University of Helsinki

Computer Science Department

PreAssignment 2016

Author:
Andres Medina
(UAF 1608168)

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Preassignment - Task 1

1 Introduction

The first task of the preassignment consists in experimentally test that the amortized complexity of $(n-1)$ calls to **inorder_next** in a binary tree is $2(n-1)$.

To achieve this task, the following strategy was followed:

1. First, we create a program that generates random Binary Trees. This allows us to had a test set in which we prove the current hypothesis.
2. After creating the random Binary Tree generator, we create a second program that allows us to transverse the binary tree in inorder *(inorder means, first visiting the left node, then the root and finally the right node).* The program also returns the amount of steps involved in this operation.
3. By using both programs, we made a table that compare the amount of steps taken to transverse every binary tree in comparison with the number of nodes of each tree.
4. Finally, we made a plot with the data of the table and by using linear regression, we get the equation corresponding to that line plot. We expect that the slope of that line plot should be something bigger or equal to $2(n-1)$ *(it should be bigger or equal because the amortized complexity correspond to an upper bound of the actual complexity of an algorithm).*

   The results obtained in the analysis are described in the results section of this paper.

2 Materials and Methods

In this section, we will describe the tools and the logic used to solve every single step that composed the task 1 of this preassignment. This section include topics like the programming framework used to solve this task and also what was the logic applied to develop those programs.

2.1 Programming Tools

For developing the required programs we choose to use the following tools:

- Python 3.5.1 as the programming language
- Github as a repository tool
- Sublime Text as the code editor

In addition, the random library of python was used for accomplish the tasks related with randomness.

2.2 Programming Logic

The two programs involved in this task were programmed by using OOP paradigm. Considering the fact that the task 1 of the preassignment involves the creation of two different programs, we choose to explain the logic of each program in a different subsection.

2.2.1 Creating a Random Binary Tree

The creation of the binary tree was implemented by developing two different classes: a binary node class and a binary tree class. The binary node class contains 3 different attributes, an Id, a reference to a left child node and a reference to a right child node while the binary tree class contains only two attributes, a list of binary nodes and the total cost of traversing the tree in inorder. By using this two classes, creating a random binary tree was possible. Also when every binary tree is created, a random tree setting method is called so that every tree created has a different and also random structure.

The random tree setting method work as follows:

- First, a integer number between 50 and 100 is choose randomly. This number will represent the number of nodes of the corresponding binary tree
- Second, a left-right flag is set by choosing a random integer number between 0 and 1

- Then, after the left-right flag is set, a random node of the tree is chosen. Only the nodes that doesn't already have the corresponding child are candidates for this random choice. *For example, if the left-right flag is set to left, only nodes that doesn't have left childs are possible candidates of this random choice. Conversely, if the left-right flag is set to right, only nodes that doesn't have right childs are possible candidates*
- Finally, the corresponding child is created in the randomly chosen node of the tree

The described logic repeats until the number of nodes of the binary tree is reached.

2.2.2 Traversing a Binary Tree in inorder

The traversing of a binary tree in inorder can be made mainly in two different ways: by using recursion and by not using recursion. In this case, we choose to implement this method using recursion as this method allow to achieve a smaller and cleaner code and also allow us to avoid the implementation of a link between a child node and it's parent node.

The idea of this implementation is mainly the following:

- We start by applying this method to the root node of the tree
- If the root node has a left child, then we call again the traverse_inorder method but this time we pass the left child node as an argument to the method
- When the corresponding node has no left child node, then we ask if the node has a right child. If the node has a right child, then we call again the traverse_inorder method but this time we pass the right child node as an argument to the method
- After no more left and right child are found, the traverse_inorder method returns. Of course we should consider a logic for counting the corresponding steps in each call of the method so that when the method ends, we have the total amount of steps already calculated.

In the next section we will show and analyze the results of the above implementations.

3 Results

When the two generated programs are run, an output table is created. This table includes three columns:

1. **Binary Tree ID** Represents the Id of the binary tree
2. **Number of nodes of the Tree** Represents the number of nodes of the binary tree
3. **Total steps of inorder traverse** Represents the amounts of steps involved in the inorder traverse operation

The results obtained in this computation are shown in the following table:

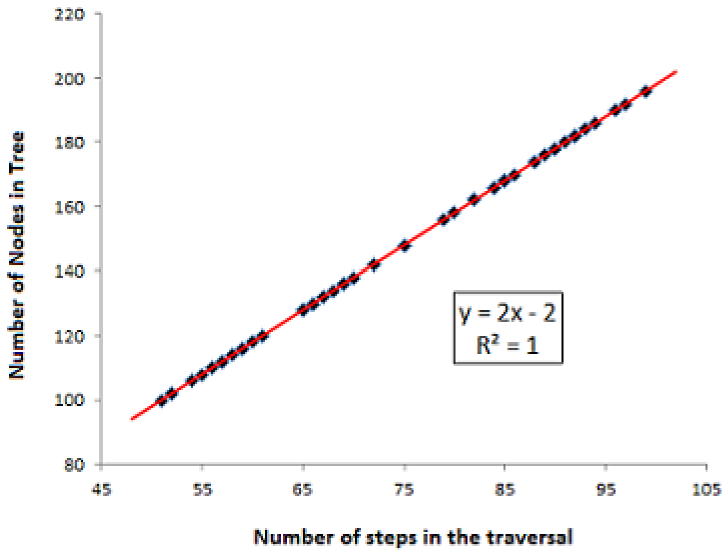
Table 1: Binary Tree Traverse Results part1

Tree Id	Number of Nodes	Total Steps
1	83	164
2	94	186
3	69	136
4	99	196
5	53	104
6	63	124
7	72	142
8	61	120
9	55	108
10	90	178
11	81	160
12	74	146
13	92	182
14	85	168
15	75	148
16	66	130
17	95	188
18	64	126
19	71	140
20	95	188
21	52	102
22	77	152
23	53	104
24	84	166
25	80	158

Table 2: Binary Tree Traverse Results part2

Tree Id	Number of Nodes	Total Steps
26	70	138
27	95	188
28	68	134
29	88	174
30	98	194
31	99	196
32	63	124
33	66	130
34	59	116
35	94	186
36	85	168
37	59	116
38	68	134
39	93	184
40	62	122
41	75	148
42	100	198
43	92	182
44	82	162
45	84	166
46	58	114
47	63	124
48	69	136
49	51	100
50	66	130

Also when we plot the results shown in the previous tables into a line graph, we obtain the following image:


220
200
180
160
140
120
100
80
45
55
65
75
85
95
105
Number of Nodes in Tree
Number of steps in the traversal
y = 2x - 2
R² = 1