

Self-Balanced Binary Search Trees

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Problem Statement:

This lab demonstrates the implementation and comparison of two types of balanced binary search trees: AVL Trees and Red-Black Trees. The goal is to analyze their performance in terms of insertion, search, and deletion operations, as well as their height.

- **AVL Tree:** A self-balancing binary search tree where the difference in heights between the left and right subtrees is at most one for every node.
- **Red-Black Tree:** A binary search tree with an additional property that ensures the tree remains balanced by enforcing specific color properties on the nodes.

Analysis :

AVL Tree :

- **Time Complexity**
 - **Insert :** $O(\log(n))$
 - **Search :** $O(\log(n))$
 - **Delete :** $O(\log(n))$
- **Space Complexity:** $O(n)$

Red Black Tree :

- **Time Complexity**
 - **Insert :** $O(\log(n))$
 - **Search :** $O(\log(n))$
 - **Delete :** $O(\log(n))$
- **Space Complexity:** $O(n)$

Self-Balanced Binary Search Trees JUNIT Tests

Test Case	AVL Tree		Red-Black Tree	
	Time (ms)	Height	Time (ms)	Height
testBigDataInsertion (10000 keys)	11.288	14	4.560	21
testVeryLargeDataSet (1000 keys)	1.908	9	0.260	16
testRandomizedInsertionOrder (100 keys)	0.159	7	0.071	7
testInsertAscendingKeys (9 keys)	0.008	3	0.005	3
testInsertDescendingKeys (9 keys)	0.006	3	0.004	3
testInsertAlternatingKeys (9 keys)	0.006	3	0.035	3
testDoubleKeys (9 keys)	0.012	3	0.010	3
testLongStringKeys (5 keys)	0.005	2	0.004	2
testInsertDuplicateStrings (15 keys)	0.004	0	0.004	0
testSearchExistingKeys (7 keys)	0.003	2	0.002	3
testSearchOnEmptyTree (5 keys)	0.004	-1	0.002	-1
testDeleteAllElementsReverse (7 keys)	0.012	-1	0.011	-1
testDeleteAllElementsSequentially (7 keys)	0.008	-1	0.005	-1
testDeleteFromEmptyTree (5 keys)	0.003	-1	0.003	-1
testDeleteNonExistentElements (8 keys)	0.006	3	0.003	4
testMixedInsertAndDelete (7 ins, 3 del)	0.009	2	0.010	2
testRepeatedInsertionsAndDeletions	0.035	-1	0.023	-1
testInsertDeleteSearch	Ins: 0.005		Ins: 0.004	
	Del: 0.006		Del: 0.005	
	Search: 0.003		Search: 0.003	

Table 1: Performance Comparison of AVL and Red-Black Trees

Statistics

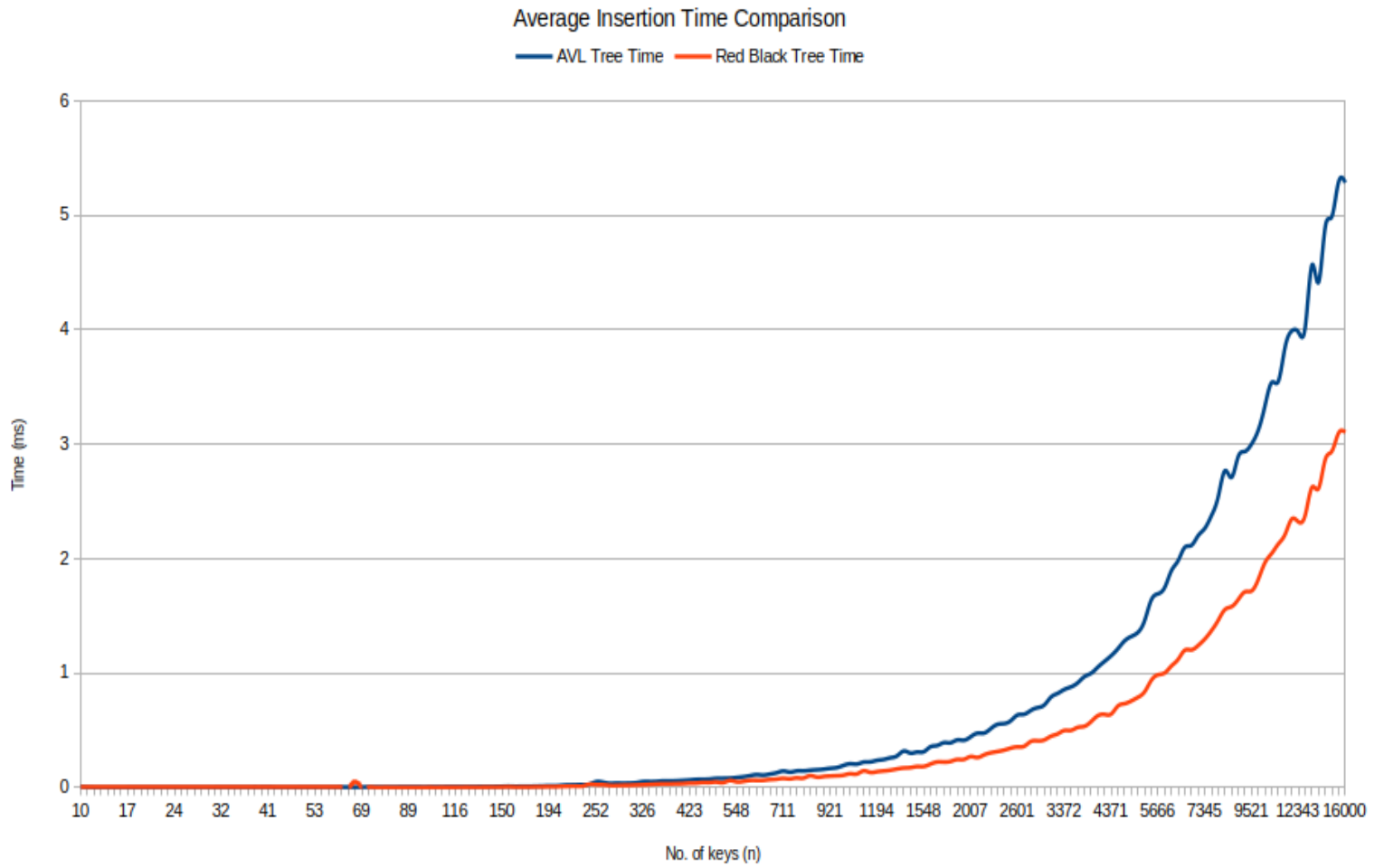


Figure 1: Insertion time comparison

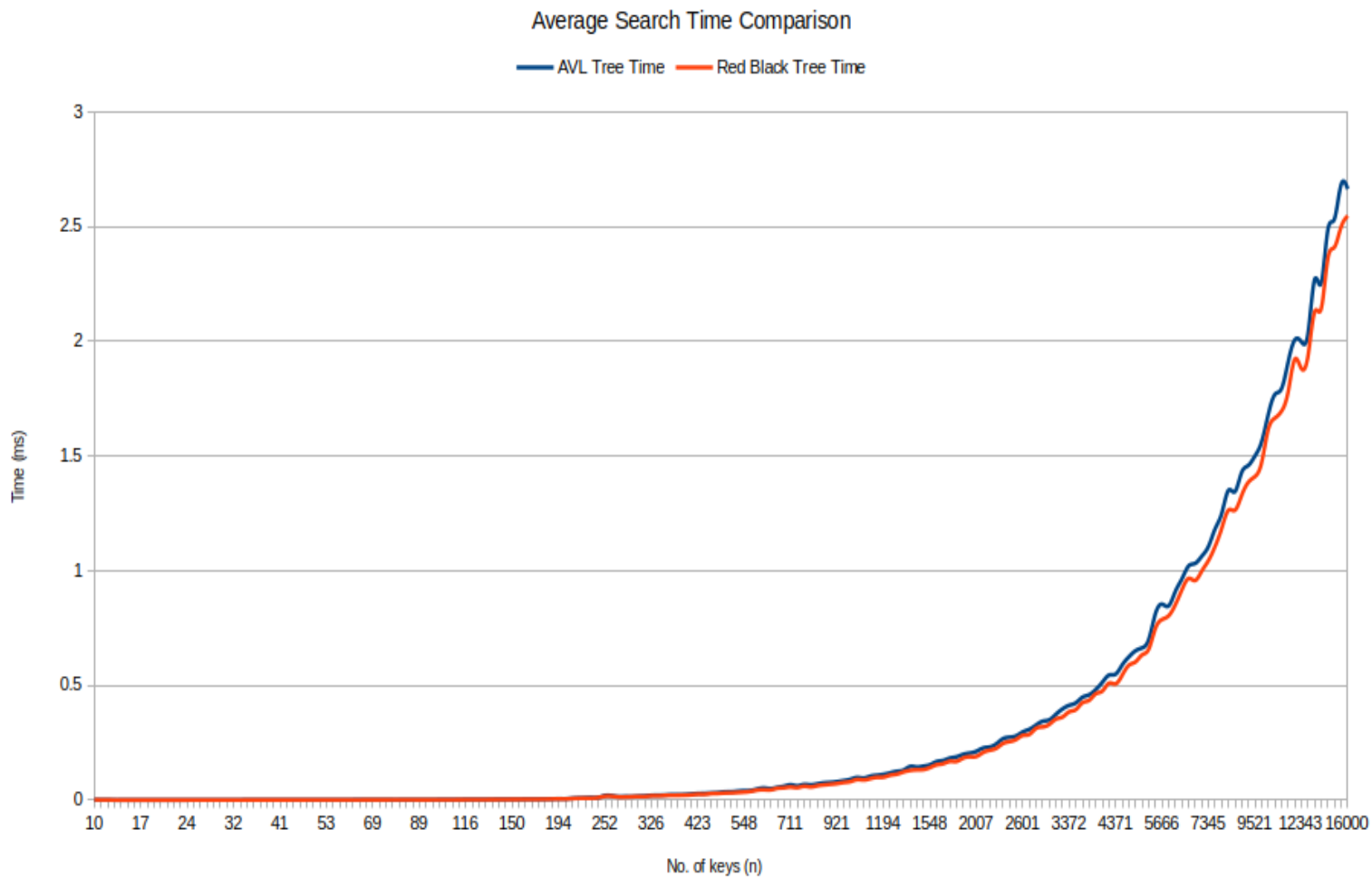


Figure 2: Search time comparison

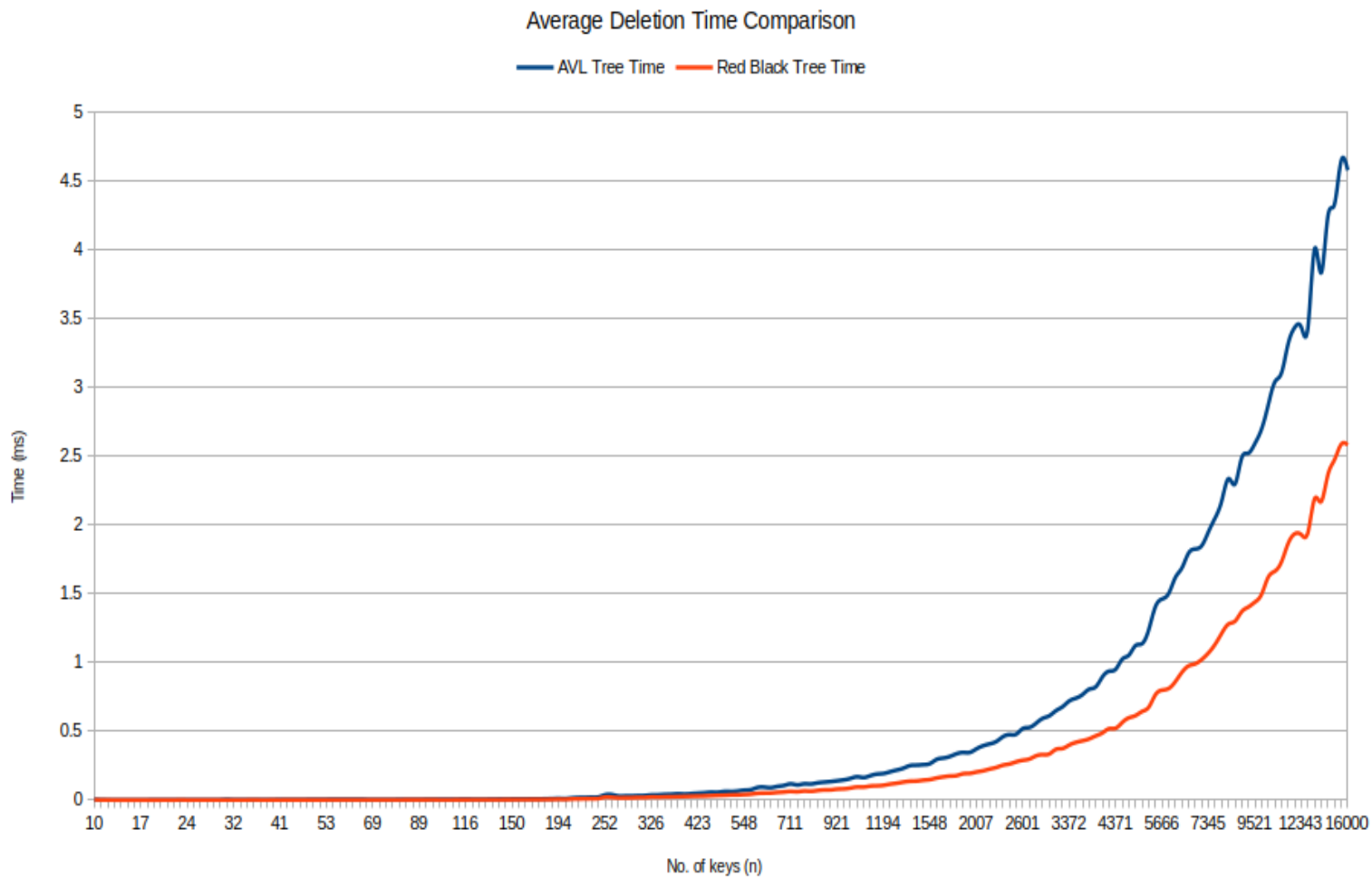


Figure 3: Deletion time comparison

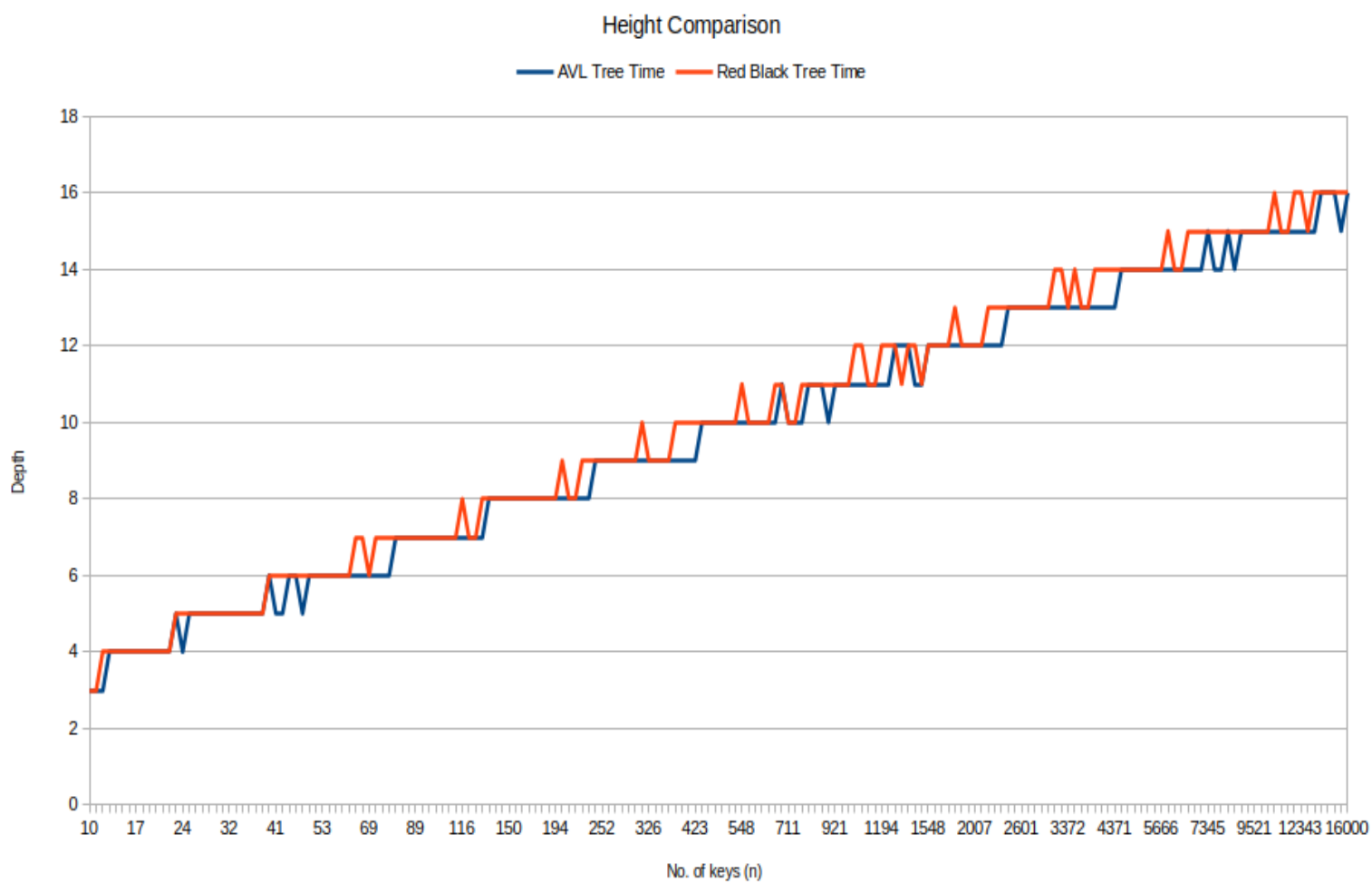


Figure 4: Height time comparison