**Document :**

**Expect approx. 60%**

**Overview :**

**Made a spell checker implementing Interface and linear, binary and hash algorithm respectively. It also can generate alternative words for misspelled words. Have written about efficiencies of this algorithm and evidence of debugging.**

**PART 1**

**An algorithm is a precise method for a solution to a problem.**

1. **LINEAR SEARCH**

* What is linear search (sequential search)and how it works: just as its name suggests linear search loop over all the elements in the (unsorted) array one by one until it finds the targeted element in the array, comparing and starting with the first element data in sequence.[1][2]. This algorithm is better for small array search.

Pseudo code:

* LinearSearch (Array, element)
* For each element in an array
* If element == targeted element
* Return that the element is found
* Else element not found

![A close up of a piece of paper

Description automatically generated](data:image/jpeg;base64,/9j/4AAQSkZJRgABAQEAYABgAAD/4R8aRXhpZgAATU0AKgAAAAgABgALAAIAAAAmAAAIYgESAAMAAAABAAEAAAExAAIAAAAmAAAIiAEyAAIAAAAUAAAIrodpAAQAAAABAAAIwuocAAcAAAgMAAAAVgAAEUYc6gAAAAgAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAFdpbmRvd3MgUGhvdG8gRWRpdG9yIDEwLjAuMTAwMTEuMTYzODQAV2luZG93cyBQaG90byBFZGl0b3IgMTAuMC4xMDAxMS4xNjM4NAAyMDE5OjEyOjE0IDE3OjIyOjQwAAAGkAMAAgAAABQAABEckAQAAgAAABQAABEwkpEAAgAAAAMwMAAAkpIAAgAAAAMwMAAAoAEAAwAAAAEAAQAA6hwABwAACAwAAAkQAAAAABzqAAAACAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA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**Explanation of linear search efficiency**

The linear algorithm’s time and efficiency depends on the sorted and unsorted list of arrays. Its efficiency depends on the time consumption by the algorithm

Time and Space performance:

Best : O(1)

When the targeted element in the array is found at the first element in the array. The best case scenario, it takes least time for the linear search to find the targeted element i.e, it calculates lower bound on the running time algorithm

Average: O(n)

Is calculated by taking all the possible inputs and calculate computing time for all of the inputs. Assuming that all cases are uniformly distributed. [3]

Sum all the cases / n+1. analysis1

Average case time =

analysis2

=O(n)

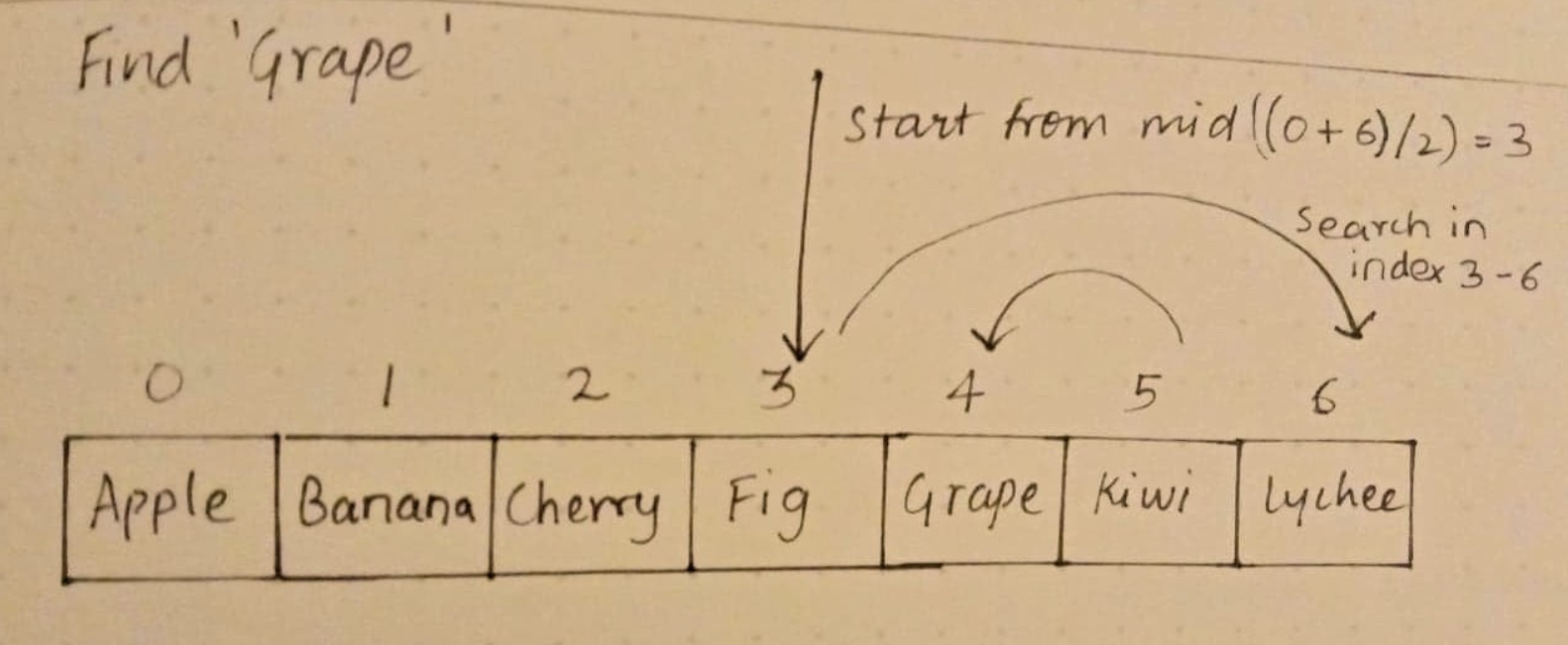
Worst-case: O(n)

When the targeted element in the array is not present in the array then it will iterate through by comparing it with every element one by one. The worst case analysis is that it calculates the worst case scenario time it will take for the linear search to find the targeted element i.e., an upper bound on the running time of an algorithm[4].

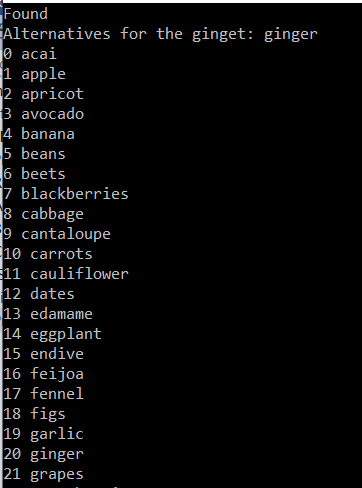
Space complexity : O(1)

Concluding that linear search is less efficient than the binary and hash algorithms. It is very time taking and less efficient when it has a big array.

1. **BINARY SEARCH**

Binary search sums the first index array size and the last array index size and divide by two to find the average which leads to the middle index array size. If the targeted string value is equal to the middle value of the array, then the search is stopped and declared success. While if not the same then, the search will be continued to the left ½ if the targeted string value is smaller than the middle data string value. Whereas if the targeted string value is greater than the middle string value, Will continue to ½ right.[5]

**Test Outputs:**



**Explanation of binary search efficiency**

* The binary search is faster than the linear search but less efficient than the hash algorithm. As it takes time to divide and actually loop through each index to find the targeted string.
* Worst case time complexity: O(log N)
* Average case time complexity: O(log N)
* Best case time complexity: O(1)
* Space complexity: O(1)

1. **CLOSED HASHING**

**Why to use hashing -**

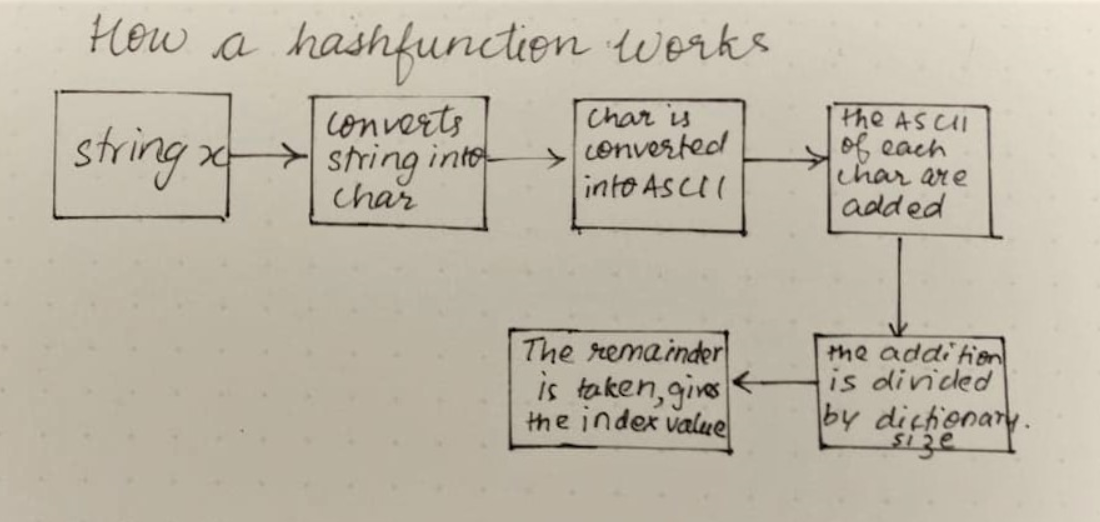
When the number of keys actually stored is small relative to the total number of possible keys, hash tables become an effective alternative to directly addressing an array, since a hash table typically uses an array of size proportional to the number of keys actually stored.[6] The point of the hash function is to reduce the range of array indices that need to be handled[7].

**How closed hashing search works and executed:**

To understand the concept of hashing it is necessary to break the algorithm into 4 steps:

1] **Hash Function**: hash function gives the index address to put in the array. It allocates the string in the index array by converting the string into an int index value. To do this, the string needs to be first converted into character further needs to be converted into ascii value. We need to add the Ascii values of each char in a string to get a total ascii value for that string. To get the index value to put in array:

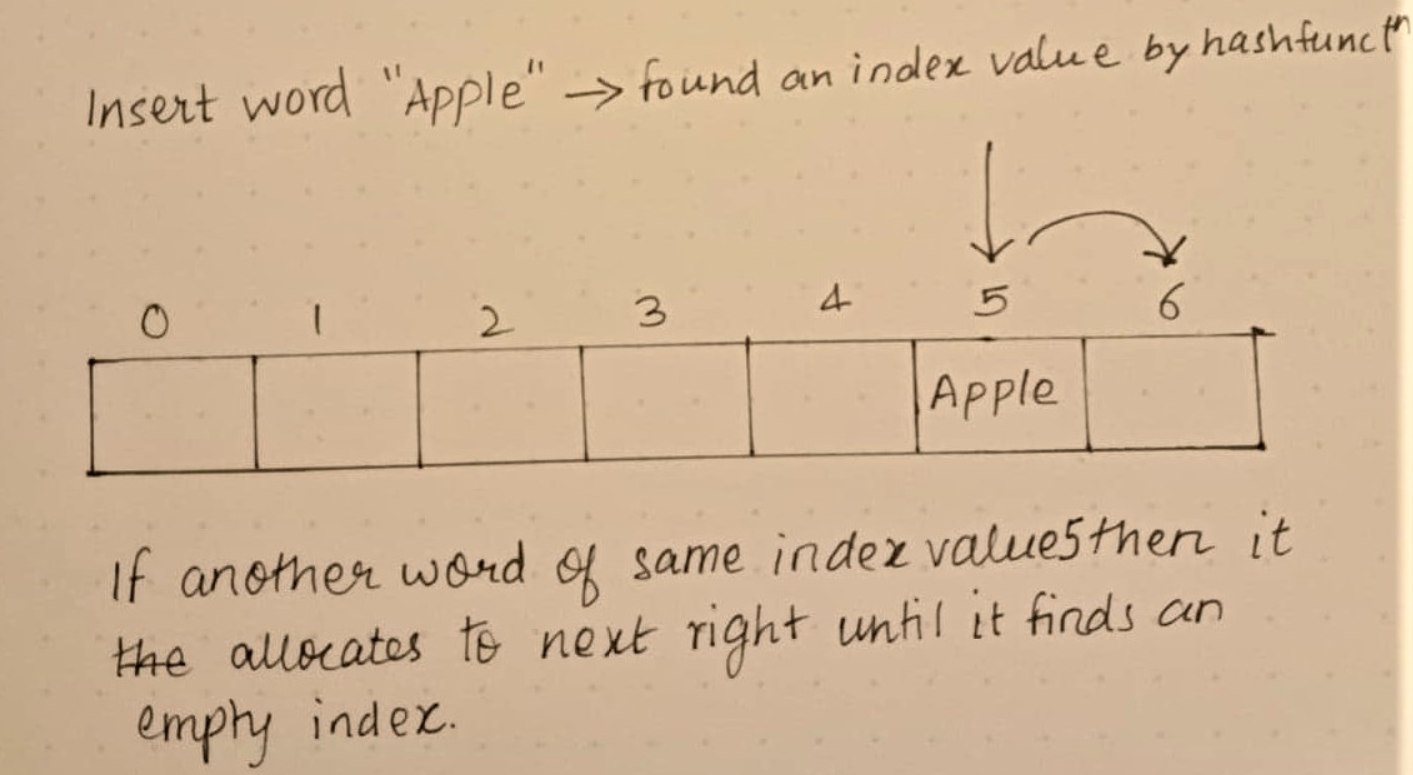
Divide the addition of the ascii values in the string by the length of the array. The remainder of the divisions would be index value of a string and identifies the allocation needed for the string to be in.



2] **Display**: To test the hash algorithm in the command output

3] **Insert**: Once the compiler knows the index value of the string it can allocate the string in the array. The value for index found in hash function will insert the string in the array. If the index in array in which it needs to be allocated is not empty then it will move to the next slot and checks if the preceding slot is empty and go on until it finds an index which is empty. But with that there comes a scenario, what if the index of the array is not empty till the end of the array. In such case, it will go back to the very first index in the array which is zero and will check through each index till it reaches the same index value number it started from. This is called collisions(linear probing) in the hashing algorithm. If all the indexes in the array are occupied, then it will give a message that the array is full and cannot allocate anymore strings in the array.

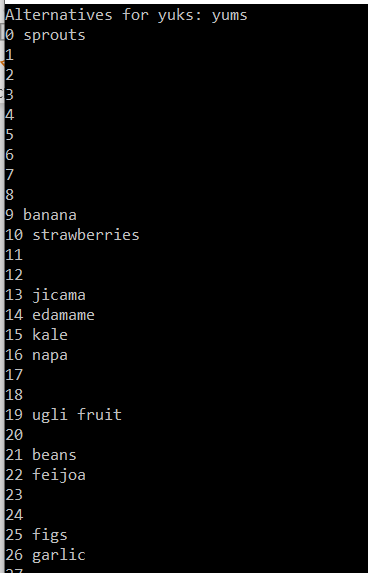
4] **Search**: Once the strings are allocated in the array. It needs to check whether the string inserted there in the array. To check this, we need a bool function where if the string is found then it's true and false if after lopping through the whole array it started from; it couldn’t find the string. When searching for an element, we systematically examine the index slots until either we find the desired element or we have ascertained that the element is not in the array[8]



**Analysis** :

In open addressing, all elements are stored in the hash table itself. the advantage of open addressing is that it avoids pointers altogether. Instead of following pointers, we compute the sequence of slots to be examined. The extra memory freed by not storing pointers provides the hash table with a larger number of slots for the same amount of memory, potentially yielding fewer collisions and faster retrieval.[9]. Linear probing is easy to implement, but it suffers from a problem known as primary clustering. Long runs of occupied slots build up, increasing the average search time.[10]

Output for hash function:



Time and efficiency in closed hashing

The hash algorithm takes time to set the data but it works faster then the binary search and linear search. As it doesn’t need to loop through the whole array searching instead it directly allocated from the index value returned from the hash function. With that it works faster because it uses ascii values directly.

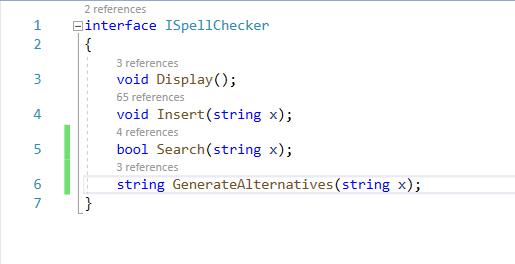
average case the complexity will be O(1)

In worst case, If too many elements were hashed into the same key, it can have a time complexity of O(n).

Best case – O(1)

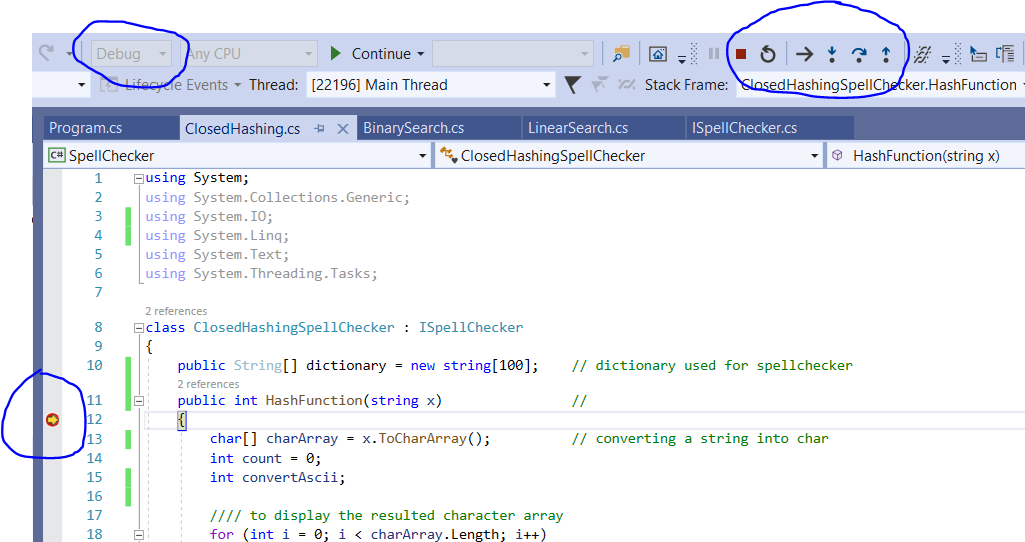
Space – O(n)

**Interface - ISpellChecker :**

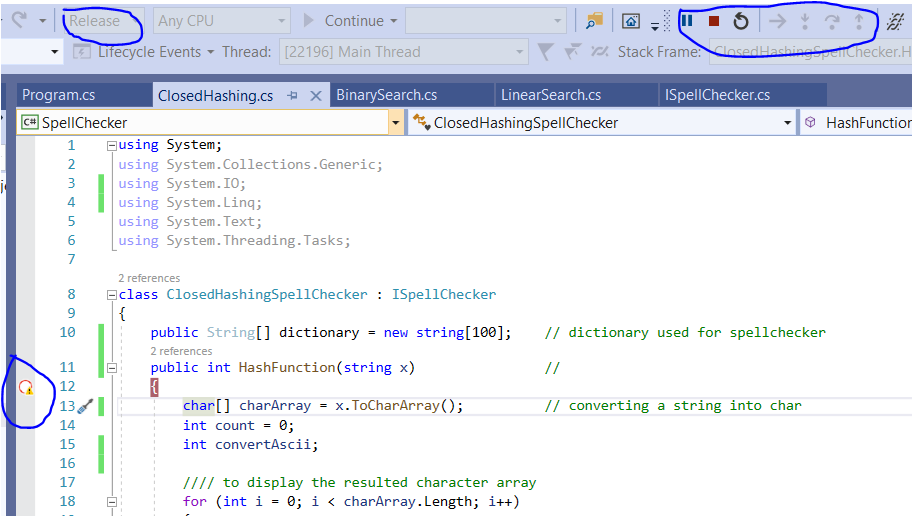


Interface allow the programmer to effectively decide which class the programmer wants the output. Interfaces include behavior from multiple sources in a class. That capability is important in C# because the language doesn't support multiple inheritance of classes.[11]. Thus the algorithm binary and hash or interfaced with ISpellChecker.

**Part 2:**



The Testing of the debugging can be found for both the versions in part 3.1.



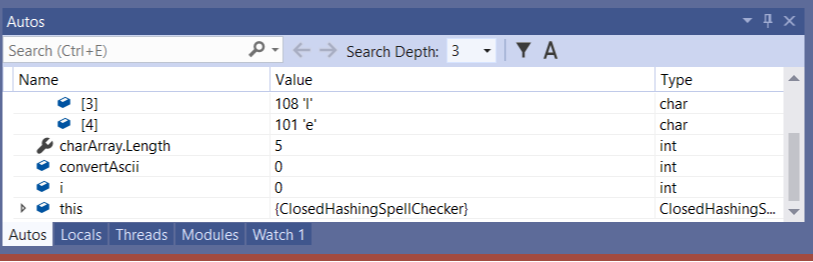
**Discussion on Optimizing software -**

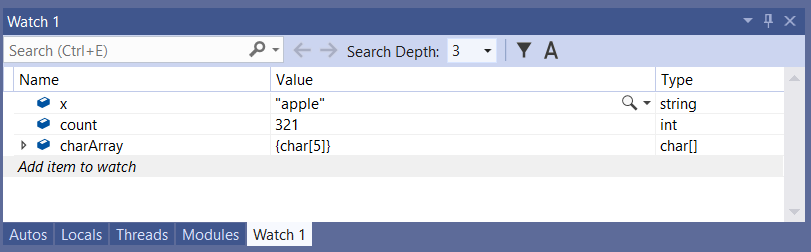
It depends. There are instances when a programmer need to look at the readability of the code and at other times a programmer may need to look at the optimization of the code. Use of classes and interfaces usually make the code less efficient as it takes lots of space. The most optimized code is written when one doesn’t use methods, classes, interfaces and functions. In the algorithms, the binary search can be more optimized if used searches like exponential search, factional search, interpolation search, or noisy binary search algorithms which can speed up the binary searches but still it wont be as better as hashing algorithm when it comes to dictionaries.[12] Optimizing the code needs detailed careful delicate understanding of how much space the code could occupy and how fast it can make it run. Even if one increase the optimization for the binary search and the linear search still the hashing algorithm would be better than the other two.

**Part 3:**

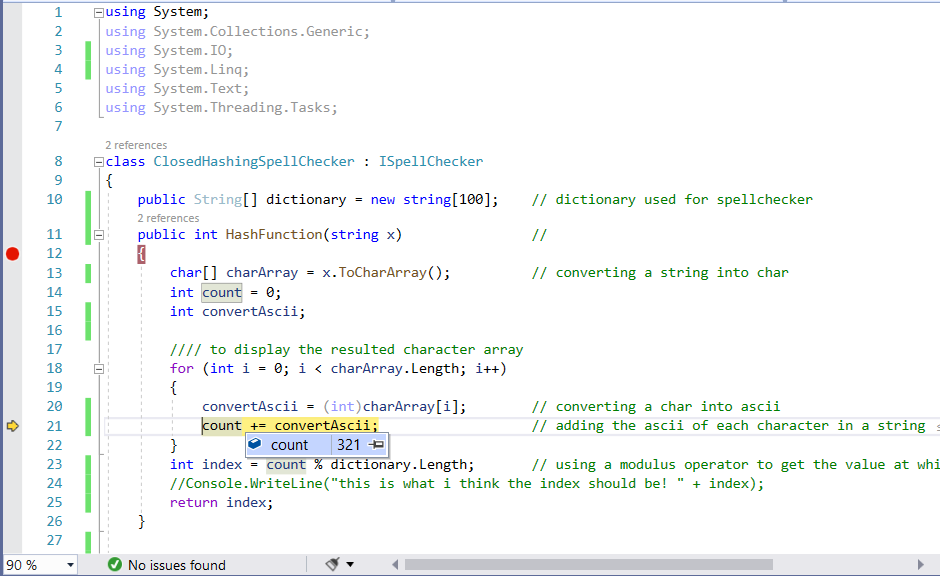
**Evidence of use of breakpoints:**

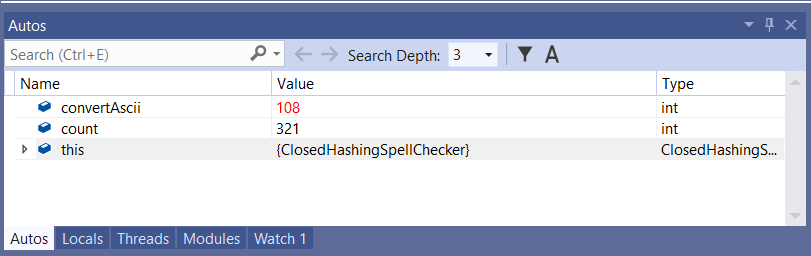
|  |
| --- |
| 1] Evidence of use of breakpoints    1] It takes the string x - ‘Apple’ entered by the user and calculates the middle position of the binary    2] To check whether the insert function inserts the string put. |
| **2] Evidence of use of single-stepping**      1] single stepping into through the hash function to check if the ascii of each character on the string is added ascii values of every other character of the string.      2] Stepping over through the generate alternatives to check if the misspelled word “yuks” is spelled properly into “yums” by iterating through the loop and checking if it gives out the true value when it finds the right word. |
| **3] Evidence of use of viewing variables, including arrays** |





1] A breakpoint on the hash function to check whether it is iterating through the loop without breaking. Also to check if the it is taking the string and converting into the desired index value position. It single steps through the loop to check if the string is converting into ascii. The ascii values can be seen when hovered over the char Array displaying each character with it in the string.





2] Viewing variables like int count and checking if the variable count is adding the ascii values of each character of the string. If hovered on integer count, we can see the total sum the variable has count till now.

References:

1) Arora, Nitin & Bhasin, Garima & Sharma, Neha. (2014). Two way Linear Search Algorithm. International Journal of Computer Applications. 107. 6-8. 10.5120/19137-9622/[Accessed 11 Dec. 2019].

2, 5) Rahim, Robbi & Nurarif, Saiful & Ramadhan, Mukhlis & Aisyah, Siti & Purba, Windania. (2017). Comparison Searching Process of Linear, Binary and Interpolation Algorithm. Journal of Physics: Conference Series. 930. 012007. 10.1088/1742-6596/930/1/012007/[Accessed 11 Dec. 2019].

3, 4) GeeksforGeeks. (2019). *Analysis of Algorithms | Set 2 (Worst, Average and Best Cases) - GeeksforGeeks*. [online] Available at: https://www.geeksforgeeks.org/analysis-of-algorithms-set-2-asymptotic-analysis/ [Accessed 15 Dec. 2019].

[6,7,8,9] Cormen, T., Leiserson, C., Rivest, R. and Stein, C. (2009). *Introduction to Algorithms*. 3rd ed. MIT Press, pp.253, 256, 269,270. (<http://kddlab.zjgsu.edu.cn:7200/students/lipengcheng/%E7%AE%97%E6%B3%95%E5%AF%BC%E8%AE%BA%EF%BC%88%E8%8B%B1%E6%96%87%E7%AC%AC%E4%B8%89%E7%89%88%EF%BC%89.pdf>)

[10] Levitin, A. (2012). *Introduction to The Design and Analysis of Algorithms*. 3rd ed. Pearson, p.273.(<https://doc.lagout.org/science/0_Computer%20Science/2_Algorithms/Introduction%20to%20the%20Design%20and%20Analysis%20of%20Algorithms%20%283rd%20ed.%29%20%5BLevitin%202011-10-09%5D.pdf> )

[11] Docs.microsoft.com. (2019). *Interfaces - C# Programming Guide*. [online] Available at: https://docs.microsoft.com/en-us/dotnet/csharp/programming-guide/interfaces/ [Accessed 15 Dec. 2019].

[12] OpenGenus IQ: Learn Computer Science. (2019). *Binary Search Algorithm*. [online] Available at: https://iq.opengenus.org/binary-search-algorithm/ [Accessed 15 Dec. 2019].