DATA STRUCTURES & ALGORITHMS

Hash Tables

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Hash Table

A data structure that provides a mapping from key to value using a technique called hashing.

The keys are used for indexing the values/data.

Effective way of implementing dictionaries.

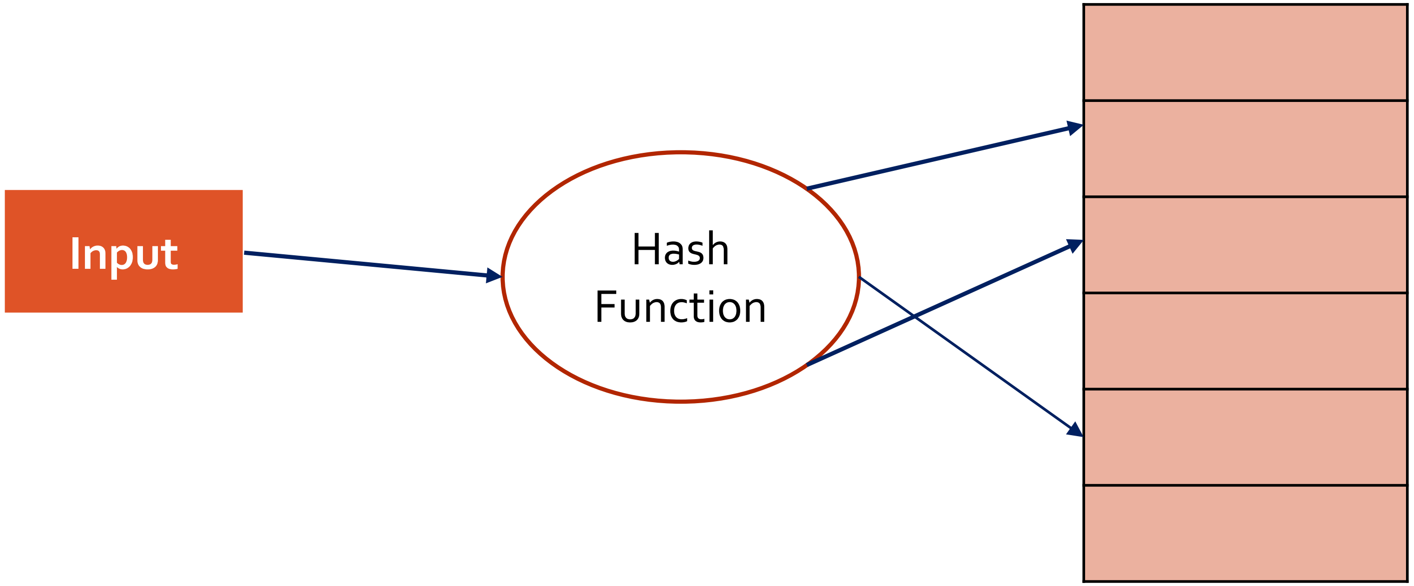
Key	Value

Key - value pairs must be unique, but values can be repeated.

Hash Function

A hash function H(x) is a function that maps a key 'x' to a whole numbers in fixed range.

Choosing an efficient hash function is a crucial part of creating a good hash table.



Can we convert floats and strings to natural numbers for hashing?

Hashing Methods

- ✓ Direct hashing
- ✓ Modulo division
- ✓ Mid square method
- ✓ Folding method
- ✓ Rotation Method
- ✓ Pseudo Random Methods

Modulo Division Method

Map a key into one of the m slots by taking the remainder of k divided by m that is

$$H(k) = k \bmod m$$

Where, m can be the list size

Example:

m= 31 and k = 78

78 mod 31

H(K) = 16

<u>With Strings</u>

Cat

ASCII : c = 99, a = 97, t = 116

99 + 95 + 116 = 312

If, m= 11 and k = 312

Then, H(K) = 4

Mid Square Method

The key k is multiplied by itself and the address is obtained by selecting an appropriate number if digits from the middle of the square.

Example:

*9452 * 9452 = 89340304*

H(k) = 3403

Folding Method

The key is partitioned into a number of parts, each of which has the same length as the required address with the possible exception of the last part.

Example:

123456789

123 + 456 + 789 = ~~*1*~~*368*

H(k) = 368

Digit Exaction Method

Selected digits are extracted from the key and used as the address.

Address = extracted digits from key

Example:

121267

H(k) = 112

Rotation Method

Usually used with the combination of other hashing mechanisms.

Example:

2500891

H(k) = 1250089

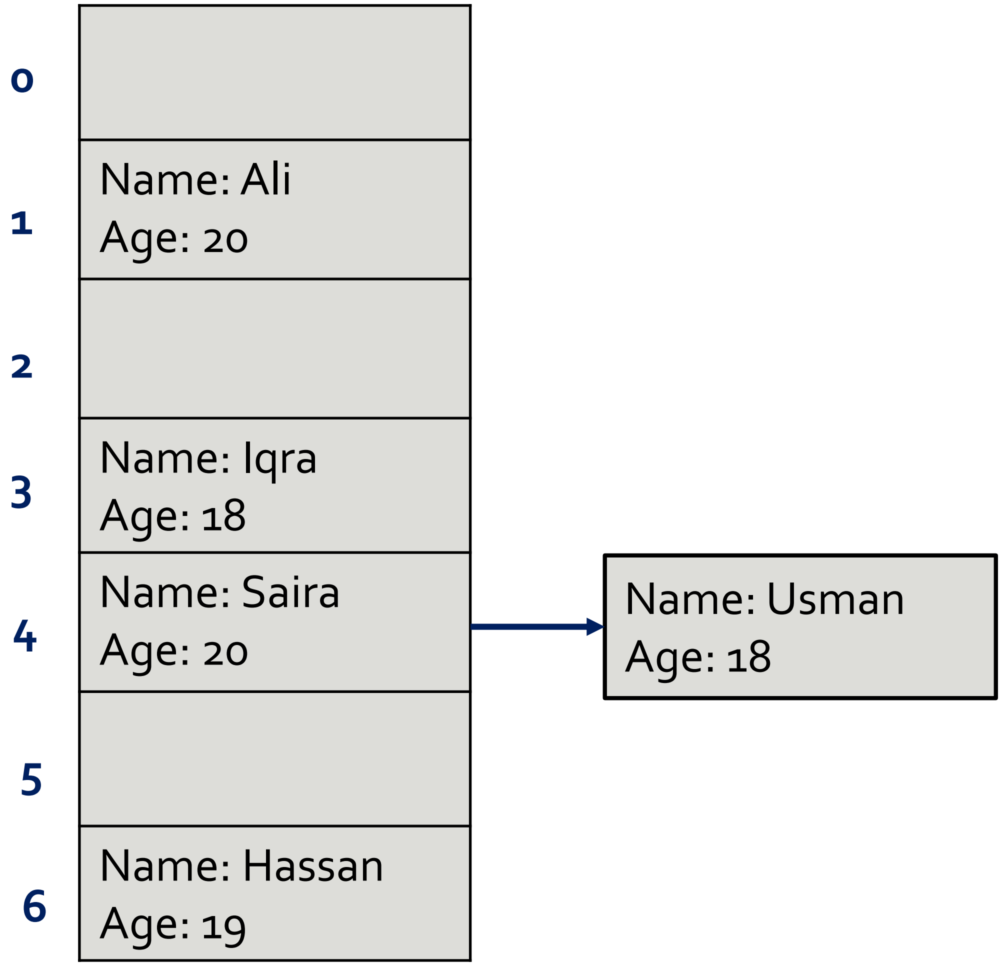
Collision

Hash function gets us a small number for a key which is a big integer or string, there is a possibility that two keys result in the same value. The situation where a newly inserted key maps to an already occupied slot in the hash table is called collision and must be handled using some collision handling techniques.

Collision Resolutions

Separate Chaining

Deals with collisions by maintaining a data structure to hold all the different values which hashed to a particular value.



Collision Resolutions

Open Addressing

Deals with hash collisions the hash table for all the object to go by offsetting if from the position to which it hashed to.

Types

- Linear probing
- Quadratic probing
- Double Hashing

0	
1	Name: Ali Age: 20
2	
3	Name: Iqra Age: 18
4	Name: Saira Age: 20
5	Name: Usman Age: 18
6	Name: Hassan Age: 19

Collision Resolutions

Open addressing

- ✓ Linear Probing

  If collision occurs, we linearly probe for next slot

- ✓ Quadratic Probing

  If collision occurs:

  (hash value + 1^2) % table size

  if again collision occurs

  (hash value + 2^2) % table size

  If again

  (hash value + 3^2) % table size

  In general : (hash value + i^2) % table size

Insert {89, 18, 49, 58, 69, 78} with h(x) =x mod 10 using separate chaining.

x = 89

h(89) = 89 mod 10 => 9

x = 18

h(18) = 18 mod 10 => 8

x = 49

h(49) = 49 mod 10 => 9 (C)

x= 58

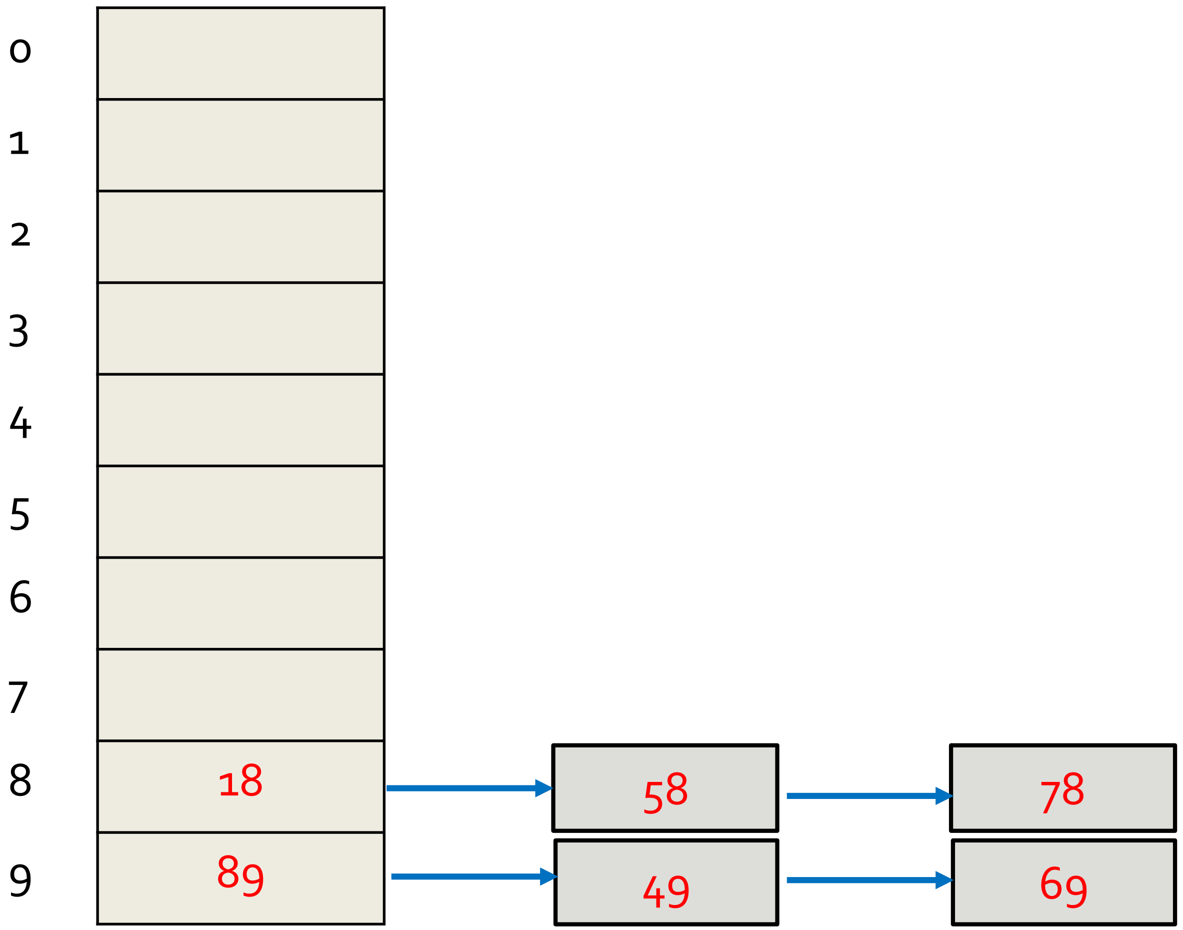
h(58) = 58 mod 10 => 8 (C)

x = 69

h(69) = 69 mod 10 => 9 (C)

x = 78

h(78) = 78 mod 10 => 8 (C)



Insert {89, 18, 49, 58, 69, 78} with h(x) =x mod 10 using linear probing.

x = 89

h(89) = 89 mod 10 => 9

x = 18

h(18) = 18 mod 10 => 8

x = 49

h(49) = 49 mod 10 => 9 (C)

x= 58

h(58) = 58 mod 10 => 8 (C)

x = 69

h(69) = 69 mod 10 => 9 (C)

x = 78

h(78) = 78 mod 10 => 8 (C)

0	49
1	58
2	69
3	78
4	
5	
6	
7	
8	18
9	89

Insert {89, 18, 49, 58, 69, 78} with h(x) =x mod 10 using quadratic probing.

x = 89

h(89) = 89 mod 10 => 9

x = 18

h(18) = 18 mod 10 => 8

x = 49

h(49) = 49 mod 10 => 9 (collision)

h1(49) = $(9 + 1^2)$ mod 10 => 0

x= 58

h(58) = 58 mod 10 => 8 (collision)

h1(58) = $(8 + 1^2)$ mod 10 => 9 (collision)

h2(58) = $(8 + 2^2)$ mod 10 => 2

x = 69

h(69) = 69 mod 10 => 9 (collision)

h1(69) = $(9 + 1^2)$ mod 10 => 0 (collision)

h2(69) = $(9 + 2^2)$ mod 10 => 3

x = 78

h(78) = 78 mod 10 => 8 (collision)

h1(78) = $(8 + 1^2)$ mod 10 => 9 (collision)

h2(78) = $(8 + 2^2)$ mod 10 => 2 (collision)

h3(78) = $(8 + 3^2)$ mod 10 => 7

0	49
1	
2	58
3	69
4	
5	
6	
7	78
8	18
9	89

Exercise

Map all integer key to the range (0,9), $h(x) = (x^2 – 6x + 9) \bmod 10$

x = 4

$h(4) = (4^2 - 6(4) + 9) \bmod 10 \Rightarrow 1$

x = 7

???

x = 0

???

x = 2

???

x = 8

???

Applications

- File management
- Comparing complex values
- Cryptography
- Security systems

Hash Table Complexity

Search	O(n)
Insertion	O(n)
Deletion	O(n)