What is a “Better” Program?

C++ Object Oriented Programming

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軟體的特性

- 軟體之所謂軟...因為沒有“硬性”不可變、不可挑戰的規則
  - 好處: 彈性很大, 山不轉路轉, 沒有標準答案, 正確運作就好...
  - 壞處: 很多小問題合在一起不斷放大, 到處藏污納垢, 沒有標準答案, 不知道到底對了沒有
- 解決方法
  - **Coding styles**
  - test-driven
  - 元件化
  - 模型化 (資料結構, 演算法, 物件化, 設計樣版)

Source Code is the Primary Document

- Jack Reeves, C++ Journal, 1992, “What is Software Design?”

  “After reviewing the software development life cycle as I understood it, I concluded that the only software **documentation** that actually seems to satisfy the criteria of an engineering design is the **source code listings**.”
- The **design of a software project** is an abstract concept:
  - It has to do with the overall shape and structure of the program as well as the detailed shape and structure of each module, class, and method.
  - It can be represented by many different diagrams and media, but its final embodiment is the source code.
- **Source code is the design**

Goals

- 透過一些編碼的潛規則，我們可以寫出一個“好”一點的 C 程式
- 除了正確性之外，程式短一點?? 執行快一點???
- “**好**”？ (in terms of test, debug, review, and extension)
  1. 容易了解，沒有邏輯上不緊密結合的資料變數或是敘述
  2. Self-explaining … 我的程式碼會說話
  3. 和觀念上的運作模型一致
  4. 容易修改，不容易改錯
  5. 沒有容易錯誤的語法
- 正確性無關：接下來是一個很簡單的例子，共有七個版本，執行結果都是正確的

Version 1

```
01 #include <stdio.h>
02
03 void main()
04 {
05    int d[] = {12, 3, 37, 8, 24, 15, 5, 33};
06    int n = 8;
07    int *d1, *d2;
08    int *p;
09    int *e;
10
11    d1 = d;
12    d2 = d+n;
13    while (d1<d2)
14    {
15       p = d1;
16       e = d1 + 1;
17       while (e<d2)
18       {
19          if (*e<*p) p = e;
20          e++;
21       }
22       n = *p;
23       *p = *d1;
24       *d1 = n;
25       d1++;
26    }
27    printf("Sorted data:\n");
28    d1 = d;
29    while (d1<d2)
30       printf(" %d", *d1++);
31    printf("\n");
32 }
```


Execution Results

Sorted data:

3 5 8 12 15 24 33 37

由小至大按順序排列

What is this program doing?

Initial view

- Input array initialized with unordered integers
- Two layers of while loops
- Some pointers to the elements of the array
- Another while loop for output the results

Don’t like it!!??

- Pointers
- Generic while loops
- Mysterious variable names (identifier means nothing)
- Deep control structures
- Looks like a snippet of low level assembly instructions

Remove Unnecessary Pointers

- Pointers are sophisticated and sometimes inevitable, but not always.
- In the case of **accessing memory blocks**, pointers are error prone, use array whenever possible.
- **Array syntax** has much better semantic meaning than the generic **pointer dereferencing and arithmetics**.

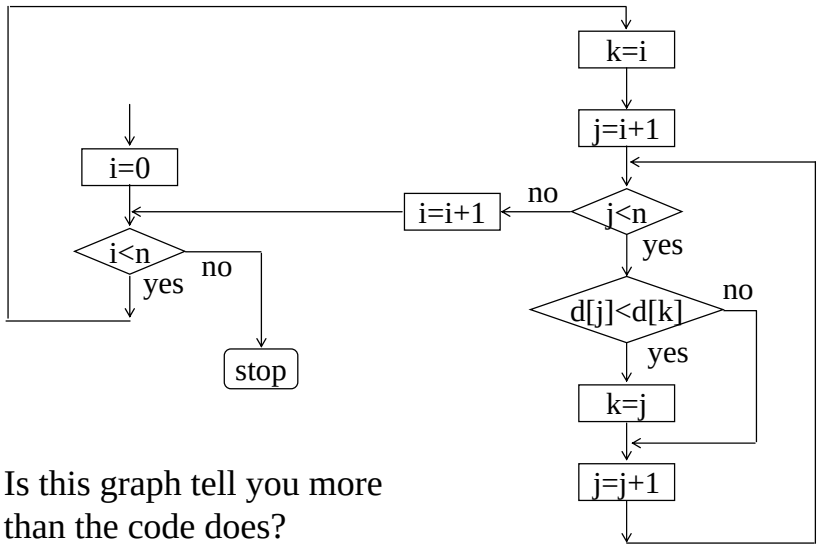
```
int array[100];
int *ptr=array;
int i, sum = 0;
…
for (i=0; i<100; i++)
   sum += *ptr++;
```

```
int array[100];
int i;
int sum = 0;
…
for (i=0; i<100; i++)
   sum += array[i];
```

Version 2

```
01 #include <stdio.h>
02
03 void main()
04 {
05    int d[] = {12, 3, 37, 8, 24, 15, 5, 33};
06    int n = 8;
07    int i, j, k;
08
09    i = 0;
10    while (i<n)
11    {
12       k = i;
13       j = i + 1;
14       while (j<n)
15       {
16          if (d[j]<d[k]) k = j;
17          j = j + 1;
18       }
19       j = d[k];
20       d[k] = d[i];
21       d[i] = j;
22       i = i + 1;
23    }
24    printf("Sorted data:\n");
25    i = 0;
26    while (i<n)
27    {
28       printf(" %d", d[i]);
29       i = i + 1;
30    }
31    printf("\n");
32 }
```


Flowchart of the Program



Is this graph tell you more than the code does?

Meaningful Identifiers

- A program is composed with a language. Just like any language in your daily life, language itself should **tell good stories** when it is used properly.
- Why does the version 1 or version 2 program look like gibberish to well trained programmers?
- Are the **identifiers** used meaningful??
  e.g.

  Hw ds Jhn lk th stk?

  or

  How does John like the steak?

Version 3

```
01 #include <stdio.h>
02
03 void main()
04 {
05    int data[] = {12, 3, 37, 8, 24, 15, 5, 33};
06    int ndata = sizeof(data) / sizeof(int);
07    int i, j;                avoid magic constants
08    int min;
09    int swapTmp;
10
11    i = 0;
12    while (i<ndata)
13    {
14       min = i;
15       j = i + 1;
16       while (j<ndata)
17       {
18          if (data[j]<data[min]) min = j;
19          j = j + 1;
20       }
21       swapTmp = data[min];
22       data[min] = data[i];
23       data[i] = swapTmp;
24       i = i + 1;
25    }
26
27    printf("Sorted data:\n");
28    i = 0;
29    while (i<ndata)
30    {
31       printf(" %d", data[i]);
32       i = i + 1;
33    }
34    printf("\n");
35 }
```

Advanced View of the Codes

Initial view

- Input array initialized with unordered integers
- Two layers of while loops
- Some pointers to the elements of the array
- Another while loop for output the results

Is it changing?

- Input array initialized with unordered integers
- Two layers of while loops, the outer one prepares ndata sub-arrays, the inner one goes through each sub-array to find something minimal.
- A snippet of memory swapping code
- Another while loop for output the results

More Meaningful Language Construct

- While loop is the most generic repetition construct in C language

```
initialize the loop condition
while (condition)
{
   …
}
```

Forget about ***goto*** please!!!

the condition is likely to change inside the loop

- When you see this construct in a program, you expect some sort of job repetition, could be an easy one or a complex one.
- For loop is a more semantically specific repetition construct in C language --- **repeat for a predetermined number of times**

```
for (i=0; i<count; i++)
{
   …
}
```


Version 4

```
01 #include <stdio.h>
02
03 void main()
04 {
05    int data[] = {12, 3, 37, 8, 24, 15, 5, 33};
06    int ndata = sizeof(data) / sizeof(int);
07    int i, j;
08    int min;
09    int swapTmp;
10
11    for (i=0; i<ndata; i++)
12    {
13       min = i;
14       for (j=i+1; j<ndata; j++)
15       {
16          if (data[j]<data[min]) min = j;
17       }
18       swapTmp = data[min];
19       data[min] = data[i];
20       data[i] = swapTmp;
21    }
22
23    printf("Sorted data:\n");
24    for (i=0; i<ndata; i++)
25       printf(" %d", data[i]);
26    printf("\n");
27 }
```


Code That Further Illustrates Itself

- **Function** is a powerful construct to **abstract** ideas, to **hide** distracting details, not just a utility for saving your typing time and removing redundancy.

  --- Version 5

- A construct like **“loop inside a loop”** is somehow beyond the concrete control of common human mind. A single layer of “loop” is better for most people to visualize in mind.

  --- Version 6

Version 5

```
01 #include <stdio.h>
02
03 void swap(int *, int *);
04 void printArrayContents(int [], int);
05
06 void main()
07 {
08    int data[] = {12, 3, 37, 8, 24, 15, 5, 33};
09    int ndata = sizeof(data) / sizeof(int);
10    int i, j;
11    int min;
12
13    for (i=0; i<ndata; i++)
14    {
15       min = i;
16       for (j=i+1; j<ndata; j++)
17       {
18          if (data[j]<data[min]) min = j;
19       }
20       swap(&data[i], &data[min]);
21    }
22
23    printArrayContents(data, ndata);
24 }
25
26 void swap(int *x, int *y)
27 {
28    int tmp;
29    tmp = *x;
30    *x = *y;
31    *y = tmp;
32 }
```


Version 5 (cont'd)

```
33
34 void printArrayContents(int data[], int ndata)
35 {
36    int i;
37    printf("Sorted data:\n");
38    for (i=0; i<ndata; i++)
39       printf(" %d", data[i]);
40    printf("\n");
41 }
```


Version 6

```
01 #include <stdio.h>
02
03 void selectionSort(int[], int);
04 void findMinimumOfAnArray(int[], int);
05 void swap(int*, int*);
06 void printArrayContents(int[], int);
07
08 void main()
09 {
10    int data[] = {12, 3, 37, 8, 24, 15, 5, 33};
11    int ndata = sizeof(data) / sizeof(int);
12
13    selectionSort(data, ndata);
14    printArrayContents(data, ndata);
15 }
16
```


Version 6 (cont'd)

```
17 void selectionSort(int data[], int ndata)
18 {
19    int i;
20    for (i=0; i<ndata; i++)
21       putMinimalElementInPlace(&data[i], ndata-i);
22 }
23
24 void putMinimalElementInPlace(int data[], int ndata)
25 {
26    int i, min;
27
28    min = 0;
29    for (i=1; i<ndata; i++)
30    {
31       if (data[i]<data[min]) min = i;
32    }
33    swap(&data[0], &data[min]);
34 }
35
```

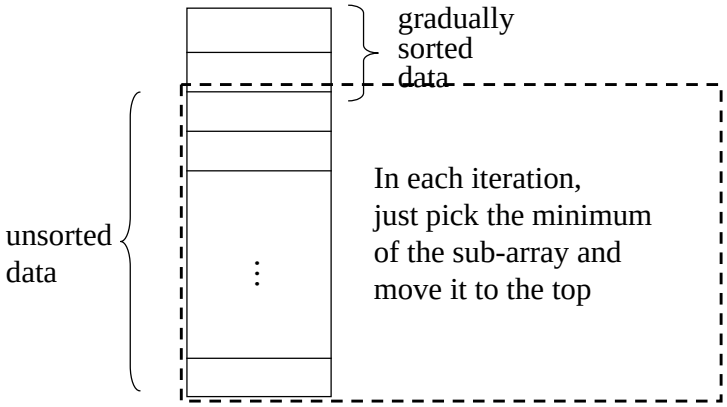
suitable level of details

```
36 void swap(int *x, int *y)
37 {
38    int tmp;
39    tmp = *x;
40    *x = *y;
41    *y = tmp;
42 }
43
```

```
44 void printArrayContents(int data[], int ndata)
45 {
46    int i;
47    printf("Sorted data:\n");
48    for (i=0; i<ndata; i++)
49       printf(" %d", data[i]);
50    printf("\n");
51 }
```

Codes with a Conceptual Model

- Flowchart is no longer needed but definitely requires a conceptual **model** for the codes to work with.



Who is responsible of this task?

- The programmer or the program reader?
- When we read the version 1 of this program, there were little clues in the codes that told us directly what the program is doing.
- Although we figure out that this is a piece of code that implements the selection sort algorithm at last, it should not take the original programmer too much effort to produce a code snippet like version 6 and its corresponding conceptual model which tell directly the story of what the program is doing.
- A piece of code is to implement some engineering design, **simplicity** is the best engineering principle. Try your best to think and express ideas in an intuitive way.

Recursive Version

- Recursive version is often the most expressive form of the underlying algorithm.

```
void selectionSort(int data[], int ndata)
{
    putMinimalElementInPlace(data, ndata);
    if (ndata>2)
        selectionSort(&data[1], ndata-1);
}
```


Efficiency Issues

- Using expressive name for all identifiers makes the program much lengthier, easier to have typos, slow in composing the program!!! Really??
  - Harddisk is cheap. Not necessary to think of space.
  - It is easier for compiler to detect typo than using x, y, z.
  - Typing should not be the bottleneck.
  - Expressive programs are easier to compose, maintain, and extend.
- Excessive function calls take CPU time to transfer arguments and to branch the control.
  - Let the compiler worry about it --- use inline function.
- Using dedicated variables for independent tasks looks like abusing memories.
  - Let the compiler worry about it.
  - Reduce error-prone codes is a far bigger concern.

Assignments

- Bubble Sort
- Quick Sort
- Minimum Spanning Tree
- Tree Traversal
- …