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03

LAB MANUAL

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Lab 01-Arrays

What is an Array?

An **array** is a collection of elements of the same type stored in contiguous memory locations. It allows accessing elements using their **index** (starting from 0).

Advantages of Arrays

1. **Random Access**: Direct access to elements using index.
2. **Efficient Storage**: Compact memory usage.
3. **Easy Traversal**: Simple loops for processing elements.
4. **Sorting/Searching**: Works well with algorithms.
5. **Fixed Size**: Useful for known-size data.

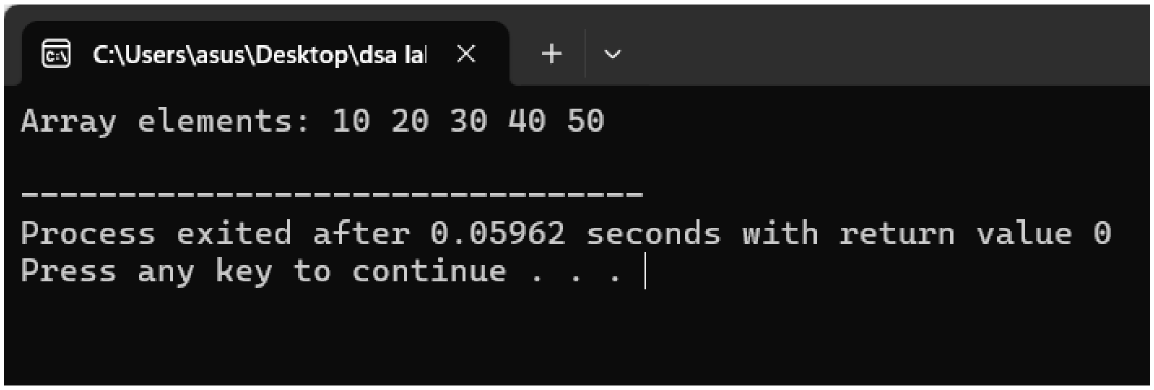
Types of Arrays

1. **One-Dimensional**: Linear collection (e.g., int arr[5];).
2. **Multi-Dimensional**: Arrays within arrays (e.g., int mat[3][3];).
3. **Dynamic Array**: Size adjusted at runtime (e.g., new int[n]; or std::vector<int>).

Examples:

1. Array Traversing

```
#include <iostream>
using namespace std;

void traverseArray(int arr[], int size) {
   cout << "Array elements: ";
   for (int i = 0; i < size; i++) {
      cout << arr[i] << " ";
   }
   cout << endl;
}

int main() {
   int arr[] = {10, 20, 30, 40, 50};
   int size = 5;
   traverseArray(arr, size);
   return 0;
}
```



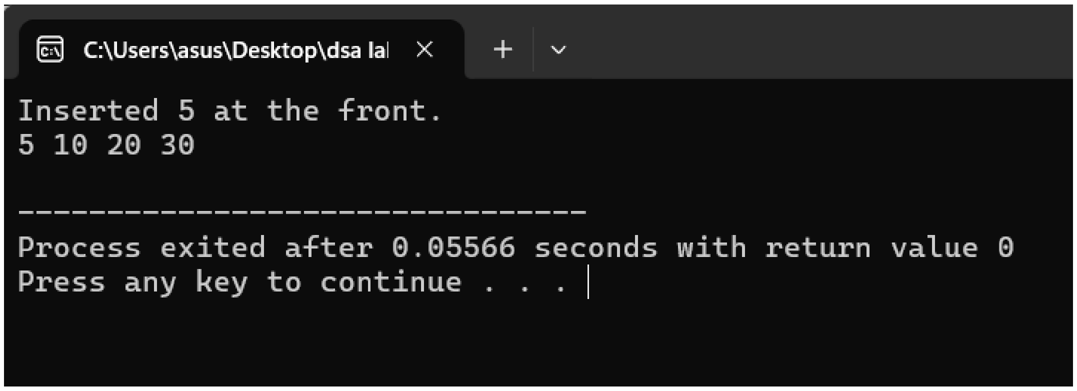
```
Array elements: 10 20 30 40 50

--------------------------------
Process exited after 0.05962 seconds with return value 0
Press any key to continue . . .
```

2. Insertion (Front, Mid, Last)

- **Insert at Front**

```
#include <iostream>
using namespace std;

void insertFront(int arr[], int &size, int element, int capacity) {
   if (size >= capacity) {
      cout << "Array is full. Cannot insert." << endl;
      return;
   }
   for (int i = size; i > 0; i--) {
      arr[i] = arr[i - 1];
   }
   arr[0] = element;
   size++;
   cout << "Inserted " << element << " at the front." << endl;
}

int main() {
   const int capacity = 10;
   int arr[capacity] = {10, 20, 30};
   int size = 3;

   insertFront(arr, size, 5, capacity);

   for (int i = 0; i < size; i++) {
      cout << arr[i] << " ";
   }
```

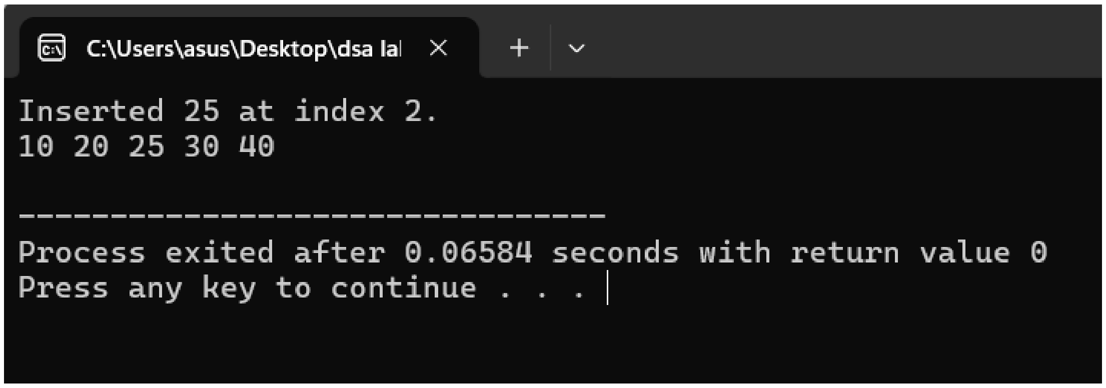
```
    cout << endl;

    return 0;
}
```



```
Inserted 5 at the front.
5 10 20 30

--------------------------------
Process exited after 0.05566 seconds with return value 0
Press any key to continue . . .
```

- **Insert in Middle**

```
#include <iostream>
using namespace std;

void insertMid(int arr[], int &size, int element, int index, int capacity) {
    if (size >= capacity) {
        cout << "Array is full. Cannot insert." << endl;
        return;
    }
    for (int i = size; i > index; i--) {
        arr[i] = arr[i - 1];
    }
    arr[index] = element;
    size++;
    cout << "Inserted " << element << " at index " << index << "." << endl;
}

int main() {
    const int capacity = 10;
    int arr[capacity] = {10, 20, 30, 40};
    int size = 4;

    insertMid(arr, size, 25, 2, capacity);

    for (int i = 0; i < size; i++) {
        cout << arr[i] << " ";
    }
    cout << endl;

    return 0;
}
```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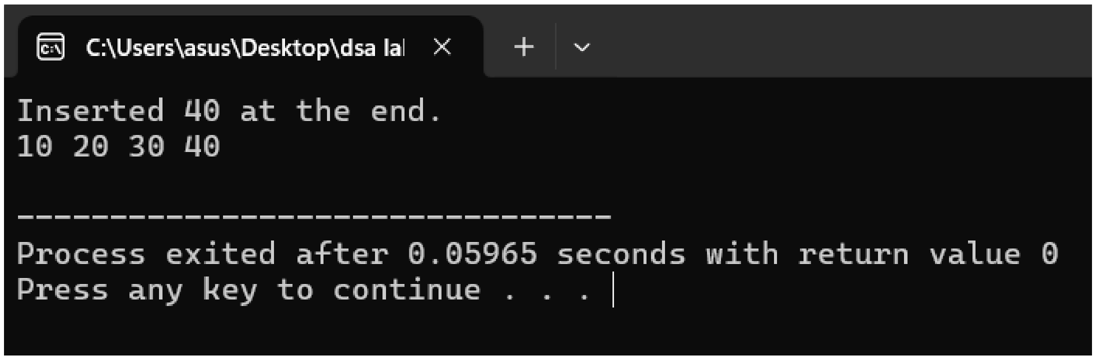
```
Inserted 25 at index 2.
10 20 25 30 40

--------------------------------
Process exited after 0.06584 seconds with return value 0
Press any key to continue . . .
```

- **Insert at Last**

```
#include <iostream>
using namespace std;

void insertLast(int arr[], int &size, int element, int capacity) {
    if (size >= capacity) {
        cout << "Array is full. Cannot insert." << endl;
        return;
    }
    arr[size++] = element;
    cout << "Inserted " << element << " at the end." << endl;
}

int main() {
    const int capacity = 10;
    int arr[capacity] = {10, 20, 30};
    int size = 3;

    insertLast(arr, size, 40, capacity);

    for (int i = 0; i < size; i++) {
        cout << arr[i] << " ";
    }
    cout << endl;
```

```
   return 0;
}
```



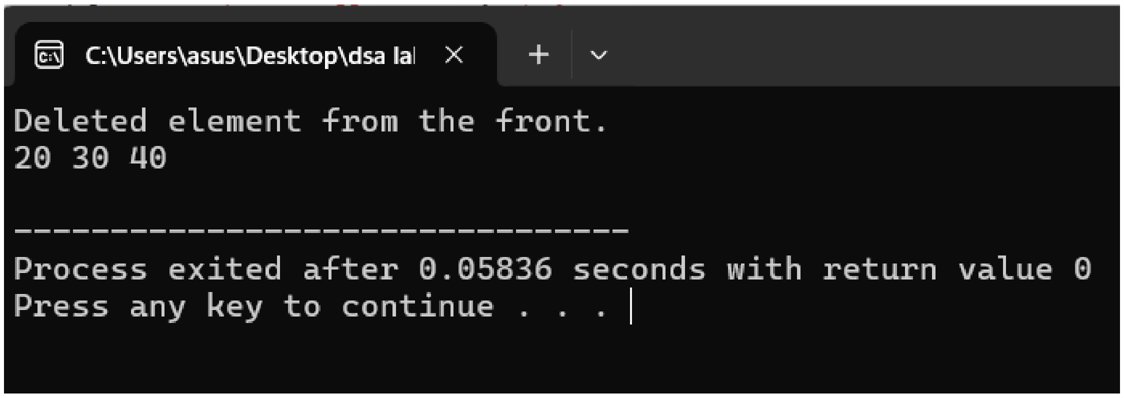
```
Inserted 40 at the end.
10 20 30 40

--------------------------------
Process exited after 0.05965 seconds with return value 0
Press any key to continue . . .
```

3. Deletion (Front, Mid, Last)

- **Delete from Front**

```
#include <iostream>
using namespace std;

void deleteFront(int arr[], int &size) {
   if (size <= 0) {
      cout << "Array is empty. Cannot delete." << endl;
      return;
   }
   for (int i = 0; i < size - 1; i++) {
      arr[i] = arr[i + 1];
   }
   size--;
   cout << "Deleted element from the front." << endl;
}

int main() {
   int arr[] = {10, 20, 30, 40};
   int size = 4;

   deleteFront(arr, size);

   for (int i = 0; i < size; i++) {
      cout << arr[i] << " ";
   }
   cout << endl;
```

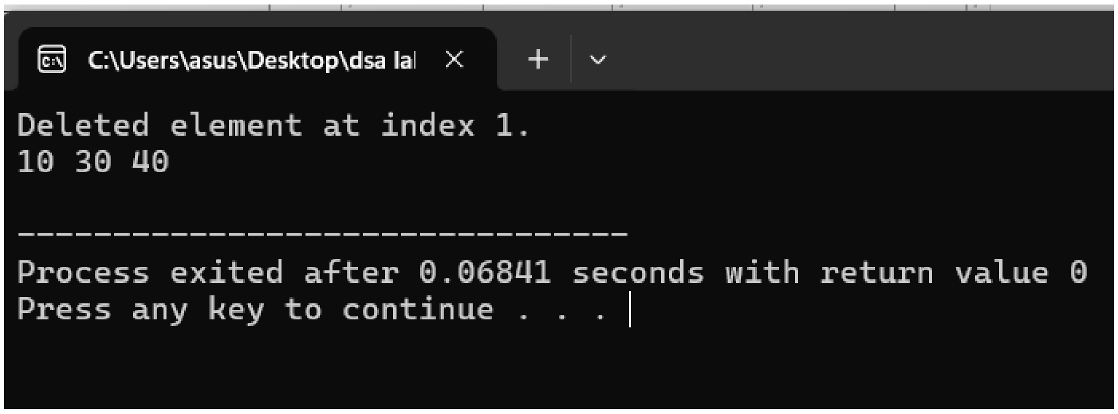
```
    return 0;
}
```



```
Deleted element from the front.
20 30 40

--------------------------------
Process exited after 0.05836 seconds with return value 0
Press any key to continue . . .
```

- **Delete from Middle**

```
#include <iostream>
using namespace std;

void deleteMid(int arr[], int &size, int index) {
    if (index < 0 || index >= size) {
        cout << "Invalid index." << endl;
        return;
    }
    for (int i = index; i < size - 1; i++) {
        arr[i] = arr[i + 1];
    }
    size--;
    cout << "Deleted element at index " << index << "." << endl;
}

int main() {
    int arr[] = {10, 20, 30, 40};
    int size = 4;

    deleteMid(arr, size, 1);

    for (int i = 0; i < size; i++) {
        cout << arr[i] << " ";
    }
    cout << endl;
    return 0;
}
```



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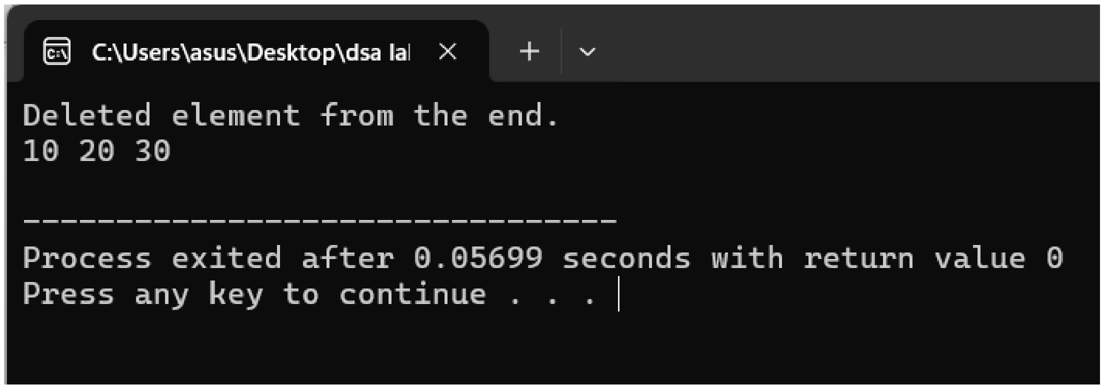
```
Deleted element at index 1.
10 30 40

--------------------------------
Process exited after 0.06841 seconds with return value 0
Press any key to continue . . .
```

- **Delete from Last**

```
#include <iostream>
using namespace std;

void deleteLast(int arr[], int &size) {
    if (size <= 0) {
        cout << "Array is empty. Cannot delete." << endl;
        return;
    }
    size--;
    cout << "Deleted element from the end." << endl;
}

int main() {
    int arr[] = {10, 20, 30, 40};
    int size = 4;

    deleteLast(arr, size);

    for (int i = 0; i < size; i++) {
        cout << arr[i] << " ";
    }
    cout << endl;

    return 0;
}
```



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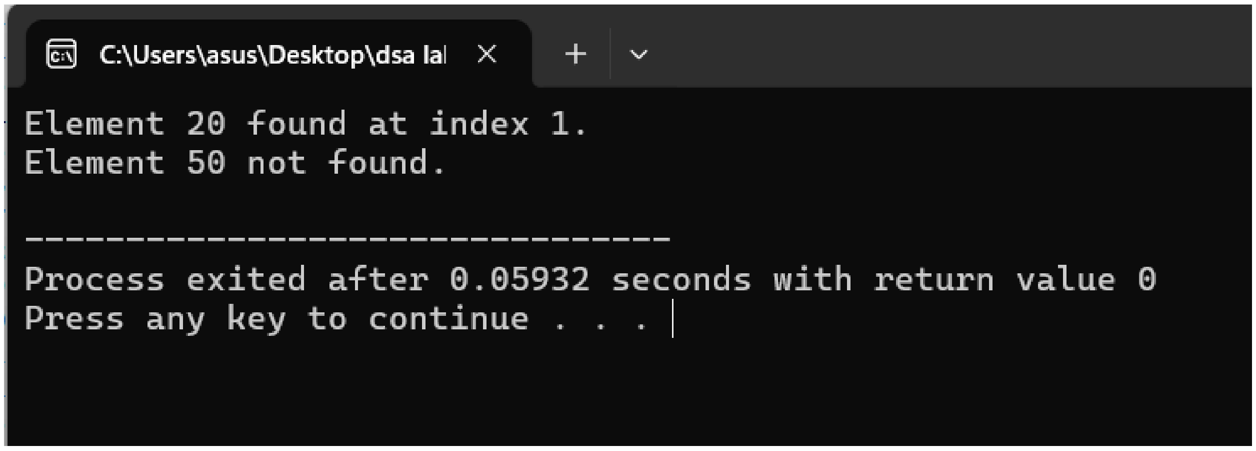
```
Deleted element from the end.
10 20 30

--------------------------------
Process exited after 0.05699 seconds with return value 0
Press any key to continue . . .
```

4. Searching

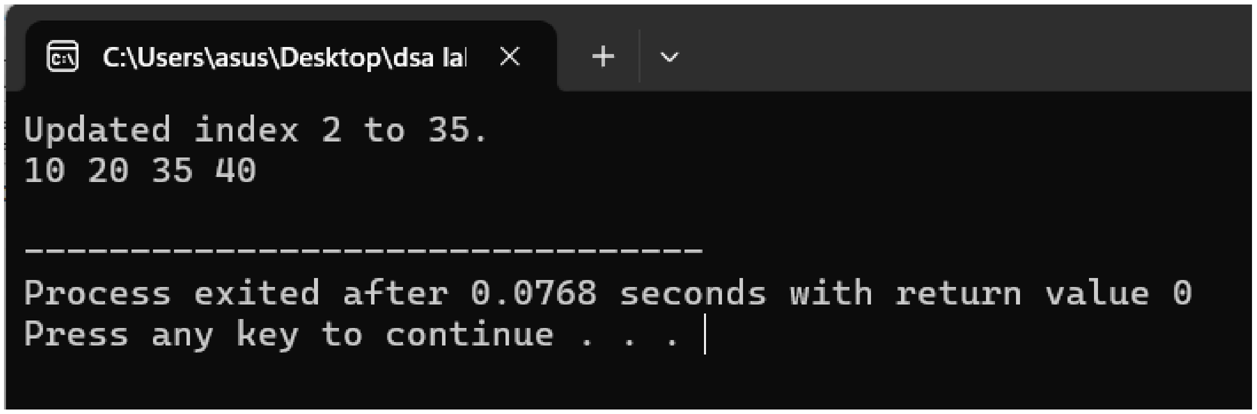
```
#include <iostream>
using namespace std;

void searchElement(int arr[], int size, int element) {
   for (int i = 0; i < size; i++) {
      if (arr[i] == element) {
         cout << "Element " << element << " found at index " << i << "." << endl;
         return;
      }
   }
   cout << "Element " << element << " not found." << endl;
}

int main() {
   int arr[] = {10, 20, 30, 40};
   int size = 4;

   searchElement(arr, size, 20);
   searchElement(arr, size, 50);

   return 0;
}
```



```
Element 20 found at index 1.
Element 50 not found.

--------------------------------
Process exited after 0.05932 seconds with return value 0
Press any key to continue . . .
```

5. **Update**

```
#include <iostream>
using namespace std;

void updateElement(int arr[], int size, int index, int newValue) {
   if (index < 0 || index >= size) {
      cout << "Invalid index." << endl;
      return;
   }
   arr[index] = newValue;
   cout << "Updated index " << index << " to " << newValue << "." << endl;
}

int main() {
   int arr[] = {10, 20, 30, 40};
   int size = 4;

   updateElement(arr, size, 2, 35);

   for (int i = 0; i < size; i++) {
      cout << arr[i] << " ";
   }
   cout << endl;

   return 0;
}
```



```
Updated index 2 to 35.
10 20 35 40

--------------------------------
Process exited after 0.0768 seconds with return value 0
Press any key to continue . . .
```

Lab 02- Stack

What is a Stack?

- A stack is a **LIFO (Last In, First Out)** data structure.
- The last item added is the first to be removed.
- Common operations: **Push** (add), **Pop** (remove), and **Peek** (view top element).

Advantages:

1. **Fast Operations**: Push and pop are O(1)O(1)O(1).
2. **Reversing Data**: Helpful in reversing strings or numbers.
3. **Memory Management**: Used in function calls and recursion.
4. **Simplifies Algorithms**: Balancing parentheses, infix-to-postfix conversion, undo/redo, etc.

Types of Stacks:

1. **Based on Implementation**:
   - **Array-Based**: Fixed size, simple.
   - **Linked List-Based**: Dynamic size.
2. **Based on Use**:
   - **Call Stack**: Handles function calls.
   - **Undo Stack**: For undo/redo operations.
   - **Expression Stack**: Evaluates mathematical expressions.

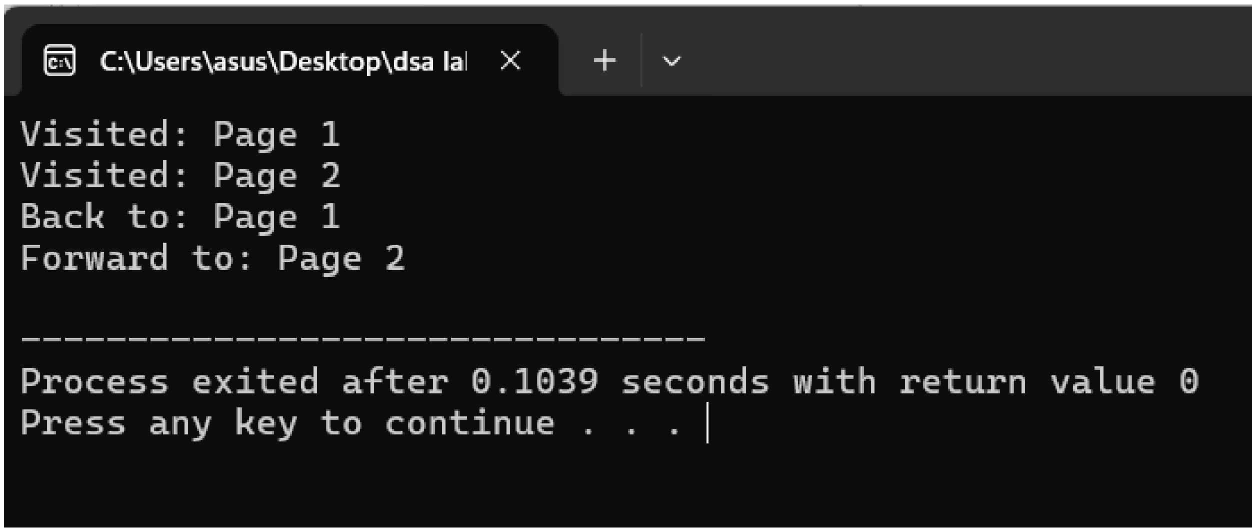
Applications:

- Backtracking (e.g., solving mazes).
- Browser history navigation.
- Managing function calls (recursion).
- Expression evaluation (infix to postfix).

Examples:

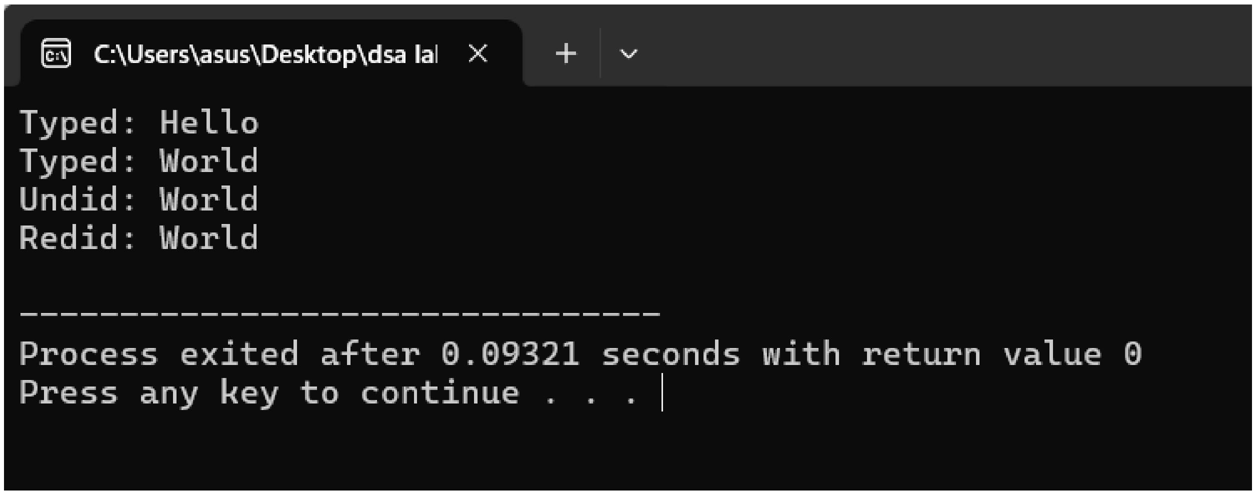
1. Browser Navigation (Back/Forward History)

```
#include <iostream>
#include <stack>
using namespace std;

class BrowserHistory {
   stack<string> backStack, forwardStack;

public:
   void visitPage(string page) {
      backStack.push(page);
      while (!forwardStack.empty()) forwardStack.pop();  // Clear forward stack
      cout << "Visited: " << page << endl;
   }

   void back() {
      if (backStack.empty()) {
         cout << "No pages in history!" << endl;
         return;
      }
      forwardStack.push(backStack.top());
      backStack.pop();
      cout << "Back to: " << (backStack.empty() ? "No page" : backStack.top()) << endl;
   }

   void forward() {
      if (forwardStack.empty()) {
         cout << "No forward page!" << endl;
         return;
      }
      backStack.push(forwardStack.top());
      forwardStack.pop();
      cout << "Forward to: " << backStack.top() << endl;
   }
};

int main() {
    BrowserHistory browser;
    browser.visitPage("Page 1");
    browser.visitPage("Page 2");
    browser.back();
    browser.forward();
    return 0;
}
```



```
Visited: Page 1
Visited: Page 2
Back to: Page 1
Forward to: Page 2

--------------------------------
Process exited after 0.1039 seconds with return value 0
Press any key to continue . . .
```

2. Undo/Redo in Text Editor

```
#include <iostream>
#include <stack>
using namespace std;

class TextEditor {
    stack<string> undoStack, redoStack;

public:
    void type(string text) {
        undoStack.push(text);
        while (!redoStack.empty()) redoStack.pop();
        cout << "Typed: " << text << endl;
    }

    void undo() {
        if (undoStack.empty()) {
            cout << "Nothing to undo!" << endl;
            return;
        }
        string lastText = undoStack.top();
        undoStack.pop();
        redoStack.push(lastText);
        cout << "Undid: " << lastText << endl;
    }

    void redo() {
        if (redoStack.empty()) {
            cout << "Nothing to redo!" << endl;
            return;
        }
        string lastText = redoStack.top();
        redoStack.pop();
        undoStack.push(lastText);
        cout << "Redid: " << lastText << endl;
    }
};

int main() {
    TextEditor editor;
    editor.type("Hello");
    editor.type("World");
    editor.undo();
    editor.redo();
    return 0;
}
```

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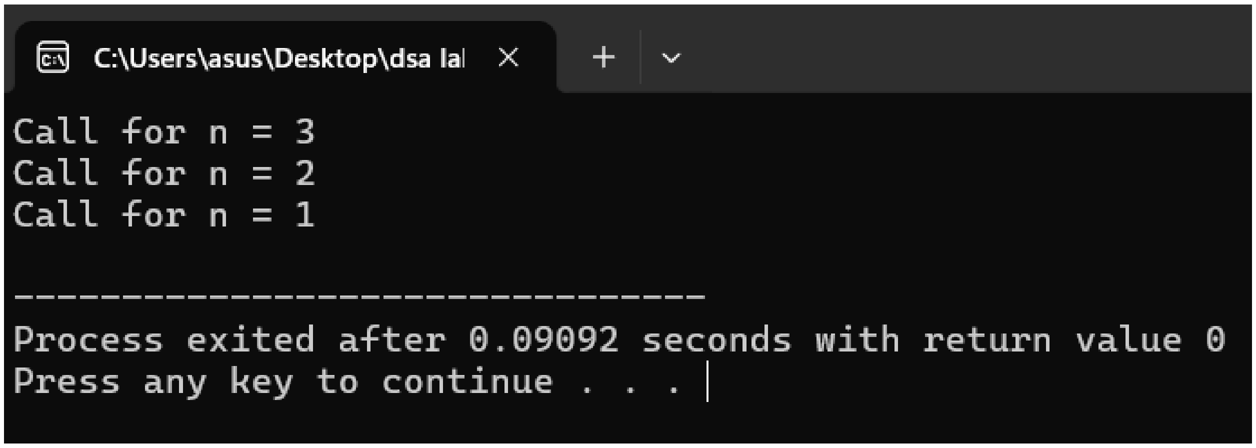
```
Typed: Hello
Typed: World
Undid: World
Redid: World

--------------------------------
Process exited after 0.09321 seconds with return value 0
Press any key to continue . . .
```

3. Function Call Stack (Recursion)

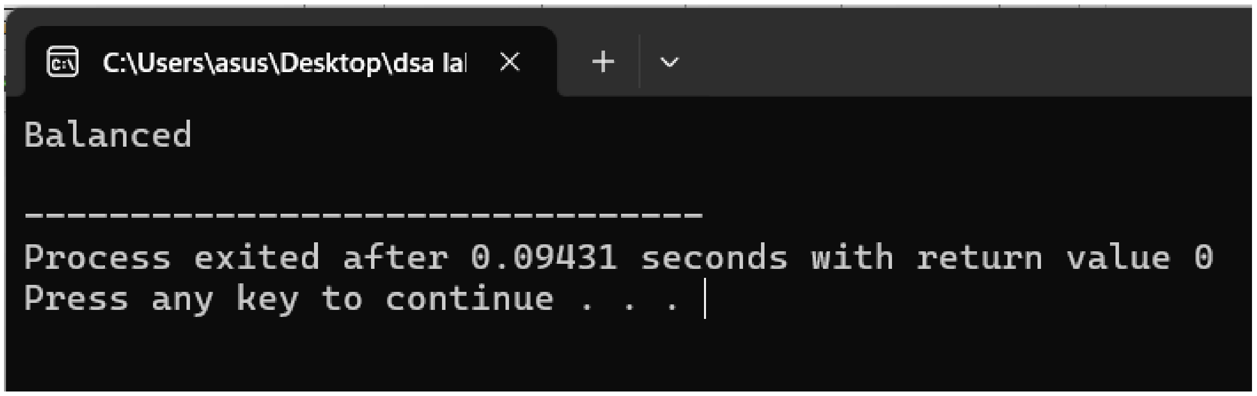
```
#include <iostream>
#include <stack>
using namespace std;

void recursiveFunction(int n) {
   stack<int> callStack;
   callStack.push(n);
   if (n > 0) {
      cout << "Call for n = " << n << endl;
      recursiveFunction(n - 1);
   }
   callStack.pop();
}

int main() {
   recursiveFunction(3);
   return 0;
}
```



```
Call for n = 3
Call for n = 2
Call for n = 1

--------------------------------
Process exited after 0.09092 seconds with return value 0
Press any key to continue . . .
```

4. Balancing Parentheses

```
#include <iostream>
#include <stack>
using namespace std;

bool isBalanced(string expression) {
   stack<char> s;
   for (char c : expression) {
        if (c == '(' || c == '{' || c == '[') {
            s.push(c);
        } else if (c == ')' || c == '}' || c == ']') {
            if (s.empty()) return false;
            char top = s.top();
            if ((c == ')' && top == '(') || (c == '}' && top == '{') || (c == ']' && top == '[')) {
                s.pop();
            } else {
                return false;
            }
        }
    }
    return s.empty();
}

int main() {
    string expression = "({[()]})";
    cout << (isBalanced(expression) ? "Balanced" : "Not Balanced") << endl;
    return 0;
}
```



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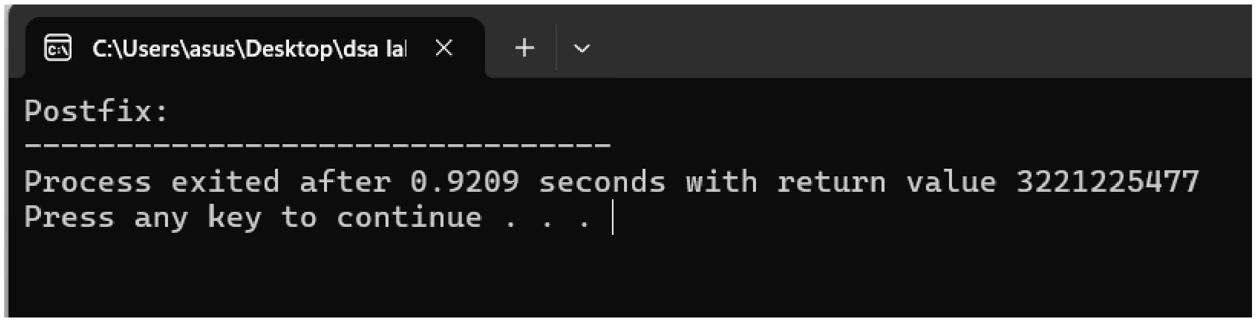
```
Balanced

--------------------------------
Process exited after 0.09431 seconds with return value 0
Press any key to continue . . .
```

5. Infix to Postfix Conversion

```
#include <iostream>
#include <stack>
#include <cctype>
using namespace std;

int precedence(char c) {
    if (c == '+' || c == '-') return 1;
    if (c == '*' || c == '/') return 2;
    return 0;
}

string infixToPostfix(string infix) {
    stack<char> s;
    string postfix = "";

    for (char c : infix) {
        if (isalnum(c)) {
            postfix += c;
        } else if (c == '(') {
            s.push(c);
        } else if (c == ')') {
            while (!s.empty() && s.top() != '(') {
                postfix += s.top();
                s.pop();
            }
            s.pop();  // Remove '('
        } else {
            while (!s.empty() && precedence(s.top()) >= precedence(c)) {
                postfix += s.top();
                s.pop();
            }
            s.push(c);
        }
    }

    while (!s.empty()) {
        postfix += s.top();
        s.pop();
    }
    return postfix;
}

int main() {
    string infix = "A+B*(C^D-E)^(F+G*H)-I";
    cout << "Postfix: " << infixToPostfix(infix) << endl;
    return 0;
}
```



```
Postfix:
--------------------------------
Process exited after 0.9209 seconds with return value 3221225477
Press any key to continue . . .
```

Lab 03 – Queue

What is a Queue?

- A **queue** is a **FIFO (First In, First Out)** data structure.
- The first element added is the first one to be removed.
- Common operations: **Enqueue** (add), **Dequeue** (remove), **Front** (view front element), **Rear** (view last element).

Advantages of a Queue:

1. **FIFO Access**: Processes elements in the order they arrive.
2. **Efficient Memory Use**: Manages resources effectively.
3. **Real-Time Systems**: Used for task scheduling and managing requests.
4. **Broad Applicability**: Useful in many scenarios like traffic management, task execution, and CPU scheduling.

Types of Queues:

1. **Linear Queue**: Basic FIFO queue.
2. **Circular Queue**: Wraps around when it reaches the end, optimizing space.
3. **Priority Queue**: Elements are processed based on priority, not arrival order.
4. **Deque**: Double-ended queue, allows adding/removing from both ends.
5. **Queue using Two Stacks**: A queue simulated using two stacks.

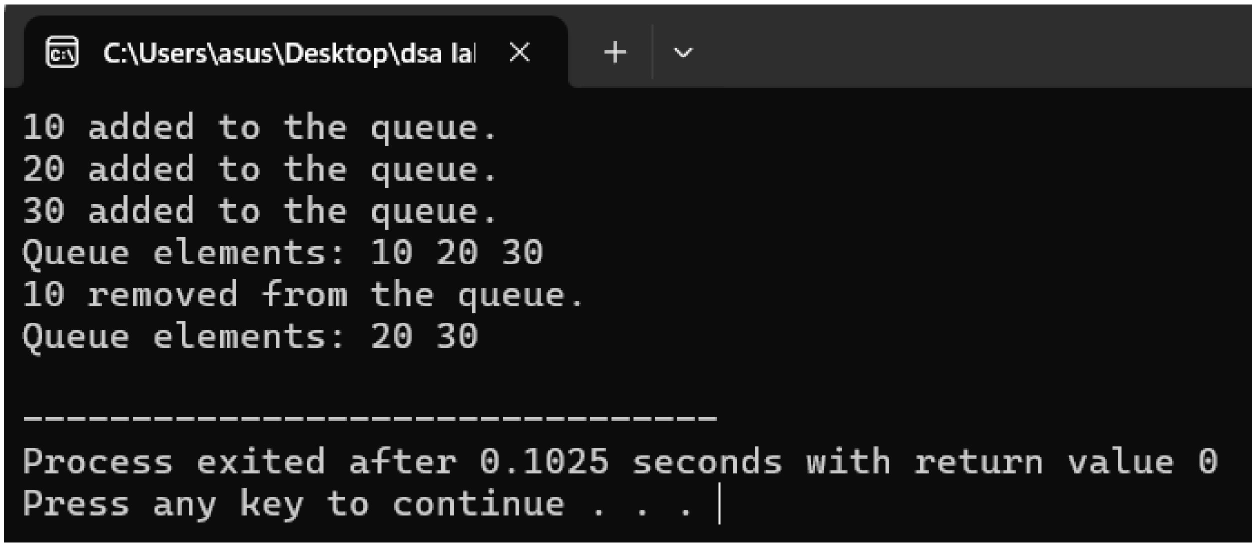
Applications:

- Task scheduling
- Print jobs management
- Call centers handling
- Traffic signals
- Graph traversal (BFS)

Examples:

1. **Linear Queue (Array-Based)**

```
#include <iostream>
using namespace std;

class LinearQueue {
    int* queue;
    int front, rear, size;

public:
    LinearQueue(int s) {
        size = s;
        queue = new int[size];
        front = rear = -1;
    }

    // Enqueue
    void enqueue(int value) {
        if (rear == size - 1) {
            cout << "Queue is full!" << endl;
        } else {
            if (front == -1) front = 0;
            queue[++rear] = value;
            cout << value << " added to the queue." << endl;
        }
    }

    // Dequeue
    void dequeue() {
        if (front == -1 || front > rear) {
            cout << "Queue is empty!" << endl;
        } else {
            cout << queue[front++] << " removed from the queue." << endl;
        }
    }

    // Display Queue
    void display() {
        if (front == -1 || front > rear) {
            cout << "Queue is empty!" << endl;
        } else {
            cout << "Queue elements: ";
            for (int i = front; i <= rear; ++i) {
                cout << queue[i] << " ";
            }
            cout << endl;
        }
    }
};

int main() {
    LinearQueue q(5);

    q.enqueue(10);
    q.enqueue(20);
    q.enqueue(30);
    q.display();

    q.dequeue();
    q.display();

    return 0;
}
```



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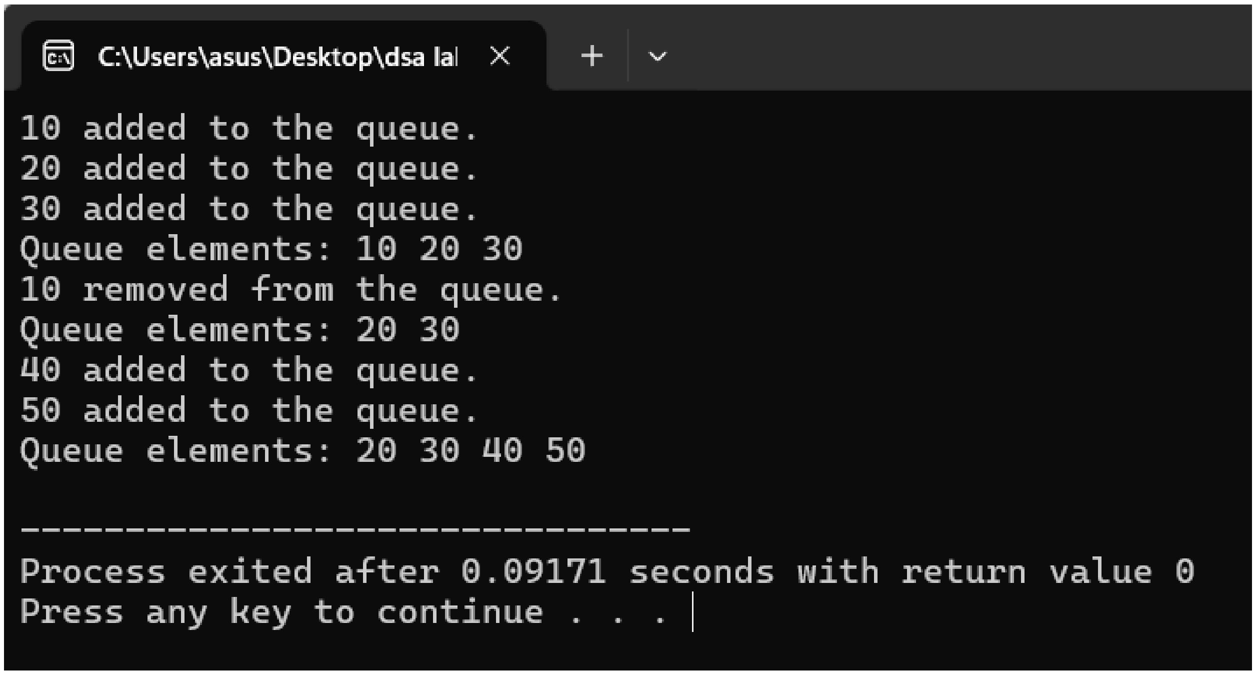
```
10 added to the queue.
20 added to the queue.
30 added to the queue.
Queue elements: 10 20 30
10 removed from the queue.
Queue elements: 20 30

--------------------------------
Process exited after 0.1025 seconds with return value 0
Press any key to continue . . .
```

2. Circular Queue (Array-Based)

```
#include <iostream>
using namespace std;
```

```
class CircularQueue {
    int* queue;
    int front, rear, size;

public:
    CircularQueue(int s) {
        size = s;
        queue = new int[size];
        front = rear = -1;
    }

    // Enqueue
    void enqueue(int value) {
        if ((rear + 1) % size == front) {
            cout << "Queue is full!" << endl;
        } else {
            if (front == -1) front = 0;
            rear = (rear + 1) % size;
            queue[rear] = value;
            cout << value << " added to the queue." << endl;
        }
    }

    // Dequeue
    void dequeue() {
        if (front == -1) {
            cout << "Queue is empty!" << endl;
        } else {
            cout << queue[front] << " removed from the queue." << endl;
            if (front == rear) {
                front = rear = -1;  // Reset the queue after last element is dequeued
            } else {
                front = (front + 1) % size;
            }
        }
    }

    // Display Queue
    void display() {
        if (front == -1) {
            cout << "Queue is empty!" << endl;
        } else {
            cout << "Queue elements: ";
            int i = front;
            while (i != rear) {
                cout << queue[i] << " ";
                i = (i + 1) % size;
            }
            cout << queue[rear] << endl;
        }
    }
};

int main() {
    CircularQueue q(5);

    q.enqueue(10);
    q.enqueue(20);
    q.enqueue(30);
    q.display();

    q.dequeue();
    q.display();

    q.enqueue(40);
    q.enqueue(50);
    q.display();

    return 0;
}
```



```
10 added to the queue.
20 added to the queue.
30 added to the queue.
Queue elements: 10 20 30
10 removed from the queue.
Queue elements: 20 30
40 added to the queue.
50 added to the queue.
Queue elements: 20 30 40 50

--------------------------------
Process exited after 0.09171 seconds with return value 0
Press any key to continue . . .
```

Lab 04 - Single Linked List (SLL)

What is a Single Linked List (SLL)?

A **Single Linked List** is a linear data structure where each node contains:

- **Data**: The information stored in the node.
- **Next**: A reference to the next node. The last node points to nullptr.

Advantages of SLL:

1. **Dynamic Size**: Grows or shrinks as needed.
2. **Efficient Insertions/Deletions**: Especially at the beginning.
3. **Memory Efficient**: Allocates memory as needed.
4. **Flexible Memory Management**: Can use non-contiguous memory.

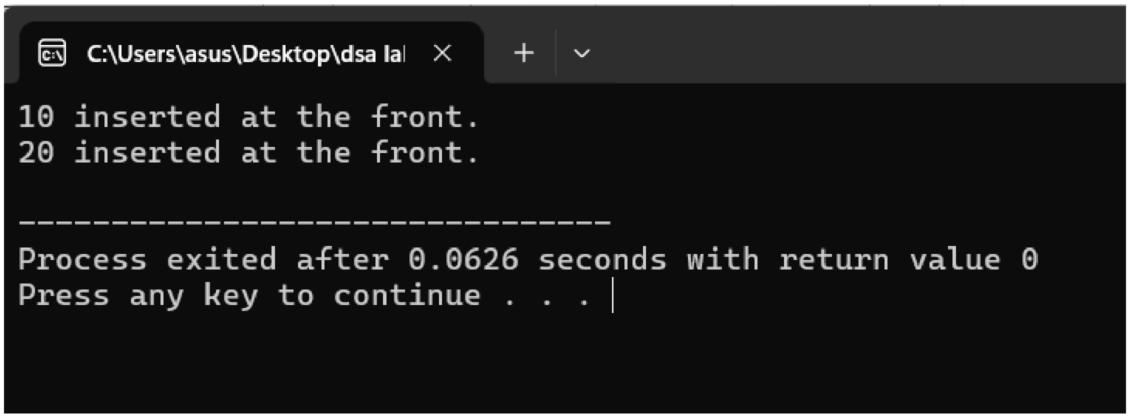
Real-Life Applications:

1. **Dynamic Memory Allocation**: Memory management in operating systems.
2. **Stacks and Queues**: Implemented using linked lists.
3. **Browser History**: Web browsers use it to store visited pages.
4. **Polynomial Representation**: Representing polynomials in math.
5. **Graph Representation**: Used for adjacency lists in graphs.
6. **Playlist Management**: Music players use it to manage playlists.

1. Insertion at Front:

```
#include <iostream>
```

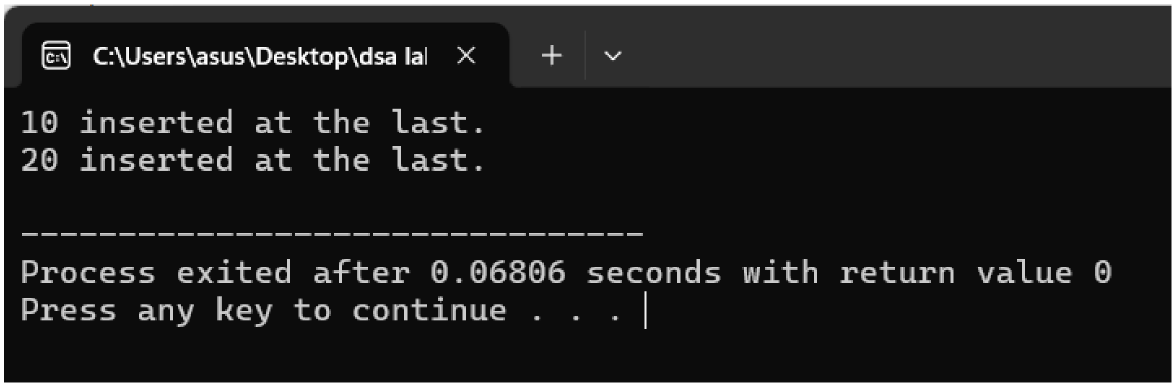
```
using namespace std;

struct Node {
   int data;
   Node* next;
};

void insertFront(Node*& head, int value) {
   Node* newNode = new Node();
   newNode->data = value;
   newNode->next = head;
   head = newNode;
   cout << value << " inserted at the front." << endl;
}

int main() {
   Node* head = nullptr;
   insertFront(head, 10);
   insertFront(head, 20);
   return 0;
}
```



```
10 inserted at the front.
20 inserted at the front.

--------------------------------
Process exited after 0.0626 seconds with return value 0
Press any key to continue . . .
```

2. Insertion at End:

```
#include <iostream>

using namespace std;


struct Node {
    int data;

    Node* next;

};


void insertLast(Node*& head, int value) {

    Node* newNode = new Node();

    newNode->data = value;

    newNode->next = nullptr;


    if (head == nullptr) {

        head = newNode;

        cout << value << " inserted at the last." << endl;

        return;

    }


    Node* temp = head;

    while (temp->next != nullptr) {

        temp = temp->next;

    }

    temp->next = newNode;

    cout << value << " inserted at the last." << endl;

}


int main() {

    Node* head = nullptr;

    insertLast(head, 10);

    insertLast(head, 20);
    return 0;
}
```



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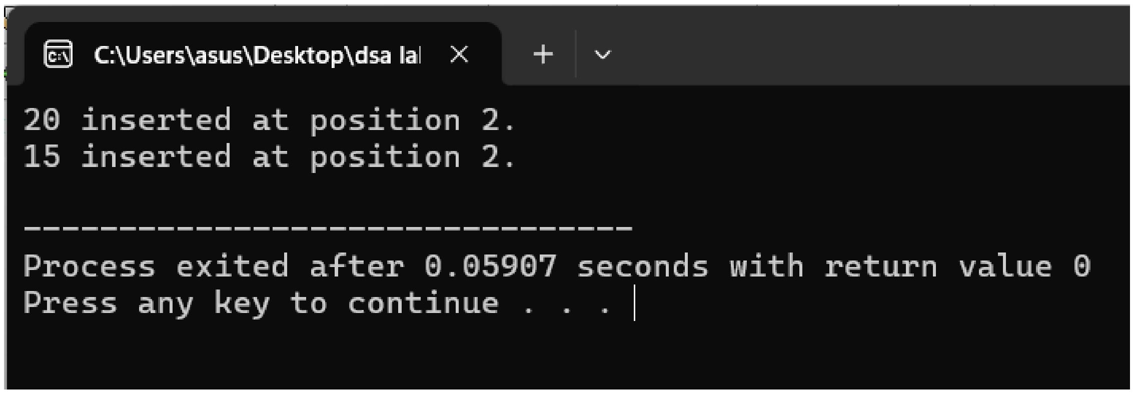
```
10 inserted at the last.
20 inserted at the last.

--------------------------------
Process exited after 0.06806 seconds with return value 0
Press any key to continue . . .
```

3. **Insertion at Middle (after a specific position):**

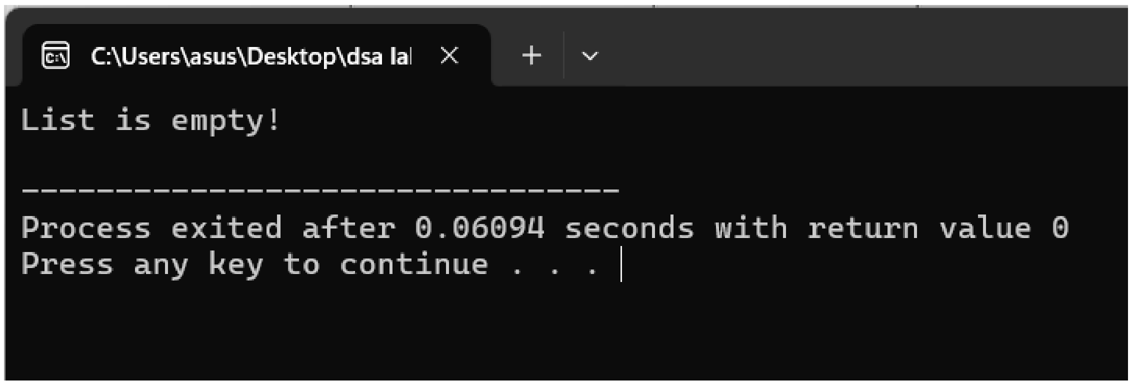
```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
};

void insertMid(Node*& head, int value, int position) {
    if (position == 1) {
        Node* newNode = new Node();
        newNode->data = value;
        newNode->next = head;
        head = newNode;
        return;
    }

    Node* newNode = new Node();
    newNode->data = value;
    Node* temp = head;

    for (int i = 1; i < position - 1 && temp != nullptr; i++) {
        temp = temp->next;
    }

    if (temp == nullptr) {
        cout << "Position out of range!" << endl;
        return;
    }

    newNode->next = temp->next;
    temp->next = newNode;
    cout << value << " inserted at position " << position << "." << endl;
}

int main() {
    Node* head = nullptr;
    insertMid(head, 10, 1); // Insert at position 1
    insertMid(head, 20, 2); // Insert at position 2
    insertMid(head, 15, 2); // Insert at position 2
    return 0;
}
```



```
C:\Users\asus\Desktop\dsa lal
20 inserted at position 2.
15 inserted at position 2.

--------------------------------
Process exited after 0.05907 seconds with return value 0
Press any key to continue . . .
```

4. **Deletion from Front:**

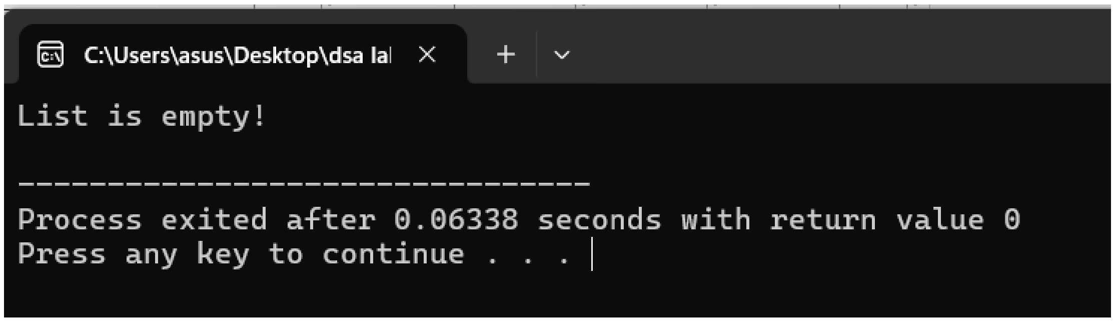
```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
};

void deleteFront(Node*& head) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }
    Node* temp = head;
    head = head->next;
    delete temp;
    cout << "Node deleted from the front." << endl;
}

int main() {
    Node* head = nullptr;
    deleteFront(head); // Testing on empty list
    return 0;
}
```



```
List is empty!

--------------------------------
Process exited after 0.06094 seconds with return value 0
Press any key to continue . . .
```

5. Deletion from Last

```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
};

void deleteLast(Node*& head) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }

    Node* temp = head;
    if (temp->next == nullptr) {
        head = nullptr;
        delete temp;
        cout << "Node deleted from the last." << endl;
        return;
    }

    while (temp->next != nullptr && temp->next->next != nullptr) {
        temp = temp->next;
    }
    delete temp->next;
    temp->next = nullptr;
    cout << "Node deleted from the last." << endl;
}

int main() {
    Node* head = nullptr;
    deleteLast(head); // Testing on empty list
    return 0;
}
```



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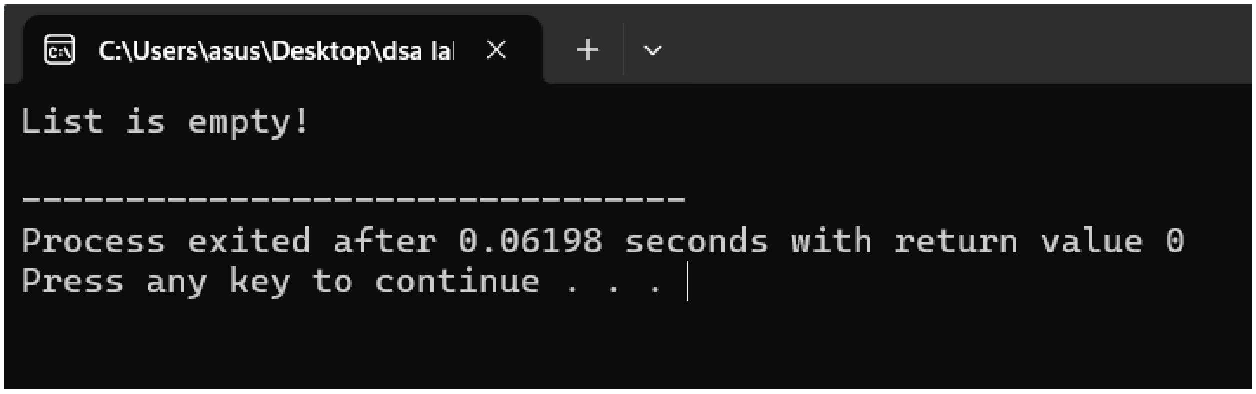
```
List is empty!

--------------------------------
Process exited after 0.06338 seconds with return value 0
Press any key to continue . . .
```

6.Deletion from Middle (Specific Position)

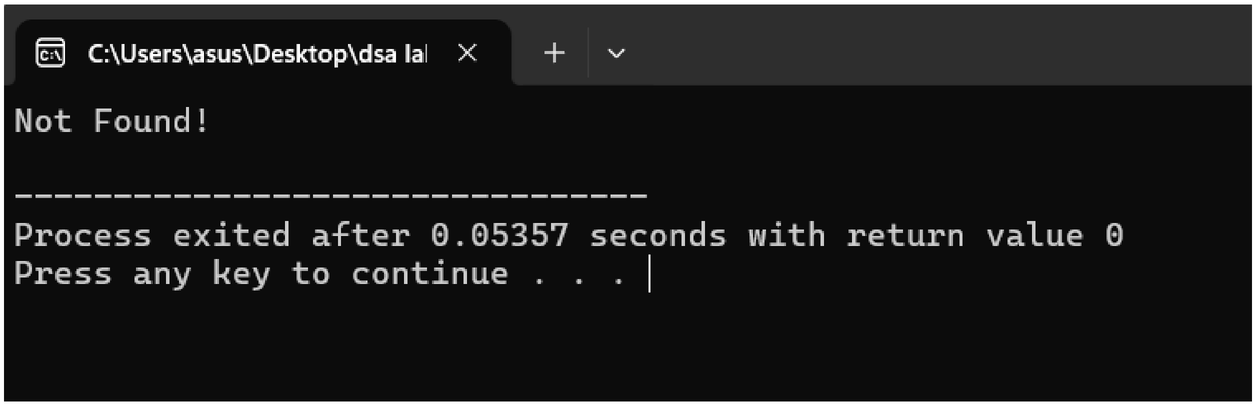
```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
};

void deleteMid(Node*& head, int position) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }

    if (position == 1) {
        Node* temp = head;
        head = head->next;
        delete temp;
        return;
    }

    Node* temp = head;
    for (int i = 1; i < position - 1 && temp != nullptr; i++) {
        temp = temp->next;
    }

    if (temp == nullptr || temp->next == nullptr) {
        cout << "Position out of range!" << endl;
        return;
    }

    Node* nodeToDelete = temp->next;
    temp->next = temp->next->next;
    delete nodeToDelete;
    cout << "Node deleted from position " << position << "." << endl;
}

int main() {
    Node* head = nullptr;
    deleteMid(head, 2); // Testing on empty list
    return 0;
}
```



```
List is empty!

--------------------------------
Process exited after 0.06198 seconds with return value 0
Press any key to continue . . .
```

7. Searching for an Element

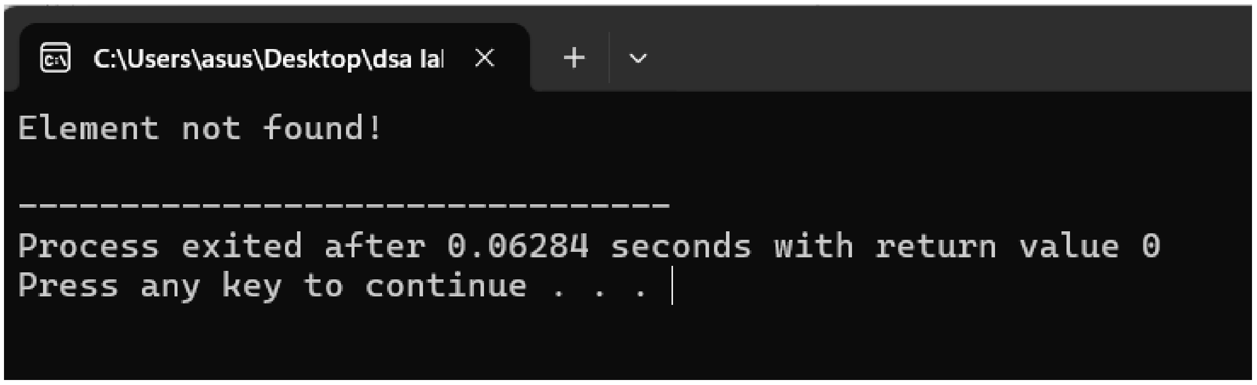
```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
};

bool search(Node* head, int value) {
    Node* temp = head;
    while (temp != nullptr) {
        if (temp->data == value) {
            return true;
        }
        temp = temp->next;
    }
    return false;
}

int main() {
    Node* head = nullptr;
    if (search(head, 10)) {
        cout << "Found!" << endl;
    } else {
        cout << "Not Found!" << endl;
    }
    return 0;
}
```



```
Not Found!

--------------------------------
Process exited after 0.05357 seconds with return value 0
Press any key to continue . . .
```

8. Updating an Element

```
#include <iostream>
using namespace std;

struct Node {
   int data;
   Node* next;
};

void update(Node* head, int oldValue, int newValue) {
   Node* temp = head;
   while (temp != nullptr) {
      if (temp->data == oldValue) {
         temp->data = newValue;
         cout << "Node with value " << oldValue << " updated to " << newValue << "." <<
endl;
         return;
      }
      temp = temp->next;
   }
   cout << "Element not found!" << endl;
}

int main() {
   Node* head = nullptr;
   update(head, 10, 20); // Testing on empty list
   return 0;
}
```

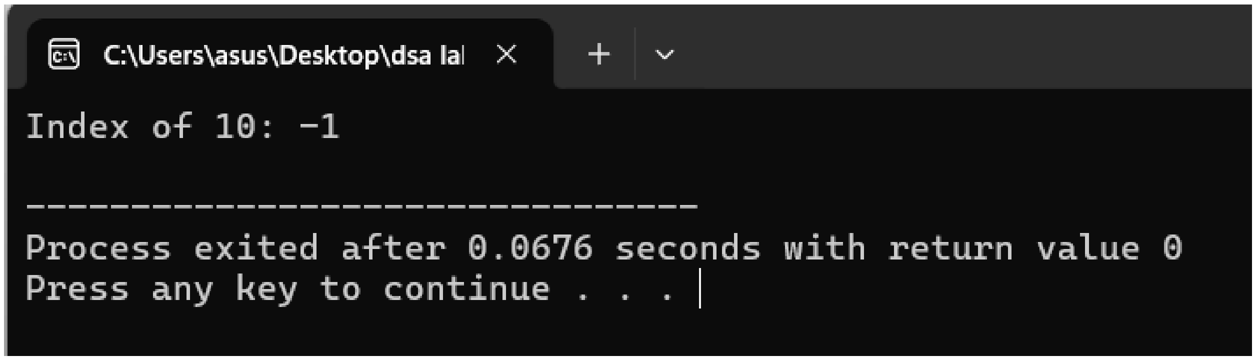


```
Element not found!

--------------------------------
Process exited after 0.06284 seconds with return value 0
Press any key to continue . . .
```

9. Finding Index of an Element

```
#include <iostream>
```

```
using namespace std;

struct Node {
   int data;
   Node* next;
};

int findIndex(Node* head, int value) {
   Node* temp = head;
   int index = 0;

   while (temp != nullptr) {
      if (temp->data == value) {
         return index;
      }
      temp = temp->next;
      index++;
   }

   return -1; // Not found
}

int main() {
   Node* head = nullptr;
   cout << "Index of 10: " << findIndex(head, 10) << endl; // Testing on empty list
   return 0;
}
```

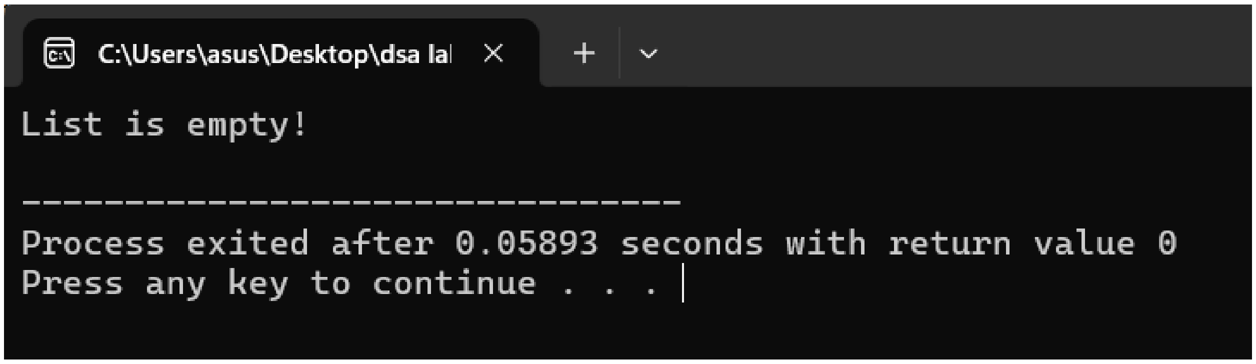


```
Index of 10: -1

--------------------------------
Process exited after 0.0676 seconds with return value 0
Press any key to continue . . .
```

10.Traversing the List

```
#include <iostream>
using namespace std;
```

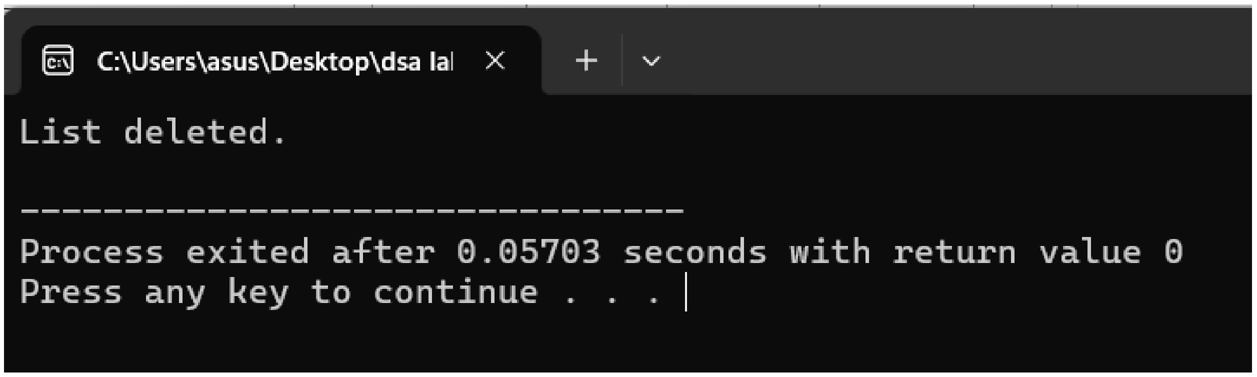
```
struct Node {
    int data;
    Node* next;
};

void traverse(Node* head) {
    Node* temp = head;
    if (temp == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }
    cout << "List elements: ";
    while (temp != nullptr) {
        cout << temp->data << " ";
        temp = temp->next;
    }
    cout << endl;
}

int main() {
    Node* head = nullptr;
    traverse(head); // Testing on empty list
    return 0;
}
```



```
List is empty!

--------------------------------
Process exited after 0.05893 seconds with return value 0
Press any key to continue . . .
```

11. Deleting the List

```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
};

void deleteList(Node*& head) {
    Node* temp;
    while (head != nullptr) {
       temp = head;
       head = head->next;
       delete temp;
    }
    cout << "List deleted." << endl;
}

int main() {
    Node* head = nullptr;
    deleteList(head); // Testing on empty list
    return 0;
}
```



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```
List deleted.

--------------------------------
Process exited after 0.05703 seconds with return value 0
Press any key to continue . . .
```

Lab 05 - Double Linked List (DLL)

What is Double Linked List (DLL)?

A **Double Linked List** is a type of linked list where each node contains three parts:

1. **Data**
2. **Next** (points to the next node)
3. **Prev** (points to the previous node)

Advantages:

1. **Bidirectional Traversal**: Can traverse both forwards and backwards.
2. **Easier Deletion**: Can delete a node easily with access to the previous node.

3. **Efficient Operations**: Insertion and deletion are more efficient at both ends.

Disadvantages:

1. **Extra Memory**: Requires more memory for the prev pointer.
2. **Complexity**: More complex than singly linked lists.

Types:

1. **Normal DLL**: Each node points to both the next and previous nodes.
2. **Circular DLL**: The last node points to the head, and the head points back to the last node.

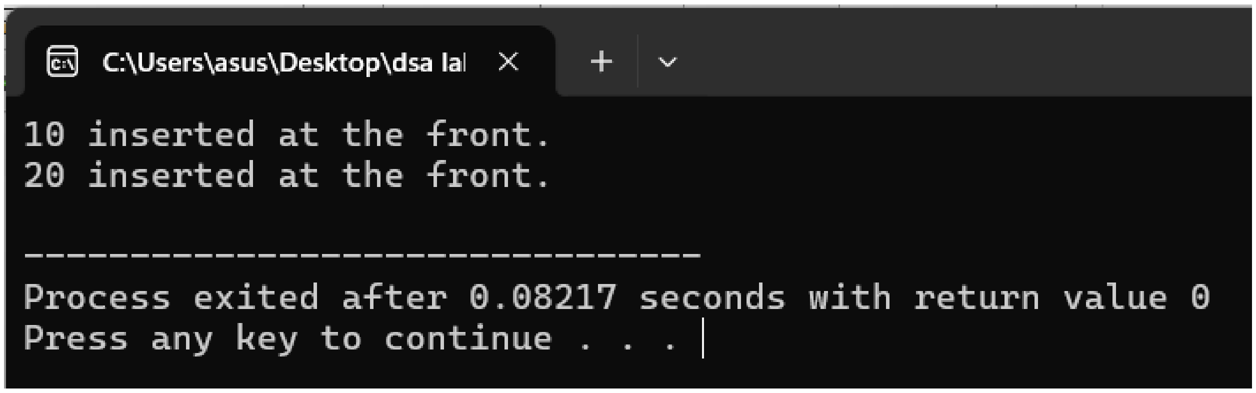
Real-life Uses:

- **Browser History**
- **Undo/Redo operations**
- **Navigation systems** (e.g., media players)

Example:

1. Insertion at the Front

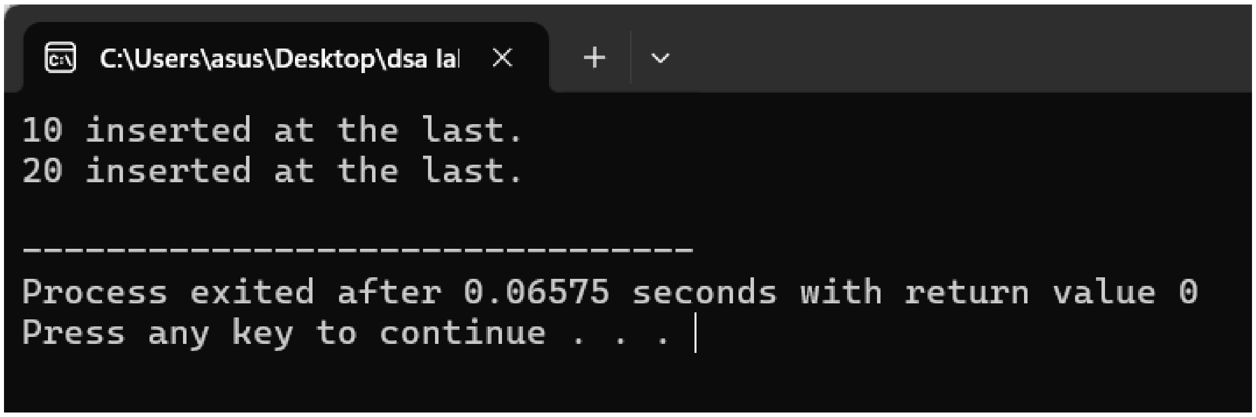
```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
    Node* prev;
};

void insertFront(Node*& head, int value) {
    Node* newNode = new Node();
    newNode->data = value;
    newNode->next = head;
    newNode->prev = nullptr;
    if (head != nullptr) {
        head->prev = newNode;
    }
    head = newNode;
    cout << value << " inserted at the front." << endl;
}

int main() {
    Node* head = nullptr;
    insertFront(head, 10);
    insertFront(head, 20);
    return 0;
}
```



```
10 inserted at the front.
20 inserted at the front.

--------------------------------
Process exited after 0.08217 seconds with return value 0
Press any key to continue . . .
```

2. Insertion at the Last

```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
    Node* prev;
};

void insertLast(Node*& head, int value) {
    Node* newNode = new Node();
    newNode->data = value;
    newNode->next = nullptr;

    if (head == nullptr) {
        newNode->prev = nullptr;
        head = newNode;
        cout << value << " inserted at the last." << endl;
        return;
    }

    Node* temp = head;
    while (temp->next != nullptr) {
        temp = temp->next;
    }
    temp->next = newNode;
    newNode->prev = temp;
    cout << value << " inserted at the last." << endl;
}

int main() {
    Node* head = nullptr;
    insertLast(head, 10);
    insertLast(head, 20);

    return 0;

}
```

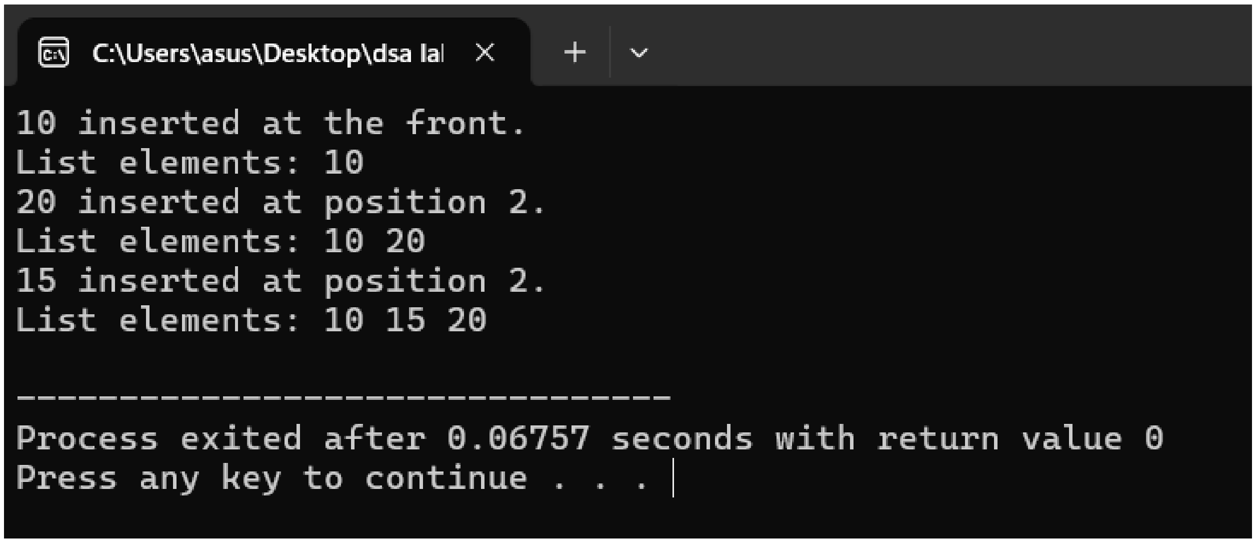


```
10 inserted at the last.
20 inserted at the last.

--------------------------------
Process exited after 0.06575 seconds with return value 0
Press any key to continue . . .
```

3. **Insertion at Middle (Specific Position)**

```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
    Node* prev;
};

// Function to insert at the front
void insertFront(Node*& head, int value) {
    Node* newNode = new Node();
    newNode->data = value;
    newNode->next = head;
    newNode->prev = nullptr;

    if (head != nullptr) {
        head->prev = newNode;
    }
    head = newNode;
    cout << value << " inserted at the front." << endl;
}

// Function to insert at the middle (specific position)
void insertMid(Node*& head, int value, int position) {
    if (position == 1) {
        insertFront(head, value);
        return;
    }

    Node* temp = head;
    for (int i = 1; i < position - 1 && temp != nullptr; i++) {
        temp = temp->next;
    }

    if (temp == nullptr) {
        cout << "Position out of range!" << endl;
        return;
    }

    Node* newNode = new Node();
    newNode->data = value;
    newNode->next = temp->next;
    newNode->prev = temp;

    if (temp->next != nullptr) {
        temp->next->prev = newNode;
    }
    temp->next = newNode;
    cout << value << " inserted at position " << position << "." << endl;
}

// Function to traverse and display the list
void traverse(Node* head) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }

    cout << "List elements: ";
    Node* temp = head;
    while (temp != nullptr) {
        cout << temp->data << " ";
        temp = temp->next;
    }
    cout << endl;
```

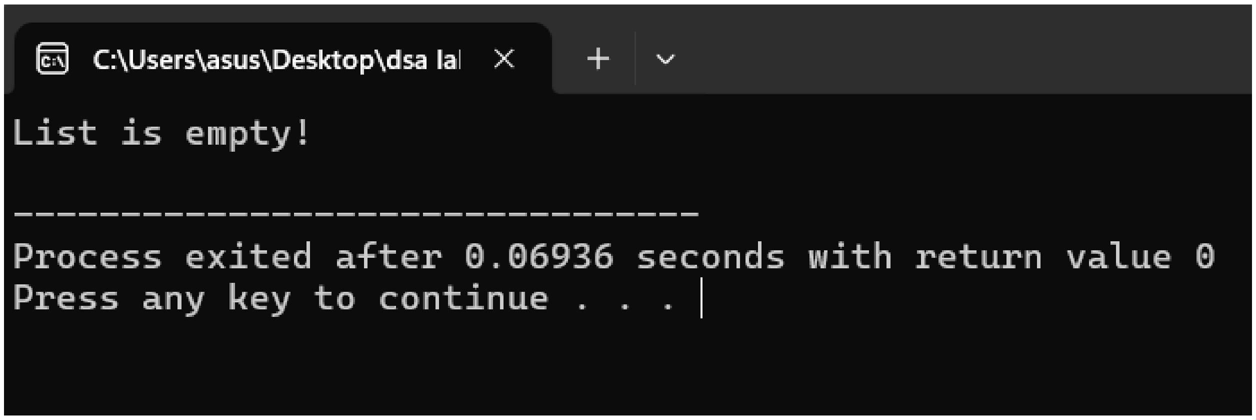
```
}

int main() {
    Node* head = nullptr;

    insertMid(head, 10, 1); // Insert at position 1
    traverse(head);

    insertMid(head, 20, 2); // Insert at position 2
    traverse(head);

    insertMid(head, 15, 2); // Insert at position 2
    traverse(head);

    return 0;
}
```



```
10 inserted at the front.
List elements: 10
20 inserted at position 2.
List elements: 10 20
15 inserted at position 2.
List elements: 10 15 20

--------------------------------
Process exited after 0.06757 seconds with return value 0
Press any key to continue . . .
```

4. Deletion from the Front

```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
    Node* prev;
};

void deleteFront(Node*& head) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }

    Node* temp = head;
    head = head->next;

    if (head != nullptr) {
        head->prev = nullptr;
    }

    delete temp;
    cout << "Node deleted from the front." << endl;
}

int main() {
    Node* head = nullptr;
    deleteFront(head); // Test on an empty list
    return 0;
}
```

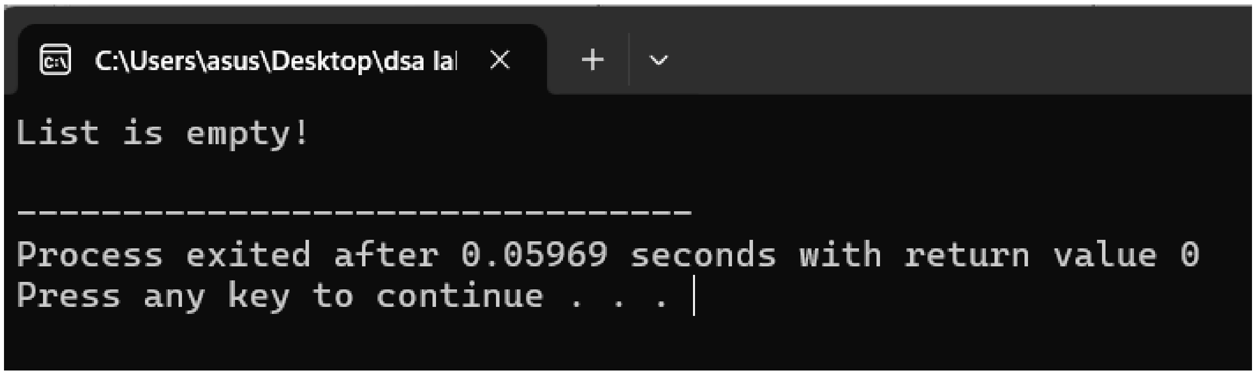


```
List is empty!

--------------------------------
Process exited after 0.06936 seconds with return value 0
Press any key to continue . . .
```

5. Deletion from the Last

```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
    Node* prev;
};
```

```
void deleteLast(Node*& head) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }

    if (head->next == nullptr) {
        delete head;
        head = nullptr;
        cout << "Node deleted from the last." << endl;
        return;
    }

    Node* temp = head;
    while (temp->next != nullptr) {
        temp = temp->next;
    }

    temp->prev->next = nullptr;
    delete temp;
    cout << "Node deleted from the last." << endl;
}

int main() {
    Node* head = nullptr;
    deleteLast(head); // Test on an empty list
    return 0;
}
```



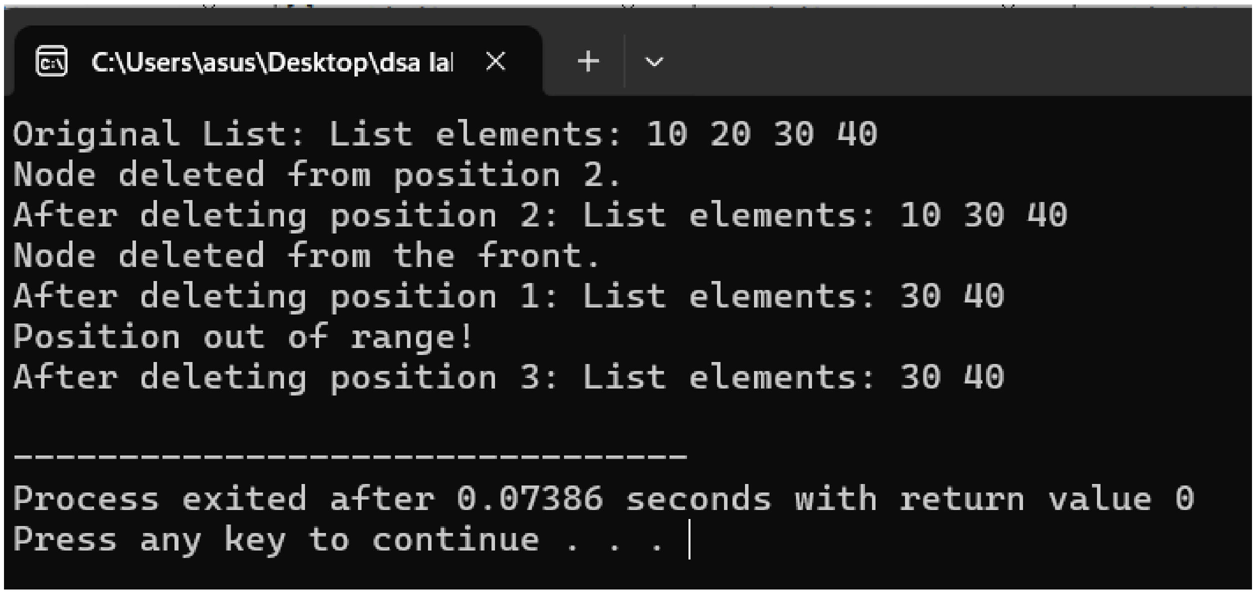
```
List is empty!

--------------------------------
Process exited after 0.05969 seconds with return value 0
Press any key to continue . . .
```

6. Deletion from the Middle (Specific Position)

```
#include <iostream>
```

```
using namespace std;

struct Node {
   int data;
   Node* next;
   Node* prev;
};

// Function to delete a node from the front
void deleteFront(Node*& head) {
   if (head == nullptr) {
      cout << "List is empty!" << endl;
      return;
   }

   Node* temp = head;
   head = head->next;

   if (head != nullptr) {
      head->prev = nullptr;
   }

   delete temp;
   cout << "Node deleted from the front." << endl;
}

// Function to delete a node from a specific position
void deleteMid(Node*& head, int position) {
   if (head == nullptr) {
      cout << "List is empty!" << endl;
      return;
   }

   if (position == 1) {
      deleteFront(head); // Reuse deleteFront
      return;
   }

   Node* temp = head;
   for (int i = 1; i < position && temp != nullptr; i++) {
      temp = temp->next;
```

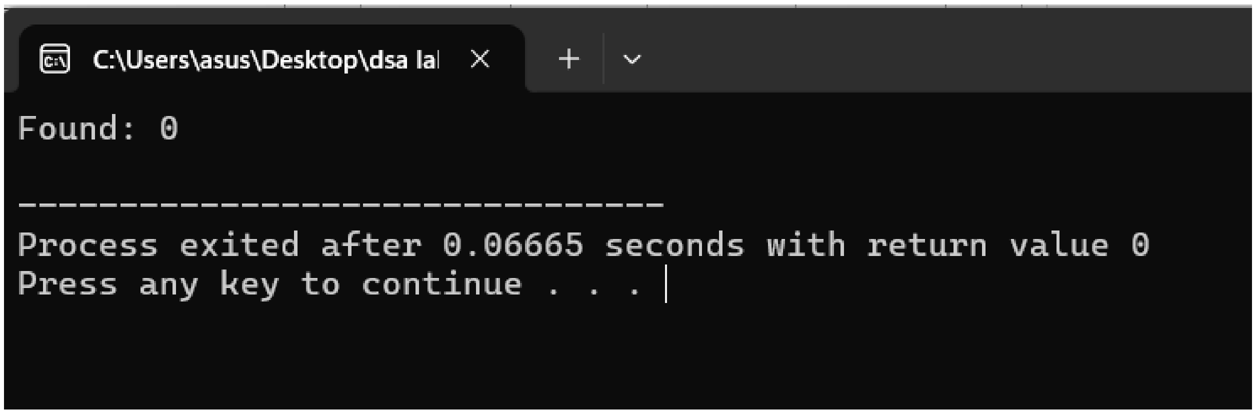
```
    }

    if (temp == nullptr) {
        cout << "Position out of range!" << endl;
        return;
    }

    if (temp->next != nullptr) {
        temp->next->prev = temp->prev;
    }

    if (temp->prev != nullptr) {
        temp->prev->next = temp->next;
    }

    delete temp;
    cout << "Node deleted from position " << position << "." << endl;
}

// Function to traverse and display the list
void traverse(Node* head) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }

    cout << "List elements: ";
    Node* temp = head;
    while (temp != nullptr) {
        cout << temp->data << " ";
        temp = temp->next;
    }
    cout << endl;
}

// Function to insert a node at the end for testing
void insertLast(Node*& head, int value) {
    Node* newNode = new Node();
    newNode->data = value;
    newNode->next = nullptr;
    if (head == nullptr) {
        newNode->prev = nullptr;
        head = newNode;
        return;
    }

    Node* temp = head;
    while (temp->next != nullptr) {
        temp = temp->next;
    }

    temp->next = newNode;
    newNode->prev = temp;
}

int main() {
    Node* head = nullptr;

    // Insert nodes for testing
    insertLast(head, 10);
    insertLast(head, 20);
    insertLast(head, 30);
    insertLast(head, 40);

    cout << "Original List: ";
    traverse(head);

    deleteMid(head, 2); // Delete the node at position 2
    cout << "After deleting position 2: ";
    traverse(head);

    deleteMid(head, 1); // Delete the node at position 1
    cout << "After deleting position 1: ";
    traverse(head);

    deleteMid(head, 3); // Delete the node at position 3
    cout << "After deleting position 3: ";
    traverse(head);

    return 0;
}
```



```
Original List: List elements: 10 20 30 40
Node deleted from position 2.
After deleting position 2: List elements: 10 30 40
Node deleted from the front.
After deleting position 1: List elements: 30 40
Position out of range!
After deleting position 3: List elements: 30 40

--------------------------------
Process exited after 0.07386 seconds with return value 0
Press any key to continue . . .
```

7. Searching

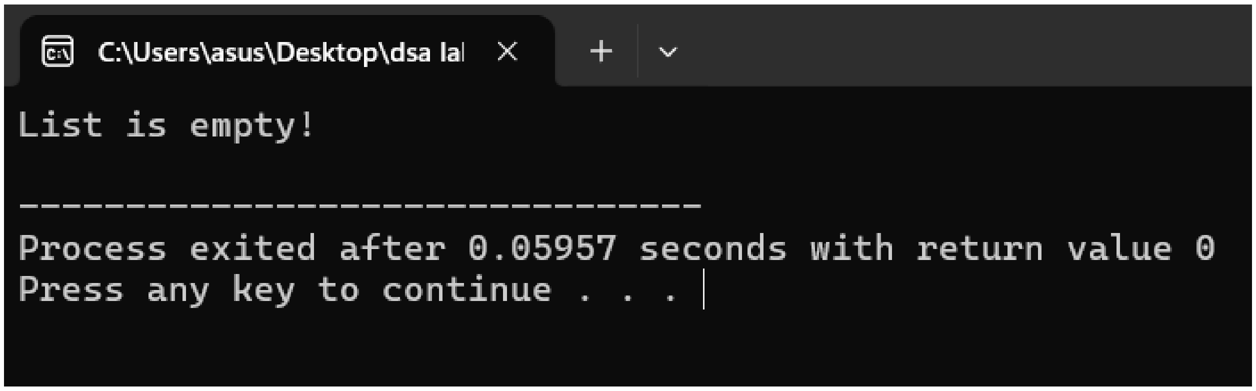
```
#include <iostream>
using namespace std;

struct Node {
   int data;
   Node* next;
   Node* prev;
};

bool search(Node* head, int value) {
   Node* temp = head;
   while (temp != nullptr) {
      if (temp->data == value) {
         return true;
      }
      temp = temp->next;
   }
   return false;
}

int main() {
   Node* head = nullptr;
   cout << "Found: " << search(head, 10) << endl; // Test on an empty list
   return 0;
}
```



```
Found: 0

--------------------------------
Process exited after 0.06665 seconds with return value 0
Press any key to continue . . .
```

8. Traversing the List

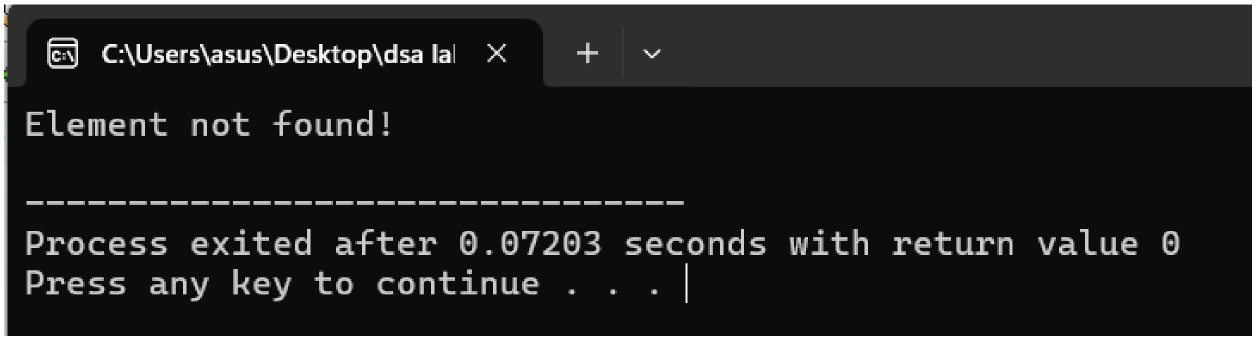
```
#include <iostream>
using namespace std;

struct Node {
   int data;
   Node* next;
   Node* prev;
};

void traverse(Node* head) {
   if (head == nullptr) {
      cout << "List is empty!" << endl;
      return;
   }

   Node* temp = head;
   cout << "List elements: ";
   while (temp != nullptr) {
      cout << temp->data << " ";
      temp = temp->next;
   }
   cout << endl;
}

int main() {
   Node* head = nullptr;
   traverse(head); // Test on an empty list
   return 0;
}
```



```
List is empty!

--------------------------------
Process exited after 0.05957 seconds with return value 0
Press any key to continue . . .
```

9. Update a Node

```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
    Node* prev;
};

void update(Node* head, int oldValue, int newValue) {
    Node* temp = head;
    while (temp != nullptr) {
        if (temp->data == oldValue) {
            temp->data = newValue;
            cout << "Updated value " << oldValue << " to " << newValue << endl;
            return;
        }
        temp = temp->next;
    }
    cout << "Element not found!" << endl;
}

int main() {
    Node* head = nullptr;
    update(head, 10, 20); // Test on an empty list
    return 0;
}
```



```
Element not found!

--------------------------------
Process exited after 0.07203 seconds with return value 0
Press any key to continue . . .
```

Lab 06 - Circular Linked List

What is Circular Linked List?

A Circular Linked List is a type of linked list where the last node points back to the first node, forming a loop.

Advantages:

1. **Continuous Traversal**: No need to reset the pointer; you can keep looping through the list.
2. **Efficient Memory Use**: Useful for tasks that require circular or repeated processing.

Applications:

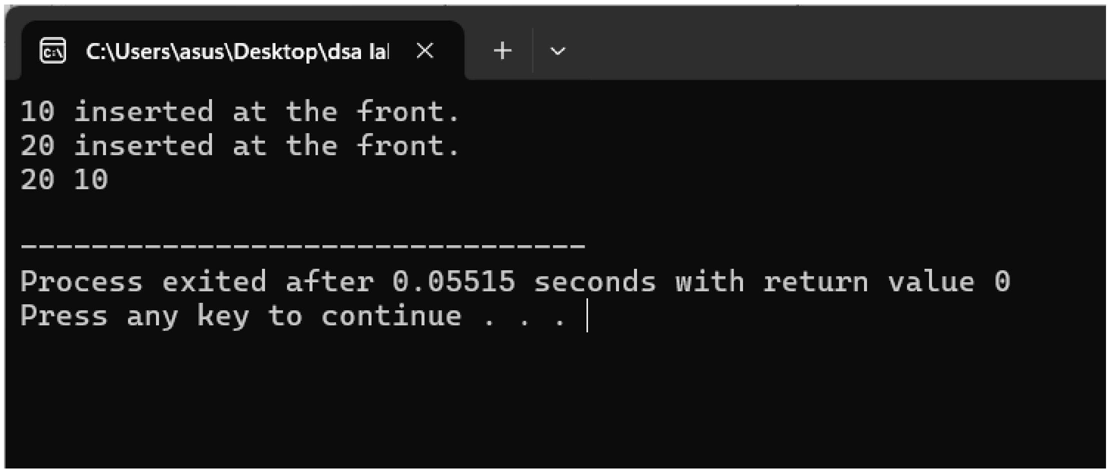
1. **Round Robin Scheduling** in OS.
2. **Circular Buffers** for data handling.
3. **Music Playlists** that loop indefinitely.
4. **Circular Queues** for continuous processing.

Example:

1. **Insertion at Front**

```
#include <iostream>
using namespace std;

struct Node {
  int data;
  Node* next;
```

```
};

void insertFront(Node*& head, int value) {
    Node* newNode = new Node();
    newNode->data = value;

    if (head == nullptr) {
        newNode->next = newNode;
        head = newNode;
    } else {
        Node* temp = head;
        while (temp->next != head) {
            temp = temp->next;
        }
        newNode->next = head;
        temp->next = newNode;
        head = newNode;
    }
    cout << value << " inserted at the front." << endl;
}

void traverse(Node* head) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }
    Node* temp = head;
    do {
        cout << temp->data << " ";
        temp = temp->next;
    } while (temp != head);
    cout << endl;
}

int main() {
    Node* head = nullptr;

    insertFront(head, 10);
    insertFront(head, 20);
    traverse(head);
    return 0;
}
```

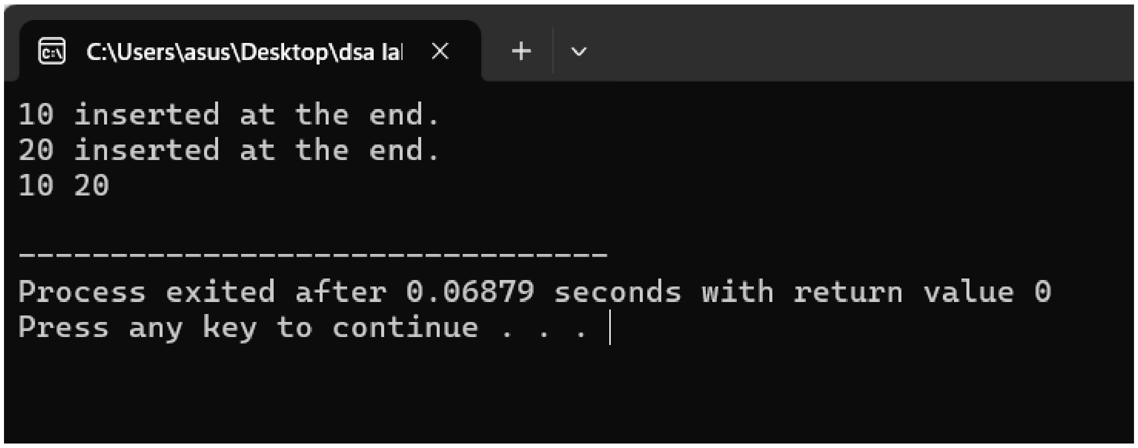


```
C:\Users\asus\Desktop\dsa lal
10 inserted at the front.
20 inserted at the front.
20 10

--------------------------------
Process exited after 0.05515 seconds with return value 0
Press any key to continue . . .
```

2. Insertion at Last

```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
};

void insertLast(Node*& head, int value) {
    Node* newNode = new Node();
    newNode->data = value;

    if (head == nullptr) {
        newNode->next = newNode;
        head = newNode;
    } else {
        Node* temp = head;
        while (temp->next != head) {
            temp = temp->next;
        }
        temp->next = newNode;
        newNode->next = head;
    }
    cout << value << " inserted at the end." << endl;
}
```

```
void traverse(Node* head) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }
    Node* temp = head;
    do {
        cout << temp->data << " ";
        temp = temp->next;
    } while (temp != head);
    cout << endl;
}

int main() {
    Node* head = nullptr;

    insertLast(head, 10);
    insertLast(head, 20);
    traverse(head);

    return 0;
}
```



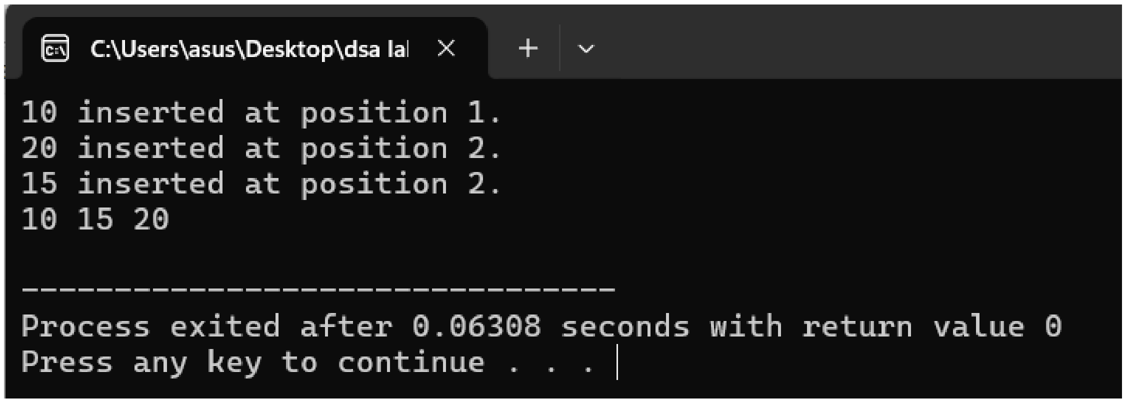
C:\Users\asus\Desktop\dsa lal

```
10 inserted at the end.
20 inserted at the end.
10 20

--------------------------------
Process exited after 0.06879 seconds with return value 0
Press any key to continue . . .
```

3. Insertion at a Specific Position

```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
};

void insertMid(Node*& head, int value, int position) {
    if (position == 1) {
        Node* newNode = new Node();
        newNode->data = value;

        if (head == nullptr) {
            newNode->next = newNode;
            head = newNode;
        } else {
            Node* temp = head;
            while (temp->next != head) {
                temp = temp->next;
            }
            newNode->next = head;
            temp->next = newNode;
            head = newNode;
        }
        cout << value << " inserted at position 1." << endl;
        return;
    }

    Node* temp = head;
    for (int i = 1; i < position - 1 && temp->next != head; i++) {
        temp = temp->next;
    }

    if (temp->next == head && position > 2) {
        cout << "Position out of range!" << endl;
        return;
    }

    Node* newNode = new Node();
    newNode->data = value;
    newNode->next = temp->next;
    temp->next = newNode;

    cout << value << " inserted at position " << position << "." << endl;
}
```

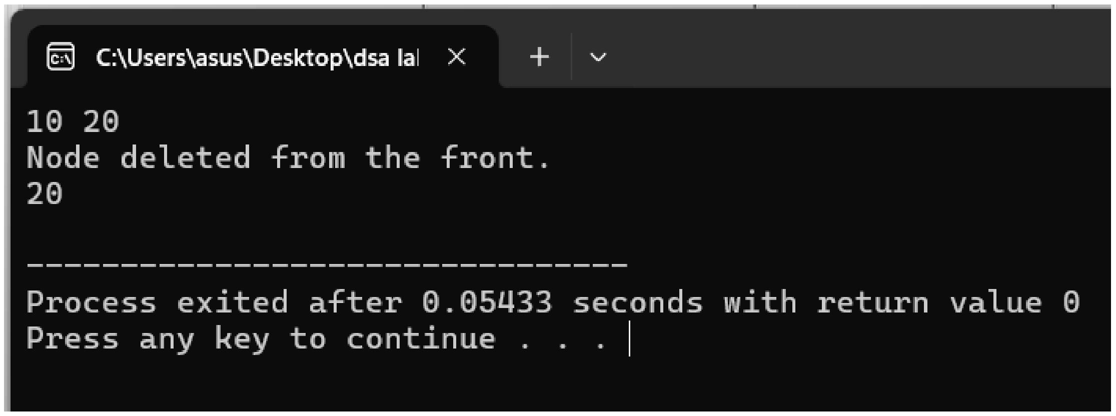
```
void traverse(Node* head) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }
    Node* temp = head;
    do {
        cout << temp->data << " ";
        temp = temp->next;
    } while (temp != head);
    cout << endl;
}

int main() {
    Node* head = nullptr;

    insertMid(head, 10, 1);
    insertMid(head, 20, 2);
    insertMid(head, 15, 2);
    traverse(head);

    return 0;
}
```



```
10 inserted at position 1.
20 inserted at position 2.
15 inserted at position 2.
10 15 20

--------------------------------
Process exited after 0.06308 seconds with return value 0
Press any key to continue . . .
```

4. Deletion from Front

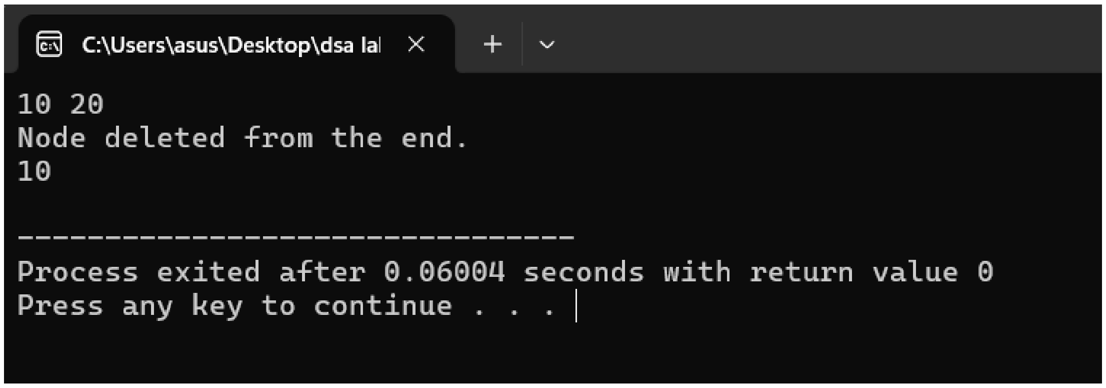
```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
};

void deleteFront(Node*& head) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }

    if (head->next == head) {
        delete head;
        head = nullptr;
    } else {
        Node* temp = head;
        Node* last = head;
        while (last->next != head) {
            last = last->next;
        }

        head = head->next;
        last->next = head;
        delete temp;
    }
    cout << "Node deleted from the front." << endl;
}

void traverse(Node* head) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }
    Node* temp = head;
    do {
        cout << temp->data << " ";
        temp = temp->next;
    } while (temp != head);
    cout << endl;
}

int main() {
    Node* head = nullptr;
    // Example: Inserting some nodes
    Node* newNode = new Node();
    newNode->data = 10;
    head = newNode;
    head->next = head;

    Node* second = new Node();
    second->data = 20;
    second->next = head;
    head->next = second;

    traverse(head);
    deleteFront(head);
    traverse(head);

    return 0;
}
```



```
C:\Users\asus\Desktop\dsa lal
10 20
Node deleted from the front.
20

--------------------------------
Process exited after 0.05433 seconds with return value 0
Press any key to continue . . .
```

5.Deletion from Last

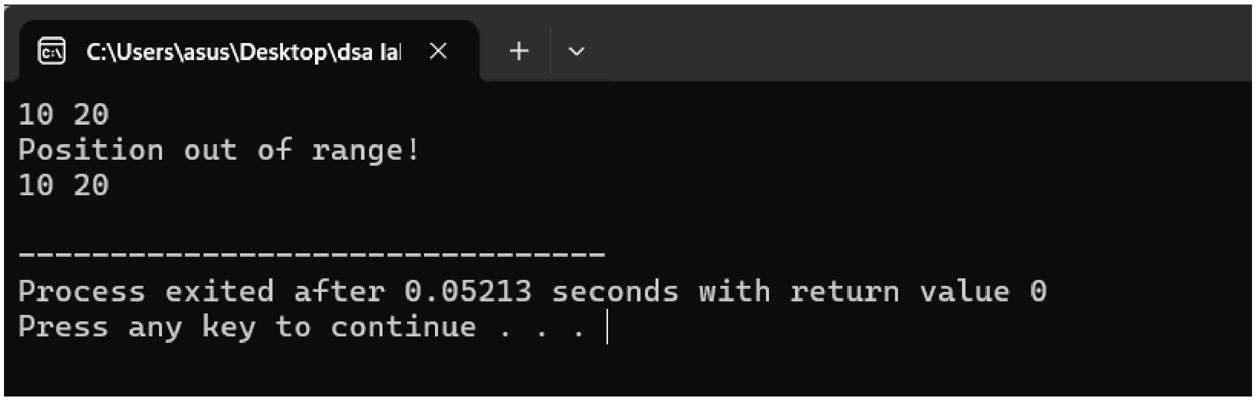
```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
};

void deleteLast(Node*& head) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }

    if (head->next == head) {
        delete head;
        head = nullptr;
    } else {
        Node* temp = head;
        Node* prev = nullptr;
        while (temp->next != head) {
            prev = temp;
            temp = temp->next;
        }
        prev->next = head;
        delete temp;
    }
    cout << "Node deleted from the end." << endl;
}

void traverse(Node* head) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }
    Node* temp = head;
    do {
        cout << temp->data << " ";
        temp = temp->next;
    } while (temp != head);
    cout << endl;
}

int main() {
    Node* head = nullptr;

    // Example: Inserting some nodes
    Node* newNode = new Node();
    newNode->data = 10;
    head = newNode;
    head->next = head;
    Node* second = new Node();
    second->data = 20;
    second->next = head;
    head->next = second;

    traverse(head);
    deleteLast(head);
    traverse(head);

    return 0;
}
```



```
10 20
Node deleted from the end.
10

--------------------------------
Process exited after 0.06004 seconds with return value 0
Press any key to continue . . .
```

6.Deletion from a Specific Position

```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
};

void deleteMid(Node*& head, int position) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }

    if (position == 1) {
        if (head->next == head) {
            delete head;
            head = nullptr;
        } else {
            Node* temp = head;
            Node* last = head;
            while (last->next != head) {
                last = last->next;
            }
            head = head->next;
            last->next = head;
            delete temp;
        }
        cout << "Node deleted from position 1." << endl;
        return;
    }

    Node* temp = head;
    Node* prev = nullptr;
    for (int i = 1; i < position && temp->next != head; i++) {
        prev = temp;
        temp = temp->next;
    }

    if (temp->next == head && position > 1) {
        cout << "Position out of range!" << endl;
        return;
    }

    prev->next = temp->next;
    delete temp;
    cout << "Node deleted from position " << position << "." << endl;
}

void traverse(Node* head) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }
    Node* temp = head;
    do {
        cout << temp->data << " ";
        temp = temp->next;
    } while (temp != head);
    cout << endl;
}

int main() {
    Node* head = nullptr;

    // Example: Inserting some nodes
    Node* newNode = new Node();
    newNode->data = 10;
    head = newNode;
    head->next = head;

    Node* second = new Node();
    second->data = 20;
    second->next = head;
    head->next = second;

    traverse(head);
    deleteMid(head, 2);
    traverse(head);

    return 0;
}
```



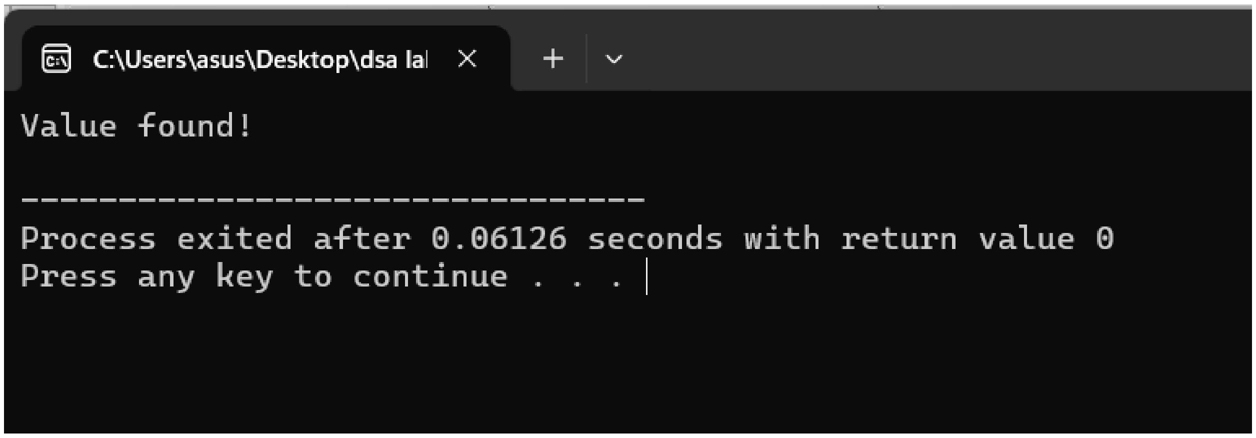
```
10 20
Position out of range!
10 20

--------------------------------
Process exited after 0.05213 seconds with return value 0
Press any key to continue . . .
```

7.Searching

```
#include <iostream>
using namespace std;
```

```
struct Node {
    int data;
    Node* next;
};

bool search(Node* head, int value) {
    if (head == nullptr) {
        return false;
    }

    Node* temp = head;
    do {
        if (temp->data == value) {
            return true;
        }
        temp = temp->next;
    } while (temp != head);

    return false;
}

int main() {
    Node* head = nullptr;

    // Example: Creating a circular linked list
    Node* newNode = new Node();
    newNode->data = 10;
    head = newNode;
    head->next = head;

    Node* second = new Node();
    second->data = 20;
    second->next = head;
    head->next = second;

    if (search(head, 20)) {
        cout << "Value found!" << endl;
    } else {
        cout << "Value not found!" << endl;
    }
```

```
   return 0;
}
```



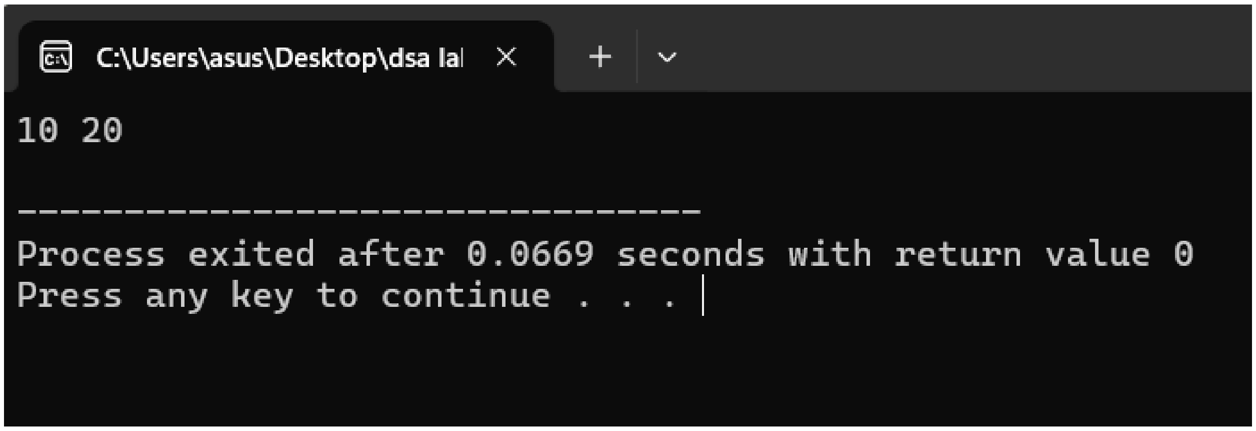
C:\Users\asus\Desktop\dsa lal

```
Value found!

--------------------------------
Process exited after 0.06126 seconds with return value 0
Press any key to continue . . .
```

8. Traversing

```
#include <iostream>
using namespace std;

struct Node {
   int data;
   Node* next;
};

void traverse(Node* head) {
   if (head == nullptr) {
      cout << "List is empty!" << endl;
      return;
   }
   Node* temp = head;
   do {
      cout << temp->data << " ";
      temp = temp->next;
   } while (temp != head);
   cout << endl;
}

int main() {
   Node* head = nullptr;

   // Example: Creating a circular linked list
   Node* newNode = new Node();
```

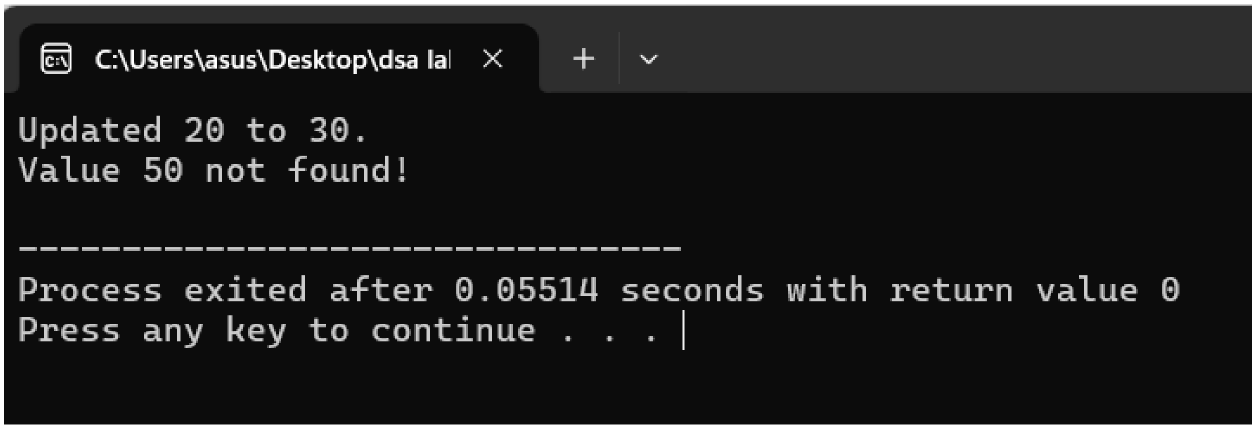
```
    newNode->data = 10;
    head = newNode;
    head->next = head;

    Node* second = new Node();
    second->data = 20;
    second->next = head;
    head->next = second;

    traverse(head);

    return 0;
}
```



```
C:\Users\asus\Desktop\dsa lal

10 20

--------------------------------
Process exited after 0.0669 seconds with return value 0
Press any key to continue . . .
```

9.Update

```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* next;
};

void update(Node* head, int oldValue, int newValue) {
    if (head == nullptr) {
        cout << "List is empty!" << endl;
        return;
    }

    Node* temp = head;
    do {
        if (temp->data == oldValue) {
            temp->data = newValue;
            cout << "Updated " << oldValue << " to " << newValue << "." << endl;
            return;
        }
        temp = temp->next;
    } while (temp != head);

    cout << "Value " << oldValue << " not found!" << endl;
}

int main() {
    Node* head = nullptr;

    // Example: Creating a circular linked list
    Node* newNode = new Node();
    newNode->data = 10;
    head = newNode;
    head->next = head;

    Node* second = new Node();
    second->data = 20;
    second->next = head;
    head->next = second;

    update(head, 20, 30);
    update(head, 50, 60);

    return 0;
}
```



```
Updated 20 to 30.
Value 50 not found!

--------------------------------
Process exited after 0.05514 seconds with return value 0
Press any key to continue . . .
```

Lab 07 - Binary Search Tree (BST)

What is Binary Search Tree (BST)?

A **Binary Search Tree** is a type of binary tree where each node has at most two children. It follows these properties:

- Left subtree nodes are smaller than the root.
- Right subtree nodes are larger than the root.
- No duplicate values are allowed.

Advantages:

1. **Efficient searching** with O(log⁡n)O(\log n)O(logn) time complexity (in balanced trees).
2. **Dynamic structure**, grows and shrinks as needed.
3. **Sorted data** can be retrieved via in-order traversal.
4. **Efficient insertion and deletion** in balanced trees.

Types of BST:

1. **Normal BST:** No balance enforced.
2. **Balanced BST:** Like AVL or Red-Black Trees, maintains O(log⁡n)O(\log n)O(logn) operations.
3. **Unbalanced BST:** Can degrade to linked list form, causing O(n)O(n)O(n) operations.

Applications:

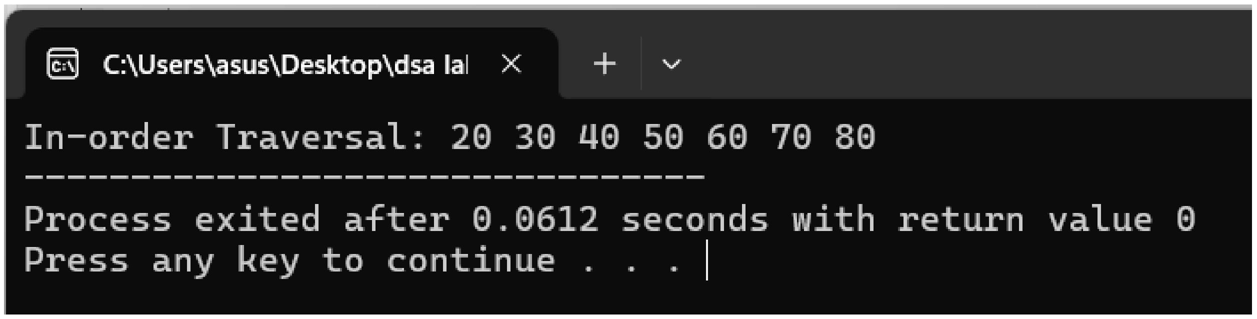
1. **Database indexing**
2. **File systems**
3. **Dictionary implementation**
4. **Routing tables** in networks

Examples:

1. Insertion in Binary Search Tree

```
#include <iostream>
using namespace std;

struct Node {
   int data;
   Node* left;
   Node* right;
};
```

```
Node* insert(Node* root, int value) {
   if (root == nullptr) {
      root = new Node();
      root->data = value;
      root->left = root->right = nullptr;
   } else if (value < root->data) {
      root->left = insert(root->left, value);
   } else {
      root->right = insert(root->right, value);
   }
   return root;
}

void inorderTraversal(Node* root) {
   if (root == nullptr) return;
   inorderTraversal(root->left);
   cout << root->data << " ";
   inorderTraversal(root->right);
}

int main() {
   Node* root = nullptr;
   root = insert(root, 50);
   insert(root, 30);
   insert(root, 20);
   insert(root, 40);
   insert(root, 70);
   insert(root, 60);
   insert(root, 80);

   cout << "In-order Traversal: ";
   inorderTraversal(root);
   return 0;
}
```

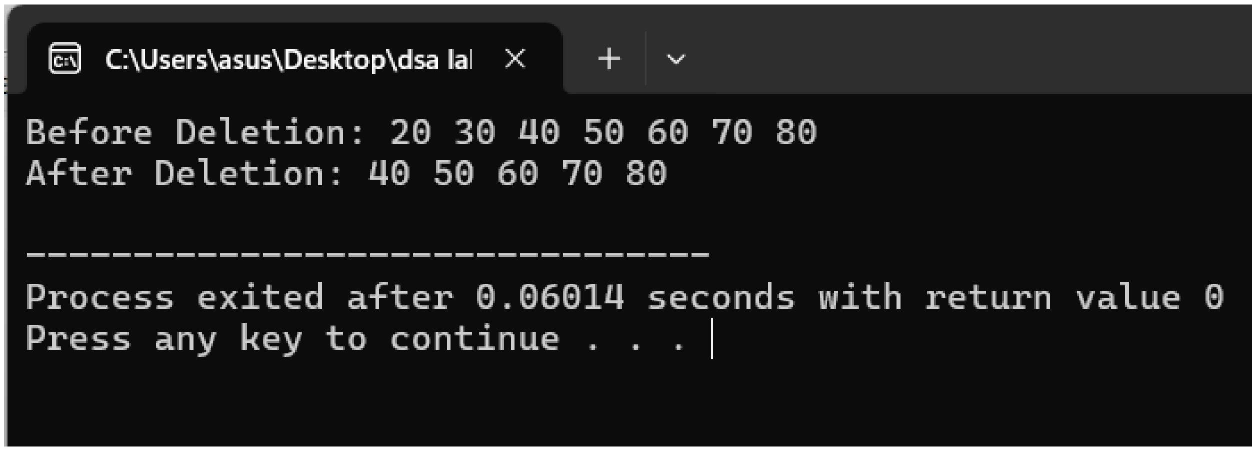

C:\Users\asus\Desktop\dsa lal

```
In-order Traversal: 20 30 40 50 60 70 80
--------------------------------
Process exited after 0.0612 seconds with return value 0
Press any key to continue . . .
```

2. Deletion in Binary Search Tree

```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* left;
    Node* right;

    // Constructor to initialize node
    Node(int value) {
        data = value;
        left = right = nullptr;
    }
};

// Insert function for Binary Search Tree
Node* insert(Node* root, int value) {
    if (root == nullptr) {
        return new Node(value);  // Create and return a new node if root is null
    }

    if (value < root->data) {
        root->left = insert(root->left, value);  // Insert in the left subtree
    } else {
        root->right = insert(root->right, value);  // Insert in the right subtree
    }

    return root;
}

// Find the minimum value node in a given tree
```

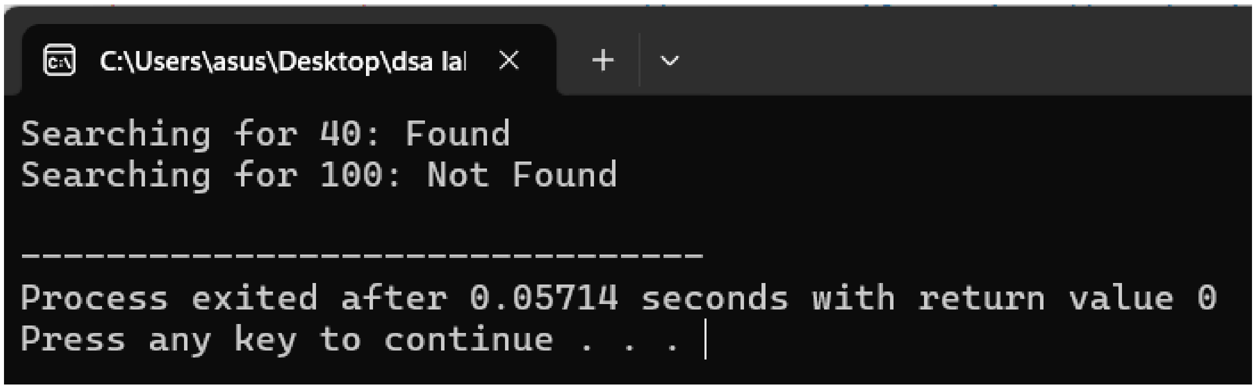
```
Node* findMin(Node* root) {
    while (root->left != nullptr) root = root->left;
    return root;
}

// Delete a node from the binary search tree
Node* deleteNode(Node* root, int value) {
    if (root == nullptr) return root;

    if (value < root->data) {
        root->left = deleteNode(root->left, value);  // Traverse left subtree
    } else if (value > root->data) {
        root->right = deleteNode(root->right, value);  // Traverse right subtree
    } else {
        // Node with only one child or no child
        if (root->left == nullptr) {
            Node* temp = root->right;
            delete root;
            return temp;
        } else if (root->right == nullptr) {
            Node* temp = root->left;
            delete root;
            return temp;
        }

        // Node with two children: get the inorder successor
        Node* temp = findMin(root->right);

        root->data = temp->data;  // Copy inorder successor's data to this node

        root->right = deleteNode(root->right, temp->data);  // Delete inorder successor
    }

    return root;
}

// In-order traversal of the binary search tree
void inorderTraversal(Node* root) {
    if (root == nullptr) return;
    inorderTraversal(root->left);
    cout << root->data << " ";
    inorderTraversal(root->right);
}

int main() {
    Node* root = nullptr;

    // Insert values into the binary search tree
    root = insert(root, 50);
    insert(root, 30);
    insert(root, 20);
    insert(root, 40);
    insert(root, 70);
    insert(root, 60);
    insert(root, 80);

    // Before Deletion
    cout << "Before Deletion: ";
    inorderTraversal(root);
    cout << endl;

    // Delete nodes
    root = deleteNode(root, 20);  // Delete node with value 20
    root = deleteNode(root, 30);  // Delete node with value 30

    // After Deletion
    cout << "After Deletion: ";
    inorderTraversal(root);
    cout << endl;

    return 0;
}
```



```
Before Deletion: 20 30 40 50 60 70 80
After Deletion: 40 50 60 70 80

--------------------------------
Process exited after 0.06014 seconds with return value 0
Press any key to continue . . .
```

3. Searching in Binary Search Tree

```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* left;
    Node* right;

    // Constructor to initialize node
    Node(int value) {
        data = value;
        left = right = nullptr;
    }
};

// Insert function for Binary Search Tree
Node* insert(Node* root, int value) {
    if (root == nullptr) {
        return new Node(value);  // Create and return a new node if root is null
    }

    if (value < root->data) {
        root->left = insert(root->left, value);  // Insert in the left subtree
    } else {
        root->right = insert(root->right, value);  // Insert in the right subtree
    }

    return root;
}

// Search function for Binary Search Tree
bool search(Node* root, int value) {
    if (root == nullptr) return false;  // Base case: if root is null, value is not found
    if (root->data == value) return true;  // If root's data matches the value, return true

    if (value < root->data) {
        return search(root->left, value);  // Search in the left subtree
    } else {
        return search(root->right, value);  // Search in the right subtree
    }
}

int main() {
    Node* root = nullptr;

    // Insert values into the binary search tree
    root = insert(root, 50);
    insert(root, 30);
    insert(root, 20);
    insert(root, 40);
    insert(root, 70);
    insert(root, 60);
    insert(root, 80);

    // Perform search operations
    cout << "Searching for 40: " << (search(root, 40) ? "Found" : "Not Found") << endl;
    cout << "Searching for 100: " << (search(root, 100) ? "Found" : "Not Found") << endl;

    return 0;
}
```



```
C:\Users\asus\Desktop\dsa lal
Searching for 40: Found
Searching for 100: Not Found

--------------------------------
Process exited after 0.05714 seconds with return value 0
Press any key to continue . . .
```

4.Traversal (In-order, Pre-order, Post-order)

In-order Traversal

```
#include <iostream>
using namespace std;

void inorderTraversal(Node* root) {
   if (root == nullptr) return;
   inorderTraversal(root->left);
   cout << root->data << " ";
   inorderTraversal(root->right);
}
```

Pre-order Traversal

```
#include <iostream>
using namespace std;

void preorderTraversal(Node* root) {
   if (root == nullptr) return;
   cout << root->data << " ";
   preorderTraversal(root->left);
   preorderTraversal(root->right);
}
```

Post-order Traversal

```
#include <iostream>
using namespace std;

void postorderTraversal(Node* root) {
   if (root == nullptr) return;
   postorderTraversal(root->left);
   postorderTraversal(root->right);
```

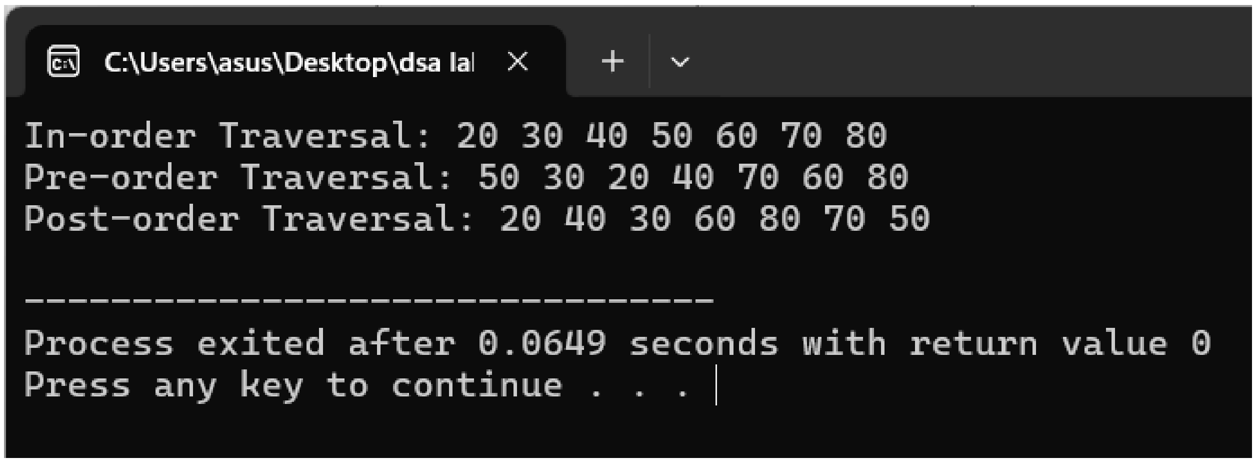
```
    cout << root->data << " ";
}
```

Main Program (Traversals)

```
#include <iostream>
using namespace std;

struct Node {
    int data;
    Node* left;
    Node* right;

    // Constructor to create a new node
    Node(int value) {
        data = value;
        left = right = nullptr;
    }
};

// Insertion function for Binary Search Tree
Node* insert(Node* root, int value) {
    if (root == nullptr) {
        return new Node(value);
    }

    if (value < root->data) {
        root->left = insert(root->left, value);
    } else {
        root->right = insert(root->right, value);
    }

    return root;
}

// In-order traversal: left, root, right
void inorderTraversal(Node* root) {
    if (root == nullptr) return;
    inorderTraversal(root->left);
    cout << root->data << " ";
    inorderTraversal(root->right);
}
```

```
// Pre-order traversal: root, left, right
void preorderTraversal(Node* root) {
   if (root == nullptr) return;
   cout << root->data << " ";
   preorderTraversal(root->left);
   preorderTraversal(root->right);
}

// Post-order traversal: left, right, root
void postorderTraversal(Node* root) {
   if (root == nullptr) return;
   postorderTraversal(root->left);
   postorderTraversal(root->right);
   cout << root->data << " ";
}

int main() {
   Node* root = nullptr;

   // Insert values into the binary search tree
   root = insert(root, 50);
   insert(root, 30);
   insert(root, 20);
   insert(root, 40);
   insert(root, 70);
   insert(root, 60);
   insert(root, 80);

   // Traversals
   cout << "In-order Traversal: ";
   inorderTraversal(root);
   cout << endl;

   cout << "Pre-order Traversal: ";
   preorderTraversal(root);
   cout << endl;

   cout << "Post-order Traversal: ";
   postorderTraversal(root);
   cout << endl;
```

```
    return 0;
}
```



C:\Users\asus\Desktop\dsa lal

```
In-order Traversal: 20 30 40 50 60 70 80
Pre-order Traversal: 50 30 20 40 70 60 80
Post-order Traversal: 20 40 30 60 80 70 50

--------------------------------
Process exited after 0.0649 seconds with return value 0
Press any key to continue . . .
```

End of Manual
