
# CS 202

# Homework Assignment 4

## Section 2

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# Q2:

**Part 1:**

My HashTable class completely contains all the function declarations in the slides. Additionally, I create another enum to determine whether the location is OCCUPIED, EMPTY or DELETED, and an void unsuccSearch( int index, int & probes ) method for the analyse method. In analyse method I use current values of HashTable as mentioned in the report for successful search. However, for unsuccessful as mentioned in the report, I initiate a search starting from at each array index and counts number of probes until reaching an empty location. Therefore, my unsuccSearch method takes the index value as a parameter and counts the number of probes until reaching an empty location. I call this function in analyse function tableSize times and find numUnsuccProbes for both LINEAR and QUADRATIC search. As mentioned, I determine numUnsuccProbes = -1 if the search is DOUBLE. I used search function for successful search.

I designed my hashTable by creating a HashNode struct that keeps a int number for key value and Condition current that shows the current condition of that node (EMPTY, DELETED or OCCUPIED). Therefore, my hash array's type is HashNode.

My constructor initializes a hashArr as a new HashNode[tableSize] and fulfil each node's current condition as EMPTY. numOfElements variable that keeps the current number of elements in hashArr is initialized with 0, size is equal to tableSize and CollisionStrategy option is implemented by constructor's second parameter. In destructor, objects of hashArr are deleted.

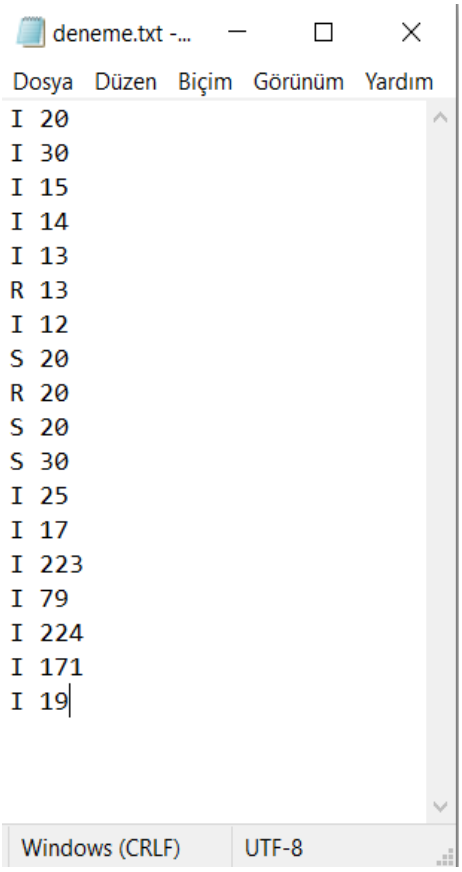
In insert method, firstly I checked whether insertion can be done by checking size. Then, according to the option, I code 3 different insertion algorithms. Each algorithm checks whether the item is inserted or not. All algorithms search EMPTY or DELETED item to insert the item. This loop ends if the searching time is equal to the size of hashArr because for all options, $h_i(key) = (hash(key) + f(i)) \bmod tableSize$ starts to repeat after $i$ value exceeds the hashArr size. Therefore, it will make no sense to continue this loop after size times. So, my stopping condition is $i < size$ where $i = 0$ initially.

Almost same algorithm is used for remove function. This time, I assigned current condition as DELETED if the removing is successful and decrease numOfElements. But this time, loop continues until finding an EMPTY location to prevent complications (namely, it does not stop if the location is DELETED which treats like an OCCUPIED location). Same stopping condition is valid for deletion algorithm.

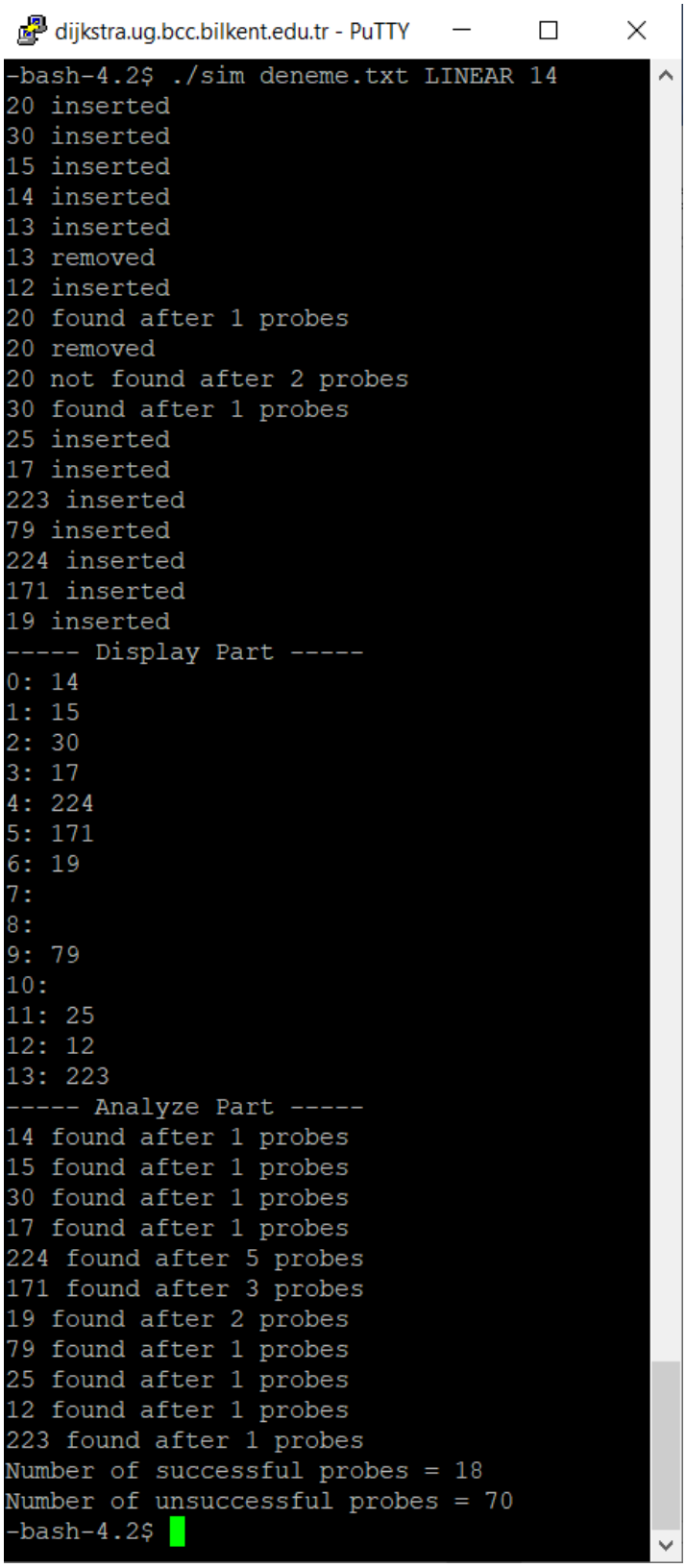
Search algorithm is almost similar with remove algorithm. It counts number of probes until finding the item. If it cannot, its stopping condition is same that $i < size$ where $i = 0$ initially.

Display function shows the item of each array location if location is OCCUPIED.

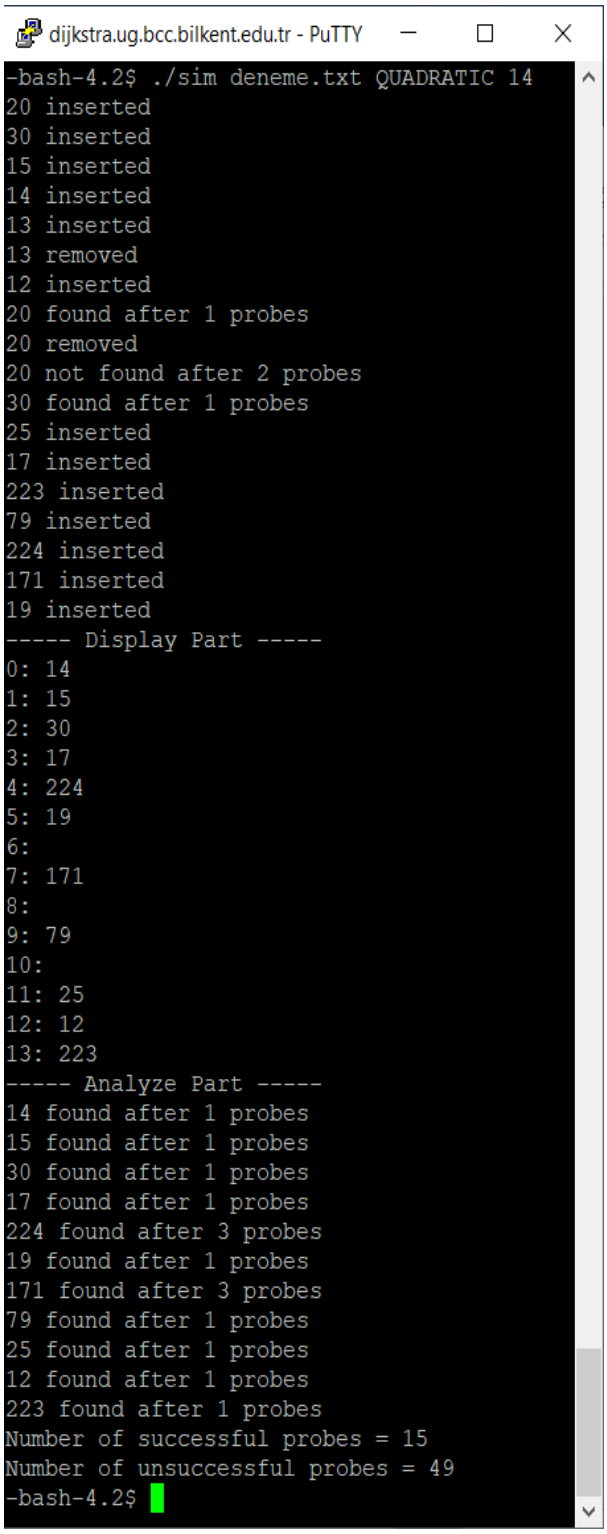
**Part 2:**



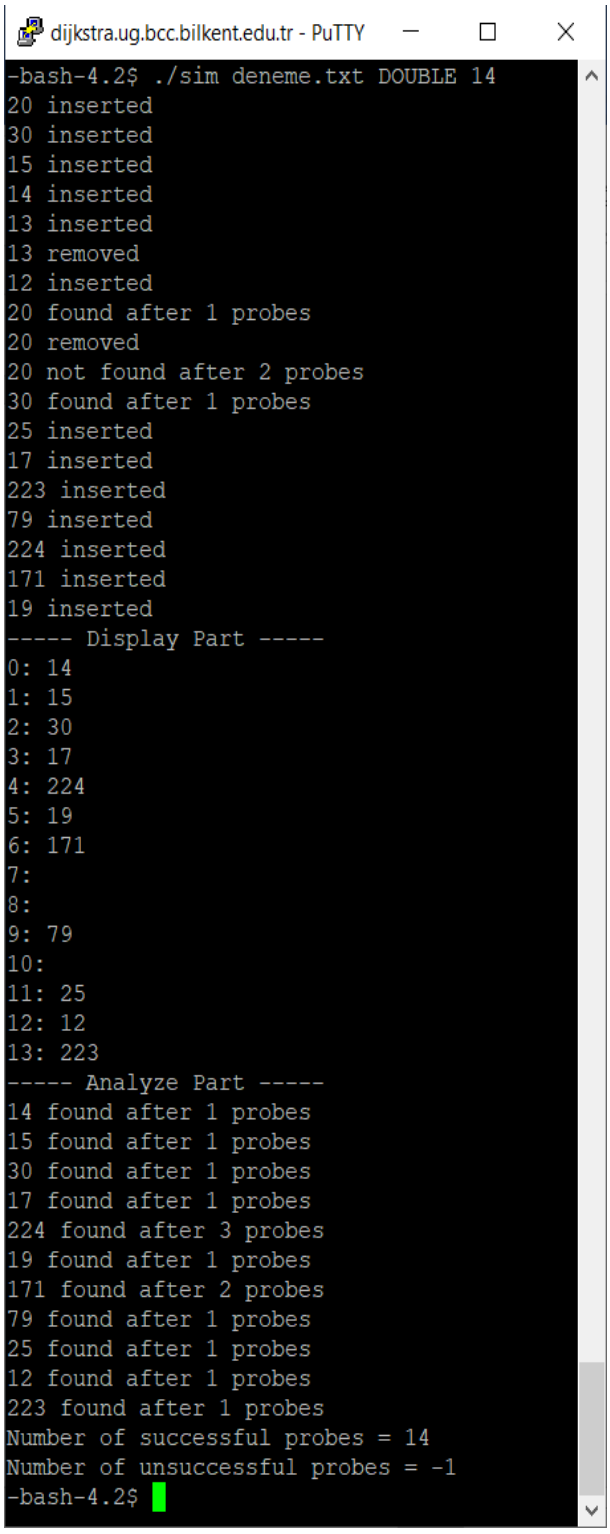

Picture (1)




Picture (2)




Picture (3)




Picture (4)

**Part 3**

**Empirical performance values:**

LINEAR:

Successful search: Average number of probes = (number of successful probes / number of items)

By picture (2), Average number of probes = 18 / 11 = 1.63

Unsuccessful search: Average number of probes = (number of unsuccessful probes / size of table)

Average number of probes = 70 / 14 = 5

QUADRATIC:

Successful search: Average number of probes = (number of successful probes / number of items)

By picture (3), Average number of probes = 15 / 11 = 1.36

Unsuccessful search: Average number of probes = (number of unsuccessful probes / size of table)

Average number of probes = 49 / 10 = 3.5

DOUBLE:

Successful search: Average number of probes = (number of successful probes / number of items)

By picture (4), Average number of probes = 14 / 11 = 1.27

Unsuccessful search: Average number of probes = -1

**Theoretical values:**

For the analysis of the average-case efficiency of hashing, the load factor $\alpha$ involves:

$\alpha$ = (current number of items) / size of table

$\alpha$ = 11 / 14 = 0.78 for the values given at pictures

LINEAR:

Successful search: for $\alpha$ = 0.78

$$\frac{1}{2}\left[1+\frac{1}{1-\alpha}\right]$$

= 2.77

Unsuccessful search: for $\alpha = 0.78$

$$\frac{1}{2}\left[1+\frac{1}{(1-\alpha)^2}\right]$$

= 10.83

QUADRATIC & DOUBLE:

Successful search: for $\alpha = 0.78$

$$\left[\frac{1}{\alpha}(\log_e \frac{1}{1-\alpha})\right] = \frac{-\log_e(1-\alpha)}{\alpha}$$

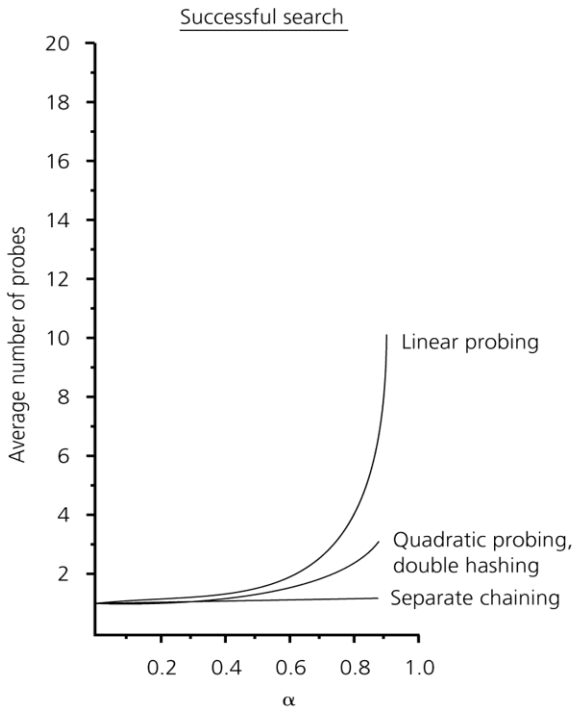
= 1.94

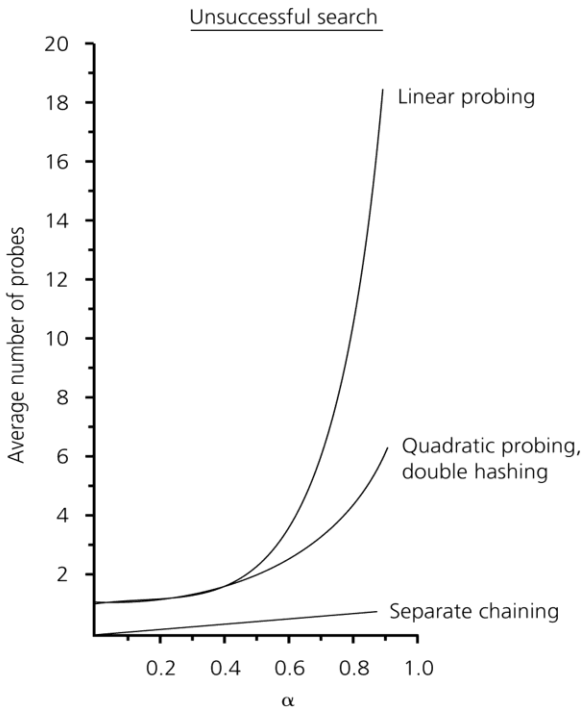
Unsuccessful search: for $\alpha = 0.78$

$$\frac{1}{1-\alpha}$$

= 4.54

**Theoretical Graph taken by Course slides:**



**Comparison – Analyse:**

I used the number of successful and unsuccessful probes gained by testing my function and calculate the empirical performance values. If we compare for each collision strategy option separately in both empirical and theoretical calculations, we can obviously observe that in both successful and unsuccessful search average number of probes is the highest for linear probing. Quadratic probing and double hashing require a smaller number of probes for searching than linear probing. Their values are too close.

We can see that in each collision strategy, average number of probes is greater in unsuccessful search than successful search. Additionally, my both empirical and theoretical values are confirmed by the theoretical graph table received by Lecture slides.

| AVERAGE NUMBER OF PROBES TABLE WITH SIZE 14 & 11 CURRENT ELEMENTS | | | | |
|---|---|---|---|---|
| | EMPIRICAL PERFORMANCE | | THEORETICAL PERFORMANCE | |
| Collision Strategy | Successful | Unsuccessful | Successful | Unsuccessful |
| LINEAR | 1.63 | 5 | 2.77 | 10.83 |
| QUADRATIC | 1.36 | 3.5 | 1.94 | 4.54 |
| DOUBLE | 1.27 | -1 | 1.94 | 4.54 |