Zhaoliang's Theory part

Theory of determining the minimum number of photos for each photo scan circle

In order to find out the minimum number of photos for each photo scan circle, we need to first decide the procedure of doing this whole thing:

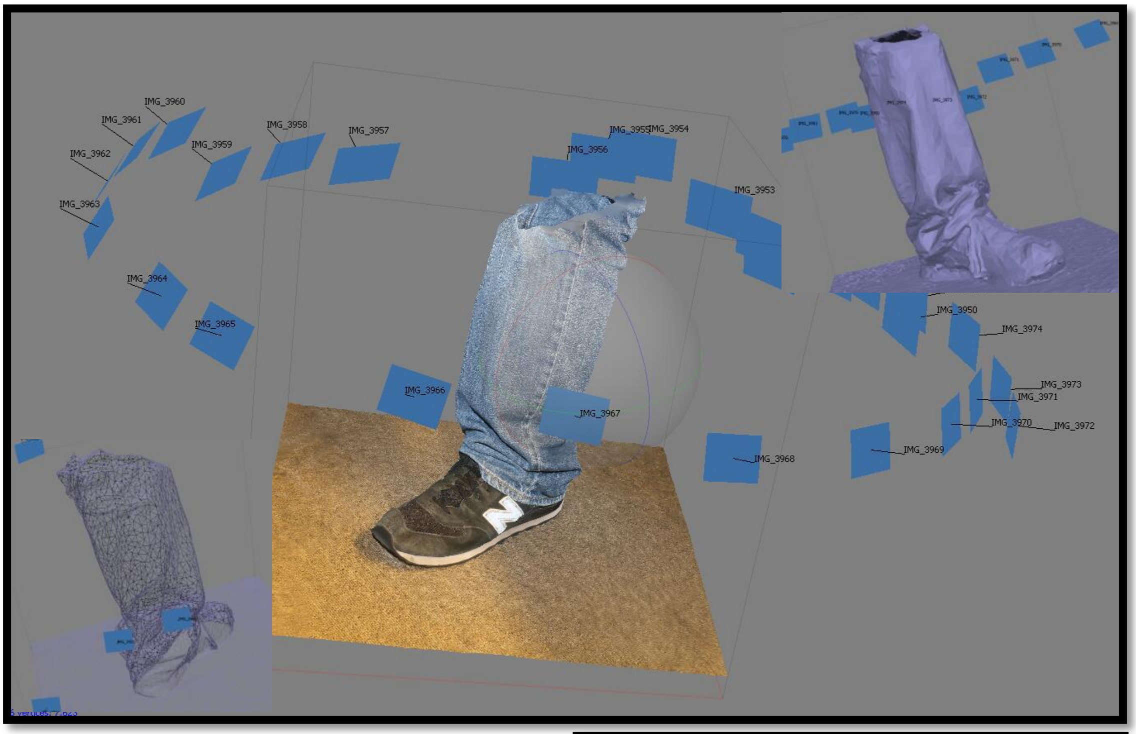
- ***Found a one circle photoscane 3D model***
- ***Reduced some photos from the acquisition pattern each time***
- ***Something interesting were discovered***
- ***Came up with a theory***
- ***Proved it the theory***

1) Carefully choose one circle photo-scan 3D model.

The model we choose should satisfy following requirement:

- Human leg
- The model surface should be accurate and smooth enough
- The model should be built based on one round photos

The model we found:

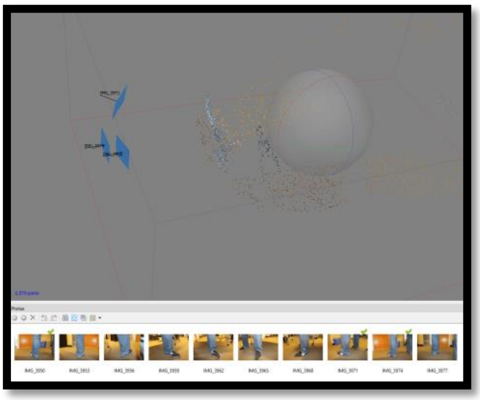


The feature of this model:

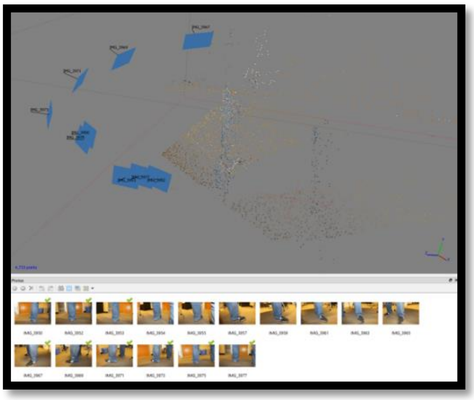
- Human leg (Tim's)
- The model is perfect
- Total photos #: 28

2) Reduced some photos from the acquisition pattern each time

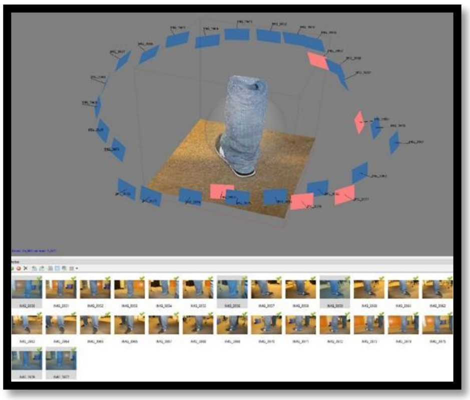
1st model:

Situation	Model result	figure
Import 10 photos	Failed	
3 were aligned		

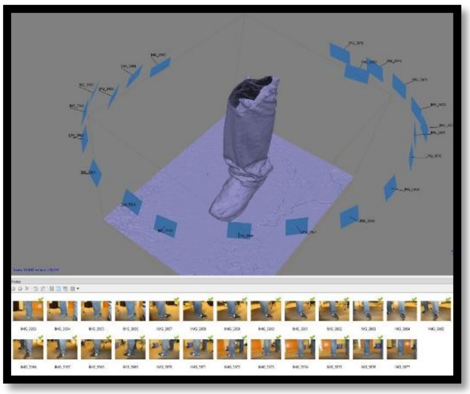
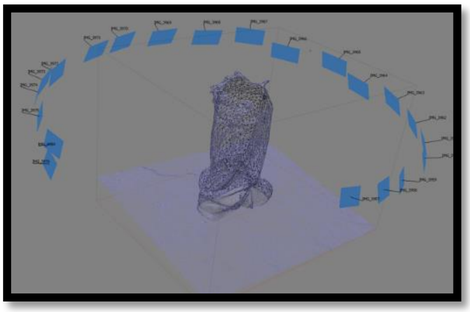
2nd model:

Situation	Model result	figure
Import 15 photos	Failed	
9 were aligned		

3rd model:

Situation	Model result	figure
Import 28 photos at the beginning	Something interesting happened	
Start to delete some from the original model		

4th model:

Situation	Model result	figure
Export 24 photos	Successful	
20 were aligned		

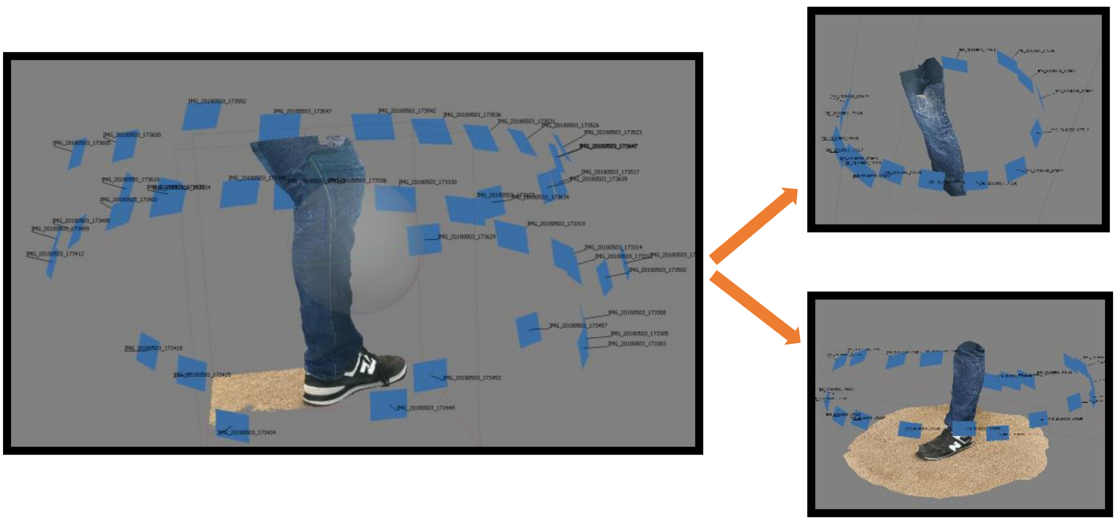
Questions about this model:

Why only 20 photos were aligned?

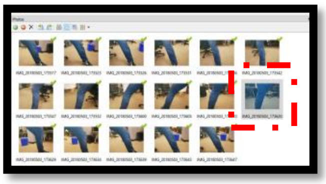
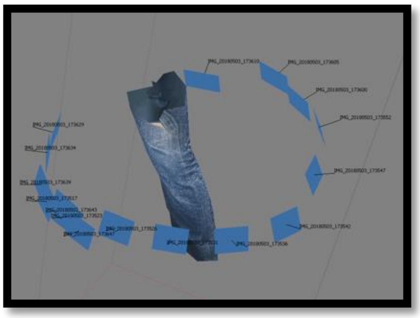
Is 20 the number of minimum number of photos for a good model?

How to make sure that 20-photos is the lower bound?

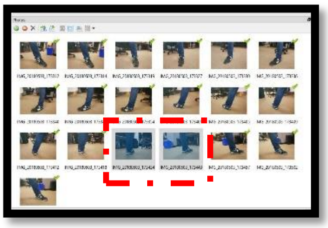
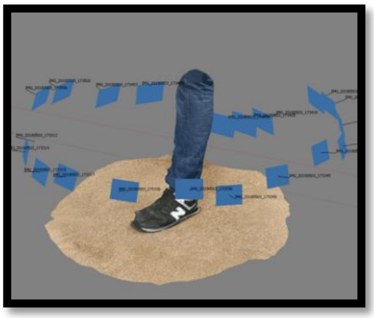
In order to verify this, we can try something in engineering way, try another perfect model to see if this is right. The requirements should be as the same as the last one but we only find it with two circle photo-scan model. So we have to cut this model into two separated round photo-scan model.



1st new model:

Situation	Model result	Photos situation
Export 18 photos	Successful 	
17 were aligned		

2nd new model:

Situation	Model result	Photos situation
Export 19 photos	Successful 	
17 were aligned		

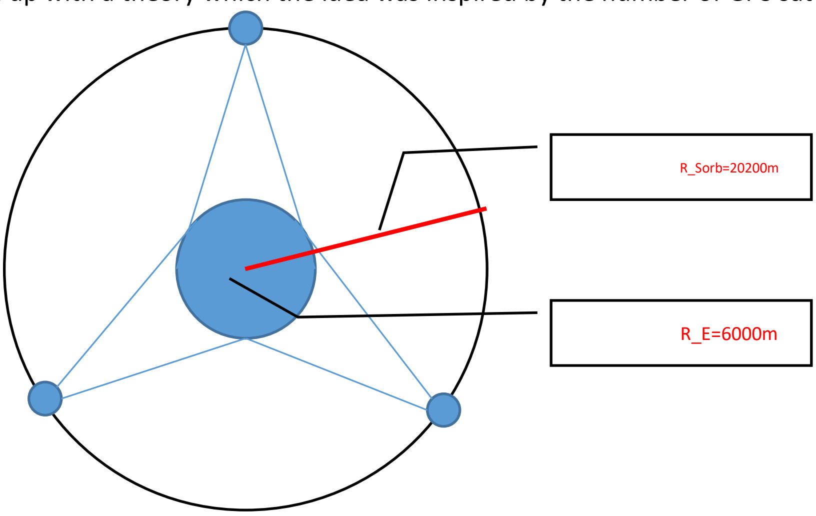
Questions about this model:

Why in this two models only 17 photos were aligned? It seems that is doesn't make any sense, but it shouldn't be.

3) Theory

Part I: a rough theory

So, we came up with a theory which the idea was inspired by the number of GPS satellite system.



In GPS case, 29 satellites are in the sky, 5 are backup. So 29 -5 =24 are working right now.

How do we calculate the overlapping percentage for each satellite?

(1) 360° /24 = 15° ; (360/3 – 15)/(360/3) = (120 -15)/120 = 87.5%

(2) 24*120 – 360 =2520 ; 2520/24 = 105; 150/120 = 87.5%

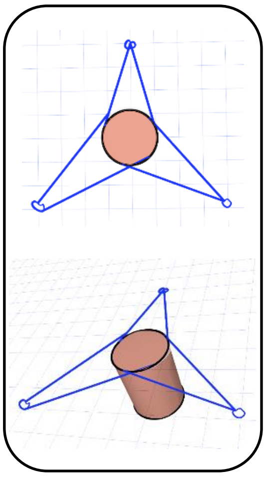
Both ways get to the same result: 87.5% overlapping percentage for each GPS satellite.

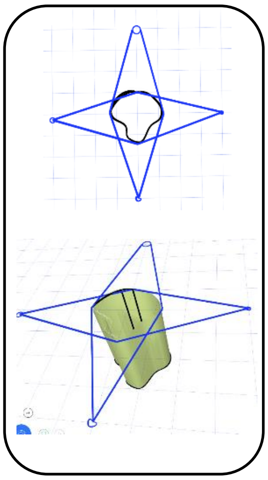
To sum up, the easy way to do the calculation is : n= 24; m = 3;

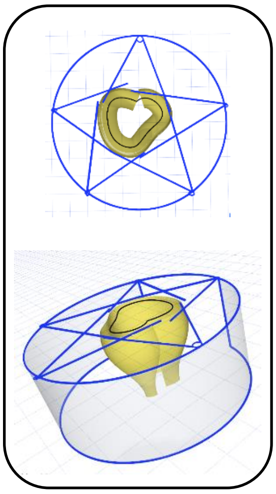
$$\frac{n-m}{m} = \frac{24-3}{24} = 87.5\%$$

So, for a sphere like earth, we would just need 3 satellites to cover all the surface, but for other object?

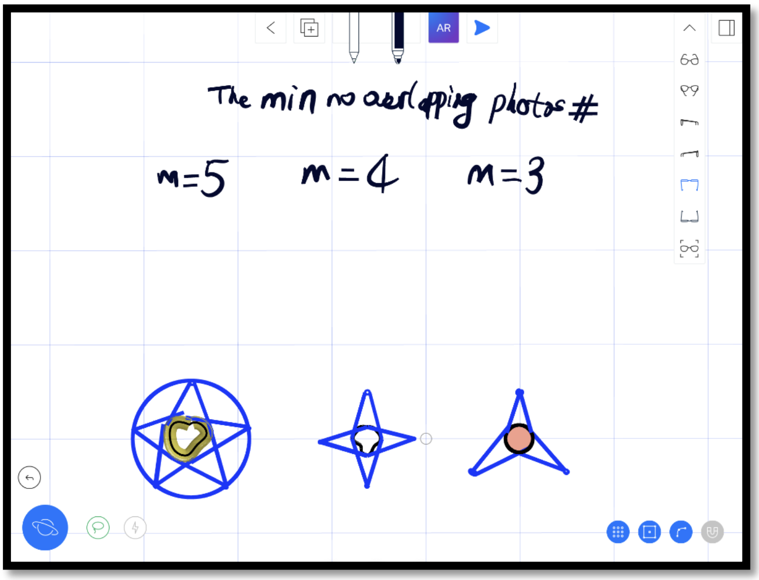
The three different kinds of object listed as follows:



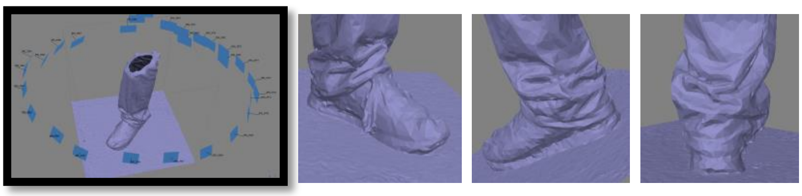




For different object, the minimum no overlapping number of photos , the parameter m is different:

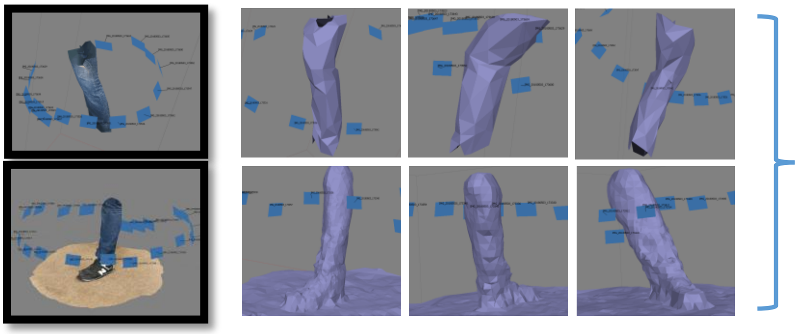


With this basic theory, now let’s go back to our previous models and calculate their overlapping percentage:



m=5;n=20;

(n-m)/n=75%



M=4;n=17;
(n-m)/n=76%

It looks like the overlapping percentage for these models are identical, all about 75%.
we then found something from agisoft user manual:

- Number of photos: more than required is better than not enough.
- Number of "blind-zones" should be minimized since PhotoScan is able to reconstruct only geometry visible from at least two cameras.

  In case of aerial photography the overlap requirement can be put in the following figures: 60% of side overlap + 80% of forward overlap.

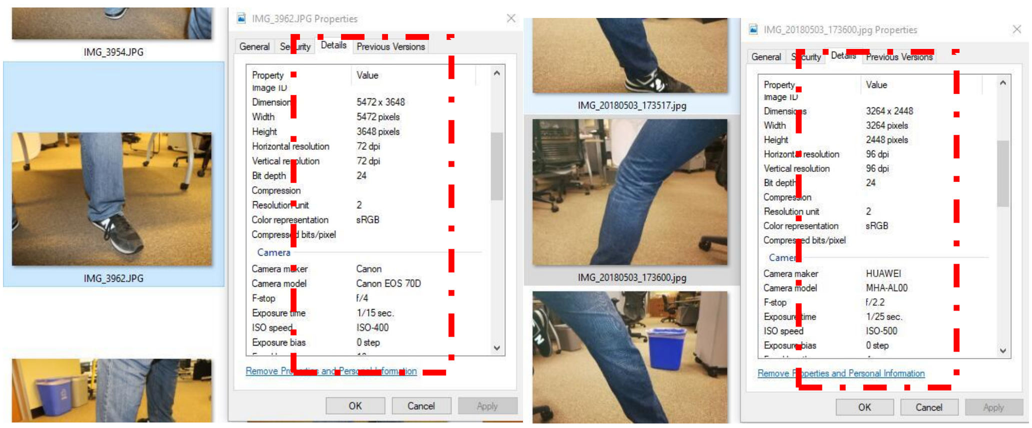
So, after discussion, we think Overlapping percentage (op) should be >=75%, but >=80% is recommended (safety op).
According to what we know so far, the first version of our theory is:

$$n = f(m, op)$$

where, m ~ relates to surface complexity of object; op is our overlapping percentage.

Part II: the resolution and number of photos

Before verify this theory is right or not, let's first look at the relationship between photo resolution and 3D model.
Let's first look at the resolution of our previous models:



Calculation about two models:

- Canon camera resolution

5472*3648 = 19961856 pixels = 20 million pixels

Photo real size :

5472*3648 / (72*72) dpi = 3850 sq.in

(n-m)/n = 75%

- Huawei camera resolution

3264*2448 =7990272 pixels = 8 million pixels

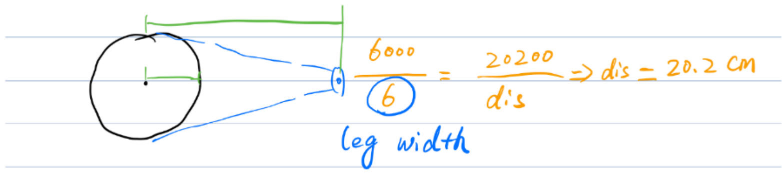
Photo real size :

5472*3648 / (96*96) dpi = 867 sq.in

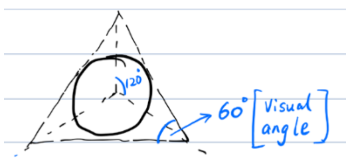
(n-m)/n = 76%

The resolution difference between two models are quiet huge, but why the resolution doesn't really matter in our case?

Back to our satellite example,



Looks like our camera should be keep 20.2 cm far from our object. But do remember this distance is based on the visual angle(VA) .



70d+18-135mm

18mmVA : 99deg

Huawei smart phone：

VA : 60deg

In practices, the safety distance is >= 30 cm, so for both of them, the number of photos doesn't matter since their VAs are wide enough to cover the whole leg.

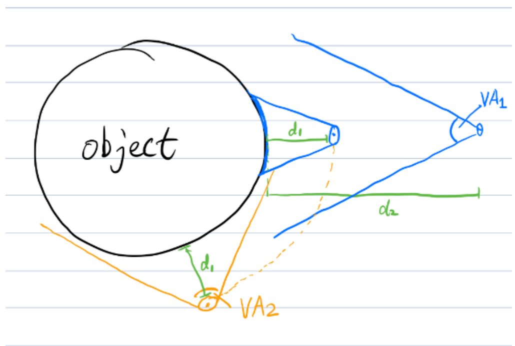
So dose resolution matters in our case? The answer is: we don't think it really matters under the condition of nowadays smart phone camera.

For cannon camera, 70d+18-135mm: as the focal distance changes, the VA changes as well.

In 18mm focal distance, the VA is 99deg ; in 100mm focal distance, the VA is 55deg

<u>OUR THEORY:</u>

- n = f (dis, VA, m, op)
- m ~ (surface complexity , dis, VA)



<u>In our case:</u>

Safety op >= 80%

m = 5

Safety dis >= 30 cm

VA >=60deg

R resolution >= 1 million pixels