Collision Resolution: Open Addressing

We must initialize the table

	T
0	14, d_1
1	21, d_4
2	19, d_5
3	2, d_6
4	5, d_7
5	12, d_2 ← pos
6	13, d_3

h(14) = 0
h(12) = 5
h(13) = 6
h(21) = 0
h(19) = 5

NULL cannot be one of the possible data items!

h(2) = 2

get(3)

h(k) = k mod 7

Records to store in the table

(14,d_1)
(12,d_2)
(13,d_3)
(21,d_4)
(19,d_5)

(2,d_6)
(5, d_7)
remove (14)

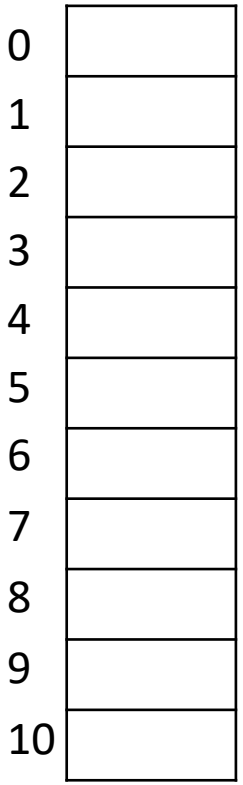
Algorithm get(k)
Input: Key k
Output: Record with key k, or
null if no record has key k

```
pos ← h(k)
|
while (T[pos] ≠ NULL) and (T[pos].getkey() ≠ k) do {
        pos ← (pos + 1) mod M
        |
}
if T[pos] = null then return null
else return T[pos]
```

Linear probing:

h(k), (h(k)+1) mod M, (h(k) + 2) mod M, ((h(k) + 3) mod M …

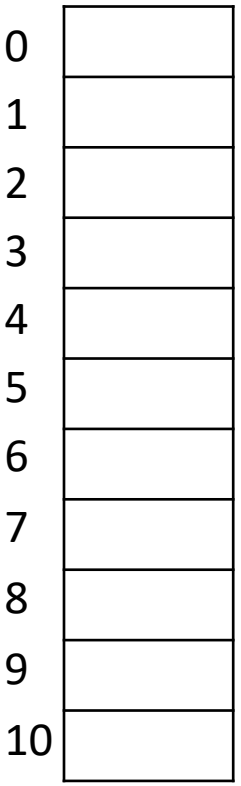
Linear Probing and Double Hashing



h(k) = k mod 11

Records to store in the table

$(3,d_1)$
$(14,d_2)$
$(25,d_3)$
$(5,d_4)$
$(28,d_5)$
$(91,d_6)$



Secondary hash function:

$h'(k) = q - (k \bmod q)$

for some prime value q

$h'(k) = 7 - (k \bmod 7)$

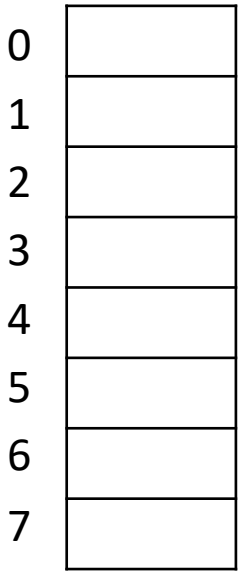
Linear probing:

h(k), (h(k)+1) mod M, (h(k) + 2) mod M, ((h(k) + 3) mod M …

Double hashing:

h(k), (h(k)+h'(k)) mod M, (h(k) + 2h'(k)) mod M, ((h(k) + 3h'(k)) mod M …

Double Hashing and Size of the Table



$h(k) = k \bmod 8$

Records to store in the table

$(2,d_1)$
$(6,d_2)$
$(10,d_3)$

Secondary hash function:

$h'(k) = q - (k \bmod q)$

for some prime value q

$h'(k) = 7 - (k \bmod 7)$

Double hashing:

h(k), (h(k)+h'(k)) mod M, (h(k) + 2h'(k)) mod M, ((h(k) + 3h'(k)) mod M …

The size of the hash table must be a prime number.

Open Addressing: put Method (linear probing)

Algorithm put (k,data, M)

In: record (k,data) to insert, size M of hash table

Out: {add record (k,data) to table, or ERROR if insertion not allowed}

```
pos ← h(k)
count ← 0
while (T[pos] != NULL) and (T[pos] != DELETED) do {
    if T[pos].getKey() = k then ERROR
    pos ← (pos + 1) mod M
    count ← count + 1
    if count = M then ERROR
}
T[pos] ← (k,data)
```

Open Addressing: put Method (double hashing)

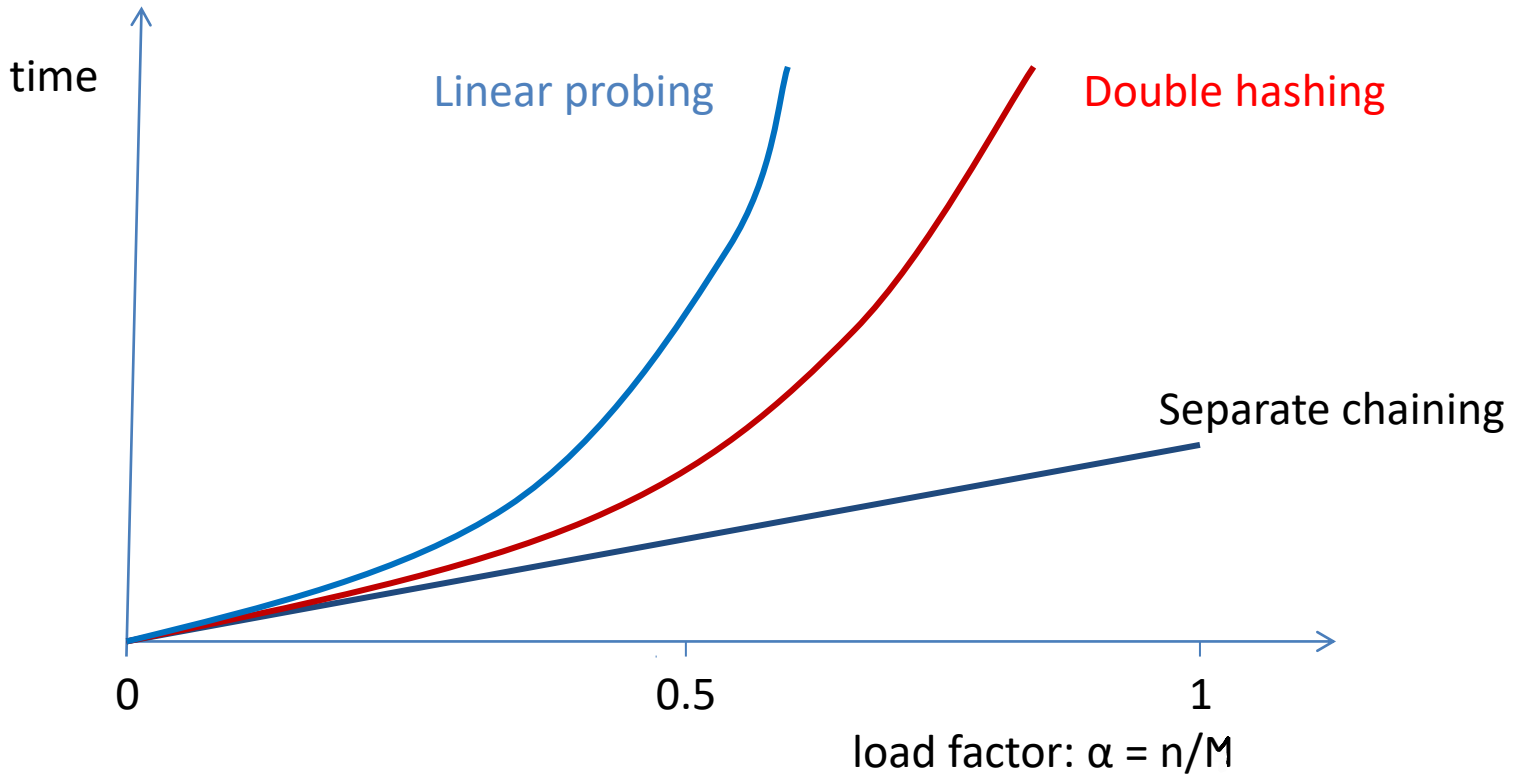
Algorithm put (k,data, M)

In: record (k,data) to insert, size N of hash table

Out: {add record (k,data) to table, or ERROR if insertion not allowed}

```
pos ← h(k)
count ← 0
while (T[pos] != NULL) and (T[pos] != DELETED) do {
    if T[pos].getKey() = k then ERROR
    pos ← (pos + h'(k)) mod M
    count ← count + 1
    if count = M then ERROR
}
T[pos] ← (k,data)
```

Average Time Complexity of get Operation



	Average number of key comparisons
Separate chaining	$1 + \alpha$
Linear Probing	$\frac{1}{2} + 1/(2(1 - \alpha)^2)$
Double Hashing	$1/(1 - \alpha)$