第 1.2 题：一元稀疏多项式计算器

实验报告

题目：设计一个一元稀疏多项式简单计算器。
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一、 需求分析

1. 按照格式输入多项式。
2. 多项式输出按照指数降序排列，输出形式为类数学表达式。
3. 多项式 a 和 b 相加，建立多项式 a+b。

二、 概要设计

1. 多项式的存储使用双向链表类，其中，每个节点有两个成员变量：cterm、eterm，分别用来存储系数、指数。其中，cterm 和 eterm 的格式应该根据使用场景设定，而根据提供的测试数据将本程序中的 cterm 设为 double 格式，eterm 设为 int 格式。为防止老师之后验证程序发现指数的小数点后数字丢失，特此说明。

2. 本程序的特点是所输入的多项式为乱序、有可能指数相等，而输出需要按照指数递减，所以链表的**查重->将相同指数项合并**和**排序**就变得格外重要。

3. 算法部分，加法的实现比较直接：对两个**已经排序后的链表**进行顺序遍历，将指数相等的项相加，不等的项直接放入链表中。

4. 此外，其他的操作都是链表中比较常见的，构造析构拷贝构造赋值重载等等。

5. 求导和减法属于拓展操作，求导思路很简单：就像人类一样 c_out = c * e, e_out = e-1。减法则是基于加法，对减数求相反数即可。

1. 节点类 node

对象：

```
node *next;     //链表中指向下一节点的指针。
node *prev;     //链表中指向上一节点的指针。
double cterm;   //存储系数
int eterm;      //存储指数
```

操作：

```
node();         //构造函数，对参数进行初始化。
```

2. 链表类 linknode

对象：

```
node *head, *rear; //双向链表的头指针和尾指针，指向链表头尾
int length;             //记录链表长
```

操作：

```
friend std::ostream & operator <<(std::ostream &os, linknode target);
//重载输出函数，输出多项式
linknode(double *c, int *e, int n);
//构造函数，根据得到的数组 c 和 e 初始化一个链表
~linknode();
//析构函数，返还链表开辟的空间
linknode(const linknode &a);
//拷贝构造函数，返回一个链表的拷贝，该拷贝占用空间为新开辟的空间
linknode operator+(linknode &another);
//加法，用以得到两个多项式加法运算结果
linknode & operator=(const linknode &target);
//赋值重载，和拷贝函数有点类似，代码都很相似，返回一个 linknode 的引用
void simplify();
//简化函数。对链表中指数相等的项进行合并
linknode sortme();
//排序函数，将链表中的所有节点按照指数降序排序
linknode derivate();
//求导函数，返回当前多项式的求导结果
linknode linknode::operator-(linknode &another);
//减法函数，返回两个多项式的减法
```

三、 详细设计

1. 节点类 node

node.h

```
class node
{
public:
node();          //构造函数，对参数进行初始化。
node *next;      //链表中指向下一节点的指针。
node *prev;      //链表中指向上一节点的指针。
double cterm; //存储系数
int eterm;       //存储指数
};
```

node.cpp

```
//单纯的初始化
node::node()
{
	cterm = 0;
	eterm = 0;
}
```

2. 链表类 linknode

linknode.h

```
class linknode
{
friend std::ostream & operator <<(std::ostream &os, linknode target);
//重载输出函数，输出多项式
public:
node *head, *rear; //双向链表的头指针和尾指针，指向链表头尾
int length;              //记录链表长
linknode(double *c, int *e, int n);
//构造函数，根据得到的数组 c 和 e 初始化一个链表
~linknode();
//析构函数，返还链表开辟的空间
linknode(const linknode &a);
//拷贝构造函数，返回一个链表的拷贝，该拷贝占用空间为新开辟的空间
linknode operator+(linknode &another);
//加法，用以得到两个多项式加法运算结果
linknode & operator=(const linknode &target);
//赋值重载，和拷贝函数有点类似，代码都很相似，返回一个 linknode 的引用
void simplify();
//简化函数。对链表中指数相等的项进行合并
linknode sortme();
//排序函数，将链表中的所有节点按照指数降序排序
linknode derivate();
//求导函数，返回当前多项式的求导结果
linknode linknode::operator-(linknode &another);
//减法函数，返回两个多项式的减法
};
```

linknode.cpp

```
std::ostream & operator <<(std::ostream &os, linknode target)
{
    node *temp = target.head->next;
    int flag = 0;
    //flag 用于记录是否有元素被输出，如果始终为 0，则在最后输出一个 0
    for (int k = 0; k < target.length; k++)
    {
        if(temp->cterm>0 && temp != target.head->next){os<<"+";}
        //输出正数时，cout 并不会帮忙加上+号，所以自己加上
        if(temp->cterm == 1 && temp->eterm != 1 && temp->eterm != 0)
        // c = 1 但 e != 1 时，不需要输出 cterm 的 1
        {
            os<< "X^" << temp->eterm;
            temp = temp->next;
            flag++;
            continue;
        }
        if(temp->cterm == -1 && temp->eterm != 1 && temp->eterm != 0)
        //c = -1 但 e != 1 时，不需要输出-1，只需要-号
        {
             os<< "-X^" << temp->eterm;
             temp = temp->next;
             flag++;
             continue;
        }
        if(temp->cterm == 0 && k == target.length-1 && flag == 0)
        //当所有元素都已经遍历，但还是没有元素被输出，输出一个 0
        {
            os<<"0";
            break;
        }
        if(temp->cterm == 0)
        //当遇到 c 为 0 时，跳过不输出
        {
            temp = temp->next;
            continue;
        }
        if(temp->cterm == 1 && temp->eterm == 1)
        //当 c 和 1 都是 1 时，输出 X
        {
            os<<"X";
            temp = temp->next;
            flag++;
            continue;
        }
        if(temp->cterm == -1 && temp->eterm != 1 && temp->eterm != 0)
        //当 c 和 1 都是 1 时，输出-X
        {
            os<< "-X^" << temp->eterm;
            temp = temp->next;
            flag++;
            continue;
        }



        if(temp->eterm == 0)
        //当 e 为 0 时，只需要输出 c（为常数）
        {
            os<<temp->cterm;
            temp = temp->next;
            flag++;
            continue;
        }
        if(temp->eterm ==1)
        //当 e 为 1 时，（c!=1  因为前面已经判断过了），  输出 c 和 X
        {
            os<<temp->cterm<<"X";
            temp = temp->next;
            flag++;
            continue;
        }

        //如果前面的所有特殊情况都不是，就很正常的输出 cX^e
        os<<temp->cterm<<"X^"<<temp->eterm;
        flag++;
        if(temp != target.rear)
        {
            temp = temp->next;
        }
    }
    return os;
}
```

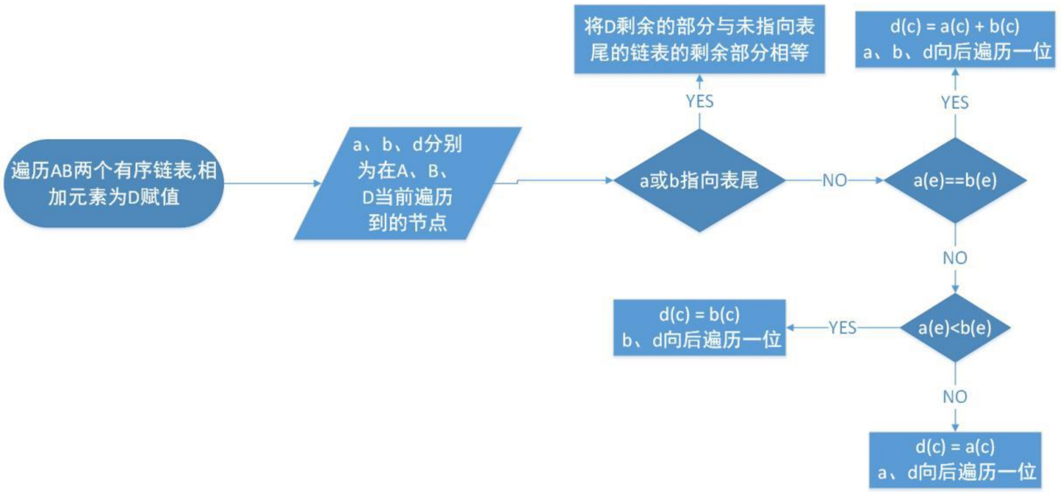
```
linknode::linknode(double *c, int *e, int n)
//构造函数，初始化变量和链表
{
    length = n;
    head = new node;
    head->next = rear = new node;
    rear->prev = head;
    for (int k = 0; k < n; k++)                //构造一个长度为 n 的链表
    {
        node *temp = new node;
        temp->cterm = c[k];
        temp->eterm = e[k];
        temp->next = rear;
        temp->prev = rear->prev;
        rear->prev->next = temp;
        rear->prev = temp; }     }
```

```
linknode::~linknode()
    //析构函数，返还所有开辟的空间
    {
        node* temp = head;
        while(temp != rear)
        //遍历返还空间
        {
            node * temp1 = temp;
            temp = temp->next;
            delete temp1;
        }
        delete rear;
    }
```

```
linknode::linknode(const linknode &a)
//拷贝构造函数，新建一个链表，将新建链表的节点值们赋值为现有链表的值
{
    length = a.length;
    head = new node;
    head->next = rear = new node;
    rear->prev = head;
    node* iter = a.head->next;

    while (iter != a.rear)
    //遍历赋值
    {
        node *temp = new node;
        temp->cterm = iter->cterm;
        temp->eterm = iter->eterm;
        temp->next = rear;
        temp->prev = rear->prev;
        rear->prev->next = temp;
        rear->prev = temp;
        iter = iter->next;
    }
}
```

```
linknode linknode::operator+(linknode &another)
//整个题目的第一块算法部分，加法重载
//基本思路：
```



```
{
    int k = length + another.length;
    double *c = new double[k]{0};
    int *e = new int [k]{0};
    linknode result(c,e,k);
    result.length = 0;
    node* iter_this, *iter_another, *iter_target;
    iter_this = this->head->next;
    iter_another = another.head->next;
    iter_target = result.head->next;

    for (int iter = 0; iter < k; iter++)
    {   //当两个遍历链表的指针有一个指向了表尾时，把 result 剩余的节点赋值为另一个
        //尚未被指向表尾的链表节点。
        if(iter_this == this->rear || iter_another == another.rear)
        {   //两种指向表尾的情况，分开讨论
            //其实这里原则上来说可以用三目写，但可读性非常差，于是换用了 if-else
            if(iter_this == this->rear)
            {
                while(iter_another != another.rear)
                {
                    iter_target ->cterm = iter_another->cterm;
                    iter_target->eterm = iter_another->eterm;
                    iter_target = iter_target->next;
                    iter_another = iter_another->next;
                    result.length++;
                }
                break;
            }
            else
            {
                while(iter_this != this->rear)
                {
                    iter_target -> cterm = iter_this->cterm;
                    iter_target -> eterm = iter_this->eterm;
                    iter_target = iter_target->next;
                    iter_this = iter_this->next;
                    result.length++;
                }
                break;
            }
        }
        //第一个判断是否指向表尾的 for 结束
        //接下来判断两个指针指向的指数是否相等
        if(iter_this->eterm != iter_another->eterm)
        {
            //不相等则对两链表中较大者指针进行向后遍历，较小者指针不变
            //这里用三目更合适一点，可读性高
            int judge = iter_this->eterm > iter_another->eterm;
            iter_target->cterm = (judge == 1)? iter_this->cterm : iter_another->cterm;
            iter_target->eterm = (judge == 1)? iter_this->eterm : iter_another->eterm;
            iter_target = iter_target->next;
            iter_this = (judge == 1) ? iter_this->next : iter_this;
            iter_another = (judge == 1) ? iter_another : iter_another->next;
            result.length++;
            continue;
        }
        else
        //两个指针指向的 e 相等，则三个指针全遍历
        {
            iter_target->cterm = iter_this->cterm + iter_another->cterm;
            iter_target->eterm = iter_another->eterm;
            iter++;
            result.length++;
            iter_another = iter_another->next;
            iter_this = iter_this->next;
            iter_target = iter_target->next;
            continue;
        }
    }
        while(iter_target != result.rear)
        //将初始化链表时，多建立的节点（因为最开始假设的表长是 length + another.length）
```

```
        //删除
        {
            node * temp = iter_target;
            iter_target = iter_target->next;
            temp->prev->next = iter_target;
            iter_target->prev = temp->prev;
            delete temp;
        }
    return result;
}
```

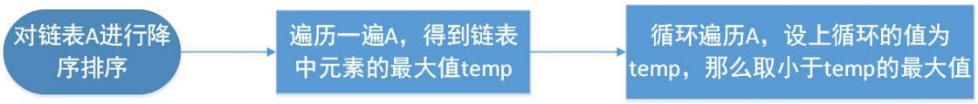
```
linknode linknode::operator-(linknode &another)
//减法，在有了加法后，减法很好实现
//思路：将原链表的所有值取相反数建立新链表
{
    double * sizeofit1 = new double [another.length];//c
    int * sizeofit2 = new int [another.length];//e
    linknode result(sizeofit1,sizeofit2,another.length);
    node* iter_this= another.head->next;
    node* iter_target = result.head->next;

    while(iter_this!=another.rear)
    {
        iter_target->cterm = -1 * iter_this->cterm;
        iter_target->eterm = iter_this->eterm;
        iter_target = iter_target->next;
        iter_this = iter_this->next;
    }
    return *this + result;
}
```

```
linknode& linknode::operator=(const linknode &a)
//赋值函数重载，和拷贝构造函数的内容基本一样，注意返回的是引用
{
    length = a.length;
    head = new node;
    head->next = rear = new node;
    rear->prev = head;
    node* iter = a.head->next;

    while (iter != a.rear)
    {
        node *temp = new node;
        temp->cterm = iter->cterm;
        temp->eterm = iter->eterm;
        temp->next = rear;
        temp->prev = rear->prev;
        rear->prev->next = temp;
        rear->prev = temp;
        iter = iter->next;
    }
    linknode result(a);
    return result;
}
```

```
linknode linknode::sortme()
  //第二部分算法，对链表进行排序，注意：这里的链表已经执行过 simplify 了，所以不会
  //现具有相同 e 的节点
```


对链表A进行降序排序
遍历一遍A，得到链表中元素的最大值temp
循环遍历A，设上循环的值为temp，那么取小于temp的最大值

```
{
    double * sizeofit1 = new double [length];//c
    int * sizeofit2 = new int [length];//e
    int temp = this->head->next->eterm;
    linknode result(sizeofit1,sizeofit2,length);
    node* iter_this= this->head->next;
    node* iter_target = result.head->next;

    iter_target->cterm = iter_this->cterm;
    iter_target->eterm = iter_this->eterm;
    //遍历一遍，得到最大值
    for (int k = 0;k < length; k++)
    {
        if(iter_this->eterm > temp)
        {
            temp = iter_this->eterm;
            iter_target->cterm = iter_this->cterm;
            iter_target->eterm = iter_this->eterm;
        }
        iter_this = iter_this->next;
    }
    //length = 1 的时候不需要再继续排序，直接返回
    if(length == 1){return result;}

    int e_temp = temp;
    double c_temp = 0;
    //每次 k 的循环取小于 last_biggest 的最大值
    for (int k =0; k < length -1; k++)
    {
        iter_target = iter_target->next;
        iter_this = this->head->next;
        int last_biggest = e_temp;
        int flag = 0;
        for (int b = 0; b < length; b++)
        {
            //当遇到第一个小于 e_temp 的值时，进行存储，flag = 1 意味着此时已经找到了小于 e_temp 的值，之后的任务是找比它大的，小于 e_temp 的最大值
            if(iter_this->eterm < e_temp && flag == 0)
            {
                e_temp = iter_this->eterm;
                c_temp = iter_this->cterm;
                flag = 1;
            }
            //当满足小于 e_temp 但大于当前存储的小于 e_temp 的最大值时，赋值
            if(iter_this->eterm > e_temp && iter_this->eterm < last_biggest && flag == 1)
            {
                e_temp = iter_this->eterm;
                c_temp = iter_this->cterm;
            }
            iter_this = iter_this->next;
        }
        iter_target->eterm = e_temp;
        iter_target->cterm = c_temp;
    }
    return result;
}




void linknode::simplify()
//简化函数，用于简化链表。思路很简单：循环遍历链表，将所有 e 相等的节点进行合并
{
    if(length == 1){return;}
    node* temp1 = this->head->next;
    node* temp2 = temp1->next;
    while(temp1 != this->rear)
    {
        temp2 = temp1->next;

        while(temp2 != this->rear)
        {
            int flag = 0;
            //当节点的 e 相等时，合并节点（c1 = c1 + c2  ），再删除 c2 节点
            if(temp1->eterm == temp2->eterm)
            {
                temp1->cterm = temp1->cterm + temp2->cterm;
                temp2->prev->next = temp2->next;
                temp2->next->prev = temp2->prev;
                length --;
                node* dele = temp2;
                temp2 = temp2->next;
                flag = 1;
                //这里如果 temp2 不指向下一个的话，delete 后 temp2 是野指针，无法实现算法
                delete dele;
            }
            temp2 = flag == 1? temp2 : temp2->next;
        }
        temp1 = temp1->next;
    }
}
```

```
linknode linknode::derivate()
//求导函数，返回当前多项式的求导结果
//基本思路也很简单，就像正常的求导一样，对每一项 c_target = e * c， e_target = e-1 即可
{
    double * sizeofit1 = new double [length];//c
    int * sizeofit2 = new int [length];//e
    int temp = this->head->next->eterm;
    linknode result(sizeofit1,sizeofit2,length);
    node* iter_this= this->head->next;
    node* iter_target = result.head->next;

    while(iter_this != this->rear)
    {
        iter_target->cterm = iter_this->cterm * iter_this->eterm;
        iter_target->eterm = iter_this->eterm - 1;          //c_target = e * c， e_target = e-1
        if(iter_this != this->rear->prev)
        {
            iter_this = iter_this->next;
            iter_target = iter_target->next;
            continue;
        }
        break;
    }
    return result;
}
```

四、 调试分析

1. 最开始的程序中没有考虑到 c 要取小数，所以 c 和 e 都是 int。后来看测试数据才发现 c 可以取小数。不过还好这种格式取错了的情况，改几个变量的定义就可以，修改时间很快。
2. 这是三个作业中最后完成的一个，经历了三个程序之后，我最深的感触就是，链表的构造、析构、赋值重载、拷贝构造都是不能避免地需要自己写的。在这个程序中我曾经试图跳过以上说的那几个函数，最后都失败了。
3. const 用的不熟练。比较成熟的代码风格应该是需要合理的使用 const 的，而我在写代码的过程中常常注意不到这个问题，以后需要注意这方面的问题。
4. 整体而言，整个程序和 1.1 有点类似，且编程难度低于 1.1

5. 算法复杂度分析

1） 时间复杂度

Node 中：

node();　//构造函数，O(1)

Linknode 中：

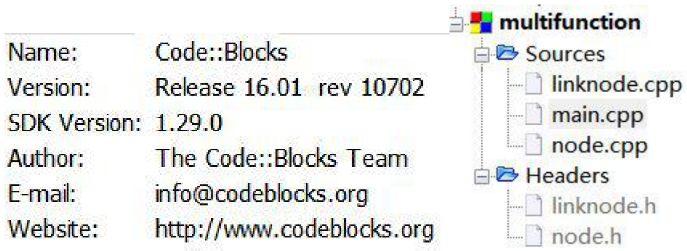
friend std::ostream & operator <<(std::ostream &os,const linknode &target);
//遍历一遍链表并输出，O(n)
linknode(double *c, int *e, int n);
//遍历两个数组对链表赋值，O(n)
~linknode();
//遍历链表并释放空间，O(n)
linknode(const linknode &a);
//遍历原链表，创建一个相等链表，O(n)
linknode operator+(linknode &another);
//算法图已放在第七页，相当于遍历一遍两个链表，O(n)
linknode & operator=(const linknode &target);
//和拷贝构造函数类似，O(n)
void simplify();
//简化函数，对每个链表节点都要进行后向遍历，O(n^2)
linknode sortme();
//排序函数，思路很像选择排序，O(n^2)
linknode linknode::derivate()
//求导函数，对链表进行遍历，O(n)
linknode linknode::operator-(linknode &another)
//减法函数，对其中一个链表遍历取相反数，并调用加法，O(n)

2） 空间复杂度

在 linknode 类中，以下四个函数空间复杂度都为 O(n),其他函数全为 O(1)
linknode(double *c, int *e, int n);
linknode(const linknode &a);
linknode operator+(linknode &another);
linknode & operator=(const linknode &target);
linknode sortme();
linknode linknode::derivate();
linknode linknode::operator-(linknode &another)

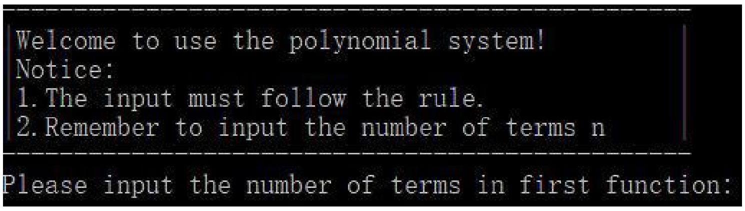
五、 用户手册

1. 本程序使用的 Code::Blocks 16.01 IDE，程序以项目（project）方式组织，如图 1 所示：



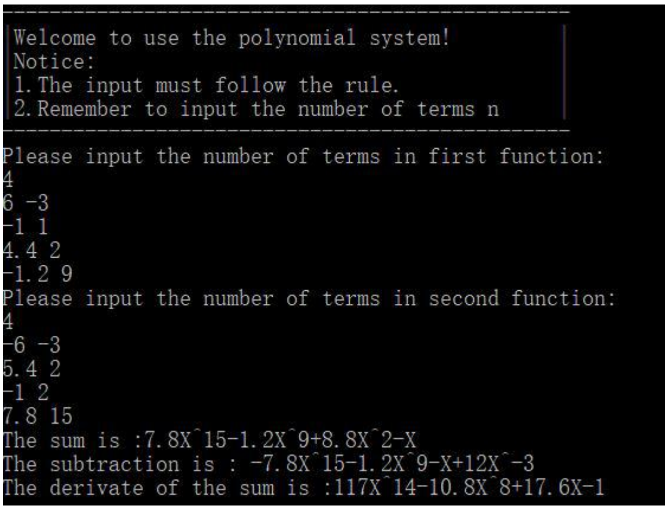
Name: Code::Blocks
Version: Release 16.01 rev 10702
SDK Version: 1.29.0
Author: The Code::Blocks Team
E-mail: info@codeblocks.org
Website: http://www.codeblocks.org

2. 依次点击菜单“Build”-> “Build and run”，显示文本方式的用户界面，如图 2 所示：



```
-----------------------------------------------
|Welcome to use the polynomial system!        |
|Notice:                                      |
|1.The input must follow the rule.            |
|2.Remember to input the number of terms n    |
-----------------------------------------------
Please input the number of terms in first function:
```

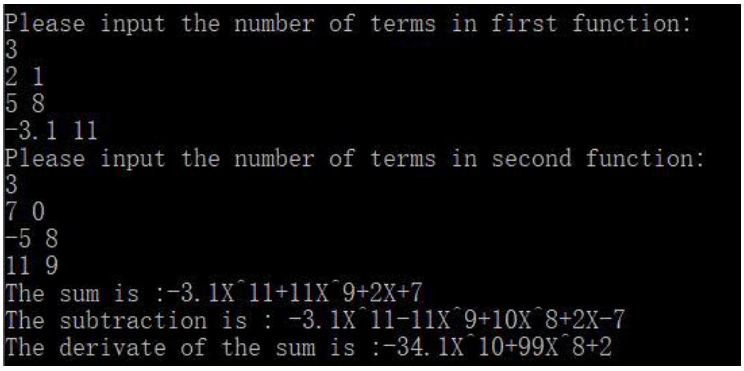
3. 接下来按照要求输入想要的多项式即可得到结果：例如：



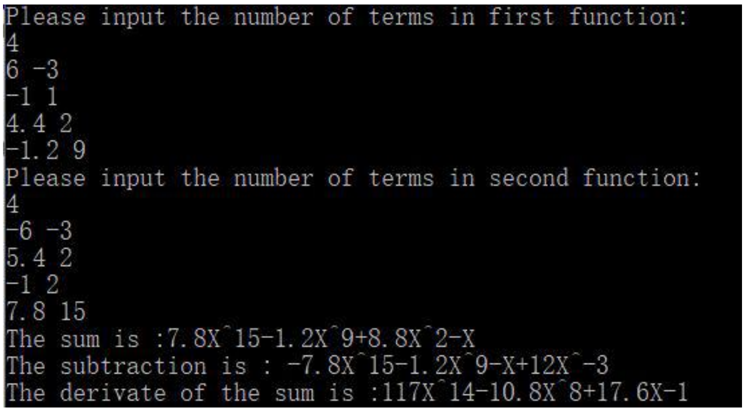
```
-----------------------------------------------
|Welcome to use the polynomial system!        |
|Notice:                                      |
|1.The input must follow the rule.            |
|2.Remember to input the number of terms n    |
-----------------------------------------------
Please input the number of terms in first function:
4
6 -3
-1 1
4.4 2
-1.2 9
Please input the number of terms in second function:
4
-6 -3
5.4 2
-1 2
7.8 15
The sum is :7.8X^15-1.2X^9+8.8X^2-X
The subtraction is : -7.8X^15-1.2X^9-X+12X^-3
The derivate of the sum is :117X^14-10.8X^8+17.6X-1
```

六、 测试结果

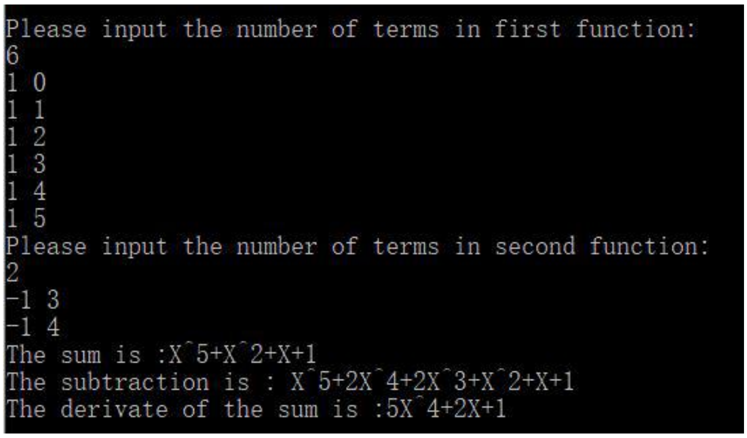
1.正序测试测试数据多项式



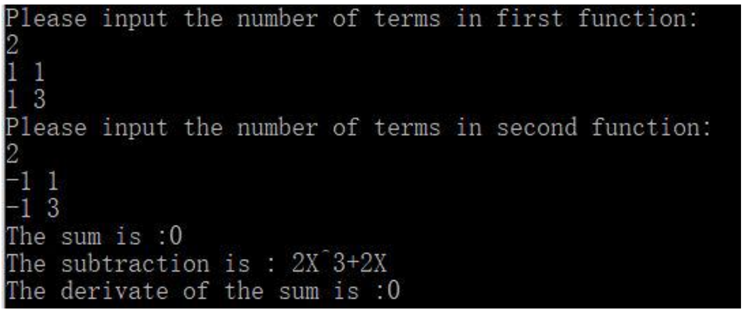
```
Please input the number of terms in first function:
3
2 1
5 8
-3.1 11
Please input the number of terms in second function:
3
7 0
-5 8
11 9
The sum is :-3.1X^11+11X^9+2X+7
The subtraction is : -3.1X^11-11X^9+10X^8+2X-7
The derivate of the sum is :-34.1X^10+99X^8+2
```



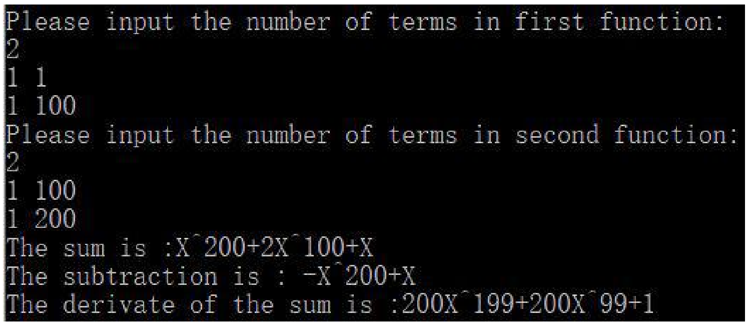
```
Please input the number of terms in first function:
4
6 -3
-1 1
4.4 2
-1.2 9
Please input the number of terms in second function:
4
-6 -3
5.4 2
-1 2
7.8 15
The sum is :7.8X^15-1.2X^9+8.8X^2-X
The subtraction is : -7.8X^15-1.2X^9-X+12X^-3
The derivate of the sum is :117X^14-10.8X^8+17.6X-1
```



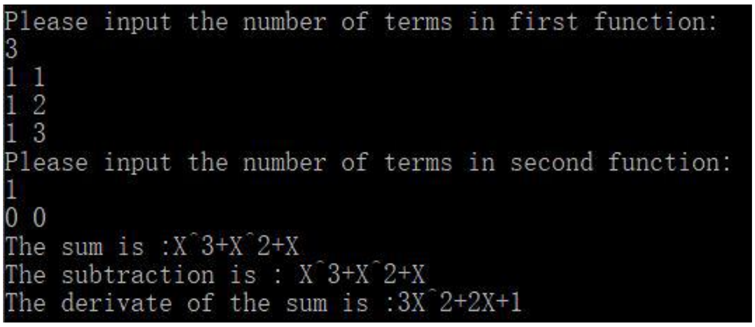
```
Please input the number of terms in first function:
6
1 0
1 1
1 2
1 3
1 4
1 5
Please input the number of terms in second function:
2
-1 3
-1 4
The sum is :X^5+X^2+X+1
The subtraction is : X^5+2X^4+2X^3+X^2+X+1
The derivate of the sum is :5X^4+2X+1
```



```
Please input the number of terms in first function:
2
1 1
1 3
Please input the number of terms in second function:
2
-1 1
-1 3
The sum is :0
The subtraction is : 2X^3+2X
The derivate of the sum is :0
```

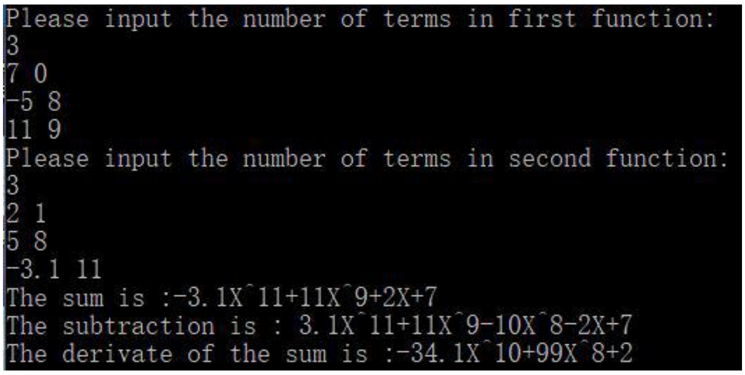


```
Please input the number of terms in first function:
2
1 1
1 100
Please input the number of terms in second function:
2
1 100
1 200
The sum is :X^200+2X^100+X
The subtraction is : -X^200+X
The derivate of the sum is :200X^199+200X^99+1
```

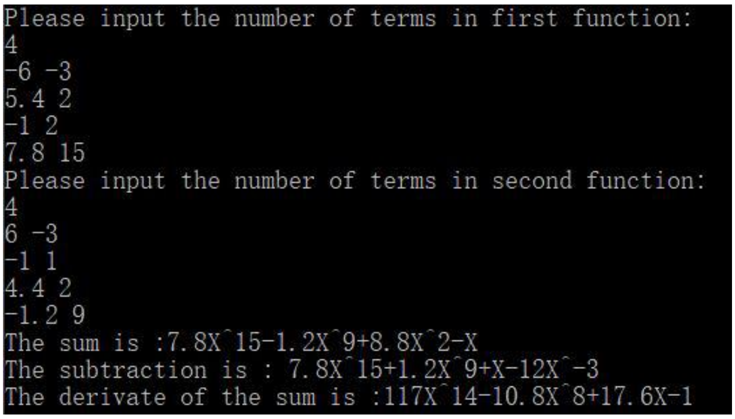


```
Please input the number of terms in first function:
3
1 1
1 2
1 3
Please input the number of terms in second function:
1
0 0
The sum is :X^3+X^2+X
The subtraction is : X^3+X^2+X
The derivate of the sum is :3X^2+2X+1
```

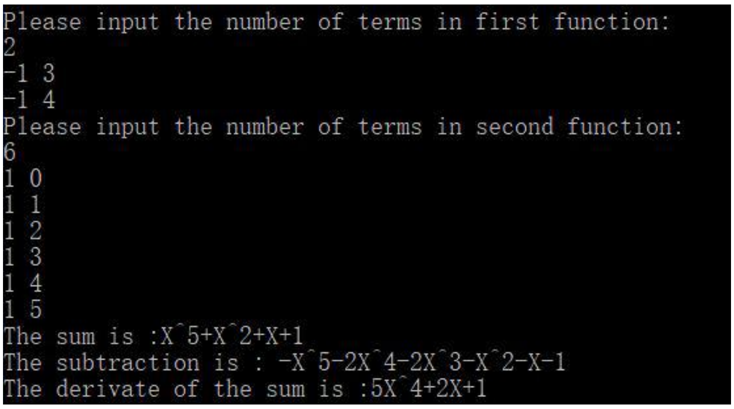
2. 逆序测试测试数据



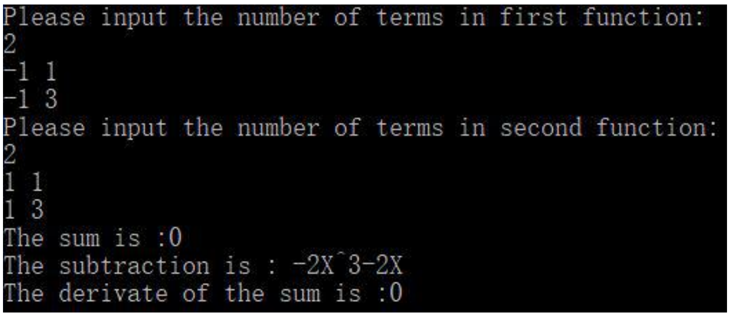
```
Please input the number of terms in first function:
3
7 0
-5 8
11 9
Please input the number of terms in second function:
3
2 1
5 8
-3.1 11
The sum is :-3.1X^11+11X^9+2X+7
The subtraction is : 3.1X^11+11X^9-10X^8-2X+7
The derivate of the sum is :-34.1X^10+99X^8+2
```



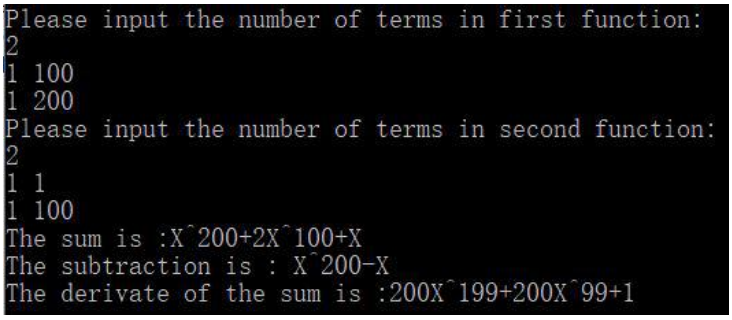
```
Please input the number of terms in first function:
4
-6 -3
5.4 2
-1 2
7.8 15
Please input the number of terms in second function:
4
6 -3
-1 1
4.4 2
-1.2 9
The sum is :7.8X^15-1.2X^9+8.8X^2-X
The subtraction is : 7.8X^15+1.2X^9+X-12X^-3
The derivate of the sum is :117X^14-10.8X^8+17.6X-1
```



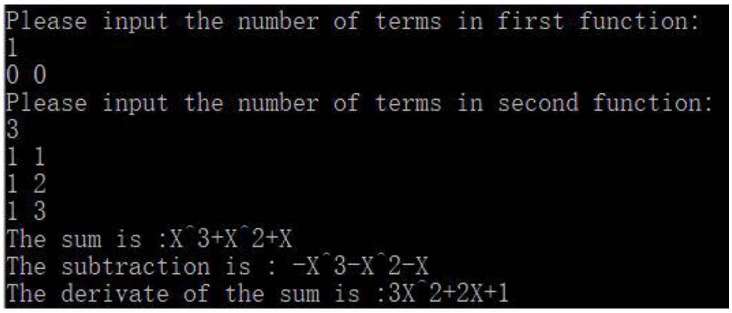
```
Please input the number of terms in first function:
2
-1 3
-1 4
Please input the number of terms in second function:
6
1 0
1 1
1 2
1 3
1 4
1 5
The sum is :X^5+X^2+X+1
The subtraction is : -X^5-2X^4-2X^3-X^2-X-1
The derivate of the sum is :5X^4+2X+1
```



```
Please input the number of terms in first function:
2
-1 1
-1 3
Please input the number of terms in second function:
2
1 1
1 3
The sum is :0
The subtraction is : -2X^3-2X
The derivate of the sum is :0
```



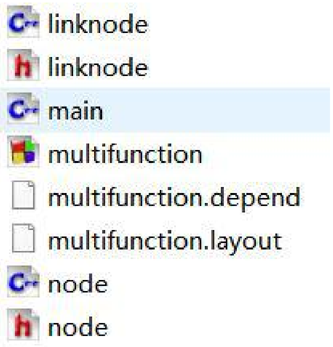
```
Please input the number of terms in first function:
2
1 100
1 200
Please input the number of terms in second function:
2
1 1
1 100
The sum is :X^200+2X^100+X
The subtraction is : X^200-X
The derivate of the sum is :200X^199+200X^99+1
```



```
Please input the number of terms in first function:
1
0 0
Please input the number of terms in second function:
3
1 1
1 2
1 3
The sum is :X^3+X^2+X
The subtraction is : -X^3-X^2-X
The derivate of the sum is :3X^2+2X+1
```

七、 附录

目录：



linknode
linknode
main
multifunction
multifunction.depend
multifunction.layout
node
node