IIC2133 - T03

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1 Note about solver

The problem is resolved using the A* algorithm since this significantly improved performance and allowed the termination of all puzzles. The report is done with respect to the results of the same solver. The heuristic cost function is the sum of the minimum distance of each tile value from its correct position. This is a lower bound since a tile needs to move this distance at the very least and each iteration can only move one tile by one cell. Some modifications had to be done to take into account the requirement of moving through walls.

2 Question 1

2.1 Implementation

The hash function used is a simple integer addition function where for item arr, hash = hash * 19 + arr[i] for $i \in [0, \ldots, |\text{arr}| - 1]$ with hash = 17 when $i = 0$. To get the slot index, we do hash mod m where m is the number of slots. At rehashing, both the max hashtable size and number of slots are doubled. Chaining is used to handle collisions.

2.2 Analysis

As shown in Figure 7, this hash function works quite well. Using an initial hashtable max size of 20, 11 slots, and load factor 0.75, the resulting hashtable has 1246 states with 1408 slots. There are 832 slots with no items.

Except for a few peaks, the figure shows that the hash values seem to be distributed quite uniformly over all the slots. This shows that using prime numbers for both the slot number and the hash function give successful results.

The maximum slot length is 6 and the mean and standard deviation of slot lengths are 0.88 and 1.29 respectively. In addition, for non-empty slots, the mean and standard deviation are 2.16 and 1.15 respectively. This means on average there are no collisions since the average slot length is 0.88 and the first insertion is not a collision. However, for non-empty slots, there is an average of

1 collision since the average slot length is 2.16 and the first insertion is not a collision. In total, there are 670 collisions (not counting the first insertion).

This means that we get a collision every other item. Overall, the results suggest a pretty good performance as insertion, deletion, and search can almost approximate the desired average complexity $\mathcal{O}(1)$.

3 Question 2

As concluded in Section 2.2, the hash function works quite well since insertion, deletion, and search approximate can almost approximate the desired average complexity $\mathcal{O}(1)$ since we only need to do one equality check at a particular slot when searching for an item due to the average slot length of $0.88 \approx 1.0$. For insertion and deletion, other than the searching part, all other parts take constant time using a chaining collision policy.

As shown in Table 1, the average slot lengths of all other puzzles round to 1.0. This means that the previous conclusion applies to these other puzzles as well.

4 Question 3

						Slot length			
name	n_slots	n_states	n_rehash	n_zero_slots	n_collisions	min	max	avg	std
3x3_0	11	14	0	2	5	0	3	1.27	0.9
3x3_1	22	29	1	11	18	0	4	1.32	1.59
3x3_2	704	934	6	382	612	0	8	1.33	1.75
3x3_3	704	764	6	390	450	0	8	1.09	1.49
3x3_4	352	449	5	189	286	0	7	1.28	1.68
3x3_5	1408	1246	7	832	670	0	6	0.88	1.29
4x4_0	11	14	0	2	5	0	3	1.27	0.9
4x4_1	22	23	1	14	15	0	5	1.05	1.59
4x4_2	44	38	2	26	20	0	4	0.86	1.23
4x4_3	176	125	4	107	56	0	4	0.71	1.04
4x4_4	44	58	2	25	39	0	8	1.32	1.88
4x4_5	44	50	2	24	30	0	5	1.14	1.55
lun_0	88	65	3	52	29	0	5	0.74	1.11
lun_1	176	152	4	105	81	0	7	0.86	1.3
lun_2	44	56	2	25	37	0	11	1.27	2.11
lun_3	176	188	4	99	111	0	6	1.07	1.44
lun_4	88	62	3	54	28	0	3	0.7	1.01
lun_5	176	180	4	97	101	0	5	1.02	1.41

Table 1: Various statistics on final hashtable for all puzzles

Table 1 shows various statistics for each puzzle. As shown in column n_rehash, the maximum number of rehashing is 7 and the minimum is 0. Since all puzzles were solved in less than 1 second, the time spent on rehashing must be less

than 1 second and therefore insignificant. Moreover, the rehashing operation is linear with respect to the number of states if puzzle size is fixed. With a maximum number of states of 1246 for puzzle 3x3_5, very little time is required for rehashing.

5 Appendix

The appendix lists the bar charts of the hashtables for the rest of the puzzles.

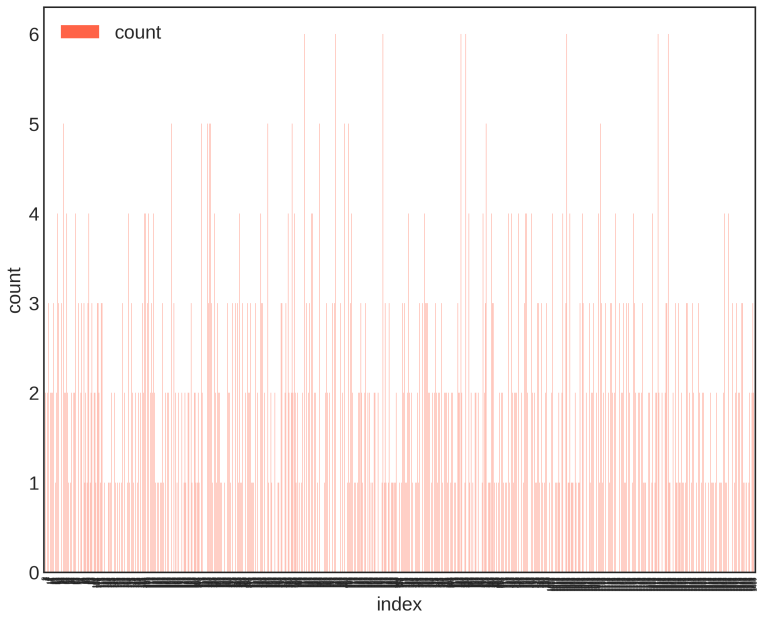

Figure 1: Bar chart showing hashtable slot counter with 1408 slots and 1246 items for puzzle 3x3_5

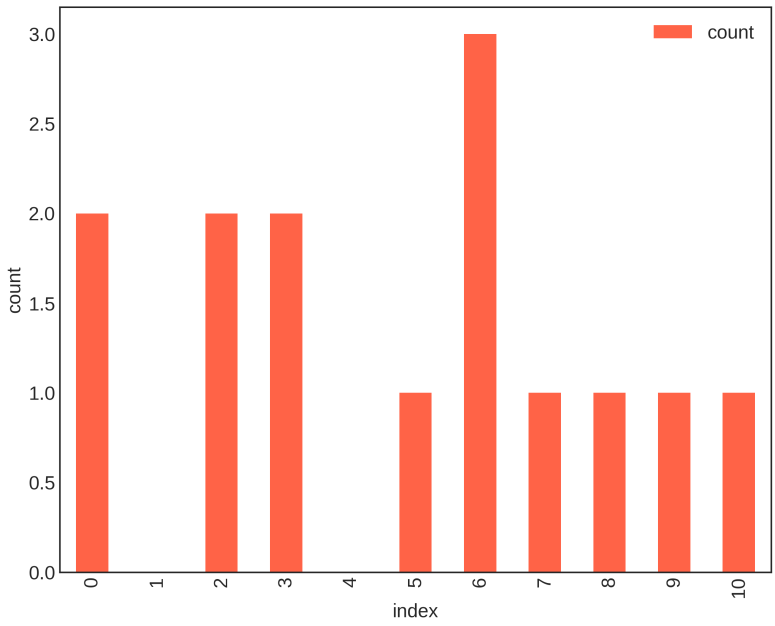

Figure 2: Bar chart showing hashtable slot counter with 11 slots and 14 items for puzzle 3x3_0

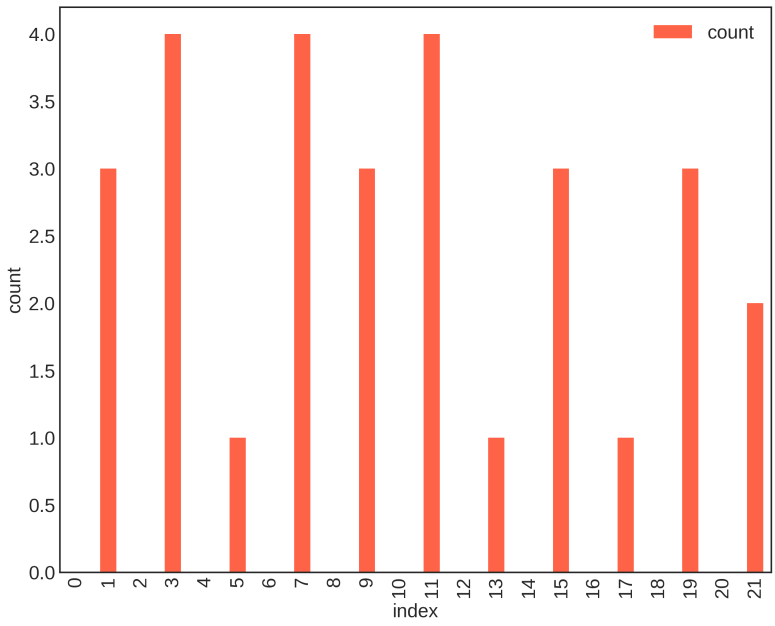

Figure 3: Bar chart showing hashtable slot counter with 22 slots and 29 items for puzzle 3x3_1

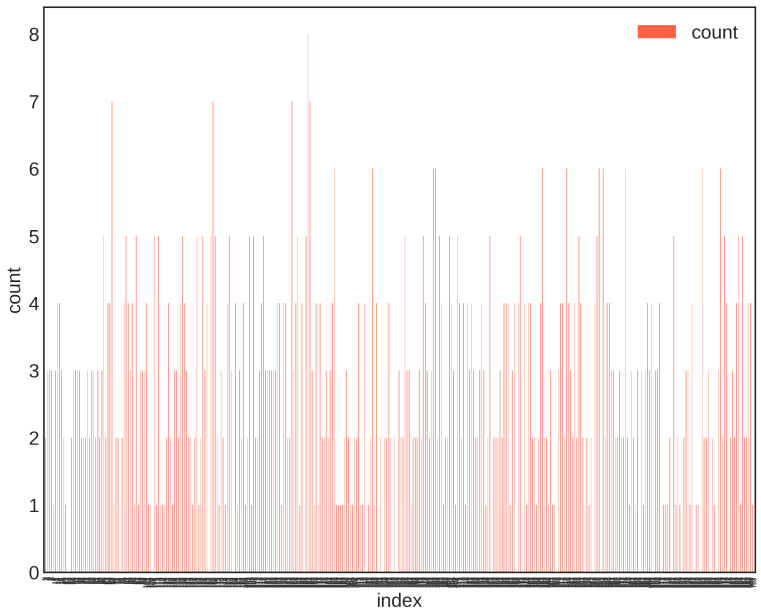

Figure 4: Bar chart showing hashtable slot counter with 704 slots and 934 items for puzzle 3x3_2

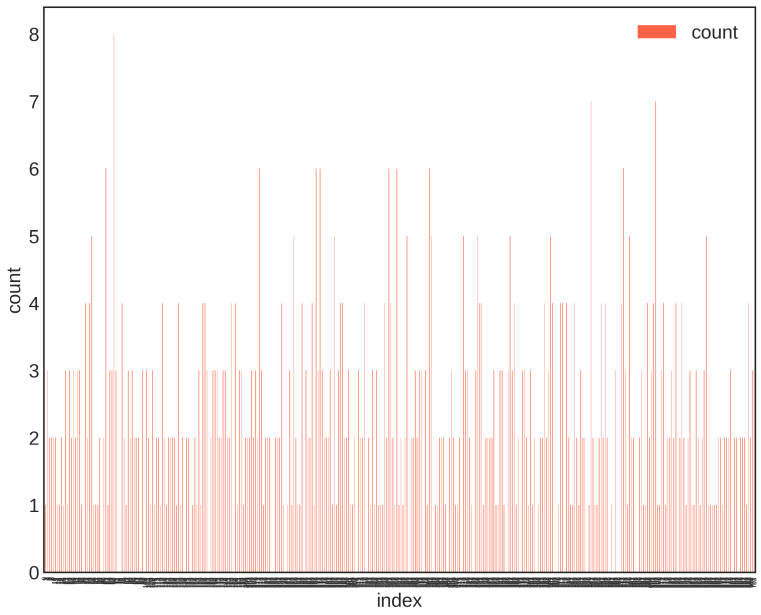

Figure 5: Bar chart showing hashtable slot counter with 704 slots and 764 items for puzzle 3x3_3

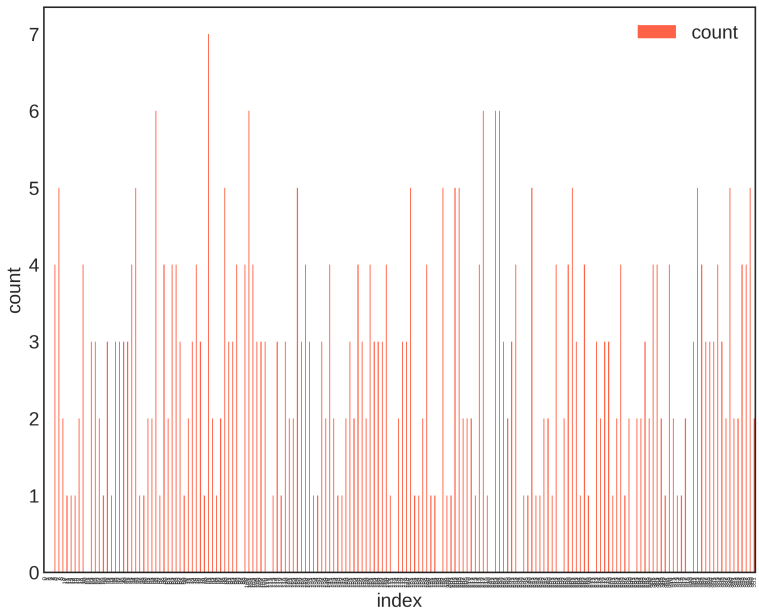

Figure 6: Bar chart showing hashtable slot counter with 352 slots and 449 items for puzzle 3x3_4

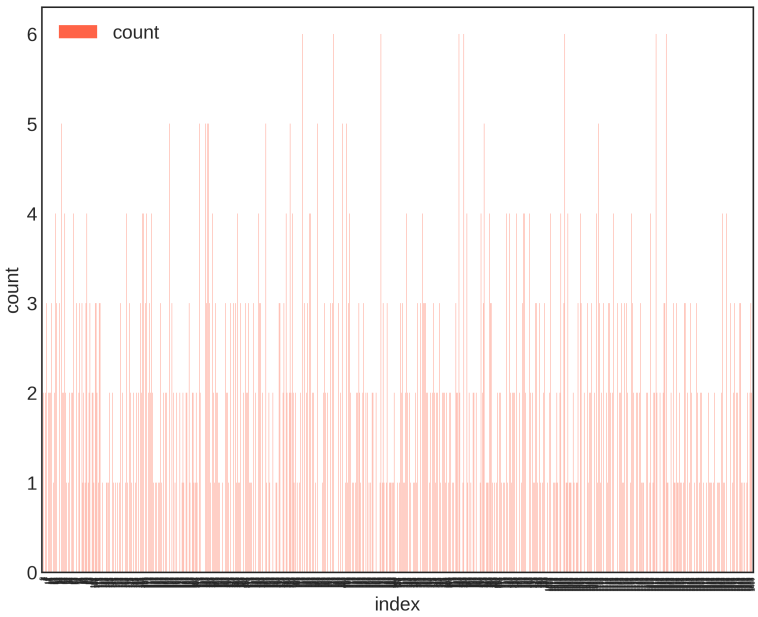

Figure 7: Bar chart showing hashtable slot counter with 1408 slots and 1246 items for puzzle 3x3_5

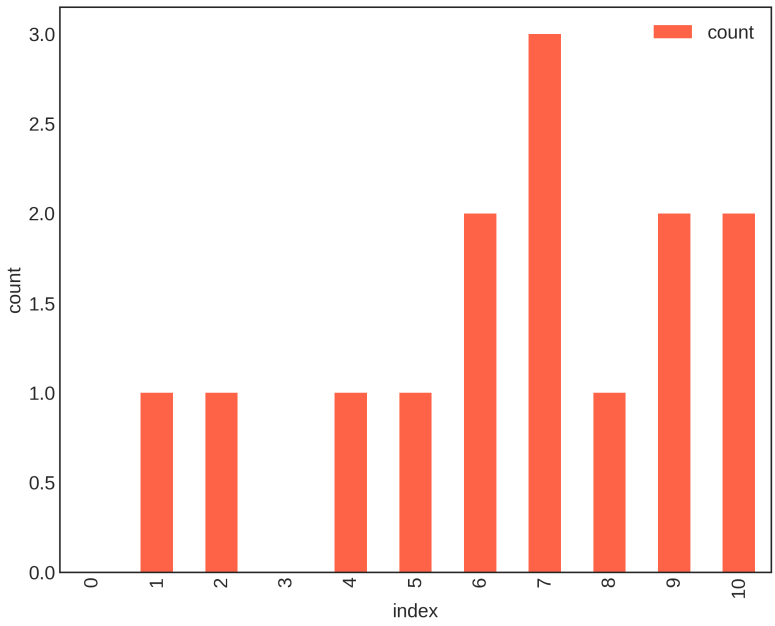

Figure 8: Bar chart showing hashtable slot counter with 11 slots and 14 items for puzzle 4x4_0

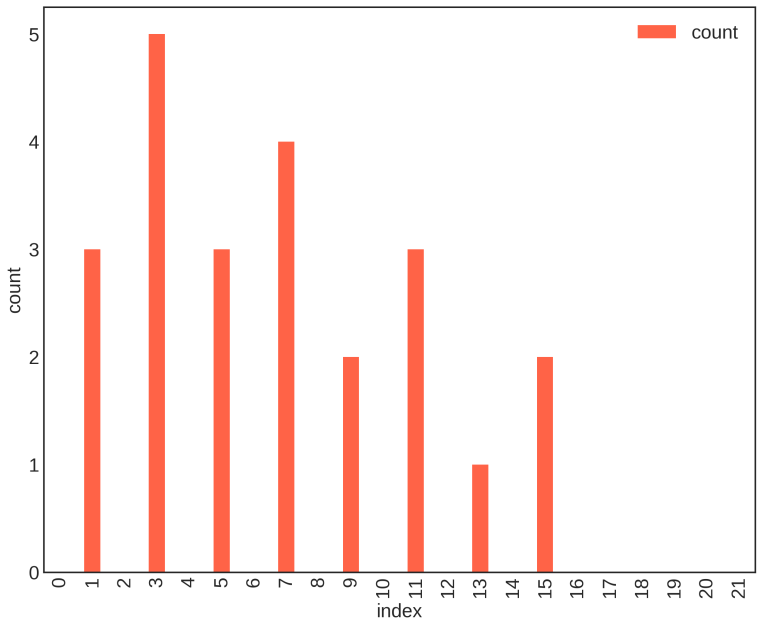

Figure 9: Bar chart showing hashtable slot counter with 22 slots and 23 items for puzzle 4x4_1

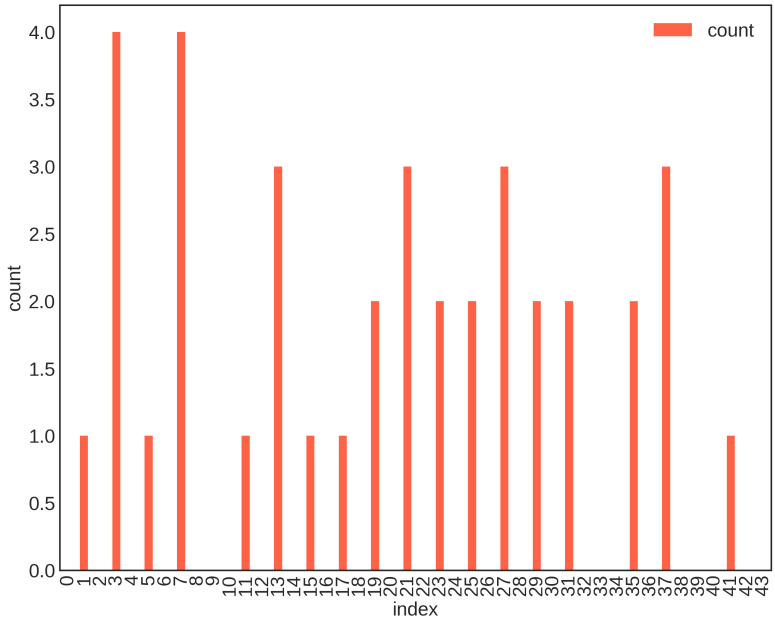

Figure 10: Bar chart showing hashtable slot counter with 44 slots and 38 items for puzzle 4x4_2

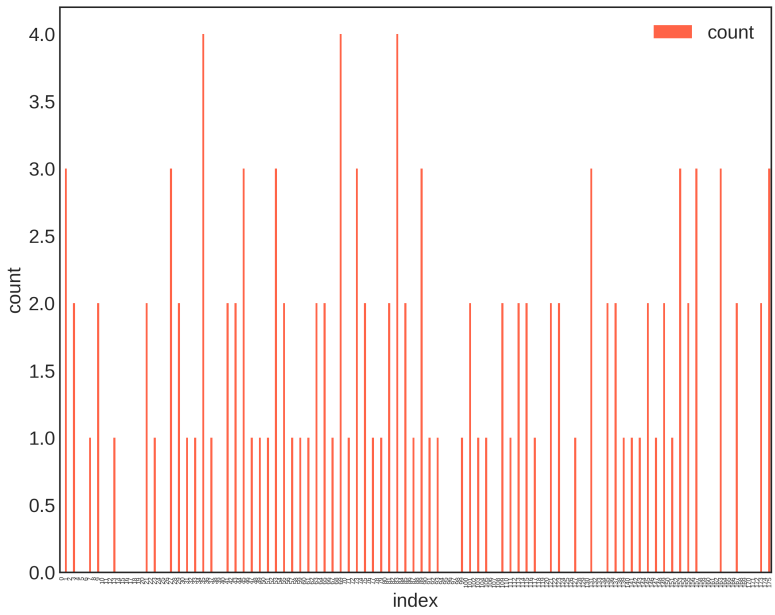

Figure 11: Bar chart showing hashtable slot counter with 176 slots and 125 items for puzzle 4x4_3

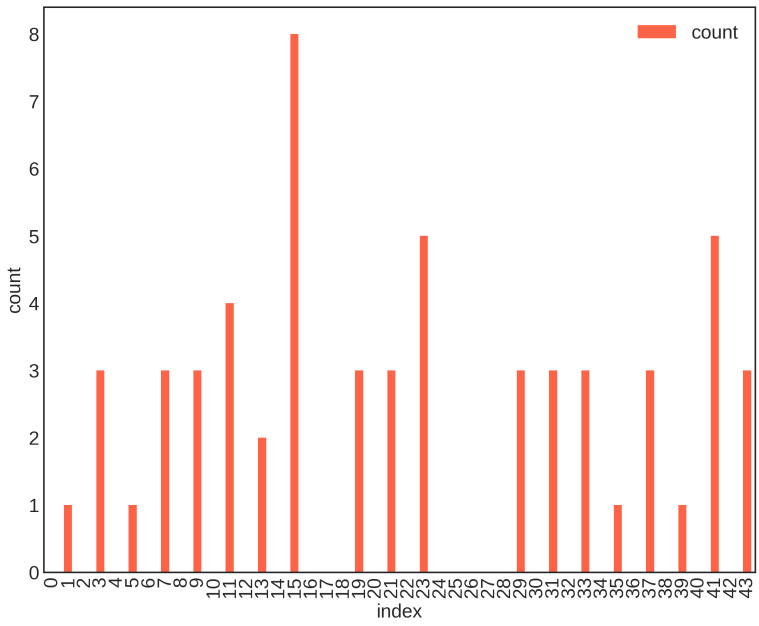

Figure 12: Bar chart showing hashtable slot counter with 44 slots and 58 items for puzzle 4x4_4

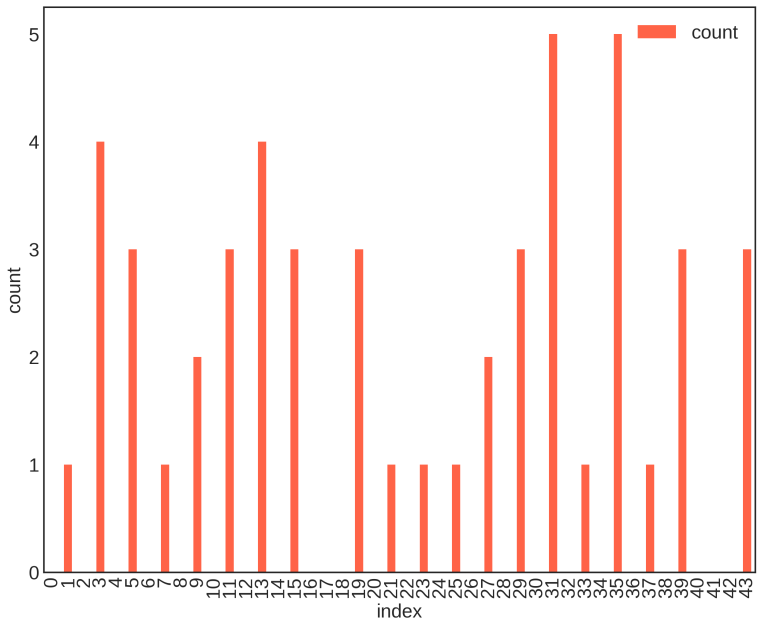

Figure 13: Bar chart showing hashtable slot counter with 44 slots and 50 items for puzzle 4x4_5

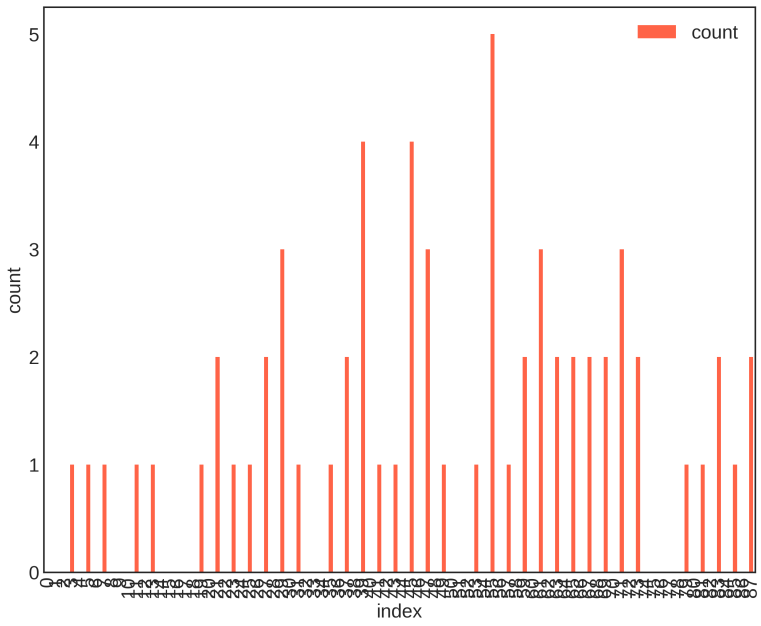

Figure 14: Bar chart showing hashtable slot counter with 88 slots and 65 items for puzzle lun_0

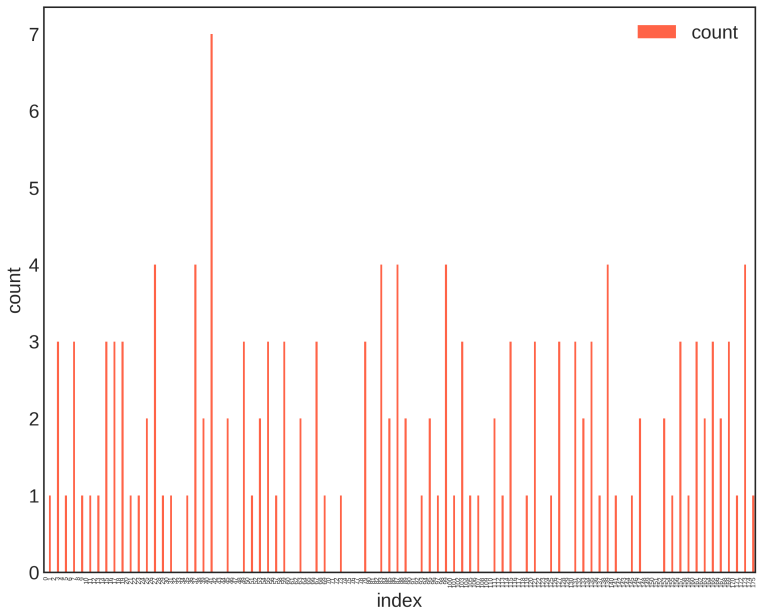

Figure 15: Bar chart showing hashtable slot counter with 176 slots and 152 items for puzzle lun_1

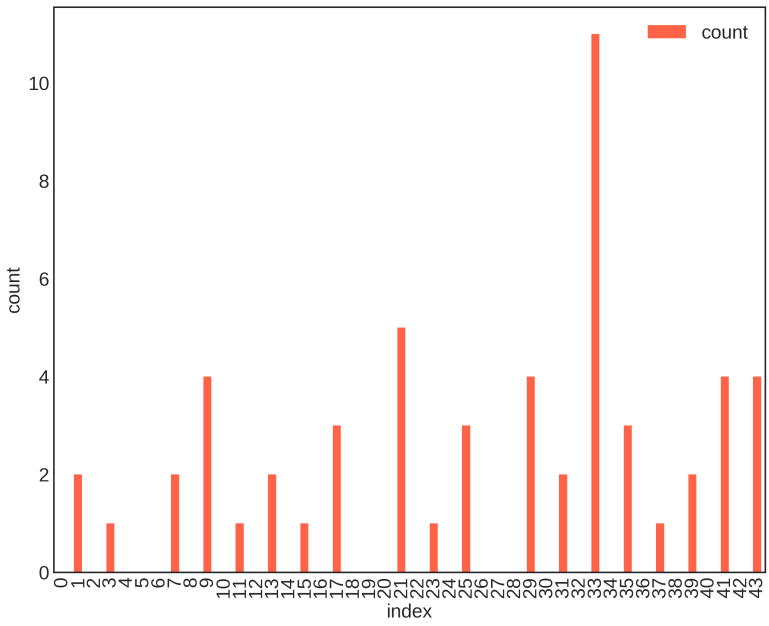

Figure 16: Bar chart showing hashtable slot counter with 44 slots and 56 items for puzzle lun_2

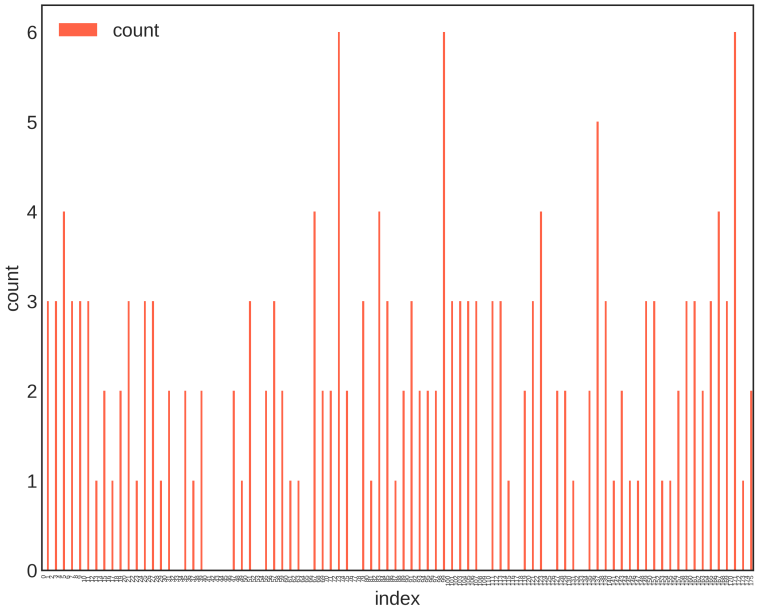

Figure 17: Bar chart showing hashtable slot counter with 176 slots and 188 items for puzzle lun_3

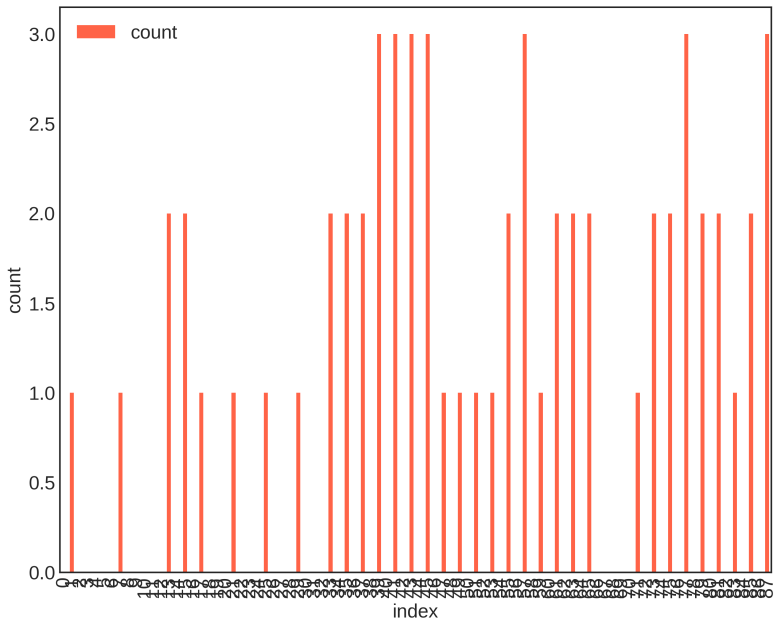

Figure 18: Bar chart showing hashtable slot counter with 88 slots and 62 items for puzzle lun_4

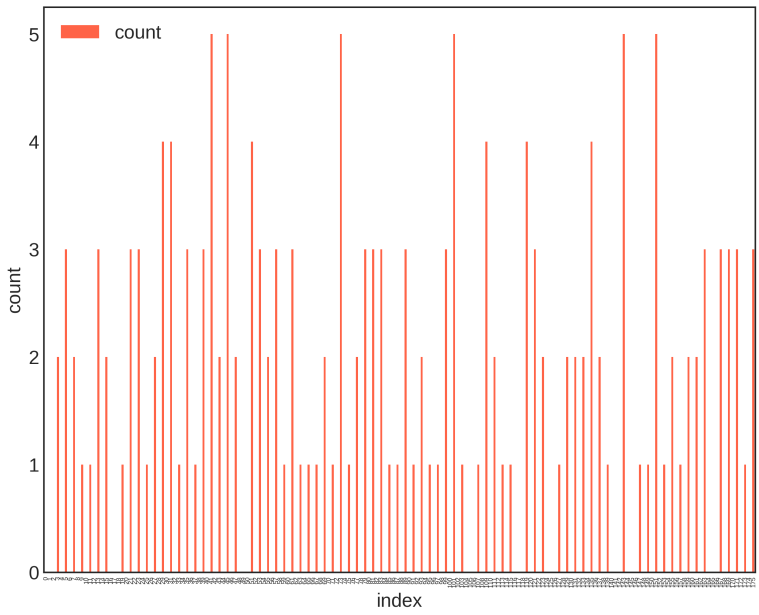

Figure 19: Bar chart showing hashtable slot counter with 176 slots and 180 items for puzzle lun_5