HUST

ĐẠI HỌC BÁCH KHOA HÀ NỘI

HANOI UNIVERSITY OF SCIENCE AND TECHNOLOGY

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DATA STRUCTURES & ALGORITHMS

HASHING

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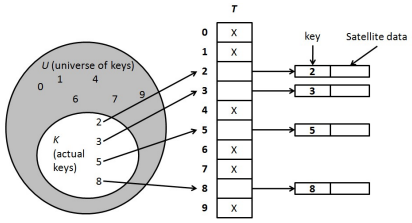
HASHING

- Mapping: a data structure storing objects/pairs (key, value)
  - put(*k*,*v*): Store an object having key *k* and value *v* to the data structure
  - get(*k*): return the object having key *k*
- Implementation
  - Binary Search Trees
  - Hash tables

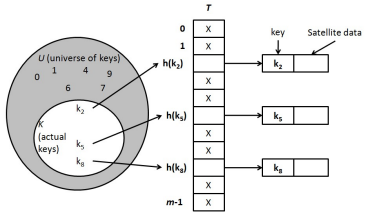
HASHING

- Direct addressing
  - Value of the key *k* is the address indicate the place in the table storing the pair (k,v)
  - Advantages: simple, fast lookup
  - Disadvantages: memory usage might be ineffective



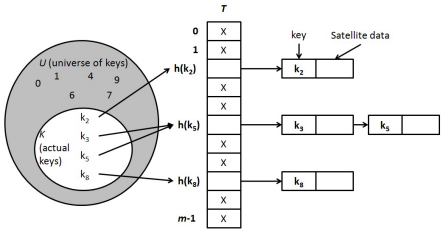
HASHING

- Hash function $h(k)$ specifies the address where the pair (k, *value*) is stored
- $h(k)$ should be simple and easy to compute



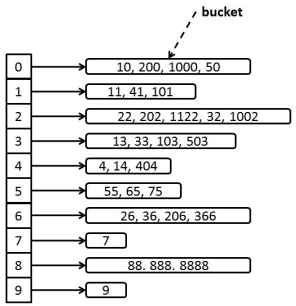
HASHING

- Collision: Two different keys have the same value of the hash function (hash code):
- Resolution:
  - Chaining: group keys having the same hash code into buckets
  - Open Addressing



HASHING: collision resolution by chaining

- Modulo: $h(k) = k \bmod m$ where m is the size of the hash table



HASHING: collision resolution by chaining

- Modulo: $h(k) = k \bmod m$ where m is the size of the hash table

HASHING: collision resolution by open addressing

- Pairs (key, value) are stored in the table itself
- Operations put(k, v) and get(k) need to probe the table until the desired slot found
  - put(k, v): probe for finding a free slot for storing (k, v)
  - get(k): probe for finding the slot where the key k is stored
  - Probing order: $h(k, 0)$, $h(k, 1)$, $h(k, 2)$, ..., $h(k, m\text{-}1)$
  - Methods
    - Linear probing: $h(k, i) = (h_1(k) + i) \bmod m$ where h_1 is normal hash function
    - Quadratic probing: $h(k, i) = (h_1(k) + c_1 i + c_2 i^2) \bmod m$ where h_1 is normal hash function
    - Double hashing: $h(k, i) = (h_1(k) + i * h_2(k)) \bmod m$ where h_1 and h_2 are normal hash functions

HASHING: collision resolution by open addressing

- get(k) and put(k, v) operations:

```
get(k)
{
  // T: the table
  i = 0;
  while(i < m) {
    j = h(k,i);
    if(T[j].key = k) {
      return T[j];
    }
    i = i + 1;
  }
  return NULL;
}
```

```
put(k, v)
{
  // T: the table
  x.key = k; x.value = v;
  i = 0;
  while(i < m) {
    j = h(k,i);
    if(T[j] = NULL) {
      T[j] = x; return j;
    }
    i = i + 1;
  }
  error("Hash table overflow");
}
```

HASHING: collision resolution by open addressing

- Exercise: A table has m slots, apply the open addressing method in which $h(k, i)$ has the form:

$$h(k, i) = (k \bmod m + i) \bmod m$$

- Initialization, the table is free, present the status of the table after inserting following sequence of keys 7, 8, 6, 17, 4, 28 into the table with m = 10

HASHING: collision resolution by open addressing

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0	1	2	3	4	5	6	7	8	9
28	x	x	x	4	x	6	7	8	17

HASHING: hash functions

- Key k is an integer
  - $h(k)$ = mod m
- Key is a string
  - $k = s[0..n\text{-}1] \rightarrow h(k) = (s[0]*256^{n-1} + s[1]*256^{n-2} + \ldots + s[n\text{-}1]*256^{0}) \bmod m$

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THANK YOU !