Jason Lai
204995126
Dis 1A

CS 161
January 23, 2020

Homework 1

1 Problem 1

Test your program on at least the first 10 Padovan numbers. Also test your program for larger values of N. What happens? Explain why in your hw1.pdf file.

For larger values of N, the program begins to take longer to calculate and return the Nth Padovan number. This is due to the increasing number of recursive calls and addition operations that the recursive function must execute for larger Padovan numbers that are further in the sequence. In other words, for Padovan numbers further in the sequence, the initial call of PAD must wait for all of its recursive calls to return and be summed in order to yield the final result. For instance, the 50th Padovan number is 922111 and takes 922110 addition operations, the 70th Padovan number is 255418101 and takes 255418100 addition operations, and the 80th Padovan number is 4250949112 and takes 4250949111 addition operations, and the number of recursive calls for each are approximately twice the number of addition operations. At around N = 80, the execution of PAD will start to hang or take copious amounts of time to finish. So, it is apparent that for larger values of N, it takes significantly more recursive calls and addition operations than it does for smaller values of N, therefore it takes the program much longer to calculate the Nth Padovan number when N is large.

Sample Execution:

```
> (PAD 0)
1
> (PAD 1)
1
> (PAD 2)
1
> (PAD 3)
2
> (PAD 4)
2
> (PAD 5)
3
> (PAD 6)
4
> (PAD 7)
5
> (PAD 8)
7
> (PAD 9)
9
```

Homework 1

Jason Lai
204995126
Dis 1A

```
> (PAD 10)
12
> (PAD 11)
16
> (PAD 12)
21
> (PAD 13)
28
> (PAD 14)
37
> (PAD 50)
922111
> (PAD 70)
255418101
> (PAD 80)
4250949112
> (PAD 85)
17342153393
> (PAD 90)
70748973084
```

2 Problem 2

Test your program on at least the first 10 values. What is the relationship between the values returned by PAD and SUMS? Explain why in you hw1.pdf file.

The relationship between the values returned by PAD and SUMS is that, for the Nth Padovan number, the return of (PAD N) is 1 more than the return of (SUMS N); that is, PAD(N) = SUMS(N) + 1. The reason the Nth SUMS number is one less than the Nth Padovan number comes from the fact that SUMS and PAD both use very similar recursion logic, however, the base case for SUMS returns 0 instead of 1, since the first three Padovan numbers are 1 and require no addition operations.

To elaborate, since SUMS calculates the number of addition operations required by PAD to calculate the Nth Padovan number, it follows that the Nth SUMS number is the sum of the number of addition operations needed to calculate the (N-2)th and (N-3)th Padovan numbers, plus the one addition operation needed to add these two numbers together to get the Nth Padovan number. However, since all three base case values for SUMS are 0, this value ends up being 1 less than the Nth Padovan number. This can be seen by looking at the sequence for SUMS in the sample execution; the SUMS sequence essentially follows the same pattern as the Padovan sequence, except every Nth number is 1 less than the Nth number in the Padovan sequence.

Sample Execution:

```
> (SUMS 0)
0
> (SUMS 1)
0
> (SUMS 2)
0
> (SUMS 3)
1
> (SUMS 4)
1
> (SUMS 5)
2
> (SUMS 6)
3
> (SUMS 7)
4
> (SUMS 8)
```

```
6
> (SUMS 9)
8
> (SUMS 10)
11
> (SUMS 11)
15
> (SUMS 12)
20
> (SUMS 13)
27
> (SUMS 14)
36
> (PAD 50)
922110
> (PAD 70)
255418100
> (PAD 80)
4250949111
```

3 Problem 3

Test your program on at least these inputs:

```
> (ANON '42)
?
> (ANON 'FOO)
?
> (ANON '(((L E) F) T))
(((?  ?)  ?)  ?)
> (ANON '(5 FOO 3.1 -0.2))
(?  ?  ?  ?)
> (ANON '(1 (FOO 3.1) -0.2))
(?  (?  ?)  ?)
> (ANON '(((1 2) (FOO 3.1)) (BAR -0.2)))
(((?  ?)  (?  ?))  (?  ?))
> (ANON '(R (I (G (H T)))))
(?  (?  (?  (?  ?))))
```

Sample Execution:

```
> (ANON '42)
?
> (ANON 'FOO)
?
> (ANON '(((L E) F) T))
(((?  ?)  ?)  ?)
> (ANON '(5 FOO 3.1 -0.2))
(?  ?  ?  ?)
> (ANON '(1 (FOO 3.1) -0.2))
(?  (?  ?)  ?)
> (ANON '(((1 2) (FOO 3.1)) (BAR -0.2)))
(((?  ?)  (?  ?))  (?  ?))
> (ANON '(R (I (G (H T)))))
(?  (?  (?  (?  ?))))
> (ANON '(1))
(?)
> (ANON '((1 2) (3 ((4 (5)) (6 7) 8) (9 10)) 11))
((?  ?)  (?  ((?  (?))  (?  ?)  ?)  (?  ?))  ?)
```