Fred Lei's interview answer

Question：

https://www.chegg.com/homework-help/questions-and-answers/three-dimensional-averaging-c-programming-please-assign-random-transparency-beginning-prog-q27825264

Step 1: Re-read the question

A. What info I can get

A1. This is a Rubik's Cube. It has 27 cubes (from R4-R5)

A2. Each small cube has different transparency, but they can be divided to several levels (from L5-L6)

A3. Find the best possible arrangement with the best overall transparency

A4. Write a program to perform the arrangement, print out the result and execution time

Step 2: Analysis

A. Draw out the cube

Bottom

9	8	7
6	5	4
3	2	1

Middle

18	17	16
15	14	13
12	11	10

Top

27	26	25
24	23	22
21	20	19

B. What is the meaning of "the best overall transparency"

Regarding cubes, they are Three-dimensional objects.

For X dimension(9 entities)

$T(x3) + T(x2) + T(x1) = \sum(T(x3)+T(x2)+T(x1)) \cong T(average)$

$[x3,x2,x1] \in \{[1,2,3],[4,5,6],[10,11,12],...\}$

For Y dimension(9 entities)

$T(y3) + T(y2) + T(y1) \cong T(average)$

$[y3,y2,y1] \in \{[1,4,7],[2,5,5],[19,22,25],...\}$

For Z dimension(9 entities)

$T(z3) + T(z2) + T(z1) \cong T(average)$

$[z3,z2,z1] \in \{[1,10,19],[5,14,23],[9,18,27],...\}$

We add all the Equation together(left side add the left, right side add the right side)

$3\sum(T(1)+T(2)+T(3)+\cdots+T(27)) \cong 27T(average)$

So

1. $T(average) = \sum(T(1)+T(2)+T(3)+\cdots+T(27))/9$
2. All sum of the entities on the X,Y,Z are equal or very close to T(average)

C. How many levels should we divide ?

- We can divide 27 cubes to only one level if we don't require very high Accuracy.
- We can divide to 27 levels if all of their transparency are different, but it will be too difficult for me and my computer to implement.
- Since this is a 3*3 Rubik's Cube, if we divide them to 3 levels(A,B,C), it will be much easier for us.

Bottom

A	C	B
B	A	C
C	B	A

Middle

B	A	C
C	B	A
A	C	B

Top

C	B	A
A	C	B
B	A	C

(BTW, the pattern is very funny)

As well, this pattern meets the requirement of Equation on B

For the X $T(x3) + T(x2) + T(x1) = A+B+C$

For the Y $T(y3) + T(y2) + T(y1) = A+B+C$

For the Z $T(z3) + T(z2) + T(z1) = A+B+C$

Step3: Modelling

A. How to divide them to 3 levels?

For a “*Best Overall Transparency*” cube, the T ∈{T(min),⋯,T(max)}

T(A) ∈{T(min),⋯, T(min) + (T(max)-T(min))/3}
T(B) ∈{T(min)+ (T(max)-T(min))/3,⋯, T(min) + 2(T(max)-T(min))/3}
T(C) ∈{T(min) +2(T(max)-T(min))/3,⋯, T(max) }

B. How to decide the “*Best Overall Transparency*” cube?
Here we will use standard Deviation to decide whether it is the “*Best Overall Transparency*” cube.

Step4: Coding and testing

A. Codes: https://github.com/suntearinheart/fortheinterview/blob/master/steps4code.c.

B. Result:

```
time consume (ticks) : 62
the  T(average) is 1.95
the arrangement of the Cube:
---------------

Bottom:
0.51 0.71 0.61
0.62 0.52 0.72
0.73 0.63 0.53

Middle:
0.64 0.54 0.74
0.75 0.65 0.55
0.56 0.76 0.66

Top:
0.77 0.67 0.57
0.58 0.78 0.68
0.69 0.59 0.79
---------------
the SD : 0.0632456
Program ended with exit code: 0
```

Step5: Improve the algorithm

Up to now, even if this program is not the best method to find out the best cube, it can find a better one as fast as it can.

Go back to step2. C. When I re-read the pattern, I found an interesting point. They are like a spiral DNA, but not X &Y. They are A&B& C. In the beginning, I was very lucky to divide them to three groups.

Now I want to do it again in the sublevel.

For A

A (S): the smaller cubes in A group
A(L): the Larger cubes in A group
A(M): the Medium cubes in A group

For B

B (S): the smaller cubes in B group
B(L): the Larger cubes in B group
B(M): the Medium cubes in B group

For C

C (S): the smaller cubes in C group
C(L): the Larger cubes in C group
C(M): the Medium cubes in C group

So, the diagram can be like this:

Bottom

A(L)1	C(M)2	B(S)3
B(M)4	A(S)5	C(L)6
C(S)7	B(L)8	A(M)9

Middle

B(S)10	A(L)11	C(M)12
C(L)13	B(M)14	A(S)15
A(M)16	C(S)17	B(L)18

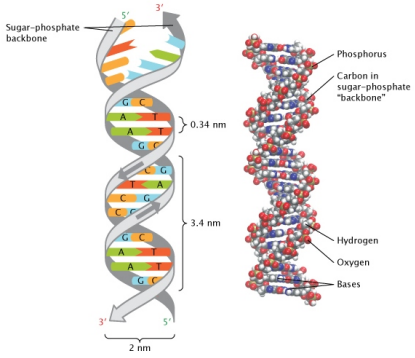
Top

C(M)19	B(S)20	A(L)21
A(S)22	C(L)23	B(M)24
B(L)25	A(M)26	C(S)27

Now, this pattern is very symmetrical.

For the spiral DNA-like method:

A(L-S-M-L-S-M-L-S-M)
C(M-L-S-M-L-S-M-L-S)
B(S-M-L-S-M-L-S-M-L)



We can improve the code!

Step6: Improved coding and testing

A. Codes:
https://github.com/suntearinheart/fortheinterview/blob/master/step6improvedcode.c

B. Result:

```
time consume (ticks) : 83
the  T(average) is 1.95
the arrangement of the Cube:
---------------

Bottom:
0.57 0.74 0.61
0.64 0.51 0.77
0.71 0.67 0.54

Middle:
0.62 0.58 0.75
0.78 0.65 0.52
0.55 0.72 0.68

Top:
0.76 0.63 0.59
0.53 0.79 0.66
0.69 0.56 0.73
---------------
the SD : 0.02
Program ended with exit code: 0
```

Congratulation! The Standard Deviation jumps from **`0.0632456`** to 0.02.

The improvement works!

Step7: Try to do the improvement again

From the spiral DNA-like method(Step3):

A(L-S-M-L-S-M-L-S-M)

C(M-L-S-M-L-S-M-L-S)

B(S-M-L-S-M-L-S-M-L)

For every A, B, C, they have 3 groups of (L-S-M,M-L-S,S-M-L).

As well, for X(L), Y(M), Z(S), X,Y,Z∈{A,B,C} , They have three entities.

I presume that there are still some other patterns, but I need more time to learn math to dig it out. Currently, I will just write one permutation program to loop out the result.

Doing(10077696) [3！ *3！ *3！][3！ *3！ *3！][3！ *3！ *3！] Times of permutation is easier than 27! Times.

Step8: Improved coding and testing

A. Codes:
https://github.com/suntearinheart/fortheinterview/blob/master/step8improvedcodes.c

B. Result:

```
time consume (ticks) : 10071786
time consume (sec) : 10
the  T(average) is 1.95
the arrangement of the Cube:
---------------

Bottom:
0.57 0.75 0.63
0.66 0.51 0.78
0.72 0.69 0.54

Middle:
0.62 0.59 0.74
0.77 0.65 0.53
0.56 0.71 0.68

Top:
0.76 0.61 0.58
0.52 0.79 0.64
0.67 0.55 0.73
---------------
the SD : 1.86267e-16
the best SD:  1.86267e-16
Program ended with exit code: 0
```

The Standard Deviation jumps from 0.02 to 1.86267e-16.

The improvement works again!

Conclusion:

1. The execution time is 10s for the last version to do 10077695 times loop.
   For this part, I can optimize by creating some threads to shorten the time.
   I believe the algorithm can be improved, if I pay more time to dig out the pattern

2. Since the codes are coded and updated based on my growing understanding from the

scratch. There are lots of spaces to improve.

Thanks
-Fred Lei