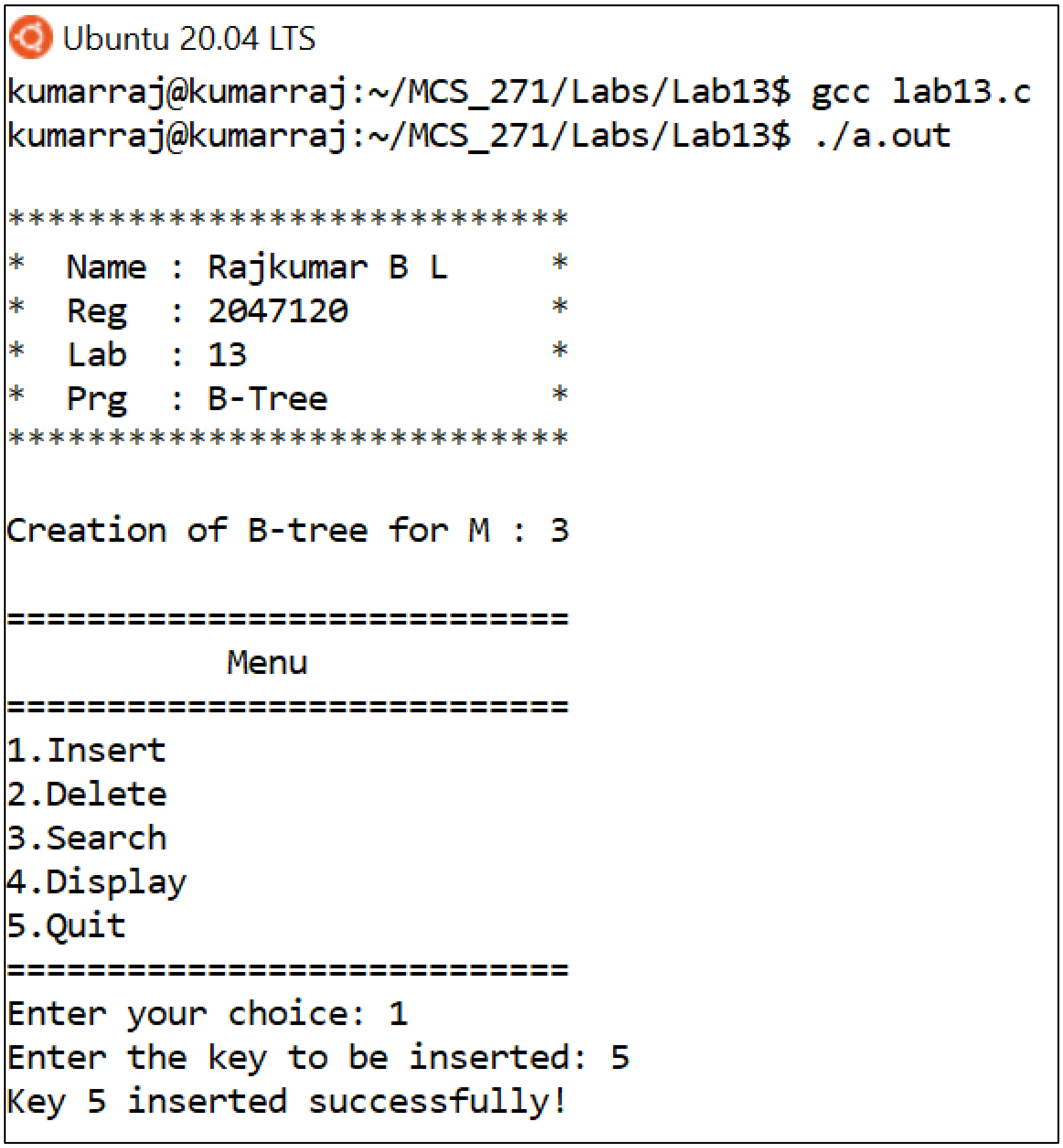
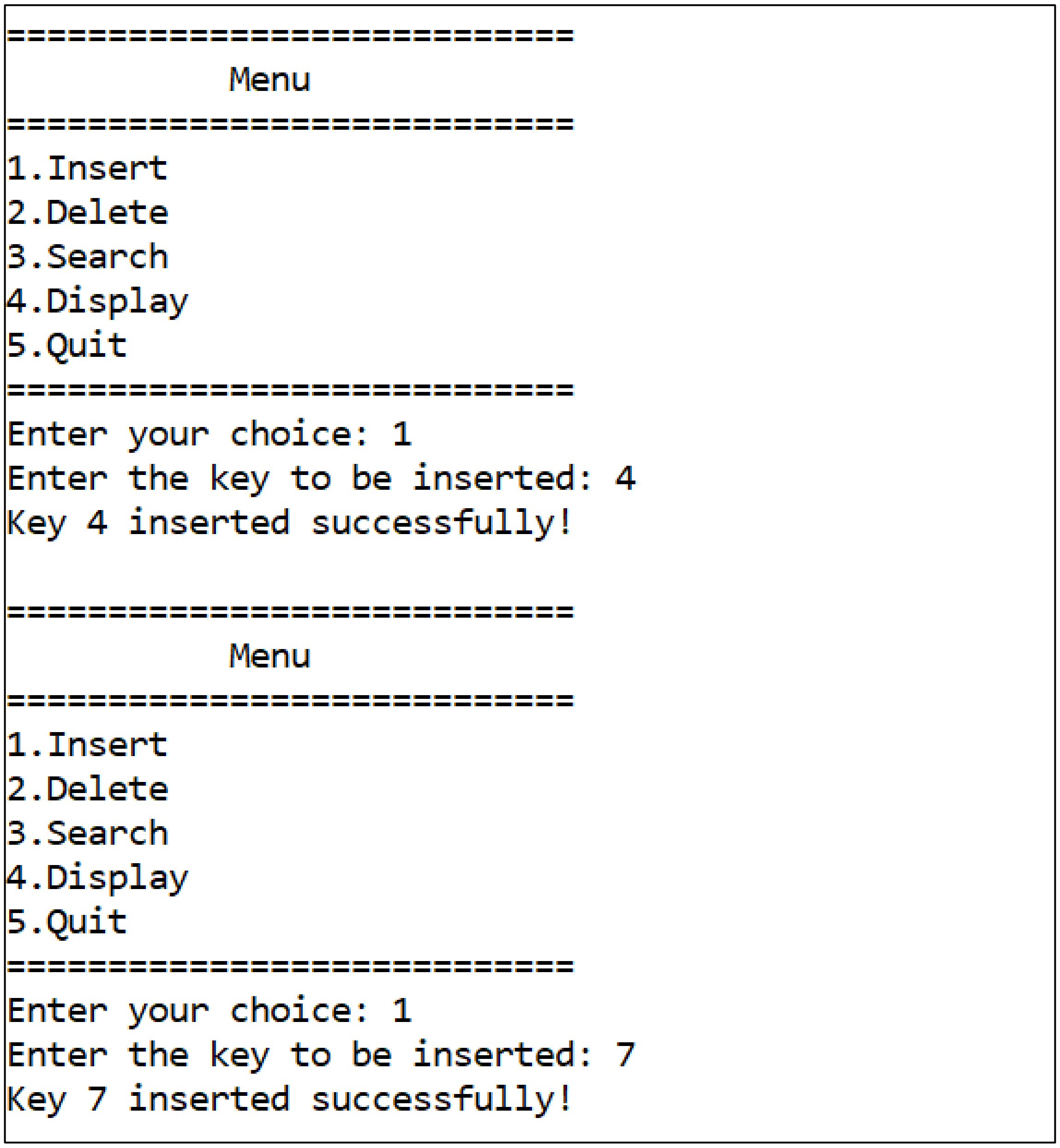
Name : Rajkumar B L
Reg.No : 2047120
Course : MCS 271 Data Structure (Lab 13 – B Tree)

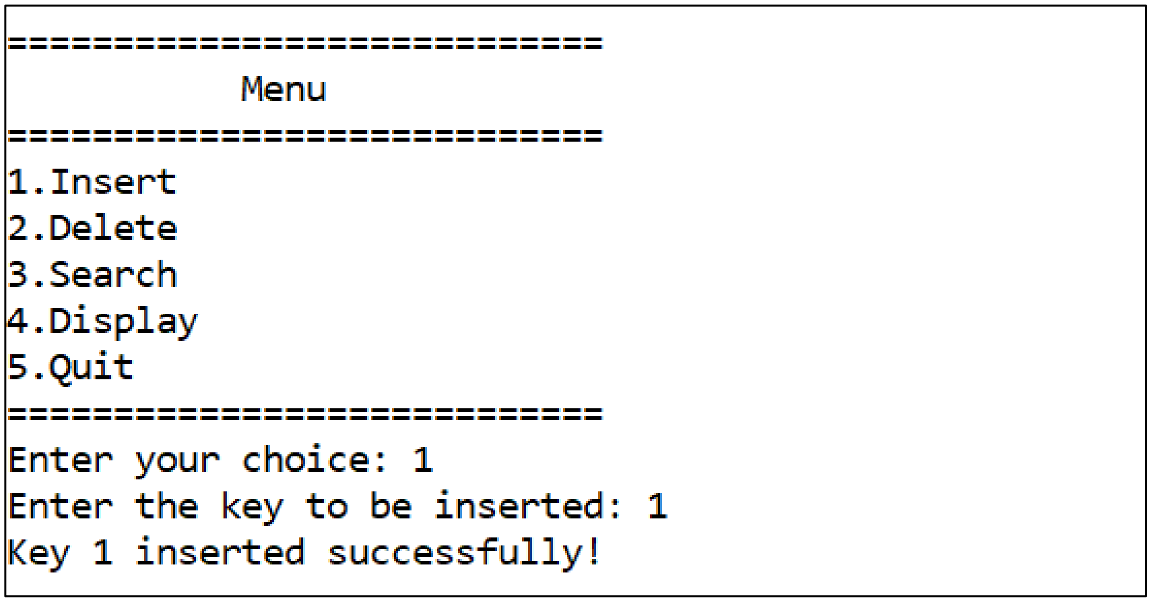
Output:-


Ubuntu 20.04 LTS

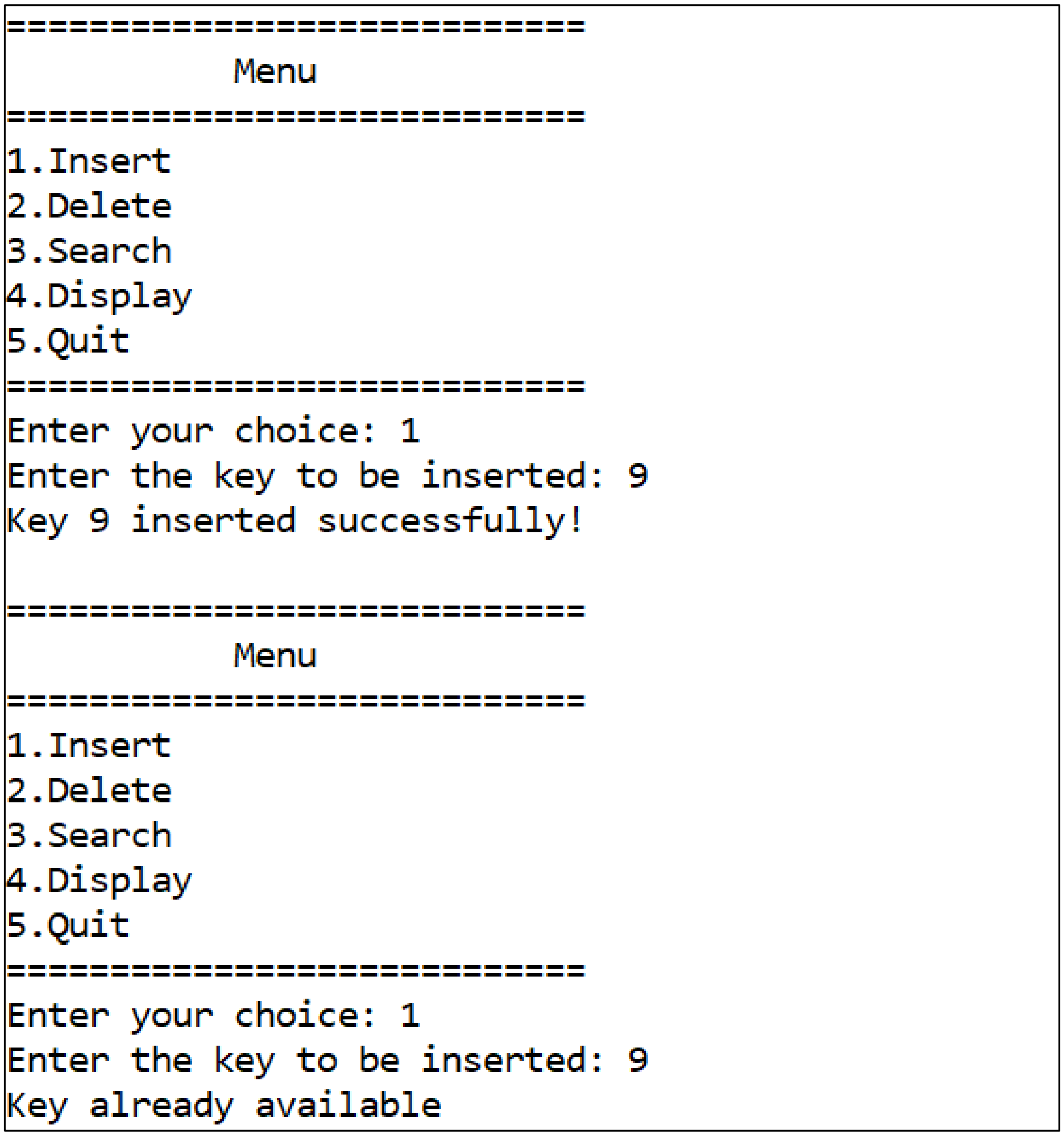
```
kumarraj@kumarraj:~/MCS_271/Labs/Lab13$ gcc lab13.c
kumarraj@kumarraj:~/MCS_271/Labs/Lab13$ ./a.out

****************************
*   Name : Rajkumar B L     *
*   Reg  : 2047120          *
*   Lab  : 13               *
*   Prg  : B-Tree           *
****************************


Creation of B-tree for M : 3

============================
           Menu
============================
1.Insert
2.Delete
3.Search
4.Display
5.Quit
============================
Enter your choice: 1
Enter the key to be inserted: 5
Key 5 inserted successfully!
```



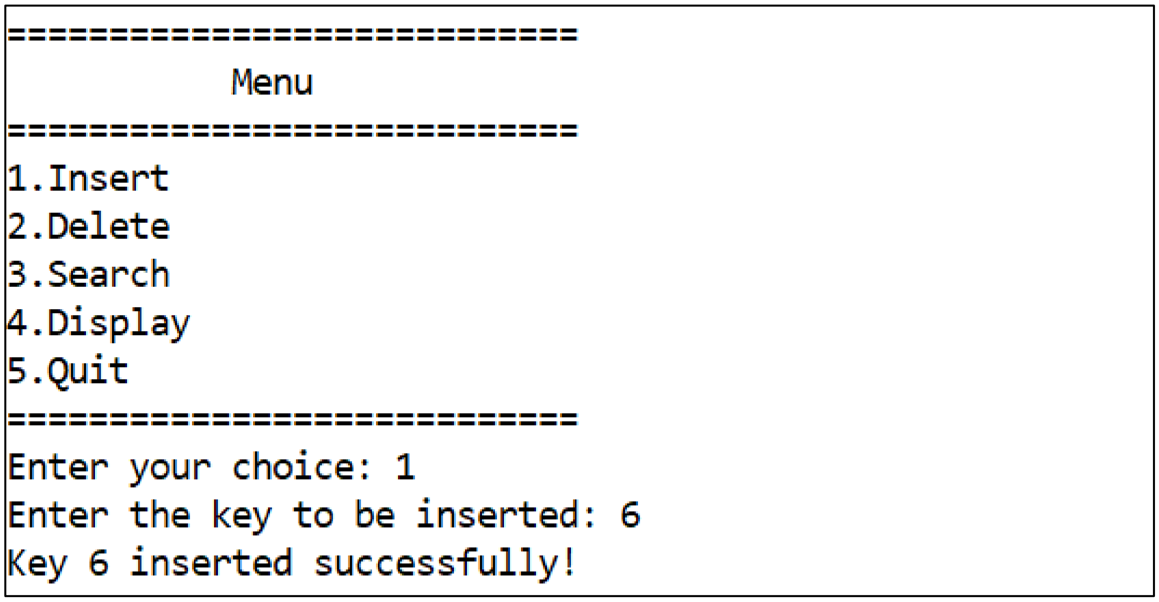
```
============================
           Menu
============================
1.Insert
2.Delete
3.Search
4.Display
5.Quit
============================
Enter your choice: 1
Enter the key to be inserted: 4
Key 4 inserted successfully!

============================
           Menu
============================
1.Insert
2.Delete
3.Search
4.Display
5.Quit
============================
Enter your choice: 1
Enter the key to be inserted: 7
Key 7 inserted successfully!
```



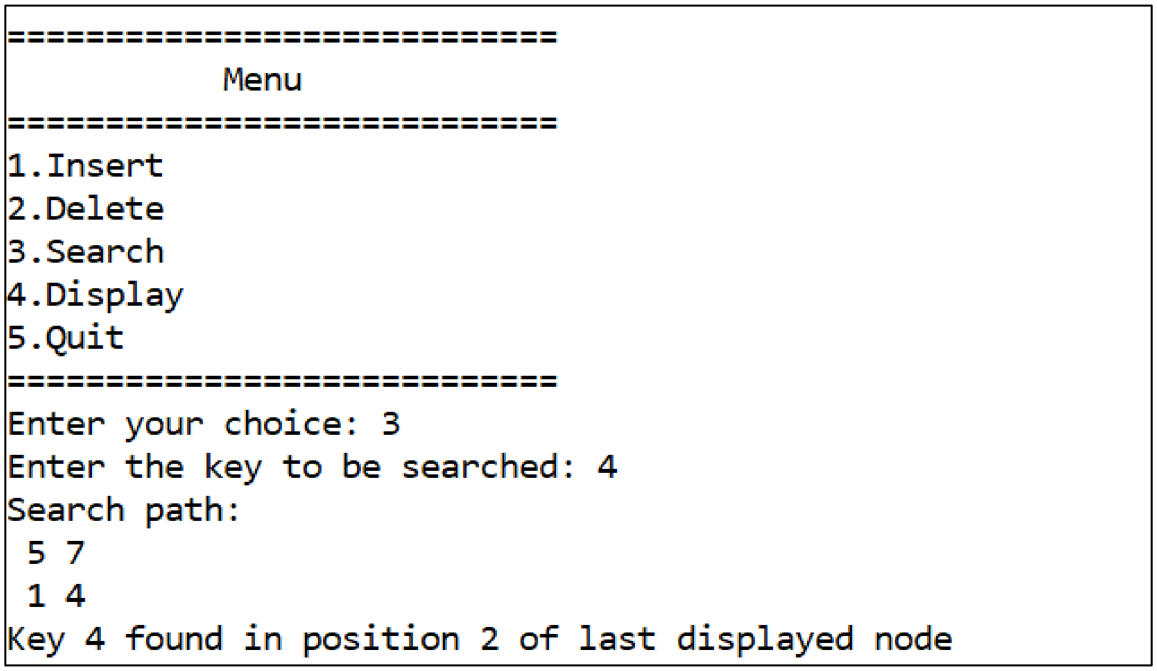
```
============================
           Menu
============================
1.Insert
2.Delete
3.Search
4.Display
5.Quit
============================
Enter your choice: 1
Enter the key to be inserted: 1
Key 1 inserted successfully!
```



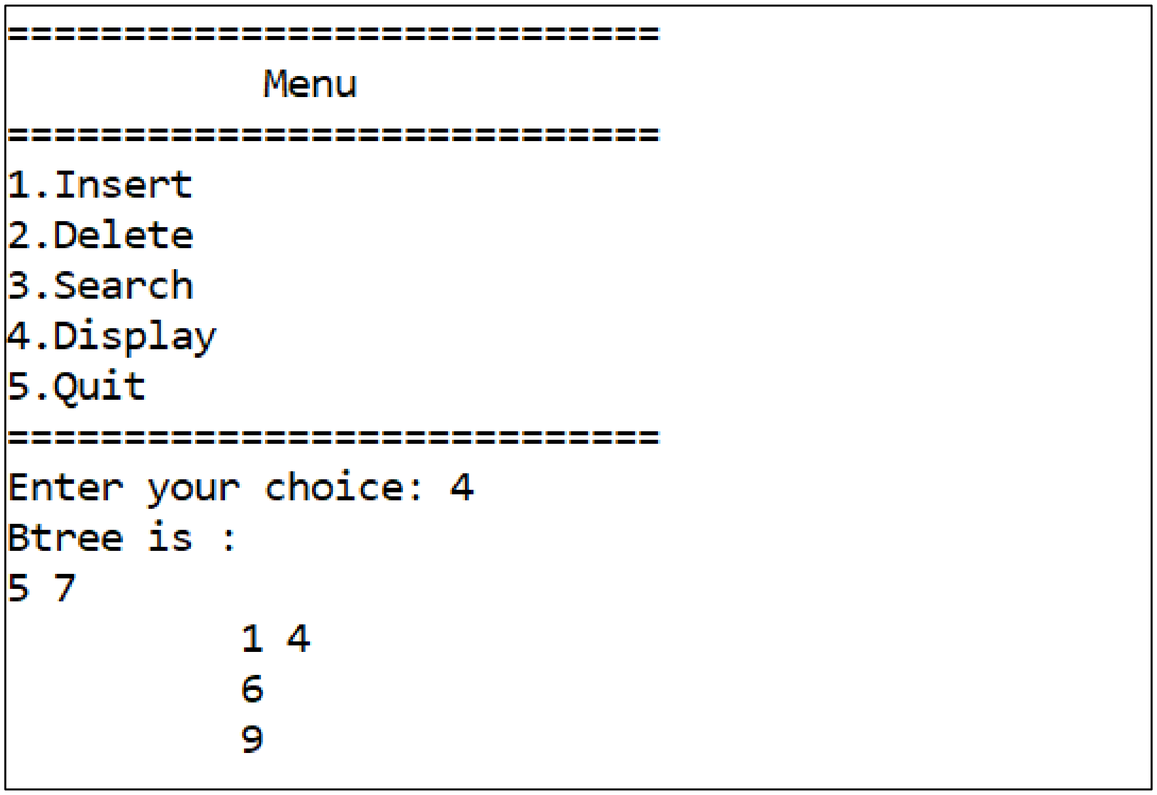
```
============================
           Menu
============================
1.Insert
2.Delete
3.Search
4.Display
5.Quit
============================
Enter your choice: 1
Enter the key to be inserted: 9
Key 9 inserted successfully!

============================
           Menu
============================
1.Insert
2.Delete
3.Search
4.Display
5.Quit
============================
Enter your choice: 1
Enter the key to be inserted: 9
Key already available
```



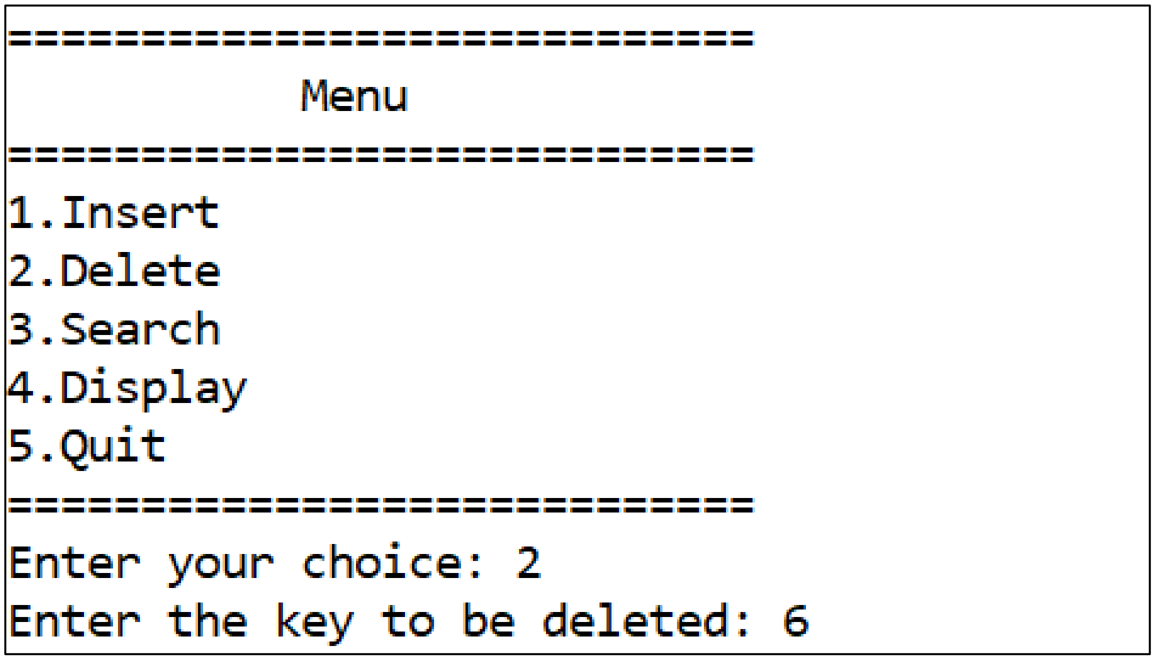
```
============================
           Menu
============================
1.Insert
2.Delete
3.Search
4.Display
5.Quit
============================
Enter your choice: 1
Enter the key to be inserted: 6
Key 6 inserted successfully!
```



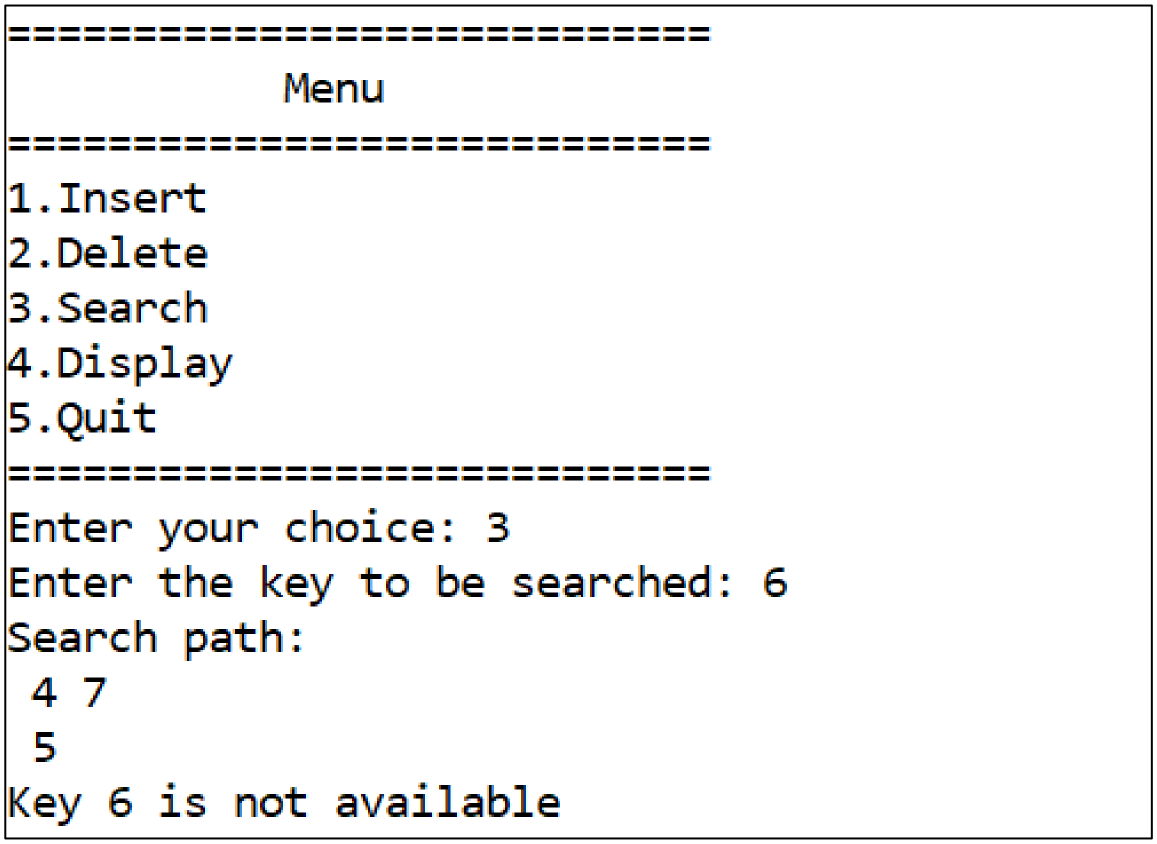
```
============================
           Menu
============================
1.Insert
2.Delete
3.Search
4.Display
5.Quit
============================
Enter your choice: 3
Enter the key to be searched: 4
Search path:
 5 7
 1 4
Key 4 found in position 2 of last displayed node
```



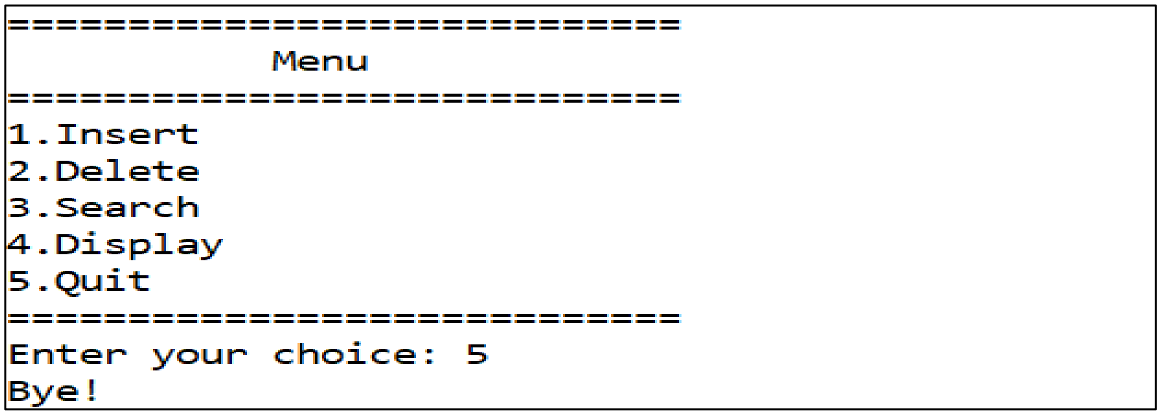
```
============================
           Menu
============================
1.Insert
2.Delete
3.Search
4.Display
5.Quit
============================
Enter your choice: 4
Btree is :
5 7
          1 4
          6
          9
```



```
============================
           Menu
============================
1.Insert
2.Delete
3.Search
4.Display
5.Quit
============================
Enter your choice: 2
Enter the key to be deleted: 6
```



```
============================
           Menu
============================
1.Insert
2.Delete
3.Search
4.Display
5.Quit
============================
Enter your choice: 3
Enter the key to be searched: 6
Search path:
 4 7
 5
Key 6 is not available
```



```
============================
           Menu
============================
1.Insert
2.Delete
3.Search
4.Display
5.Quit
============================
Enter your choice: 5
Bye!
```

Code:-

```c
/**********************
 * Name : Rajkumar B L
 * Reg  : 2047120
 * Lab  : 13
 * Program : B-Tree
 * ********************/
#include <stdio.h>
#include <stdlib.h>

#define M 3

typedef struct _node
{
    int n; /*n < M No. of keys in node will always less than order of B tree*/
    int keys[M - 1];
    struct _node *p[M]; /* (n+1 pointers will be in use) */
} node;

node *root = NULL;

typedef enum KeyStatus
{
    Duplicate,
    SearchFailure,
    Success,
    InsertIt,
    LessKeys,

} KeyStatus;

void insert(int key);
void display(node *root, int);
void DelNode(int x);
void search(int x);
KeyStatus ins(node *r, int x, int *y, node **u);
int searchPos(int x, int *key_arr, int n);
KeyStatus del(node *r, int x);
void eatline(void);
void inorder(node *ptr);

int main()
{

    printf("\n****************************\n*  Name : Rajkumar B L     *\n*  Reg  : 2047120
 *\n*  Lab  : 13               *\n*  Prg  : B-Tree           *\n****************************\n\n");
    int key;
    int choice;

    printf("Creation of B-tree for M : %d\n", M);
    do
    {
        printf("\n============================\n\t   Menu\n============================\n");
        printf("1.Insert\n2.Delete\n3.Search\n4.Display\n5.Quit\n");
        printf("============================\n");
        printf("Enter your choice: ");
        scanf("%d", &choice);
        eatline();
        switch (choice)
        {
        case 1:
            printf("Enter the key to be inserted: ");
            scanf("%d", &key);
            eatline();
            insert(key);
            break;

        case 2:
            printf("Enter the key to be deleted: ");
            scanf("%d", &key);
            eatline();
            DelNode(key);
            break;

        case 3:
            printf("Enter the key to be searched: ");
            scanf("%d", &key);
            eatline();
            search(key);
            break;

        case 4:
            printf("Btree is :\n");
            display(root, 0);
            break;

        case 5:
            printf("Bye!\n\n");
            exit(1);

        default:
            printf("Invalid Choice\n");
            break;
        }
    } while (choice != 5);

    return 0;
}

void insert(int key)
{
    node *newnode;
    int upKey;
    KeyStatus value;
    value = ins(root, key, &upKey, &newnode);
    if (value == Duplicate)
        printf("Key already available\n");
    else
        printf("Key %d inserted successfully!\n", key);
    if (value == InsertIt)
    {
        node *uproot = root;
        root = (node *)malloc(sizeof(node));
        root->n = 1;
        root->keys[0] = upKey;
        root->p[0] = uproot;
        root->p[1] = newnode;
    }
}

KeyStatus ins(node *ptr, int key, int *upKey, node **newnode)
{
    node *newPtr, *lastPtr;
    int pos, i, n, splitPos;
    int newKey, lastKey;
    KeyStatus value;
    if (ptr == NULL)
    {
        *newnode = NULL;
        *upKey = key;
        return InsertIt;
    }

    n = ptr->n;
    pos = searchPos(key, ptr->keys, n);
    if (pos < n && key == ptr->keys[pos])
        return Duplicate;
    value = ins(ptr->p[pos], key, &newKey, &newPtr);
    if (value != InsertIt)
        return value;
    /*If keys in node is less than M-1 where M is order of B tree*/
    if (n < M - 1)
    {
        pos = searchPos(newKey, ptr->keys, n);
        /*Shifting the key and pointer right for inserting the new key*/
        for (i = n; i > pos; i--)
        {
            ptr->keys[i] = ptr->keys[i - 1];
            ptr->p[i + 1] = ptr->p[i];
        }

        /*Key is inserted at exact location*/
```

```c
        ptr->keys[pos] = newKey;
        ptr->p[pos + 1] = newPtr;
        ++ptr->n; /*incrementing the number of keys in node*/
        return Success;
    }

    /*If keys in nodes are maximum and position of node to be inserted is last*/

    if (pos == M - 1)
    {
        lastKey = newKey;
        lastPtr = newPtr;
    }

    else
    { /*If keys in node are maximum and position of node to be inserted is not last*/
        lastKey = ptr->keys[M - 2];
        lastPtr = ptr->p[M - 1];
        for (i = M - 2; i > pos; i--)
        {
            ptr->keys[i] = ptr->keys[i - 1];
            ptr->p[i + 1] = ptr->p[i];
        }

        ptr->keys[pos] = newKey;
        ptr->p[pos + 1] = newPtr;
    }

    splitPos = (M - 1) / 2;
    (*upKey) = ptr->keys[splitPos];
    (*newnode) = (node *)malloc(sizeof(node)); /*Right node after split*/
    ptr->n = splitPos; /*No. of keys for left splitted node*/
    (*newnode)->n = M - 1 - splitPos; /*No. of keys for right splitted node*/
    for (i = 0; i < (*newnode)->n; i++)
    {
        (*newnode)->p[i] = ptr->p[i + splitPos + 1];
        if (i < (*newnode)->n - 1)
            (*newnode)->keys[i] = ptr->keys[i + splitPos + 1];
        else
            (*newnode)->keys[i] = lastKey;
    }
    (*newnode)->p[(*newnode)->n] = lastPtr;
    return InsertIt;
}

void display(node *ptr, int blanks)
{
    if (ptr)
    {
        int i;
        for (i = 1; i <= blanks; i++)
```

```c
            printf(" ");
        for (i = 0; i < ptr->n; i++)
            printf("%d ", ptr->keys[i]);
        printf("\n");
        for (i = 0; i <= ptr->n; i++)
            display(ptr->p[i], blanks + 10);
    }
}

void search(int key)
{
    int pos, i, n;
    node *ptr = root;
    printf("Search path:\n");
    while (ptr)
    {
        n = ptr->n;
        for (i = 0; i < ptr->n; i++)
            printf(" %d", ptr->keys[i]);
        printf("\n");
        pos = searchPos(key, ptr->keys, n);
        if (pos < n && key == ptr->keys[pos])
        {
            printf("Key %d found in position %d of last displayed node\n", key, i);
            return;
        }

        ptr = ptr->p[pos];
    }

    printf("Key %d is not available\n", key);
}

int searchPos(int key, int *key_arr, int n)
{
    int pos = 0;
    while (pos < n && key > key_arr[pos])
        pos++;
    return pos;
}

void DelNode(int key)
{
    node *uproot;
    KeyStatus value;
    value = del(root, key);

    switch (value)
    {
    case SearchFailure:
        printf("Key %d is not available\n", key);
        break;

    case LessKeys:
        uproot = root;
        root = root->p[0];
        free(uproot);
        printf("Key %d deleted successfully!\n", key);
        break;

    default:
        return;
    }
}

KeyStatus del(node *ptr, int key)
{
    int pos, i, pivot, n, min;
    int *key_arr;
    KeyStatus value;
    node **p, *lptr, *rptr;

    if (ptr == NULL)
        return SearchFailure;
    n = ptr->n;
    key_arr = ptr->keys;
    p = ptr->p;
    min = (M - 1) / 2;
    //Search for key to delete
    pos = searchPos(key, key_arr, n);
    if (p[0] == NULL)
    {
        if (pos == n || key < key_arr[pos])
            return SearchFailure;
        /*Shift keys and pointers left*/
        for (i = pos + 1; i < n; i++)
        {
            key_arr[i - 1] = key_arr[i];
            p[i] = p[i + 1];
        }

        return --ptr->n >= (ptr == root ? 1 : min) ? Success : LessKeys;
    }

    if (pos < n && key == key_arr[pos])
    {
        node *qp = p[pos], *qp1;
        int nkey;

        while (1)
        {
            nkey = qp->n;
            qp1 = qp->p[nkey];
            if (qp1 == NULL)
                break;
            qp = qp1;
        }

        key_arr[pos] = qp->keys[nkey - 1];
        qp->keys[nkey - 1] = key;
    }

    value = del(p[pos], key);
    if (value != LessKeys)
        return value;

    if (pos > 0 && p[pos - 1]->n > min)
    {
        pivot = pos - 1; /*pivot for left and right node*/
        lptr = p[pivot];
        rptr = p[pos];

        /*Assigns values for right node*/
        rptr->p[rptr->n + 1] = rptr->p[rptr->n];

        for (i = rptr->n; i > 0; i--)
        {
            rptr->keys[i] = rptr->keys[i - 1];
            rptr->p[i] = rptr->p[i - 1];
        }

        rptr->n++;
        rptr->keys[0] = key_arr[pivot];
        rptr->p[0] = lptr->p[lptr->n];
        key_arr[pivot] = lptr->keys[--lptr->n];
        return Success;
    }

    if (pos < n && p[pos + 1]->n > min)
    {
        pivot = pos; /*pivot for left and right node*/
        lptr = p[pivot];
        rptr = p[pivot + 1];
        /*Assigns values for left node*/
        lptr->keys[lptr->n] = key_arr[pivot];
        lptr->p[lptr->n + 1] = rptr->p[0];
        key_arr[pivot] = rptr->keys[0];
        lptr->n++;
        rptr->n--;

        for (i = 0; i < rptr->n; i++)
        {
            rptr->keys[i] = rptr->keys[i + 1];
            rptr->p[i] = rptr->p[i + 1];

        } /*End of for*/

        rptr->p[rptr->n] = rptr->p[rptr->n + 1];
        return Success;
    }

    if (pos == n)
        pivot = pos - 1;

    else
        pivot = pos;
    lptr = p[pivot];
    rptr = p[pivot + 1];
    lptr->keys[lptr->n] = key_arr[pivot];
    lptr->p[lptr->n + 1] = rptr->p[0];
    for (i = 0; i < rptr->n; i++)
    {
        lptr->keys[lptr->n + 1 + i] = rptr->keys[i];
        lptr->p[lptr->n + 2 + i] = rptr->p[i + 1];
    }

    lptr->n = lptr->n + rptr->n + 1;
    free(rptr); /*Remove right node*/

    for (i = pos + 1; i < n; i++)
    {
        key_arr[i - 1] = key_arr[i];
        p[i] = p[i + 1];
    }

    return --ptr->n >= (ptr == root ? 1 : min) ? Success : LessKeys;
}

void eatline(void)
{
    char c;
    while ((c = getchar()) != '\n');
}

void inorder(node *ptr)
{

    if (ptr)
    {
        if (ptr->n >= 1)
        {
            inorder(ptr->p[0]);
            printf("%d ", ptr->keys[0]);
            inorder(ptr->p[1]);
            if (ptr->n == 2)
            {
                printf("%d ", ptr->keys[1]);
                inorder(ptr->p[2]);
            }
        }
    }
}
```