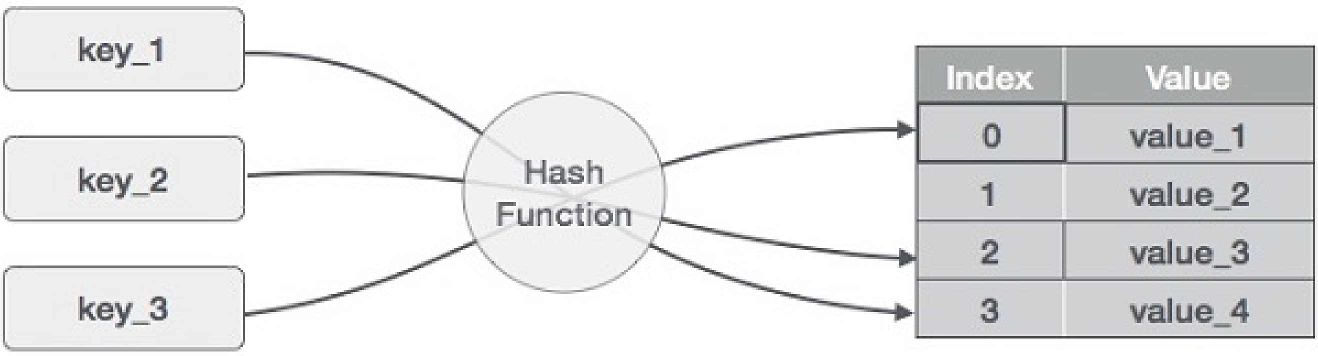
Hash Table Data structure

Hash Table is a data structure which stores data in an associative manner. In a hash table, data is stored in an array format, where each data value has its own unique index value. Access of data becomes very fast if we know the index of the desired data.

Thus, it becomes a data structure in which insertion and search operations are very fast irrespective of the size of the data. Hash Table uses an array as a storage medium and uses hash technique to generate an index where an element is to be inserted or is to be located from.

Hashing

Hashing is a technique to convert a range of key values into a range of indexes of an array. We're going to use modulo operator to get a range of key values. Consider an example of hash table of size 20, and the following items are to be stored. Item are in the (key,value) format.



- (1,20)
- (2,70)
- (42,80)
- (4,25)
- (12,44)
- (14,32)

- (17,11)
- (13,78)
- (37,98)

Sr.No.	Key	Hash	Array Index
1	1	1 % 20 = 1	1
2	2	2 % 20 = 2	2
3	42	42 % 20 = 2	2
4	4	4 % 20 = 4	4
5	12	12 % 20 = 12	12
6	14	14 % 20 = 14	14
7	17	17 % 20 = 17	17
8	13	13 % 20 = 13	13
9	37	37 % 20 = 17	17

Linear Probing

As we can see, it may happen that the hashing technique is used to create an already used index of the array. In such a case, we can search the next empty location in the array by looking into the next cell until we find an empty cell. This technique is called linear probing.

Sr.No.	Key	Hash	Array Index	After Linear Probing, Array Index
1	1	1 % 20 = 1	1	1
2	2	2 % 20 = 2	2	2
3	42	42 % 20 = 2	2	3
4	4	4 % 20 = 4	4	4

5	12	12 % 20 = 12	12	12
6	14	14 % 20 = 14	14	14
7	17	17 % 20 = 17	17	17
8	13	13 % 20 = 13	13	13
9	37	37 % 20 = 17	17	18

Basic Operations

Following are the basic primary operations of a hash table.

- **Search** − Searches an element in a hash table.
- **Insert** − Inserts an element in a hash table.
- **Delete** − Deletes an element from a hash table.

DataItem

Define a data item having some data and key, based on which the search is to be conducted in a hash table.

```
struct DataItem {
   int data;
   int key;
};
```

Hash Method

Define a hashing method to compute the hash code of the key of the data item.

```
int hashCode(int key){
   return key % SIZE;
}
```

Search Operation

Whenever an element is to be searched, compute the hash code of the key passed and locate the element using that hash code as index in the array. Use linear probing to get the element ahead if the element is not found at the computed hash code.

```
struct DataItem *search(int key) {
   //get the hash
   int hashIndex = hashCode(key);

   //move in array until an empty
   while(hashArray[hashIndex] != NULL) {

      if(hashArray[hashIndex]->key == key)
         return hashArray[hashIndex];

      //go to next cell
      ++hashIndex;

      //wrap around the table
      hashIndex %= SIZE;
   }

   return NULL;
}
```

Example

Following are the implementations of this operation in various programming language –

C | C++ | Java | Python

```
#define SIZE 10 // Define the size of the hash table
struct DataItem {
    int key;
};
struct DataItem *hashArray[SIZE]; // Define the hash table as an
int hashCode(int key) {
    // Return a hash value based on the key
    return key % SIZE;
}
struct DataItem *search(int key) {
    // get the hash
    int hashIndex = hashCode(key);

    // move in array until an empty slot is found or the key is
    while (hashArray[hashIndex] != NULL) {
        // If the key is found, return the corresponding DataIte
        if (hashArray[hashIndex]->key == key)
            return hashArray[hashIndex];

        // go to the next cell
        ++hashIndex;

        // wrap around the table
        hashIndex %= SIZE;
    }
    // If the key is not found, return NULL
    return NULL;
}

int main() {

    // Initializing the hash table with some sample DataItems
    struct DataItem item2 = {25}; // Assuming the key is 25
    struct DataItem item3 = {64}; // Assuming the key is 64
    struct DataItem item4 = {22}; // Assuming the key is 22
```

```
    // Calculate the hash index for each item and place them in

    int hashIndex2 = hashCode(item2.key);
    hashArray[hashIndex2] = &item2;

    int hashIndex3 = hashCode(item3.key);
    hashArray[hashIndex3] = &item3;

    int hashIndex4 = hashCode(item4.key);
    hashArray[hashIndex4] = &item4;

    // Call the search function to test it
    int keyToSearch = 64; // The key to search for in the hash t
    struct DataItem *result = search(keyToSearch);
    printf("The element to be searched: %d", keyToSearch);
    if (result != NULL) {
        printf("\nElement found");
    } else {
        printf("\nElement not found");
    }

    return 0;
}
```

Output

```
The element to be searched: 64
Element found
```

Insert Operation

Whenever an element is to be inserted, compute the hash code of the key passed and locate the index using that hash code as an index in the array. Use linear probing for empty location, if an element is found at the computed hash code.

```
void insert(int key,int data) {
   struct DataItem *item = (struct DataItem*) malloc(sizeof(struct D
   item->data = data;
   item->key = key;

   //get the hash
   int hashIndex = hashCode(key);

   //move in array until an empty or deleted cell
   while(hashArray[hashIndex] != NULL && hashArray[hashIndex]->key
      //go to next cell
      ++hashIndex;

      //wrap around the table
      hashIndex %= SIZE;
   }

   hashArray[hashIndex] = item;
}
```

Example

Following are the implementations of this operation in various programming languages −

C C++ Java Python

```
#include <stdio.h>
#include <stdlib.h>
#define SIZE 4 // Define the size of the hash table
struct DataItem {
    int key;
};
struct DataItem *hashArray[SIZE]; // Define the hash table as an
int hashCode(int key) {
    // Return a hash value based on the key
```

```
    return key % SIZE;
}
void insert(int key) {
   // Create a new DataItem using malloc
   struct DataItem *newItem = (struct DataItem*)malloc(sizeof(st

   if (newItem == NULL) {
      // Check if malloc fails to allocate memory
      fprintf(stderr, "Memory allocation error\n");
      return;
   }

   newItem->key = key;
   // Initialize other data members if needed

   // Calculate the hash index for the key
   int hashIndex = hashCode(key);

   // Handle collisions (linear probing)
   while (hashArray[hashIndex] != NULL) {
      // Move to the next cell
      ++hashIndex;
      // Wrap around the table if needed
      hashIndex %= SIZE;
   }

   // Insert the new DataItem at the calculated index
   hashArray[hashIndex] = newItem;
}
int main() {
   // Call the insert function with different keys to populate t
   insert(42); // Insert an item with key 42
   insert(25); // Insert an item with key 25
   insert(64); // Insert an item with key 64
   insert(22); // Insert an item with key 22

   // Output the populated hash table
   for (int i = 0; i < SIZE; i++) {
      if (hashArray[i] != NULL) {
```

```
            printf("Index %d: Key %d\n", i, hashArray[i]->key);
        } else {
            printf("Index %d: Empty\n", i);
        }
    }

    return 0;
```

Output

```
Index 0: Key 64
Index 1: Key 25
Index 2: Key 42
Index 3: Key 22
```

Delete Operation

Whenever an element is to be deleted, compute the hash code of the key passed and locate the index using that hash code as an index in the array. Use linear probing to get the element ahead if an element is not found at the computed hash code. When found, store a dummy item there to keep the performance of the hash table intact.

```
struct DataItem* delete(struct DataItem* item) {
   int key = item->key;

   //get the hash
   int hashIndex = hashCode(key);

   //move in array until an empty
   while(hashArray[hashIndex] !=NULL) {

      if(hashArray[hashIndex]->key == key) {
         struct DataItem* temp = hashArray[hashIndex];

         //assign a dummy item at deleted position
```

```
         hashArray[hashIndex] = dummyItem;
         return temp;
      }
      //go to next cell
      ++hashIndex;

      //wrap around the table
      hashIndex %= SIZE;
   }
   return NULL;
}
```

Example

Following are the implementations of the deletion operation for Hash Table in various programming languages −

C | C++ | Java | Python

```
#include <stdio.h>
#include <stdlib.h>
#define SIZE 5 // Define the size of the hash table
struct DataItem {
   int key;
};
struct DataItem *hashArray[SIZE]; // Define the hash table as an

int hashCode(int key) {
   // Implement your hash function here
   // Return a hash value based on the key
}
void insert(int key) {
   // Create a new DataItem using malloc
   struct DataItem *newItem = (struct DataItem*)malloc(sizeof(st
   if (newItem == NULL) {
      // Check if malloc fails to allocate memory
      fprintf(stderr, "Memory allocation error\n");
      return;
```

```
    }

    newItem->key = key;
    // Initialize other data members if needed

    // Calculate the hash index for the key
    int hashIndex = hashCode(key);

    // Handle collisions (linear probing)
    while (hashArray[hashIndex] != NULL) {
       // Move to the next cell
       ++hashIndex;
       // Wrap around the table if needed
       hashIndex %= SIZE;
    }

    // Insert the new DataItem at the calculated index
    hashArray[hashIndex] = newItem;

    // Print the inserted item's key and hash index
    printf("Inserted key %d at index %d\n", newItem->key, hashInd
}
void delete(int key) {
    // Find the item in the hash table
    int hashIndex = hashCode(key);
    while (hashArray[hashIndex] != NULL) {
       if (hashArray[hashIndex]->key == key) {
          // Mark the item as deleted (optional: free memory)
          free(hashArray[hashIndex]);
          hashArray[hashIndex] = NULL;
          return;
       }
       // Move to the next cell
       ++hashIndex;
       // Wrap around the table if needed
       hashIndex %= SIZE;
    }
    // If the key is not found, print a message
    printf("Item with key %d not found.\n", key);
```

```
}
int main() {
   // Call the insert function with different keys to populate t
   printf("Hash Table Contents before deletion:\n");
   insert(1); // Insert an item with key 42
   insert(2); // Insert an item with key 25
   insert(3); // Insert an item with key 64
   insert(4); // Insert an item with key 22
   int ele1 = 2;
   int ele2 = 4;
   printf("The key to be deleted: %d and %d", ele1, ele2);
   delete(ele1); // Delete an item with key 42
   delete(ele2); // Delete an item with key 25
   // Print the hash table's contents after delete operations
   printf("\nHash Table Contents after deletion:\n");
   for (int i = 1; i < SIZE; i++) {
      if (hashArray[i] != NULL) {
         printf("Index %d: Key %d\n", i, hashArray[i]->key);
      } else {
         printf("Index %d: Empty\n", i);
      }
   }
   return 0;
```

Output

```
Hash Table Contents before deletion:
Inserted key 1 at index 1
Inserted key 2 at index 2
Inserted key 3 at index 3
Inserted key 4 at index 4
The key to be deleted: 2 and 4
Hash Table Contents after deletion:
Index 1: Key 1
Index 2: Empty
Index 3: Key 3
Index 4: Empty
```

Complete implementation

Following are the complete implementations of the above operations in various programming languages −

C C++ Java Python

```
#include <stdio.h>
#include <string.h>
#include <stdlib.h>
#include <stdbool.h>
#define SIZE 20
struct DataItem {
   int data;
   int key;
};
struct DataItem* hashArray[SIZE];
struct DataItem* dummyItem;
struct DataItem* item;

int hashCode(int key) {
   return key % SIZE;
}
struct DataItem *search(int key) {
   //get the hash
   int hashIndex = hashCode(key);

   //move in array until an empty
   while(hashArray[hashIndex] != NULL) {

      if(hashArray[hashIndex]->key == key)
         return hashArray[hashIndex];

      //go to next cell
      ++hashIndex;

      //wrap around the table
      hashIndex %= SIZE;
```

```
   }
   return NULL;
}
void insert(int key,int data) {
   struct DataItem *item = (struct DataItem*) malloc(sizeof(stru
   item->data = data;
   item->key = key;

   //get the hash
   int hashIndex = hashCode(key);

   //move in array until an empty or deleted cell
   while(hashArray[hashIndex] != NULL && hashArray[hashIndex]->k
      //go to next cell
      ++hashIndex;
      //wrap around the table
      hashIndex %= SIZE;
   }
   hashArray[hashIndex] = item;
}
struct DataItem* delete(struct DataItem* item) {
   int key = item->key;
   //get the hash
   int hashIndex = hashCode(key);
   //move in array until an empty
   while(hashArray[hashIndex] != NULL) {

      if(hashArray[hashIndex]->key == key) {
         struct DataItem* temp = hashArray[hashIndex];
         //assign a dummy item at deleted position
         hashArray[hashIndex] = dummyItem;
         return temp;
      }
      //go to next cell
      ++hashIndex;

      //wrap around the table
      hashIndex %= SIZE;
   }
```

```
   return NULL;
}
void display() {
   int i = 0;

   for(i = 0; i<SIZE; i++) {
      if(hashArray[i] != NULL)
         printf("(%d,%d) ",hashArray[i]->key,hashArray[i]->data)
   }

   printf("\n");
}
int main() {
   dummyItem = (struct DataItem*) malloc(sizeof(struct DataItem)
   dummyItem->data = -1;
   dummyItem->key = -1;
   insert(1, 20);
   insert(2, 70);
   insert(42, 80);
   insert(4, 25);
   insert(12, 44);
   insert(14, 32);
   insert(17, 11);
   insert(13, 78);
   insert(37, 97);
   printf("Insertion done: \n");
   printf("Contents of Hash Table: ");
   display();
   int ele = 37;
   printf("The element to be searched: %d", ele);
   item = search(ele);
   if(item != NULL) {
      printf("\nElement found: %d\n", item->key);
   } else {
      printf("\nElement not found\n");
   }
   delete(item);
   printf("Hash Table contents after deletion: ");
```

```
    display();
```

Output

```
Insertion done:
Contents of Hash Table: (1,20) (2,70) (42,80) (4,25) (12,44) (13,78) (14,32
The element to be searched: 37
Element found: 37
Hash Table contents after deletion: (1,20) (2,70) (42,80) (4,25) (12,44) (13
```