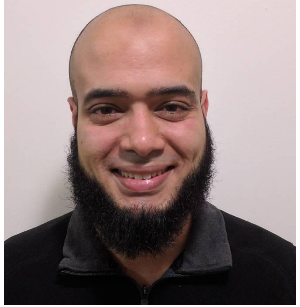
Data Structures

Effective Coding and Debugging for linked list

Mostafa S. Ibrahim
Teaching, Training and Coaching for more than a decade!

Artificial Intelligence & Computer Vision Researcher
PhD from Simon Fraser University - Canada
Bachelor / Msc from Cairo University - Egypt
Ex-(Software Engineer / ICPC World Finalist)



Draining your time

- Linked list challenges
  - Often involve deletion, insertion, and **relinking** of multiple nodes
- Linked list coding may drain your time
  - Several coding bugs
  - Several run-time errors
  - Hard to visualize
- Thinking time
  - It will also take time to get the right idea, but this is the ok part
- Take this video very seriously
  - It provides coding and debugging tips to save you as much time as possible!

Before thinking/coding

- List several test cases and their answers
- Consider lists of different sizes / even-odd size
- Consider the problem - and what might be tricky test cases
- This will make you aware of what kind of issues you need to handle
- Later, evaluate your code against all test cases
- Common mistakes
  - Avoiding the above before thinking about a tentative solution
  - To test over weak cases
  - We can all miss some good case, but the code should at least work for several cases

Thinking skills

- KISS: Keep it simple stupid
    - Some problems seem impossible at first - but you can do them! Calm down
    - Most problems can be coded elegantly in a few lines.
        - Sadly, too many instructors and websites take a longer path
    - Try to make things as simple as possible
- Sketch out your thoughts on paper, NOT on your computer
    - A very common mistake is to rush to code your idea
    - This can waste hours with run-time errors and buggy outputs
    - Think deeply when writing down your ideas. **Draw each step**.
        - Use addresses if needed
    - Verify & trace different test cases
    - This will boost your abstract thinking skills, save your time and boost your confidence
- Finally: Compare with my codes. Learn from them!

Coding skills

- Think modular
    - Avoid writing a lengthy function (even with code comments)
    - Every time you notice something can be converted to a helpful method, do it
    - Pick very clear names
    - The more you solve, the more you will notice how functions can be reused or recycled!
    - Document your functions: input, output and any conditions
- Tip: before coding decide the minimum number of needed elements
    - 1 node? 2 nodes? 3 nodes?
    - Without enough nodes, some approaches are destined to fail

Coding mistakes

- Incorrect algorithm
- Wrong order of operations
    - Sometimes you need to take a copy of a node’s next before cancelling its next
- Run time errors
    - node->next will throw an RTE if node is null
    - node->next->next will throw an RTE if node->next is null
    - Double-check them every time you use them in your code. Ensure:
        - The logic is correct
        - You are verifying against null first

Data Integrity

- Data integrity is the overall accuracy, completeness, and **consistency** of data
- What is our data?
  - head, tail and length
    - E.g. Head and tail should be null if empty
    - E.g. Length must be really the length of the items
- Write a function that verifies a linked list is correct
- Run it after your main algorithm is done (or intermediate if possible)
  - It can catch so many mistakes!
- Take 10 minutes to code it

Data Integrity

```
void debug_verify_data_integrity() {
    if (length == 0) {
        assert(head == nullptr);
        assert(tail == nullptr);
        return;
    }

    assert(head != nullptr);
    assert(tail != nullptr);
    assert(tail->next == nullptr);
```

Data Integrity

```
if (length == 1)
    assert(head == tail);
else {
    assert(head != tail);

    if (length == 2)
        assert(head->next == tail);
    else if (length == 3) {
        assert(head->next);
        assert(head->next->next == tail);
    }
}
```

Data Integrity

```
int len = 0;
Node *prev = nullptr;
for (Node *cur = head; cur; prev = cur, cur = cur->next, len++)
    assert(len < 10000);    // Consider infinite cycle?

assert(length == len);
assert(length == (int)debug_data.size());
assert(prev == tail);   // last node is tail
```

Node Destructor

- When we start deleting nodes (see future lectures), it is good to double-check what is removed

```
struct Node {
    int data { };
    Node* next { };
    Node(int data) : data(data) {}
    ~Node() {
        cout << "Destroy value: " << data <<" at address "<< this<< "\n";
    }
};
```

ToString for comparisons

- To easily compare your function result vs expected output, let's convert the data into a string, using this function:

```
string debug_to_string() {
    if (length == 0)
        return "";
    ostringstream oss;
    for (Node* cur = head; cur; cur = cur->next) {
        oss << cur->data;
        if (cur->next)
            oss << " ";
    }
    return oss.str();
}
```

Testing

- For each test case, develop its list & operations
- Update it
- Compare its content with the expected output
- From main, run all of your test functions

```
void test1() {
    cout << "\n\ntest1\n";
    LinkedList list;

    list.insert_end(1);
    list.insert_end(2);
    list.insert_end(3);
    list.insert_end(4);
    // some actions
    list.print();

    string expected = "1 2 3 4";
    string result = list.debug_to_string();
    if (expected != result) {
        cout << "no match:\nExpected: " <<
                expected << "\nResult  : " << result << "\n";
        assert(false);
    }
    list.debug_print_list("********");
}
```

Testing: Observe RTE

```
int main() {
    test1();
    test2();
    //test3();

    // must see it, otherwise RTE
    cout << "\n\nNO RTE\n";

    return 0;
}
```

```
test2
1 2 3 4
********
1 2 head
2 3
3 4
4 X tail
************


NO RTE
```

Prevent crashes

- Most of the code doesn't handle pointer copies correctly
  - It is not needed
- But students forget and do copy them
- These lines of code below will prevent this
  - It stops a linked list being returned from a function
  - It prevents a linked list being passed without &
  - It prevents a linked list being assigned

```
// Below 2 deletes prevent copy and assign to avoid this mistake
LinkedList() {
}
LinkedList(const LinkedList&) = delete;
LinkedList &operator=(const LinkedList &another) = delete;
```

Visualizing linked list

- In many cases, our links will be separated (-> next)
- This makes printing difficult
- A good way is to track the nodes and print their info
- Use a seperate vector to keep a record of the current nodes
- Print the queue nodes itself - not the linked list nodes

Visualizing linked list

- You don’t need to understand the details
  - Use these 2 functions to add/remove a node

```
vector<Node*> debug_data;   // add/remove nodes you use

void debug_add_node(Node* node) {
    debug_data.push_back(node);
}
void debug_remove_node(Node* node) {
    auto it = std::find(debug_data.begin(), debug_data.end(), node);
    if (it == debug_data.end())
        cout << "Node does not exist\n";
    else
        debug_data.erase(it);
}
```

Printing a single node info

- This function prints the node info
  - Its data
  - If it's a head or tail
  - Its value and next value
- The function is called by another debug function
  - You can call it anytime

```
void debug_print_node(Node* node, bool is_seperate = false) {
    if (is_seperate)
        cout << "Sep: ";
    if (node == nullptr) {
        cout << "nullptr\n";
        return;
    }
    cout << node->data << " ";
    if (node->next == nullptr)
        cout << "X ";
    else
        cout << node->next->data << " ";

    if (node == head)
        cout << "head\n";
    else if (node == tail)
        cout << "tail\n";
    else
        cout << "\n";
}
```

Printing all nodes

- Example:
- 1 2 head
- 2 3
- 3 4
- 4 X tail

- Example:
- 3 4
- 4 X tail
- 1 2 head
- 2 3

```
void debug_print_list(string msg = "") {
    if (msg != "")
        cout << msg << "\n";
    for (int i = 0; i < (int) debug_data.size(); ++i)
        debug_print_node(debug_data[i]);
    cout << "************\n"<<flush;
}
```

Debugger

- Your IDE’s debugger will also help you discover several mistakes!
- Make sure you're comfortable using your IDE's debugger
- Prepare test cases. Draw out the steps
- Run the debugger and confirm it matches!

```
Node* chain_head = p.first;
Node* chain_tail = p.second.first;
next_chain_head = p.second.second;
tail = chain_tail;

if(!head)   // first chain
    head = chain_head;
```

Code template

- Base your algorithms on my code
- Utilize the debugging facilities in it

"Acquire knowledge and impart it to the people."

"Seek knowledge from the Cradle to the Grave."