Complex Engineering Problem

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Complex Engineering Problem

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in

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Internal Examiner	External Examiner

Director
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Declaration

I declare that the work contained in this thesis is my own, except where explicitly stated otherwise. In addition this work has not been submitted to obtain another degree or professional qualification.

Signed: ____________________

Date: ____________________

Acknowledgments

Dedicated to ....

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Chapter 1

Problem Statement

The main objectives of this Complex Engineering Problem are:

- To develop programs that store and manage the given data by using four different data structures, that are:
    1. Hash Table (Quadratic Probing)
    2. Array
    3. Linked List
    4. Binary Tree
- Implement the following operations on the given data:
    1. Insert all of the given data in a data structure.
    2. Print data of data structure in sorted order (traverse in sorted order) (numerically or alphabetically).
    3. Find records.
    4. Delete half of the data from the data structure.
- To measure execution time and memory consumption for each operation.
- To compare operations on different data structures depending on their execution time and memory consumption and conclude which data structure is the best for each operation.

Chapter 2

File Input

2.1 Methodology

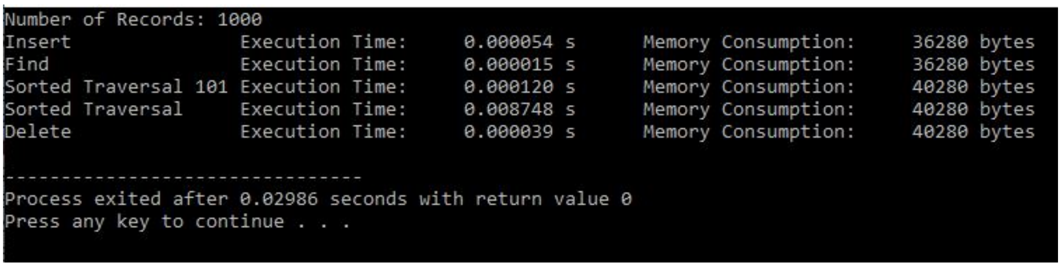
The workflow for file input routines is follows:

- File is opened in reading mode with **fopen()**
- Reading the data file using **fscanf()** from the first line. Ignore the first string read as it is needed. Next line contains the number of records read and it store as an integer. From the next line we have the data of employees.
- Creating a structure which has fields of ”ID”(Integer), ”Name”(String), ”City”(String) and ”Service”(String).
- Allocating memory for an array of ”pointers to structures”.
- Records are read from the file and are stored in the allocated structures and then pointers to these structures are linked to the array.
- File is closed after storing the data with **fclose()**

So after these processes we have *an array of pointers to structures* containing the data of the files.

Chapter 3

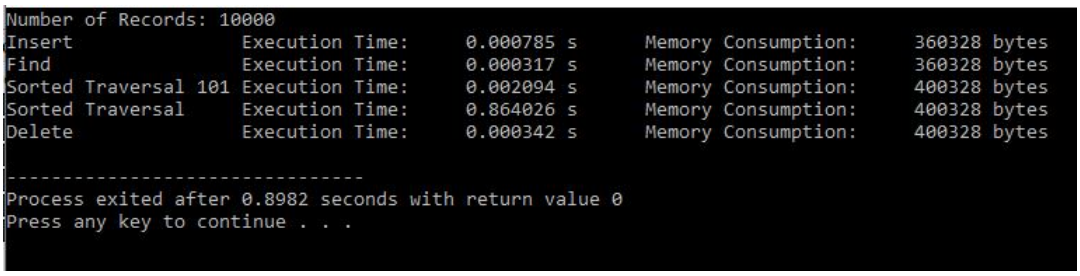
Hash Table Implementation



```
Number of Records: 1000
Insert              Execution Time:     0.000054 s      Memory Consumption:     36280 bytes
Find                Execution Time:     0.000015 s      Memory Consumption:     36280 bytes
Sorted Traversal 101 Execution Time:    0.000120 s      Memory Consumption:     40280 bytes
Sorted Traversal    Execution Time:     0.008748 s      Memory Consumption:     40280 bytes
Delete              Execution Time:     0.000039 s      Memory Consumption:     40280 bytes

--------------------------------
Process exited after 0.02986 seconds with return value 0
Press any key to continue . . .
```

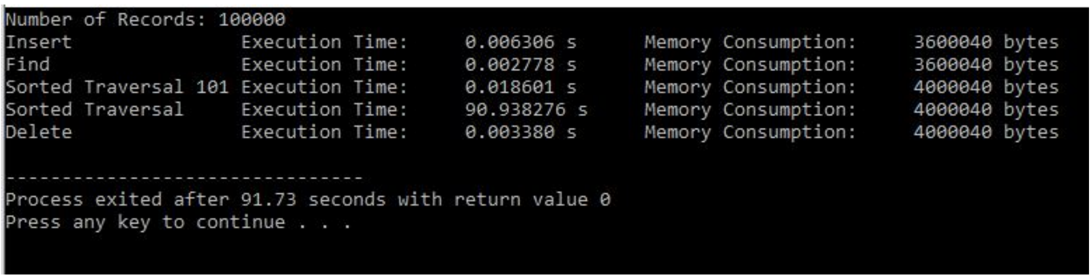
Figure 3.1: Results for hash implementation with data size 1000.



```
Number of Records: 10000
Insert              Execution Time:     0.000785 s      Memory Consumption:     360328 bytes
Find                Execution Time:     0.000317 s      Memory Consumption:     360328 bytes
Sorted Traversal 101 Execution Time:    0.002094 s      Memory Consumption:     400328 bytes
Sorted Traversal    Execution Time:     0.864026 s      Memory Consumption:     400328 bytes
Delete              Execution Time:     0.000342 s      Memory Consumption:     400328 bytes

--------------------------------
Process exited after 0.8982 seconds with return value 0
Press any key to continue . . .
```

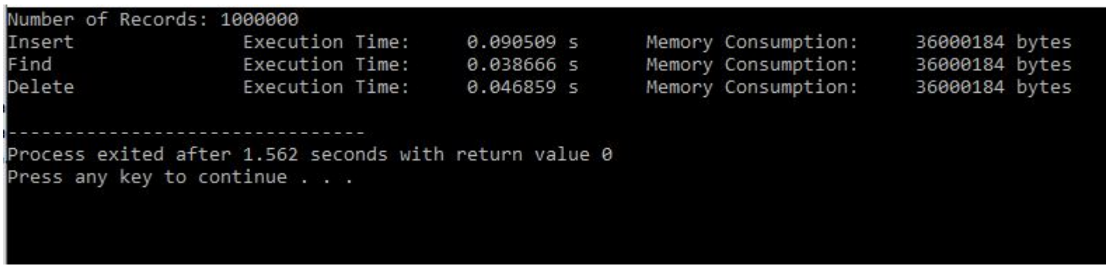
Figure 3.2: Results for hash implementation with data size 10000.



```
Number of Records: 100000
Insert              Execution Time:     0.006306 s      Memory Consumption:     3600040 bytes
Find                Execution Time:     0.002778 s      Memory Consumption:     3600040 bytes
Sorted Traversal 101 Execution Time:    0.018601 s      Memory Consumption:     4000040 bytes
Sorted Traversal    Execution Time:     90.938276 s     Memory Consumption:     4000040 bytes
Delete              Execution Time:     0.003380 s      Memory Consumption:     4000040 bytes

--------------------------------
Process exited after 91.73 seconds with return value 0
Press any key to continue . . .
```

Figure 3.3: Results for hash implementation with data size 100000.



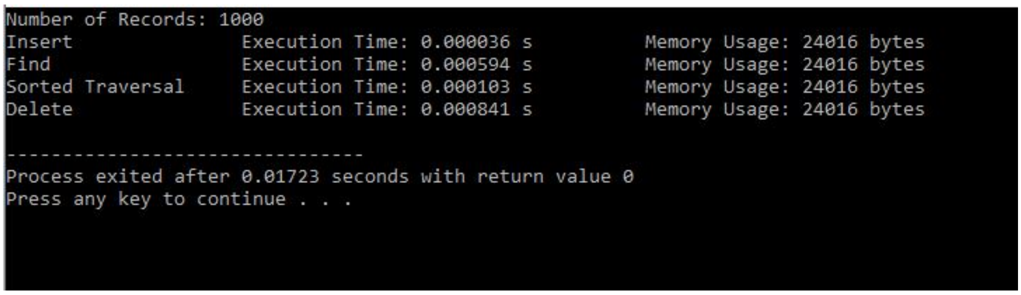
```
Number of Records: 1000000
Insert              Execution Time:     0.090509 s      Memory Consumption:     36000184 bytes
Find                Execution Time:     0.038666 s      Memory Consumption:     36000184 bytes
Delete              Execution Time:     0.046859 s      Memory Consumption:     36000184 bytes

--------------------------------
Process exited after 1.562 seconds with return value 0
Press any key to continue . . .
```

Figure 3.4: Results for hash implementation with data size 1000000.

Chapter 4

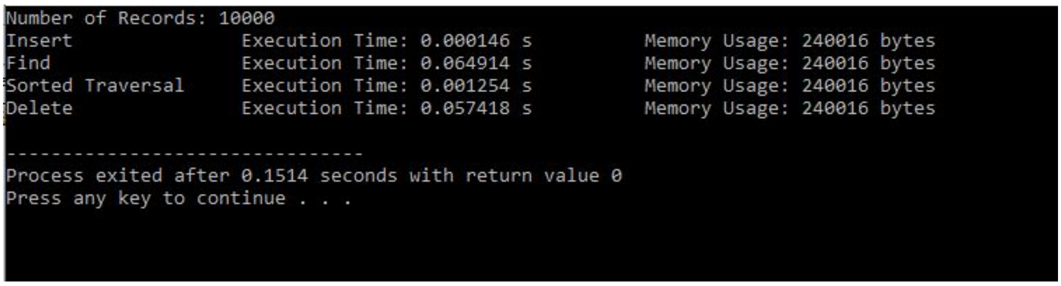
Array Implementation



```
Number of Records: 1000
Insert                Execution Time: 0.000036 s          Memory Usage: 24016 bytes
Find                  Execution Time: 0.000594 s          Memory Usage: 24016 bytes
Sorted Traversal      Execution Time: 0.000103 s          Memory Usage: 24016 bytes
Delete                Execution Time: 0.000841 s          Memory Usage: 24016 bytes

--------------------------------
Process exited after 0.01723 seconds with return value 0
Press any key to continue . . .
```

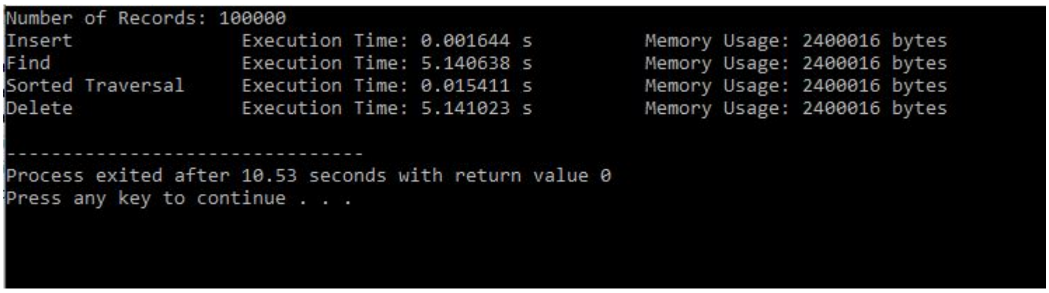
Figure 4.1: Results for array implementation with data size 1000.



```
Number of Records: 10000
Insert                Execution Time: 0.000146 s          Memory Usage: 240016 bytes
Find                  Execution Time: 0.064914 s          Memory Usage: 240016 bytes
Sorted Traversal      Execution Time: 0.001254 s          Memory Usage: 240016 bytes
Delete                Execution Time: 0.057418 s          Memory Usage: 240016 bytes

--------------------------------
Process exited after 0.1514 seconds with return value 0
Press any key to continue . . .
```

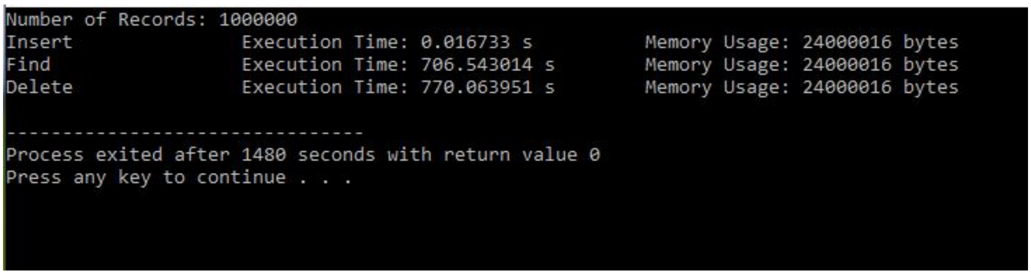
Figure 4.2: Results for array implementation with data size 10000.



```
Number of Records: 100000
Insert               Execution Time: 0.001644 s         Memory Usage: 2400016 bytes
Find                 Execution Time: 5.140638 s         Memory Usage: 2400016 bytes
Sorted Traversal     Execution Time: 0.015411 s         Memory Usage: 2400016 bytes
Delete               Execution Time: 5.141023 s         Memory Usage: 2400016 bytes

--------------------------------
Process exited after 10.53 seconds with return value 0
Press any key to continue . . .
```

Figure 4.3: Results for array implementation with data size 100000.



```
Number of Records: 1000000
Insert               Execution Time: 0.016733 s         Memory Usage: 24000016 bytes
Find                 Execution Time: 706.543014 s       Memory Usage: 24000016 bytes
Delete               Execution Time: 770.063951 s       Memory Usage: 24000016 bytes

--------------------------------
Process exited after 1480 seconds with return value 0
Press any key to continue . . .
```

Figure 4.4: Results for array implementation with data size 1000000.

Chapter 5

Linked List Implementation

5.1 Methodology

Singley linked lists are used to carryout basic operations on the data array. These basic operations and their working are as follows:

5.1.1 Insertion

Insertion is done by dynamically allocating nodes. Keys i.e., ID's of employees and data is linked with these node. Finally, nodes are inserted at the head of the list.

Time Complexity: **O(1)**
Space Complexity: **O(N)**

5.1.2 Finding

There is no order in the linked list data like trees so find operation is carried out by simply traversing the list until the required key is found or tail of the list is reached.

Time Complexity: **O(N)**
Space Complexity: **O(N)**

5.1.3 Sorted Traversal

For sorted traversal, first of all list should be sorted by any convenient sorting algorithm and then traversed from head to tail.

Sorting Algrithm Used: **Quick Sort O(log N)**
Time Complexity: **O(N log N)**
Space Complexity: **O(N)**
Note: Sorted traversal time complexity is dependent upon sorting algorithm used

5.1.4 Deletion

Deletion is carried out by finding the node to be deleted. This step involves traversing the list. After finding, the node is bypassed by link adjusment and is deleted.

Time Complexity: $\mathbf{O(N)}$
Space Complexity: $\mathbf{O(N)}$

Chapter 6

Tree Implementation

6.1 Methodology

Balanced trees are used to carryout basic operation on the data array. These basic operations and their working are as follows:

6.1.1 Insertion

Id's of employees are used to populate the self-balancing binary search tree i.e., *AVL trees* and then data is linked with the corresponding nodes. Tree is balanced by the phenomenon of left, right, left-right and right-left rotations.

Time Complexity: **O(log N)**
Space Complexity: **O(N)**

6.1.2 Finding

In AVL trees the nodes are arranged in specfic order. Left child node always have key less than the root node and right child will have key greater than the root node. So finding a tree node involves comparing the "key to be found" at each node if its less then only traverse the left subtree and if its larger then traverse the right subtree. In our case we found the even indexed records from data array in tree and measured its execution time and memory consumption.

Time Complexity: **O(log N)**
Space Complexity: **O(N)**

6.1.3 Sorted Traversal

Due to the order propety of AVL trees sorting traversal can be done simply by *in-order traversal* of the tree. In order traversal involves first traversing the left sub-tree recursively then visiting the root node and finally right sub-tree is traversed recursively.

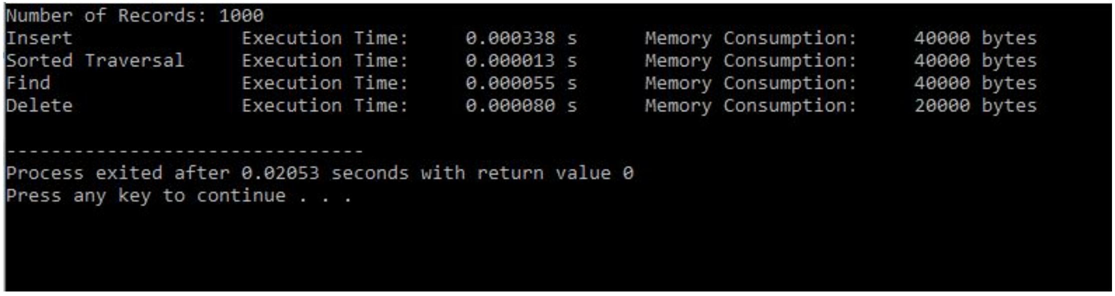
Time Complexity: **O(N)** *Note: This time complexity is only for traversal*
Space Complexity: **O(N)**

6.1.4 Deletion

Deletion is carried out by going to the tree node to be deleted and then finding the minimum key or element in its right subtree and replacing the node's key with this minimum key. In this way, the order of AVL tree is maintained. In this engineering problem, we deleted all the odd indexed records from the tree.

Time Complexity: **O(log N)**
Space Complexity: **O(N)**

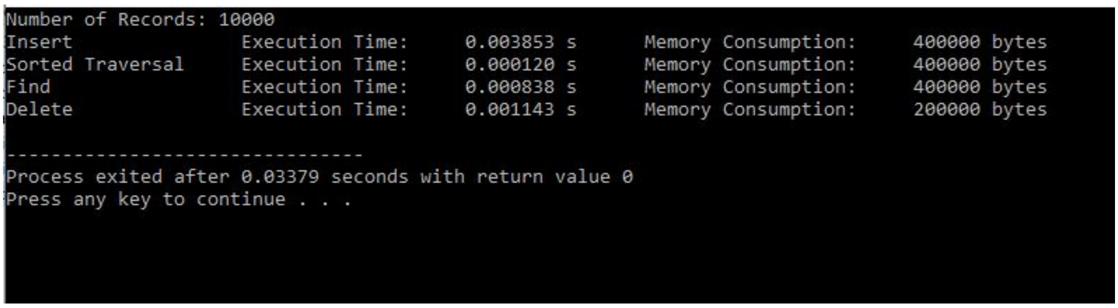
6.2 Execution Times and Memory Consumptions



```
Number of Records: 1000
Insert               Execution Time:     0.000338 s      Memory Consumption:     40000 bytes
Sorted Traversal     Execution Time:     0.000013 s      Memory Consumption:     40000 bytes
Find                 Execution Time:     0.000055 s      Memory Consumption:     40000 bytes
Delete               Execution Time:     0.000080 s      Memory Consumption:     20000 bytes

--------------------------------
Process exited after 0.02053 seconds with return value 0
Press any key to continue . . .
```

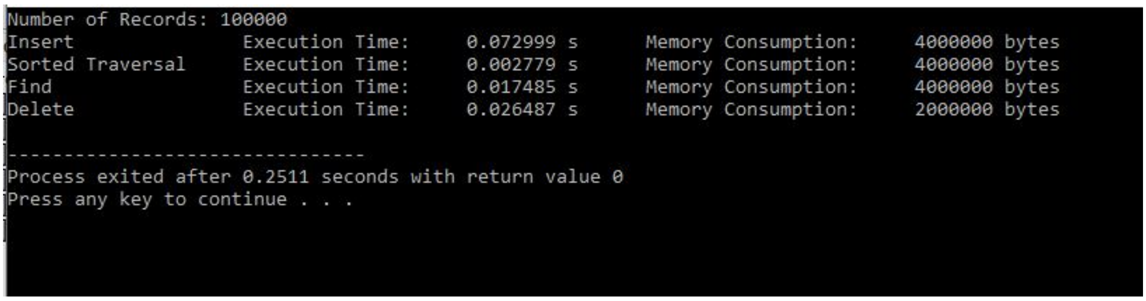
Figure 6.1: Results for tree implementation with data size 1000.



```
Number of Records: 10000
Insert               Execution Time:     0.003853 s      Memory Consumption:     400000 bytes
Sorted Traversal     Execution Time:     0.000120 s      Memory Consumption:     400000 bytes
Find                 Execution Time:     0.000838 s      Memory Consumption:     400000 bytes
Delete               Execution Time:     0.001143 s      Memory Consumption:     200000 bytes

--------------------------------
Process exited after 0.03379 seconds with return value 0
Press any key to continue . . .
```

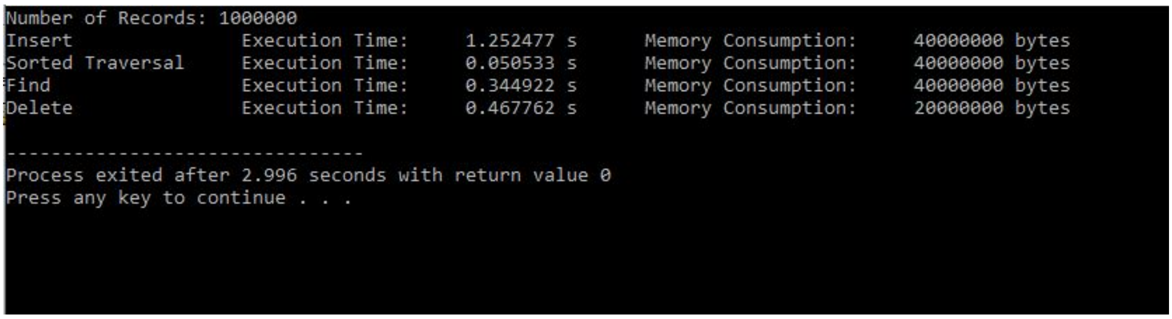
Figure 6.2: Results for tree implementation with data size 10000.



```
Number of Records: 100000
Insert               Execution Time:     0.072999 s      Memory Consumption:     4000000 bytes
Sorted Traversal     Execution Time:     0.002779 s      Memory Consumption:     4000000 bytes
Find                 Execution Time:     0.017485 s      Memory Consumption:     4000000 bytes
Delete               Execution Time:     0.026487 s      Memory Consumption:     2000000 bytes

--------------------------------
Process exited after 0.2511 seconds with return value 0
Press any key to continue . . .
```

Figure 6.3: Results for tree implementation with data size 100000.



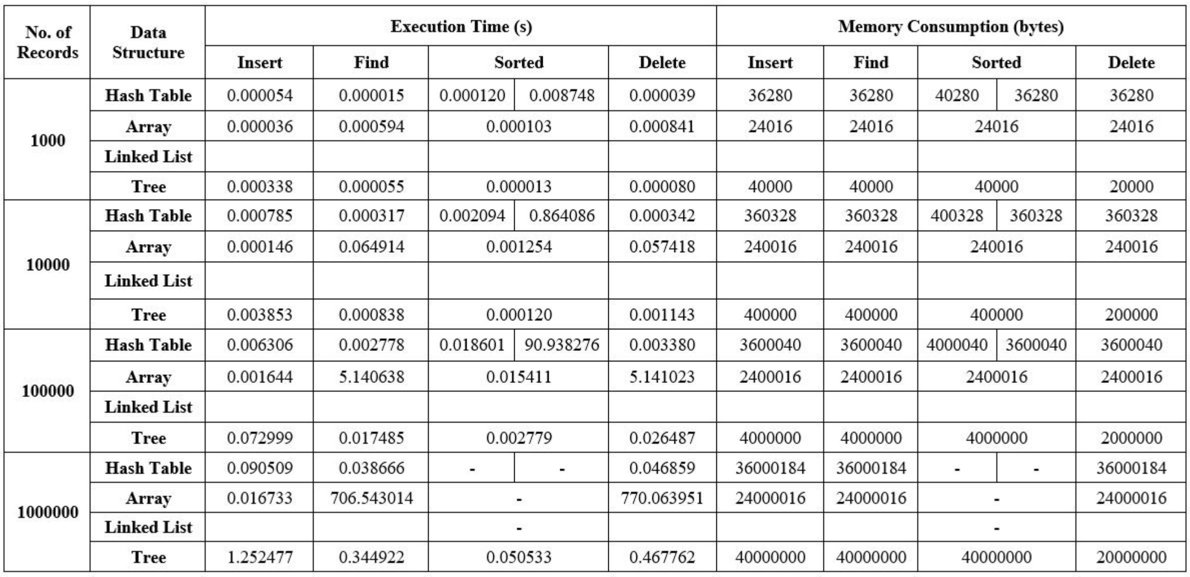
```
Number of Records: 1000000
Insert               Execution Time:     1.252477 s      Memory Consumption:     40000000 bytes
Sorted Traversal     Execution Time:     0.050533 s      Memory Consumption:     40000000 bytes
Find                 Execution Time:     0.344922 s      Memory Consumption:     40000000 bytes
Delete               Execution Time:     0.467762 s      Memory Consumption:     20000000 bytes

--------------------------------
Process exited after 2.996 seconds with return value 0
Press any key to continue . . .
```

Figure 6.4: Results for tree implementation with data size 1000000.

Chapter 7

Results



No. of Records	Data Structure	Execution Time (s)					Memory Consumption (bytes)				
		Insert	Find	Sorted		Delete	Insert	Find	Sorted		Delete
1000	Hash Table	0.000054	0.000015	0.000120	0.008748	0.000039	36280	36280	40280	36280	36280
	Array	0.000036	0.000594	0.000103		0.000841	24016	24016	24016		24016
	Linked List										
	Tree	0.000338	0.000055	0.000013		0.000080	40000	40000	40000		20000
10000	Hash Table	0.000785	0.000317	0.002094	0.864086	0.000342	360328	360328	400328	360328	360328
	Array	0.000146	0.064914	0.001254		0.057418	240016	240016	240016		240016
	Linked List										
	Tree	0.003853	0.000838	0.000120		0.001143	400000	400000	400000		200000
100000	Hash Table	0.006306	0.002778	0.018601	90.938276	0.003380	3600040	3600040	4000040	3600040	3600040
	Array	0.001644	5.140638	0.015411		5.141023	2400016	2400016	2400016		2400016
	Linked List										
	Tree	0.072999	0.017485	0.002779		0.026487	4000000	4000000	4000000		2000000
1000000	Hash Table	0.090509	0.038666	-	-	0.046859	36000184	36000184	-	-	36000184
	Array	0.016733	706.543014	-		770.063951	24000016	24000016	-		24000016
	Linked List			-					-		
	Tree	1.252477	0.344922	0.050533		0.467762	40000000	40000000	40000000		20000000

Figure 7.1: Combined results for all data structures and operations.

References

[1]