HASH TABLE

In case of the Hash Table the element is stored in slot *h(k)*; that is, we use a hash function *h* to compute the slot from the key *k*.
Hash function *h* maps the universe *U* of keys into the slots of a hash table *T[0..m–1], h: U→{0,1,…,m–1},* where the size *m* of the hash table is typically much less than |U|.
There is one hitch: two keys may hash to the same slot. We call this situation a **collision**.

Define the Hash function with the division method

- In the division method for creating hash functions, we map a key *k* into one of *m* slots by taking the remainder of *k* divided by *m*.
- The hash function is ***h(k) = k mod m***.
- For example, if the hash table has size *m=12,* then the possible hash values are between 0 and 11. If the hash table has size *m=12* and the key is *k=100*, then *h(k)=4*.

Methods for collision problems:

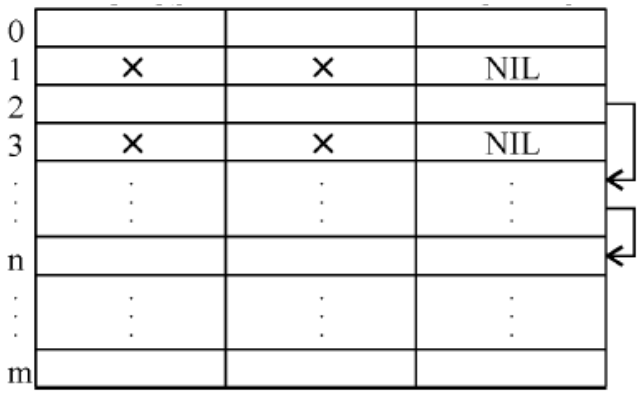
- Open addressing
- Open addressing with chaining
- Separate chaining with Linked List

Open addressing

- If we have collisions (Linear Probing):
  - the alternative slot for a value after a collision is calculated by adding 1 to the current computed slot and taking modulus based on the table size: *alternative slot = (1 + current slot) mod (table size)*
  - So we move towards the end of the table and find the first empty slot, and we place the element into the table. If we reach the end of the table, we start it from the beginning.

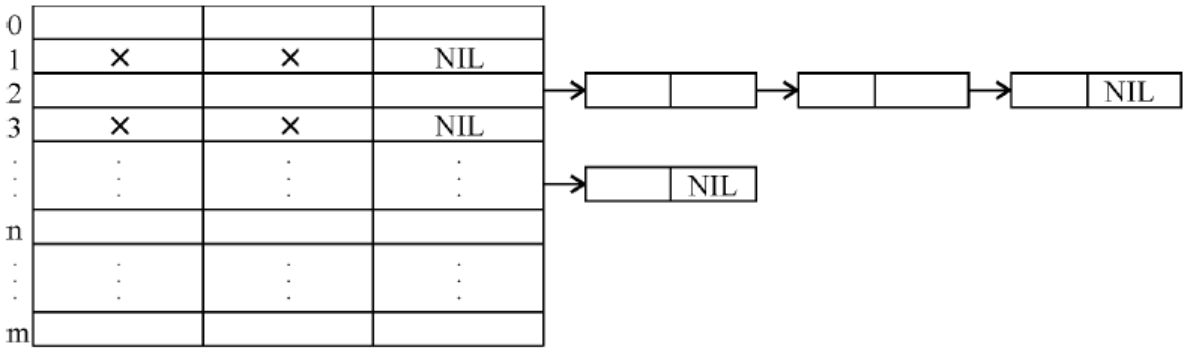
Open addressing with chaining

- In case of the open addressing method we know nothing about the places of the overflow element. So we use another column, whose name will be the Pointer.
- In this pointer column we write the address (index) of the overflow value. If there is no overflow, we place the NIL pointer.



Separate chaining with Linked List

- In chaining, we place all the elements that hash to the same slot into the same linked list.



1. Exercise: There is a hash table which is capable of storing 9 elements.
Define the hash function with the division method.
The following key-value pairs are given:

19 blue
27 red
51 green
13 blue
37 brown
31 pink
25 orange

Place the elements in the table using the following methods:

- Open addressing
- Open addressing with chaining
- Separate chaining with Linked List

Solution

m = 9 (size of the table)

h(k) = k mod 9

Open addressing method

– in case of collision, insert the key-value pair at next free slot

	Key	Value
0	27	red
1	19	blue
2	37	brown
3		
4	13	blue
5	31	pink
6	51	green
7	25	orange
8		

Open addressing with chaining method

– in case of collision, save the index of the overflow value

	Key	Value	Pointer
0	27	red	NIL
1	19	blue	2
2	37	brown	NIL
3			
4	13	blue	5
5	31	pink	NIL
6	51	green	NIL
7	25	orange	NIL
8			

Separate chaining with Linked List

– place all the elements that hash to the same slot into the same linked list

	Key	Value	Pointer
0	27	red	NIL
1	19	blue	→
2			
3			
4	13	blue	→
5			
6	51	green	NIL
7	25	orange	NIL
8			

37	brown	NIL

31	pink	NIL

2. Exercise: There is a hash table which is capable of storing 9 elements. Define the hash function with the division method. The following key-value pairs are given:

2 Honda
7 Suzuki
9 Mercedes
15 Opel
18 Ford
14 BMW
11 Toyota
21 Tesla

Place the elements in the table using the following methods:

- Open addressing
- Open addressing with chaining
- Separate chaining with Linked List

Solution

m = 9 (size of the table)
h(k) = k mod 9

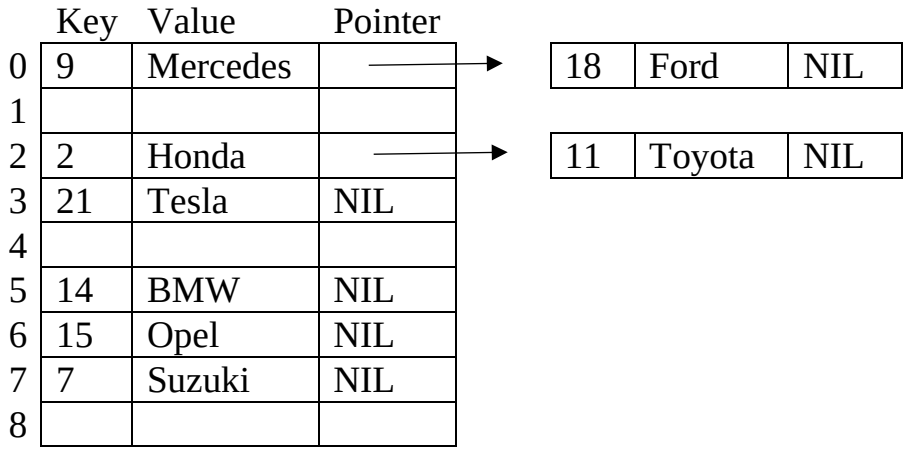
Open addressing method

	Key	Value
0	9	Mercedes
1	18	Ford
2	2	Honda
3	11	Toyota
4	21	Tesla
5	14	BMW
6	15	Opel
7	7	Suzuki
8		

Open addressing with chaining method

	Key	Value	Pointer
0	9	Mercedes	1
1	18	Ford	NIL
2	2	Honda	3
3	11	Toyota	4
4	21	Tesla	NIL
5	14	BMW	NIL
6	15	Opel	NIL
7	7	Suzuki	NIL
8			

Separate chaining with Linked List



3. Exercise: There is a hash table which is capable of storing 14 elements. Define the hash function with the division method. The following key-value pairs are given:

19	Blue
27	Red
51	Green
12	Blue
37	Brown
31	Pink
17	Orange
32	White
16	Black
34	Yellow
22	Purple
30	Gold

Place the elements in the table using the following methods:

- Open addressing
- Open addressing with chaining
- Separate chaining with Linked List

Solution

m = 14 (size of the table)

h(k) = k mod 14

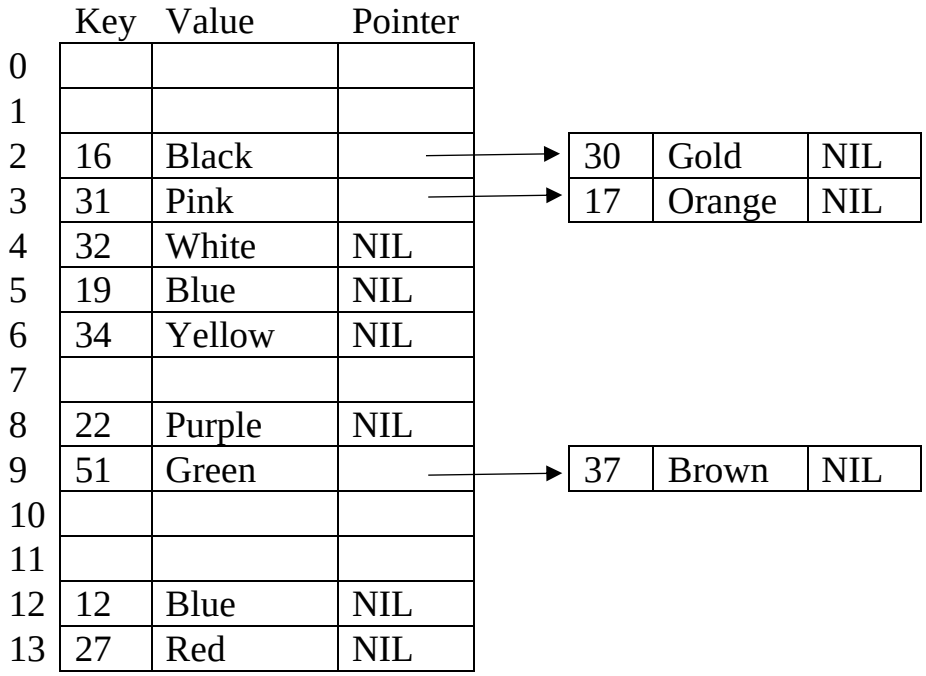
Open addressing method

	Key	Value
0		
1		
2	16	Black
3	31	Pink
4	17	Orange
5	19	Blue
6	32	White
7	34	Yellow
8	22	Purple
9	51	Green
10	37	Brown
11	30	Gold
12	12	Blue
13	27	Red

Open addressing with chaining method

	Key	Value	Pointer
0			
1			
2	16	Black	11
3	31	Pink	4
4	17	Orange	6
5	19	Blue	NIL
6	32	White	7
7	34	Yellow	NIL
8	22	Purple	NIL
9	51	Green	10
10	37	Brown	NIL
11	30	Gold	NIL
12	12	Blue	NIL
13	27	Red	NIL

Separate chaining with Linked List



PRACTICE AT HOME

4. Exercise: There is a hash table which is capable of storing 16 elements. Define the hash function with the division method. The following key-value pairs are given:

2	Canada
7	USA
19	Germany
15	France
26	Hungary
34	Romania
21	Spain
28	Portugal
20	Brasilia
55	China
37	Turkey
48	Argentina
74	Denmark

Place the elements in the table using the following methods:

- Open addressing
- Open addressing with chaining
- Separate chaining with Linked List