

ESO207 Programming Assignment 1

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2021-08-30

1 Problem Statements

Polynomials may be represented as linked lists. Consider a polynomial

$$p(x) = a_1x^{e_1} + a_2x^{e_2} + a_3x^{e_3} + \dots + a_{n-1}x^{e_{n-1}} + a_nx^{e_n}$$

with non-zero terms, $p(x)$ where $0 \leq e_1 < e_2 < \dots < e_{n-1} < e_n$ are (non-negative) integers. We assume that coefficients a_1, \dots, a_n are non-zero integers. Polynomial $p(x)$ can be represented as a linked list of nodes. Each node has three fields: coefficient, exponent and link to the next node. Let us assume that list is a doubly linked list, with sentinel node, sorted in ascending order of exponents.

(a) (marks 5+15)

Write pseudo-code to add two polynomials $p(x)$ and $q(x)$ in this representation. Your algorithm should take $O(n+m)$ time, where n, m are the number of terms in $p(x)$ and $q(x)$ respectively. Implement your pseudo-code as an actual program.

(b) (marks 10+20)

Write pseudo-code to multiply two polynomials $p(x)$ and $q(x)$ in this representation. Do runtime complexity analysis of your algorithm in terms of n, m , the number of terms in $p(x)$ and $q(x)$ respectively. State this complexity in 'O' notation. Implement your pseudo-code as an actual program.

Note that output list should satisfy all constraints (non-zero coefficients, exponents in strict ascending order etc.) of representation of a polynomial. Make your code non-destructive, that is, it should not modify the lists for $p(x)$ and $q(x)$.

2 Programming Problem 1

2.1 Problem Description

We are required to add the polynomials according to the given input where we are first given two integers n and m which are followed by $2n$ and $2m$ integers in the next two lines. The main complexities and boundary cases in the problem were to design a $O(m+n)$ algorithm and to recognize that zero polynomials are the exceptional cases which do not directly fit into the algorithm and so are to be specifically handled. To take care of integer overflow we by default use big integers as our storage containers.

2.2 Data Structure Usage

We will be using a dynamically allocated doubly linked list with a sentinel node for easier and error free implementation.

2.3 Algorithm Explanation

The algorithm is quite simple. We just take two temporary node pointers which will correspond to the current term of that particular polynomial in the addition process. There are 3 major cases as follows -

- **1st polynomial already traversed**
In this case we just add the term of 2nd polynomial to the answer polynomials doubly linked list. Here we don't need to check anything as the question statement says that the coefficients will anyways be non-zero.
- **2nd polynomial already traversed**
Similar to the case above with the difference that this time we will be traversing the 1st polynomial and adding new nodes to the resultant polynomial.
- **Both polynomials are being traversed**
This is the most complex case of the mentioned three with some exceptions to be handled within. While we are simultaneously traversing the 1st and 2nd polynomial the currently checked term might have different variable exponents. In that case we cannot add them and we simply need to add one of them to the list. We chose to add the element with smaller exponent into the list as it ensures the automatic sorting of the resultant polynomial. In case of the exponents being equal we need to confirm that the coefficients don't add to zero. In case they do then we just skip these terms however if not then we add them. So it can easily be seen that in this case the iteration would be a bit more costly as compared 1st and 2nd case iteration.

2.4 Pseudo Code

These are the variables used -

- **HEAD** - The first element of addition polynomial.
- **HEAD1** - The first element of first polynomial.
- **HEAD2** - The first element of second polynomial.
- **SENT** - Sentinel node for addition polynomial.

****** - Similar goes for TAIL,TAIL1,TAIL2,SENT1,SENT2

Algorithm 1: List Making Algorithm

Input : The two linked lists showing $p(x)$ and $q(x)$ and pointers to make output polynomial $r(x)$

Output: No output

```
1 temp1 = HEAD1 and temp2 = HEAD2
2 /* Temporary pointers to traverse along the available
   polynomials. */
3 while temp1! = SENT1 or temp2! = SENT2 do
4   if temp1 == SENT1 then
5     TAIL.insert – node(temp2) // insert-node() is a function
      which makes a new node and adds to the list
      temp2 ← (temp2 → next)
6   else
7     if temp2 == SENT2 then
8       TAIL.insert – node(temp1)
9       temp1 ← (temp1 → next)
10    else
11      if temp1 → exp == temp2 → exp then
12        if temp1 → cof! = temp2 → cof then
13          a=make-
            node(temp1 → cof + temp2 → cof, temp1 → cof)
            /* make-node() function allocates memory for a
              new node and fills with the parameters given */
14          TAIL.insert – node(a)
15        else
16          end if
17          temp1 ← (temp1 → next)
18          temp2 ← (temp2 → next)
19        else
20          if temp1 → exp < temp2 → exp then
21            TAIL.insert – node(temp1)
22            temp1 ← (temp1 → next)
23          else
24            TAIL.insert – node(temp2)
25            temp2 ← (temp2 → next)
26          end if
27        end if
28      end if
29    end if
30 end while
31 return
```

3 Programming Problem 2