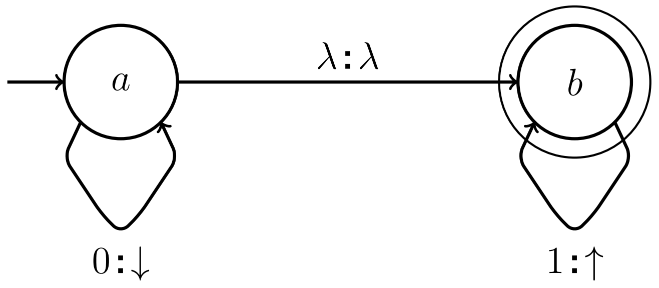
Programming Dictionary

By Charles Cook

Begun on Dec. 6th, 2018

1 Compiler Theoretical Foundations

Push Down Automata for strings of the form 0^n1^n



Key:

Symbol	Meaning
a, b	State Node
0, 1	Symbol to Print
$\downarrow$	Push (onto the stack)
$\uparrow$	Pull (off of the stack)
λ	Null operation (no print, push, or pull)

Derivation Examples: 01, 00001111, 0000000011111111.

2 Programming Tools & Languages: First Ten Questions

2.1 Swap Function

2.1.1 Pseudocode for *swap*

```
void swap(a, b) {
        temp = a;
        a = b;
        b = temp;
}

void swapNoTemp(a, b) {
        a += b; // a = a + b
        b -= a; // b = b - (a + b) = -a
        b *= -1; // b = a
        a -= b; // a = a + b - a = b
}
```

2.1.2 *swaptest.c*

```
#include <stdio.h>
void swap(int *a, int *b) {
        *a += *b;
        *b -= *a;
        *b *= -1;
        *a -= *b;
}

int main() {
        int x, y, z;
        x = 10;
        y = 13;
        z = 2;

        swap(&x, &y);
        swap(&x, &z);
        swap(&y, &z);
        printf("x: &d\ny: &d\nz: &d\n", x, y, z);

        return 0;
}
```

2.1.3 *swaptest.cpp*

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

void swap(int *a, int *b) {
        *a += *b;
        *b -= *a;
        *b *= -1;
        *a -= *b;
}

int main() {
        int x, y;
        x = 13;
        y = 29;

        cout << x << ", " << y << "\n";
        swap(x, y);
        cout << x << ", " << y << "\n";

        return 0;
}
```

2.2 Reverse an array with no extra space (pseudocode)

```
void reverseArray(array, int length) {
        for (int i = 0; i < length / 2; i++) {
                swap(array[i], array[length - i - 1]);
        }
}
```

2.3 Reverse a doubly linked list (pseudocode)

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

void reverseDLL(head, tail) {
        struct Node tempH = head;
        struct Node tempT = tail;

        while (tempH -> next != tempT -> prev && tempH != tempT) {
                swap(tempH -> data, tempT -> data);
        }
}
```

2.4 Reverse a doubly linked list recursively (pseudocode)

```
void reverseDLL_Recursive(head, tail) {
        if (head -> next != tail -> prev && head != tail) {
                swap(head -> data, tail -> data);
                reverseDLL_Recursive(head -> next, tail -> prev);
        }
}
```

2.5 Pointer to a Pointer

A use of a pointer-to-a-pointer in C would be to insert an element into a sorted singly-linked list. Take the following list:

```
head:
 [2] -> [4] -> [7] -> [10] -> [13]
```

Say we want to insert the node **[9]** into the list; If we make a pointer-to-pointer, call it **pp**, and make it point to the **next** attribute of each node, we can insert **[9]** as follows:

First, we set the value of **pp** to be the **head** of the list:

***pp = head;**

where head is the pointer to the first struct in the list. We can visualize this below:

```
 pp
  |
  V
head:
 [2] -> [4] -> [7] -> [10] -> [13]
```

***pp** is **[2]**, and **[2] -> data** is 2, which is less than 9. Until we find a candidate ***pp -> data** that is greater than 9, we keep going by setting **pp** to the address of the next node with ***pp = &(*pp -> next).**

```
 pp -+
     |
head:V
 [2] -> [4] -> [7] -> [10] -> [13]
```

***pp** is **[2] -> next** which is **[4]**, **[4] -> data** is 4 which is less than 9, keep going; ***pp = &(*pp -> next)**

```
 pp --------+
            |
head:       V
 [2] -> [4] -> [7] -> [10] -> [13]
```

`*pp` is **`[4] -> next`** which is **`[7]`**, **`[7] -> data`** is 7 which is less than 9, keep going; **`*pp = &(*pp -> next)`**

```
 pp ---------------+
                   |
head:              V
 [2] -> [4] -> [7] -> [10] -> [13]
```

Paydirt! **`*pp -> data`** is 10, which is greater than 9. Now we do the following:

`[9] -> next = *pp;`

```
 pp ---------------+
                   |
head:              V
 [2] -> [4] -> [7] -> [10] -> [13]
                      ^
                      |
                 [9] -+
```

`*pp = [9];`

```
 pp ---------------+
                   |
head:              V
 [2] -> [4] -> [7] -+ [10] -> [13]
                   /  ^
                  V   |
                 [9] -+
```

The list is still ordered, and **`pp`** is needed no longer.

2.6 Sorting Algorithm with $O(n)$ Complexity

An optimised Bubble Sort that stops after doing a pass thru an array wherein no swaps occur will run in $O(n)$ time on an already-sorted list. In a sorted list, comparing every element with its next element all the way to the end will not prompt Bubble Sort to perform any swaps at all. When a single pass of the array is completed and no swaps have occured, a proper Bubble Sort will stop, as no swaps is a sign of a sorted list.

2.7 Selection Sort Complexity

Consider the worst case of Selection Sort: a completely-reversed array, say $(6, 5, 4, 3, 2, 1)$. On the first pass, 1 is selected, and has to be moved 5 indices, $n - 1$. On the second pass, 2 is selected, and has to be moved 4 indices, $n - 2$. This eventually boils down to $n - 1 + n - 2 + n - 3 + n - 4 + n - 5$ operations; given $n = 6$, this becomes $6 - 1 + 6 - 2 + 6 - 3 + 6 - 4 + 6 - 5 = 5 + 4 + 3 + 2 + 1 = 5 * 6/2$ (per Gauss' Formula). If we reintroduce n, we get $\frac{(n-1)*n}{2} = \frac{n^2-n}{2}$. Overall, Selection Sort's worst case (and average case) boils down to $O(n^2)$.

2.8 Insertion Sort Complexity

Consider again $(6,5,4,3,2,1)$. On the first pass of Insertion Sort, the 5 is swapped 1 time, $n-5$. On the second pass, the 4 is swapped 2 times, $n-4$. Note the pattern. Overall, there are $n-5+n-4+n-3+n-2+n-1$. Recall from the previous problem on Selection Sort that this boils down to $\frac{(n-1)n}{2} = \frac{n^2-n}{2}$. Insertion Sort is also worst-case and average-case $O(n^2)$ complexity.

2.9 *ordered* Predicate in Prolog

2.9.1 *sorted.pl*

```
ordered([X]).
ordered([X, Y|Z]) :- X < Y, ordered([Y|Z]).
```

2.9.2 Output on $[1,2,4,8,16]$ with trace-on in GProlog

```
| ?- ordered([1,2,4,8,16]).
      1    1  Call: ordered([1,2,4,8,16]) ?
      2    2  Call: 1<2 ?
      2    2  Exit: 1<2 ?
      3    2  Call: ordered([2,4,8,16]) ?
      4    3  Call: 2<4 ?
      4    3  Exit: 2<4 ?
      5    3  Call: ordered([4,8,16]) ?
      6    4  Call: 4<8 ?
      6    4  Exit: 4<8 ?
      7    4  Call: ordered([8,16]) ?
      8    5  Call: 8<16 ?
      8    5  Exit: 8<16 ?
      9    5  Call: ordered([16]) ?
      9    5  Exit: ordered([16]) ?
      7    4  Exit: ordered([8,16]) ?
      5    3  Exit: ordered([4,8,16]) ?
      3    2  Exit: ordered([2,4,8,16]) ?
      1    1  Exit: ordered([1,2,4,8,16]) ?

true ?

yes
{trace}
| ?-
```

2.10 Labelled Path (with cost) in Prolog

2.10.1 ASCII-art chart of my path

```
                           +-[11]-> (d) -[7]-> (f)
(a) -[1]-> (b) -[3]-> (c) -+
                           +-[5]-> (e) -+-[13]-> (g)
                                        |
                                        +-[19]-> (h)
```

2.10.2 *charliesPath.pl*

```
link(a, b, 1).
link(b, c, 3).
link(c, d, 11).
link(c, e, 5).
link(d, f, 7).
link(e, g, 13).
link(e, h, 19).

path(Origin, Destination, Distance) :- link(Origin, Destination, Distance).
path(Origin, Destination, TotalDistance) :-
        link(Origin, Intermediate, DistanceA),
        path(Intermediate, Destination, DistanceB),
        TotalDistance is DistanceA + DistanceB
.
```

2.10.3 Recursion Analysis

Whenever path is called with two locations that are indirectly linked, the first thing that will happen is that all directly linked locations to the Origin will be checked; these are the Intermediate locations. These locations will eached be checked to see if they have a direct link to the Destination, otherwise their directly linked locations will act as new Intermediates and themselves go through the same check.

Once an Intermediate is found that directly connects to the Destination, the recursion will cease and the value of true will be returned, along with the total distance. If all recursion becomes exhausted and no satisfactory Intermediate is found, the value of false will be returned.

3 Programming Tools & Languages: Last Ten Questions

3.1 Number of nodes in a linked list (pseudocode)

```
int numberOfNodes(head) {
        int n = 1;
        temp = head;

        while (temp -> next != NULL) {
                n += 1;
                temp = temp -> next;
        }

        return n;
}
```

3.2 Number of nodes in a linked list (pseudocode, $O(\frac{n}{2})$ complexity)

```
int numberOfNodesQuick(head) {
        int n = 1;
        temp = head;

        while (temp -> next != NULL && temp -> next -> next != NULL) {
                n += 2;
                temp = temp -> next -> next;
        }

        if (temp -> next != NULL) {
                n += 1;
        }

        return n;
}
```

3.3 Return middle node of linked list (pseudocode)

```
node middleNode(head, int length) {
        temp = head;

        for (int i = 0; i < length / 2; i++) {
                temp = temp -> next;
        }

        return temp;
}
```

3.4 Return middle node of linked list with two pointers

Declare two pointers and initialize them with the head value. Let the first pointer be known as the one-jump, and the second as the two-jump. While the two-jump pointer's next is not equal to NULL and it's next-next is not equal to NULL, have the one-jump pointer take on the next value one node ahead, and have the two-jump pointer take on the next value two nodes ahead. When the two-jump has a next that is NULL, the one-jump will be in the middle.

For example, if a linked list has 9 nodes, the two-jump will go from node 1 to 3 to 5 to 7 to 9, then stop. The one-jump will go from node 1 to 2 to 3 to 4 to 5, then stop. 5 is halfway between node 1 and node 9.

3.5 Circualr singly-linked list check with two pointers

Declare two pointers as before when finding the middle node of a linked list: one-jump and two-jump. A circular linked list can be detected if you repeatedly have the one-jump update to its next node, and have the two-jump update to its next-next node. If ever the nodes ever are equal, i.e. they are pointing to the same node, then there is a cycle in the list. If there wasn't, the two-jump would reach a terminal point well ahead of the one-jump.

3.6 Reachability

3.7 Stable vs. Non-Stable Sorting Algorithms

A stable sorting algorithm is one that preserves the order of elements of equal value from before sorting to after sorting. Insertion Sort is stable, because when an equal value element is inserted, it will not be able to move beyong another equal value element, because the citeria for an insertion swap requires the lower element to be strictly less than the higher element. Selection Sort, in its simplest implementation, is not stable. If a minimum finding function that uses a linear search is used, the last instance of an equal value element will become the first instance, breaking stability.

3.8 Fundamental Data Structures

- Array
- Dictionary (a.k.a. Hash Table, Associative Array)
- Linked List (singly or doubly linked)
- Binary Search Tree (Lefthand children are smaller, righthand are larger)
- Heap Tree (In a maximum heap, all children are smaller)
- Stack

3.9 P vs. NP

The "P" in P vs. NP stands for polynomial. If an algorithm qualifies for a P-class problem, then the Big-O complexity of the algorithm is modelled by a polynomial expression; In short, the algorithm runs in polynomial-class time in reference to the size of the input. Alternatly, if an algorithm is of the NP-class, its time complexity is non-polynomial, which is ususally worse than polynomial complexity. For example, there are only NP-class algorithms for solutions to the Travelling Salesman Problem, which entales travelling to every node in a graph (every city in a region) and returning to your starting location while minimizing distance.

3.10 Class vs. Struct

A struct is a composite data type with multiple data fields of any type defined in the programming language. A class combines the data-ordering of a struct with associated functions called methods, which manipulate the data ordered by the class. When a class is instantiated, the instance is referred to as an object.