HABIB UNIVERSITY

Data Structures & Algorithms

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Hash Table Operations – Collision Handling Using Double Hashing – Key Offset Rehashing

Student 1: _____

For a hash table with size = 15, use Fold Shift method for primary hash function to get the slot index, and secondary hash function is defined as: **$h_2(k) = 13 – (k \bmod N)$** to resolve Collisions.

1. setitem(112233)

- Hash Function = Fold Shift
- Key Parts:
  k1 = 11, k2 = 22, k3 = 33
- Sum of keys= 11 + 22 + 33 = 66
- Slot index = 66 mod 15 = 6
- Empty slot, no collision so slot index = 6 gets key = 112233

0	
1	
2	
3	
4	
5	
6	**112233**
7	
8	
9	
10	
11	
12	
13	
14	

2. setitem(2197856)

- Hash Function = Fold Shift
- Key Parts:
  k1 = 21, k2 = 97, k3 = 85, k4= 6
- Sum of keys=21+97+85+6=209
- Discard 2 and get 09
- Slot index = 09 mod 15 = 09
- Empty slot, no collision so slot index = 9 gets key = 2197856

0	
1	
2	
3	
4	
5	
6	112233
7	
8	
9	**2197856**
10	
11	
12	
13	
14	

3. setitem(12345)

- Hash Function = Fold Shift
- Key Parts:
  k1 = 12, k2 = 34, k3 = 5
- Sum of keys=12+34+5=51
- Slot index = 51 % 15 = 6
- Already a key present at slot index = 6, so use key offset rehashing and rehash they key as:
- **$h'(k)=[h_1(k)+(1 * h_2(k))] \bmod N$**
  $h'(12345) = [h_1(12345) + (1 * h_2(12345))] \bmod N$
- $h_1(12345)=6$(as deduced above)
- $h_2(12345) = 13 – (12345 \% 15) = 13 – 0 = 13$
- $h'(12345) = [6 + (1 * 13)] \bmod 15 = [6 + 13] \bmod 15 = 19 \bmod 15 = 4$
- Empty slot, no collision so slot index = 4 gets key = 12345

0	
1	
2	
3	
4	**12345**
5	
6	112233
7	
8	
9	2197856
10	
11	
12	
13	
14	

4. getitem(112233)

- Hash Function = Fold Shift
- Key Parts:
  k1 = 11, k2 = 22, k3 = 33
- Sum of keys= 11 + 22 + 33 = 66
- Slot index = 66 mod 15 = 6
- Go to slot index 6 to see if the key exists. It does, so it returns **True**
- Hash Table does not change

0	
1	
2	
3	
4	12345
5	
6	112233
7	
8	
9	2197856
10	
11	
12	
13	
14	

5. delitem(112233)

- Hash Function = Fold Shift
- Key Parts:
  k1 = 11, k2 = 22, k3 = 33
- Sum of keys= 11 + 22 + 33 = 66
- Slot index = 66 mod 15 = 6
- Go to slot index 6 to see if the key exists. It does, so it deletes the key from that slot

0	
1	
2	
3	
4	12345
5	
6	
7	
8	
9	2197856
10	
11	
12	
13	
14	

6. setitem(15151515)

- Hash Function = Fold Shift
- Key Parts:
  k1 = 15, k2 = 15, k3 = 15, k4 = 15
- Sum of keys = 15 + 15 + 15 + 15 = 60
- Slot index = 60 mod 15 = 0
- Empty slot, no collision so slot index = 0 gets key = 15151515

0	**15151515**
1	
2	
3	
4	12345
5	
6	
7	
8	
9	2197856
10	
11	
12	
13	
14	

7. setitem(21627)

- Hash Function = Fold Shift
- Key Parts:
  k1 = 21, k2 = 62, k3 = 7
- Sum of keys = 21 + 62 + 7 = 90
- Slot index = 90 % 15 = 0
- Already a key present at slot index = 0, so use key offset rehashing and rehash they key as:
- **$h'(k)=[h_1(k)+(1 * h_2(k))] \bmod N$**
  $h'(21627) = [h_1(21627) + (1 * h_2(21627))] \bmod N$
- $h_1(21627) = 0$ (as deduced above)
- $h_2(21627) = 13 – (21627 \% 15) = 13 – 12 = 1$
- $h'(21627) = [0 + (1 * 1)] \bmod 15 = [0 + 1] \bmod 15 = 1 \bmod 15 = 1$
- Empty slot, no collision so slot index = 1 gets key = 21627

0	15151515
1	**21627**
2	
3	
4	12345
5	
6	
7	
8	
9	2197856
10	
11	
12	
13	
14	

8. setitem(1313)

- Hash Function = Fold Shift
- Key Parts:
  k1 = 13, k2 = 13
- Sum of keys= 13 + 13 = 26
- Slot index = 26 mod 15 = 11
- Empty slot, no collision so slot index = 11 gets key = 1313

0	15151515
1	21627
2	
3	
4	12345
5	
6	
7	
8	
9	2197856
10	
11	**1313**
12	
13	
14	

9. setitem(281817)

- Hash Function = Fold Shift
- Key Parts:
  k1 = 28, k2 = 18, k3 = 17
- Sum of keys= 28 + 18 + 17 = 63
- Slot index = 63 mod 15 = 3
- Empty slot, no collision so slot index = 3 gets key = 281817

0	15151515
1	21627
2	
3	**281817**
4	12345
5	
6	
7	
8	
9	2197856
10	
11	1313
12	
13	
14	

10. getitem(13131)

- Hash Function = Fold Shift
- Key Parts:
  k1 = 13, k2 = 13, k3 = 1
- Sum of keys= 13 + 13 + 1 = 27
- Slot index = 27 mod 15 = 12
- Go to slot index 12 to see if the key exists. It does not, so try rehashing to check next possible slot
- Use key offset rehashing and rehash they key as:
- **$h'(k)=[h_1(k)+(1 * h_2(k))] \bmod N$**
  $h'(13131) = [h_1(13131) + (1 * h_2(13131))] \bmod N$
- $h_1(13131) = 12$ (as deduced above)
- $h_2(13131) = 13 – (13131 \% 15) = 13 – 6 = 7$
- $h'(13131) = [12 + (1 * 7)] \bmod 15 = [12 + 7] \bmod 15 = 19 \bmod 15 = 4$
- Go to slot index 4 to see if the key exists. It does not, so try rehashing to check next possible slot
- This continues until the rehashing results back to slot index 12, by which time all the slots would have been checked and 13131 would not have been found, so it gives an error that the key does not exist, and returns **False**
- Hash Table does not change

0	15151515
1	21627
2	
3	281817
4	12345
5	
6	
7	
8	
9	2197856
10	
11	1313
12	
13	
14	

11. setitem(98765432)

- Hash Function = Fold Shift
- Key Parts:
  k1 = 98, k2 = 76, k3 = 54, k4 = 32
- Sum of keys = 98 + 76 + 54 + 32 = 260
- Discard 2 to get 60
- Slot index = 60 mod 15 = 0
- Already a key present at slot index = 0, so use key offset rehashing and rehash they key as:
- **$h'(k)=[h_1(k)+(1 * h_2(k))] \bmod N$**
  $h'(98765432) = [h_1(98765432) + (1 * h_2(98765432))] \bmod N$
- $h_1(98765432) = 0$ (as deduced above)
- $h_2(98765432) = 13 – (98765432 \% 15) = 13 – 2 = 11$
- $h'(21627) = [0 + (1 * 11)] \bmod 15 = [0 + 11] \bmod 15 = 11 \bmod 15 = 11$
- Already a key present at slot index = 11, so use key offset rehashing and rehash they key as:
- **$h'(k)=[h_1(k)+(2 * h_2(k))] \bmod N$**
  $h'(98765432) = [h_1(98765432) + (2 * h_2(98765432))] \bmod N$
- $h_1(98765432) = 0$ (as deduced above)
- $h_2(98765432) = 13 – (98765432 \% 15) = 13 – 2 = 11$
- $h'(21627) = [0 + (2 * 11)] \bmod 15 = [0 + 22] \bmod 15 = 22 \bmod 15 = 7$
- Empty slot, no collision so slot index = 7 gets key = 98765432

0	15151515
1	21627
2	
3	281817
4	12345
5	
6	
7	**98765432**
8	
9	2197856
10	
11	1313
12	
13	
14	

12. setitem(667)

- Hash Function = Fold Shift
- Key Parts:
  k1 = 66, k2 = 7
- Sum of keys = 66 + 7 = 73
- Slot index = 73 mod 15 = 13
- Empty slot, no collision so slot index = 13 gets key = 667

0	15151515
1	21627
2	
3	281817
4	12345
5	
6	
7	98765432
8	
9	2197856
10	
11	1313
12	
13	**667**
14	

13. setitem(555555)

- Hash Function = Fold Shift
- Key Parts:
  k1 = 55, k2 = 55, k3 = 55
- Sum of keys = 55 + 55 + 55 = 165
- Slot index = 165 % 15 = 0
- Already a key present at slot index = 0, so use key offset rehashing and rehash they key as:
- **$h'(k)=[h_1(k)+(1 * h_2(k))] \bmod N$**
  $h'(555555) = [h_1(555555) + (1 * h_2(555555))] \bmod N$
- $h_1(555555) = 0$ (as deduced above)
- $h_2(555555) = 13 – (555555 \% 15) = 13 – 0 = 13$
- $h'(555555) = [0 + (1 * 13)] \bmod 15 = [0 + 13] \bmod 15 = 13 \bmod 15 = 13$
- Already a key present at slot index = 13, so use key offset rehashing and rehash they key as:
- **$h'(k)=[h_1(k)+(2 * h_2(k))] \bmod N$**
  $h'(555555) = [h_1(555555) + (2 * h_2(555555))] \bmod N$
- $h_1(555555) = 0$ (as deduced above)
- $h_2(555555) = 13 – (555555 \% 15) = 13 – 0 = 13$
- $h'(555555) = [0 + (2 * 13)] \bmod 15 = [0 + 26] \bmod 15 = 26 \bmod 15 = 11$
- Already a key present at slot index = 11, so use key offset rehashing and rehash they key as:
- **$h'(k)=[h_1(k)+(3 * h_2(k))] \bmod N$**
  $h'(555555) = [h_1(555555) + (3 * h_2(555555))] \bmod N$
- $h_1(555555) = 0$ (as deduced above)
- $h_2(555555) = 13 – (555555 \% 15) = 13 – 0 = 13$
- $h'(555555) = [0 + (3 * 13)] \bmod 15 = [0 + 39] \bmod 15 = 39 \bmod 15 = 9$
- Already a key present at slot index = 9, so use key offset rehashing and rehash they key as:
- **$h'(k)=[h_1(k)+(4 * h_2(k))] \bmod N$**
  $h'(555555) = [h_1(555555) + (4 * h_2(555555))] \bmod N$
- $h_1(555555) = 0$ (as deduced above)
- $h_2(555555) = 13 – (555555 \% 15) = 13 – 0 = 13$
- $h'(555555) = [0 + (4 * 13)] \bmod 15 = [0 + 52] \bmod 15 = 52 \bmod 15 = 7$
- Already a key present at slot index = 7, so use key offset rehashing and rehash they key as:
- **$h'(k)=[h_1(k)+(5 * h_2(k))] \bmod N$**
  $h'(555555) = [h_1(555555) + (5 * h_2(555555))] \bmod N$
- $h_1(555555) = 0$ (as deduced above)
- $h_2(555555) = 13 – (555555 \% 15) = 13 – 0 = 13$
- $h'(555555) = [0 + (5 * 13)] \bmod 15 = [0 + 65] \bmod 15 = 65 \bmod 15 = 5$
- Empty slot, no collision so slot index = 5 gets key = 555555

0	15151515
1	21627
2	
3	281817
4	12345
5	**555555**
6	
7	98765432
8	
9	2197856
10	
11	1313
12	
13	667
14	

14. delitem(1234)

- Hash Function = Fold Shift
- Key Parts:
  k1 = 12, k2 = 34
- Sum of keys= 12 + 34 = 46
- Slot index = 46 mod 15 = 1
- Go to slot index 1 to see if the key exists. It does not, so try rehashing to check next possible slot
- Use key offset rehashing and rehash they key as:
- **$h'(k)=[h_1(k)+(1 * h_2(k))] \bmod N$**
  $h'(1234) = [h_1(1234) + (1 * h_2(1234))] \bmod N$
- $h_1(1234) = 1$ (as deduced above)
- $h_2(1234) = 13 – (1234 \% 15) = 13 – 4 = 9$
- $h'(1234) = [1 + (1 * 9)] \bmod 15 = [1 + 9] \bmod 15 = 10 \bmod 15 = 10$
- Go to slot index 10 to see if the key exists. It does not, so try rehashing to check next possible slot
- This continues until the rehashing results back to slot index 1, by which time all the slots would have been checked and 1234 would not have been found, so it gives an error that the key does not exist, and does not delete anything
- Hash Table does not change

0	15151515
1	21627
2	
3	281817
4	12345
5	555555
6	
7	98765432
8	
9	2197856
10	
11	1313
12	
13	667
14	