Project #2 — Scheme Exercises
CS 152 Section 5 — Fall 2021
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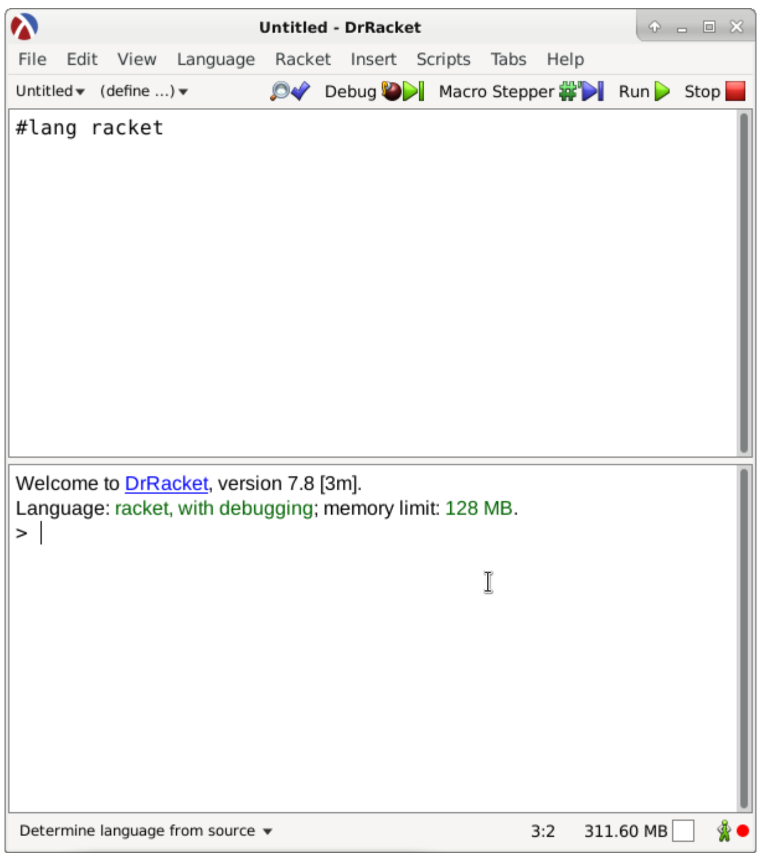
PAIRS ALLOWED: You may choose to work in pairs on this project. Keep in mind that once you begin working as partners, you may not change partners during the duration of the project, though you may either choose a different partner or work alone in the next project that allows pairs.

Prelude – Installing and Using DrRacket

We will be using the DrRacket IDE in this course for running Scheme programs. DrRacket is available for Windows, macOS, and Linux. You can download it by going to https://racket-lang.org, clicking on the "Download" button on the top right of the page, and choosing the appropriate platform for your computer.

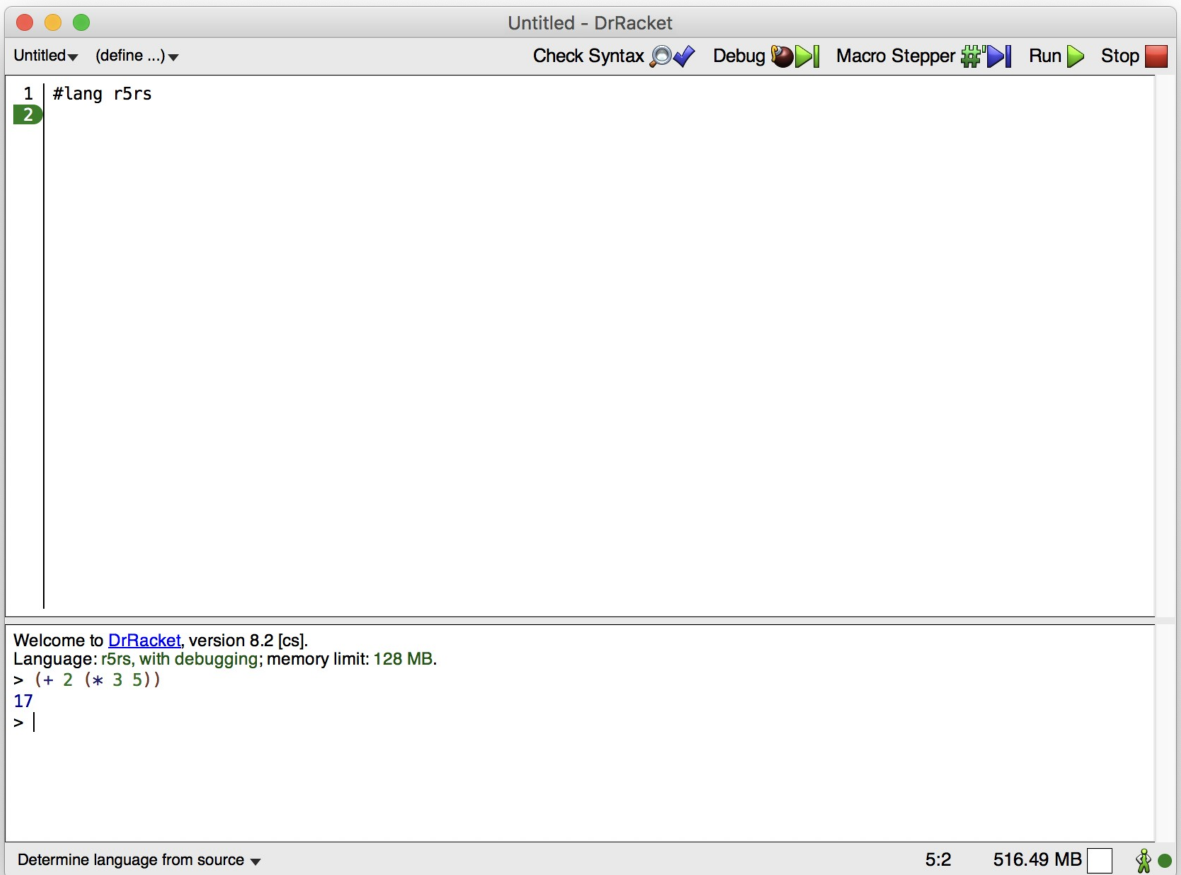
Once you have Racket installed, open DrRacket. Here is what DrRacket looks like on Linux; it should look similar on Windows and macOS:



Note that the window has two sections. The first section where you see "`#lang racket`" is the source code file. The second section is the interpreter, which some programmers call the REPL, which stands for the "Read Eval Print Loop," which describes how the user interface for interactive Lisp interpreters is implemented. (This REPL terminology has been now widely applied to other interactive interpreters, such as those for Python and JavaScript.) When you write your programs, you're going to use the upper portion. However, if you just want to evaluate an expression on the fly, you can use the REPL on the lower portion.

Now, notice the "`#lang racket`" in the source code file section of DrRacket. That indicates that the program written below that line will be in the Racket programming language, which is a variant of Scheme and is the default setting in DrRacket. For this assignment, however, we will be using the R5RS version of Scheme[1]. The complete language specification can be found at https://schemers.org/Documents/Standards/R5RS/HTML/. To use R5RS, replace the line "`#lang racket`" with "`#lang r5rs`" and then click "Run" on the toolbar above the source code section.

Let's try out the R5RS REPL by evaluating `(+ 2 (* 3 5))`. Type "`(+ 2 (* 3 5))`" at the prompt (with no quotes) and press Enter. Note that the following screenshot is from the macOS version of DrRacket:



When you write your code, you are going to use the upper portion of the window, and you are going to use the Run button to run your code, either the entirety of the source code or a selection of it.

1 There are more recent versions of Scheme such as R6RS and R7RS. However, the DrRacket implementation of R6RS lacks REPL support, and DrRacket currently does not support R7RS, the latest version of the Scheme standard.

For a more detailed tutorial of the DrRacket IDE, please visit the DrRacket IDE manual at https://docs.racket-lang.org/drracket/.

Warmup Exercises (40 points)

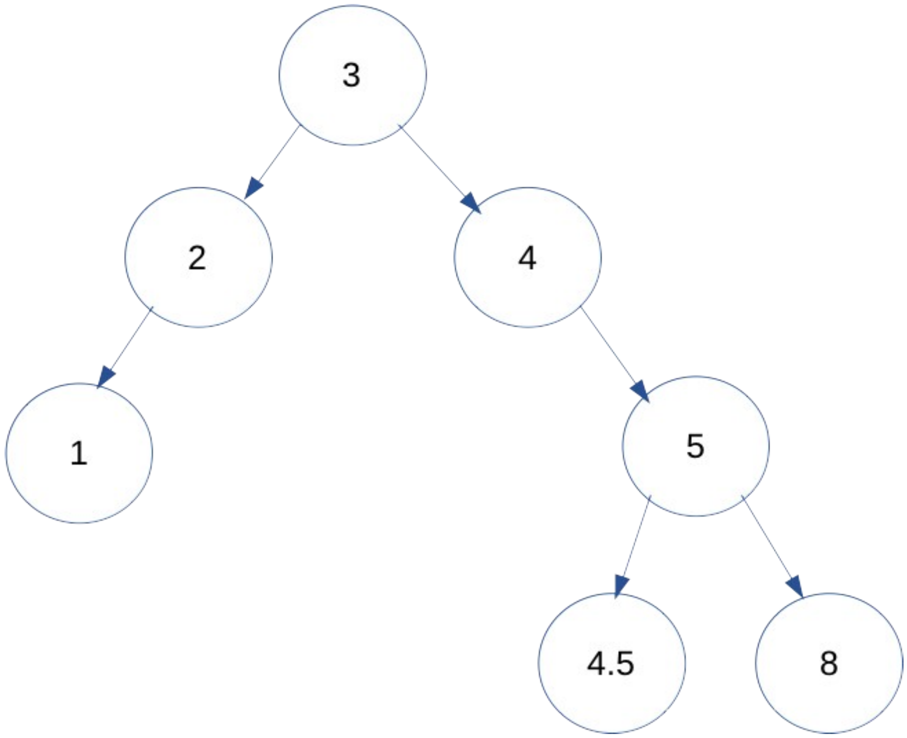
1. (10 points) Write a function named `fizz-buzz` that accepts no arguments. The fizz-buzz function outputs numbers 1 to 100 (inclusive) and prints them line-by-line as standard output. If a number is divisible by 3, we print "fizz" instead of the number. If a number is divisible by 5, we print "buzz" instead of the number. If a number is divisible by both 3 and 5 (e.g., 15), we print "fizzbuzz" instead of the number.

   Hint: Scheme provides a remainder function (e.g., `(remainder 3 2)` evaluates to `1`.) The display function accepts both numbers and strings. Note, though, that unlike Java's System.out.println() function, display does not automatically append a new line.

2. (10 points) Write a function named `sum-and-average` that accepts one argument `elems` that is a list of length 1 or more consisting of numbers. This computes the sum of all of the numbers in the list as well as the average. It returns a `cons` pair where the first element is the sum and the second element is the average. For traversing the list, you are limited to using the Scheme functions `first` (or `car`) and `rest` (or `cdr`) and performing recursion; you may not take advantage of maps and `for-each`.
3. (10 points) Write a function named `linear-search` that accepts two arguments: `items` and `key`. This function performs a linear search on the list items, determining whether key (an integer) is among those items. The function evaluates to true (`#t`) if the key is found, and false (`#f`) is the key is not found. For this function, when it comes to operating on the list, you are only allowed to use the Scheme functions `first` and `rest` (though you may choose to use `car` and `cdr`, instead); you may not use Scheme's built-in search functions, nor are you allowed to take advantage of maps and `for-each`.
4. (10 points) Write a function named `my-remove` that accepts two arguments: `items` (a list) and `key`. This function returns a new list that does not have any elements that match the key. Once again, you may only use `first` and `rest` (or `car` and `cdr`) for traversing the existing list, and for creating the new list, you are limited to the `cons`, `list`, and `append` functions.

Binary Search Tree (60 points)

We will be writing a binary search tree in Scheme. Recall from CS 146 that a binary search tree is a data structure that allows for the storage of elements in a manner that is amenable to performing searches in O(log n) in the average case. For example, suppose we are adding the elements 3, 4, 2, 5, 8, 1, and 4.5 (in that order) to construct a binary search tree. We will end up with the resulting tree:



In Scheme, we could represent the above binary search tree as a collection of embedded lists:

```
(3 (2 (1)) (4 () (5 (4.5) (8))))
```

Each node is a list with up to three elements. The first element of the list refers to the node's value. If a node is terminal (i.e., has no children), then it is represented as a one-element list. If a list has only two elements, that means the node only has a left child. If a node has only a right child, then it has three elements, but because there is no left child, the second element is the empty list `()`. A node with both a left and right child has three elements: the value, the left child, and the right child.

Let's do each insertion step by step:

```
3 => (3)
4 => (3 () (4))
2 => (3 (2) (4))
5 => (3 (2) (4 () (5)))
8 => (3 (2) (4 () (5 () (8))))
1 => (3 (2 (1)) (4 () (5 () (8))))
4.5 => (3 (2 (1)) (4 () (5 (4.5) (8))))
```

Note that no duplicate elements are allowed in the binary search tree.

Write the following functions as follows (note: you may assume that all elements in the binary search tree are numbers):

1. (22.5 points) `add-to-binary-search-tree` with two arguments `bst` (the binary search tree) and `item`, which is the item to be inserted into the binary search tree. This function returns a

new binary search tree in its correct order. Note that if `item` is already in the binary search tree, then this function simply returns the existing binary search tree.

2. (7.5 points) `create-binary-search-tree` with argument `items`, a list of items to be inserted into the binary search tree. This function returns a new binary search tree with all of the items inside, excluding duplicates.
3. (15 points) `search-binary-search-tree` with two arguments `bst` (the binary search tree) and `key`, which is the item to search for in the binary search tree. This function returns `#t` if found and `#f` otherwise.
4. (15 points) `binary-search-tree-to-list` with two arguments `bst` (the binary search tree) and `traversal`, a symbol that indicates the traversal method. If the symbol is `preorder`, then place the elements in a list using preorder traversal. If the symbol is `inorder`, then use inorder traversal. If the symbol is `postorder`, then use postorder traversal.

Rules (applies to all functions)

- All function arguments must be specified in the order specified in this document. This is to make testing submissions easier.
- No side effects are allowed with the exception of the `display` function and other functions that print to the screen.
- No mutation is allowed; this includes the use of `set!`
- No `do` loops; either use recursion or map/filter/fold style functions except where otherwise prohibited. I will allow the use of `for-each` given R5RS Scheme's lack of fold/reduce functions in the standard.
- Make sure all of your code cleanly runs when turning it in; if I cannot evaluate your function, that function gets a grade of zero.
- All programs must start with `#lang r5rs`. They must also use only the R5RS Scheme standard library as described in the official specification of the language, which is located at https://schemers.org/Documents/Standards/R5RS/HTML/.
- Please refrain from defining custom macros.

Note that violations of the above rules may lead to point deductions up to and including earning a zero grade on the affected functions or the entire project. If you are unsure whether your code follows these rules, please ask me before submitting your assignment.

Recommendations and Hints

- **START EARLY.** The binary search tree was tricky for my students to implement last year, and so please allow yourself plenty of time to complete this project by the deadline.
- I highly recommend writing some test cases for your code. One of the nice things about coding without side effects is that you can just use simple equality functions to test what your functions evaluate to.
- Functional programming can sometimes feel like a mind-bending exercise for beginners. I highly recommend working out your programs on paper and thinking about how you would express with recursion, map, filter, and/or fold what you would normally express with loops in your Java programs. In some ways it's like learning how to code again. But don't feel discouraged; remember the first time you learned how to program, or the first time you learned how to write in assembly language. With practice, though, then functional programming will be second nature for you.
- Helper functions are vital in an immutable world. Remember that you can have as many arguments as you can in your helper functions.

- You are allowed to define your own top-level functions besides the ones that have been specified as common helper functions, but these functions are subject to the same restrictions as the others (for example, these functions can't take advantage of any features that the functions specified cannot take advantage of).

Instructions for Turning In the Assignment

Please place all of your functions in a file called `project2.scm`. This is the file that you will be turning in to me via Canvas.