and returns that *thing*.

The function makeParser must make a scanner by calling Scanner.makeScanner. It must also make a variable called token. The scanner reads tokens from the file whose pathname is path. The variable token holds the token most recently read by the scanner. The scanner and the variable must be visible to the parser returned by makeParser, but invisible to all other functions.

nextThing ()

(10 points.) This function does all the work for the parser returned by makeParser. It examines token and uses it to decide what kind of *thing* it will read. Then it reads the

thing, constructs an OCaml object which represents that *thing*, and returns the object. It does this in the following way.

If `token` is `CloseParenToken`	then	raise `Can'tParse`.
If `token` is `EndToken`	then	raise `Can'tParse`.
If `token` is `NumberToken` *n*	then	return `Number` *n*.
If `token` is `OpenParenToken`	then	read a Lisp list and return it.
If `token` is `SymbolToken "nil"`	then	return `Nil` (see below).
If `token` is `SymbolToken` *s*	then	return `Symbol` *s*.

Note that `nil` will be read by the token scanner as a `SymbolToken`. However, it must be treated as if it is OCaml's `Nil`.

`nextThings ()`

(10 points.) This is a helper that `nextThing` uses to read a Lisp list. When it is called, `token` is the first token after the `OpenParenToken` that begins the list. The function `nextThings` reads a series of zero or more *thing*'s from the file whose pathname is `path`. It stops reading when it encounters a `CloseParenToken` or an `EndFileToken`. If `nextThings` reads zero *things*, then it must return `Nil`. If it reads one or more *thing*'s t_1, t_2 ..., t_n, then it must return a Lisp list of those `thing`'s, like this.

`Cons (`t_1`, Cons (`t_2 …, `Cons (`t_n`, Nil)` … `))`

If `nextThings` encounters a `CloseParenToken`, then it must skip that token. If it encounters an `EndToken`, then it must raise `Can'tParse`, because this means the Lisp list ended without a `CloseParenToken`.

Here are some hints about how to write these functions. The scanner and the parser are designed according to similar rules, as follows.

- The scanner reads characters. The parser reads tokens.

- The scanner uses a variable `ch` to hold the most recently read character from a file. The parser uses a variable `token` to hold the most recently read token from a file.

- The scanner can tell what kind of token it was about to read by examining the first character of that token (in `ch`). The parser can tell what kind of *thing* it is about to read by examining the first token of that *thing* (in `token`).

- Whenever a function in the scanner was called, `ch` always holds the first character of the token to be read. Whenever a function in the parser is called, `token` always holds the first token of the *thing* to be read.

- Whenever a function in the scanner returns, `ch` always holds the next character after the token that was just read. Whenever a function in the parser returns, `token` always holds the next token after the *thing* that was just read.

To make some of these rules work, it is necessary to skip tokens after they are read. If `nextToken` is the name of the scanner created by `makeParser`, then we can skip a token by writing `token := nextToken ()`. For example, after `nextThing` reads a `SymbolToken`, it must skip that token in this way.

3. Examples.

The file **`things.txt`** on Canvas contains a series of example Lisp expressions. The file **`testsP2.ml`** on Canvas contains a series of calls to a parser created by `makeParser`. Each call reads the next Lisp expression from `things.txt`, converts it to an OCaml object, and prints that object.

You can use **`things.txt`** and **`testsP2.ml`** to test whether your parser works. However, unlike the tests that come with lab assignments, the tests in **`testsP2.ml`** are not worth points! The TA's will grade this project by reading your code, not by counting how many tests succeed and fail.

4. Deliverables.

Unlike the lab assignments, **YOU ARE NOT ALLOWED TO WORK WITH A PARTNER ON THIS PROJECT.** Although you may discuss the project with others in a general way, **IT MUST BE WRITTEN ENTIRELY BY YOURSELF.** The project is worth **50 points,** and will be due at **11:55 PM** on **November 30, 2022.**

The file **`parser.ml`,** available on Canvas, contains definitions for the OCaml type `thing` and the OCaml module `Scanner`. It also has space for you to put your code for `Parser`, the module that you must write for this project. Write your code in that space, and submit a copy of `parser.ml` with your code in it. If you don't know how or where to submit this file, then please ask your lab TA. **DOUBLE CHECK** to make sure you have submitted the correct file, both **BEFORE AND AFTER** you turn it in.