無人機測繪製圖與影像判釋

期中報告

第四組　　2021.04.22

實驗概況

Background

圖片來源：https://www.36kr.com/p/1642015981569

實驗概況

載具與參數

載具

-無人直升機　搭載SONY RXI RMII 三相機系統

感測器規格

-解析度：7952×5304

-焦　距：35mm

-像元大小：4.525um

-中間垂直拍攝(M), 另兩台分別傾斜30°拍攝

實驗概況

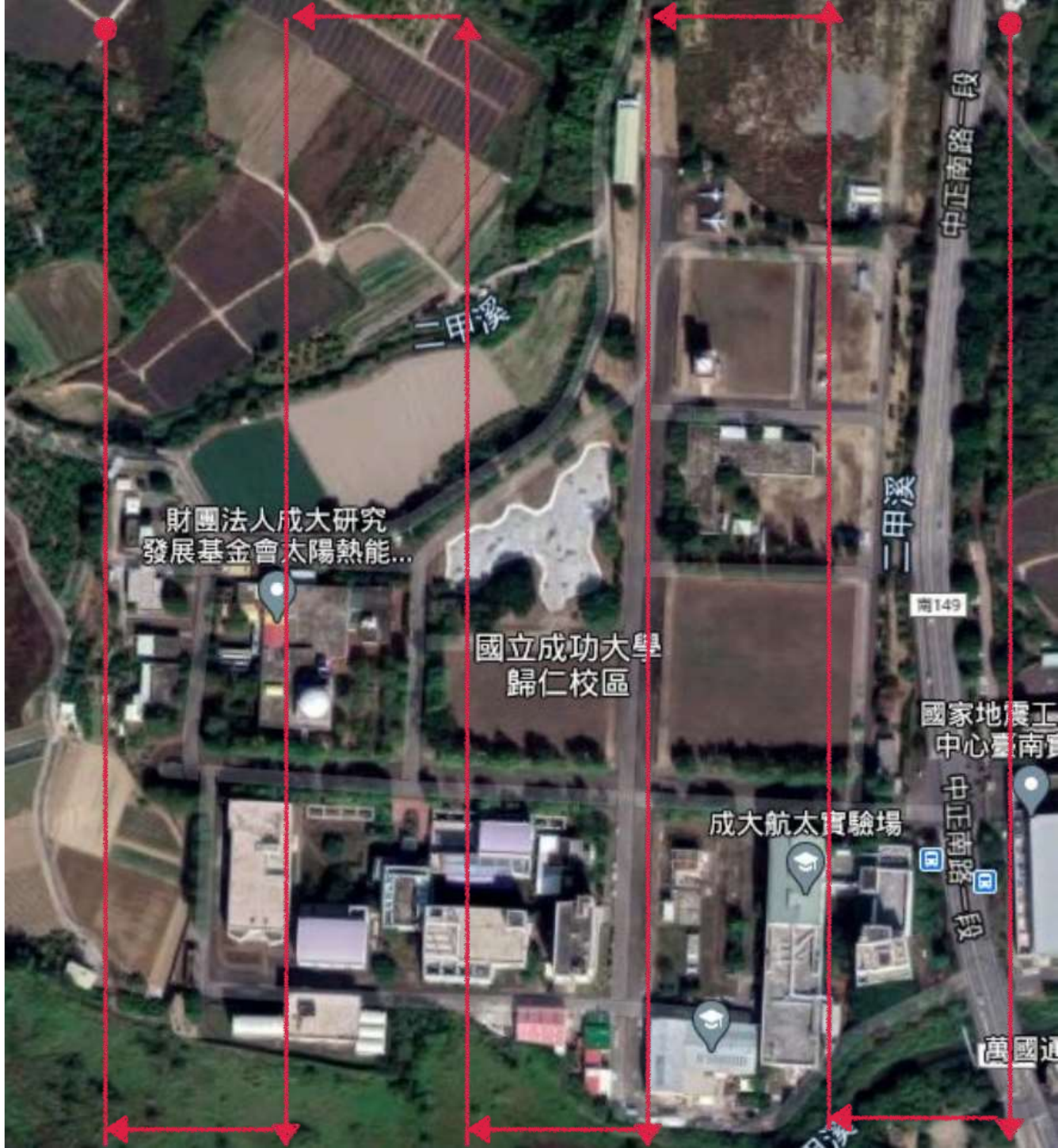
實驗區域與飛行計畫

地點
-成大歸仁校區

飛行計畫
-距地高度：150m
-飛行高度：170m
-航線方向與數量：南北方向共7條
-GSD =150*100*0.004525/20=3.39cm

重疊率
-垂直相機：前後重疊80%，左右重疊30%
-拼接相片：前後重疊80%，左右重疊80%

控制點數量
去除無法辨識的點位後，選用15個控制點，12個檢核點



影像方位重建

Image Orientation Reconstruction

圖片來源：https://www.pacecat.com/list_13.html

基本原理

數學核心：共線條件式

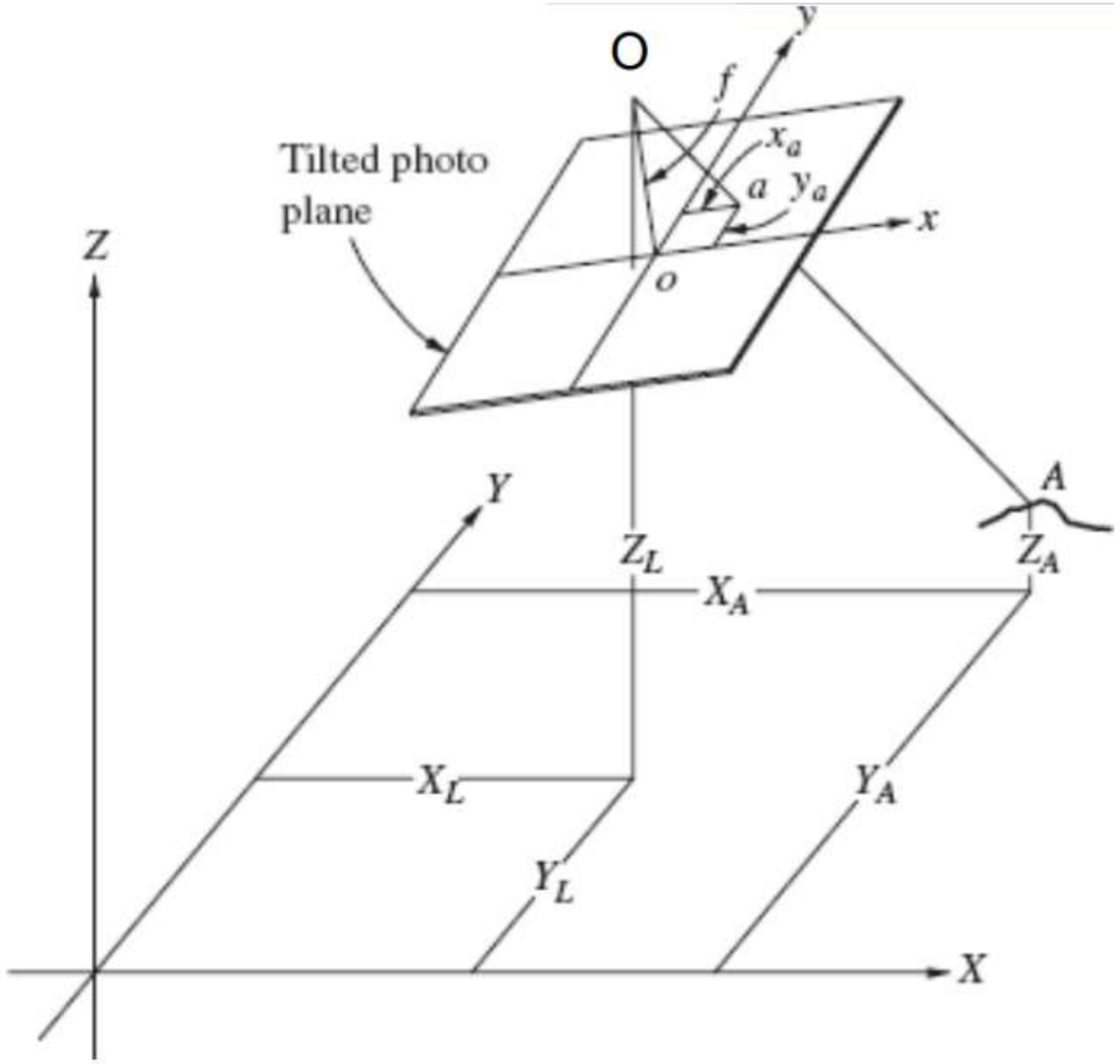
參數

-像主點坐標(x_p, y_p)
-相片上物件A坐標(x_a, y_a)
-相機透視中心的物空間坐標(X_O, Y_O, Z_O)
-物件A的物空間坐標(X_a, Y_a, Z_a)

$v_i = \lambda M \cdot V_O$

$$x_a - x_p = -f \frac{(m_{11}(X_A - X_O) + m_{12}(Y_A - Y_O) + m_{13}(Z_A - Z_O))}{(m_{31}(X_A - X_O) + m_{32}(Y_A - Y_O) + m_{33}(Z_A - Z_O))}$$

$$y_a - y_p = -f \frac{(m_{21}(X_A - X_O) + m_{22}(Y_A - Y_O) + m_{23}(Z_A - Z_O))}{(m_{31}(X_A - X_O) + m_{32}(Y_A - Y_O) + m_{33}(Z_A - Z_O))}$$



基本原理

求解影像外方位參數

定義

-照片的位置和姿態參數

算法：空間後方交會

-已知量：非共線的三個以上地面控制點（X_i, Y_i, Z_i）

-觀測量：在相片中拍攝到的控制點坐標(x_i, y_i)

-求：EOP (Xo, Yo, Zo, ω, φ, κ)

$$x_a - x_p = -f\frac{(m_{11}(X_A-X_O)+m_{12}(Y_A-Y_O)+m_{13}(Z_A-Z_O))}{(m_{31}(X_A-X_O)+m_{32}(Y_A-Y_O)+m_{33}(Z_A-Z_O))} \cdots (1)$$

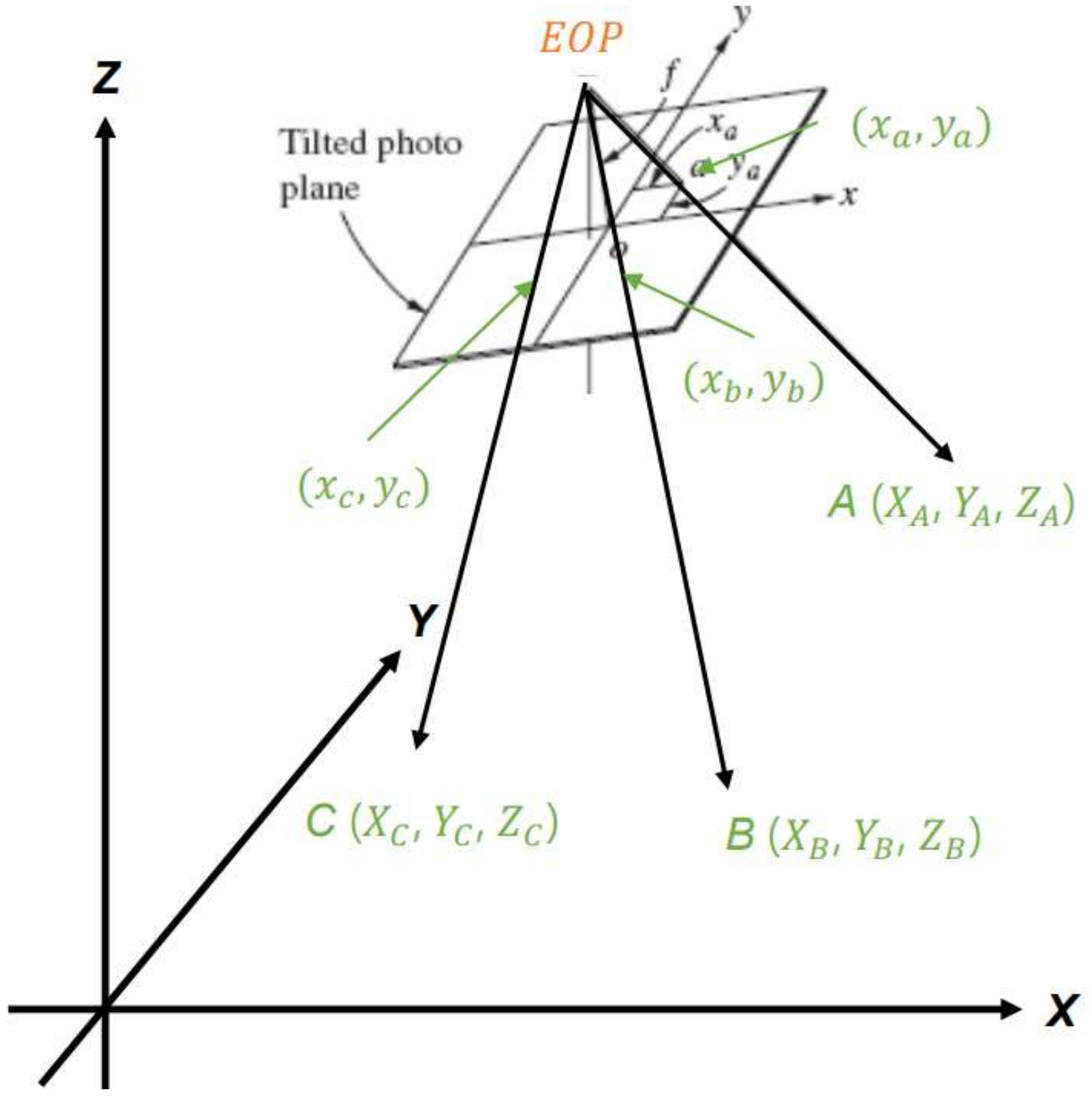
$$y_a - y_p = -f\frac{(m_{21}(X_A-X_O)+m_{22}(Y_A-Y_O)+m_{23}(Z_A-Z_O))}{(m_{31}(X_A-X_O)+m_{32}(Y_A-Y_O)+m_{33}(Z_A-Z_O))} \cdots (2)$$

$$x_b - x_p = -f\frac{(m_{11}(X_B-X_O)+m_{12}(Y_B-Y_O)+m_{13}(Z_A-Z_O))}{(m_{31}(X_B-X_O)+m_{32}(Y_B-Y_O)+m_{33}(Z_B-Z_O))} \cdots (3)$$

$$y_b - y_p = -f\frac{(m_{21}(X_B-X_O)+m_{22}(Y_B-Y_O)+m_{23}(Z_A-Z_O))}{(m_{31}(X_B-X_O)+m_{32}(Y_B-Y_O)+m_{33}(Z_B-Z_O))} \cdots (4)$$

$$x_c - x_p = -f\frac{(m_{11}(X_C-X_O)+m_{12}(Y_C-Y_O)+m_{13}(Z_A-Z_O))}{(m_{31}(X_C-X_O)+m_{32}(Y_C-Y_O)+m_{33}(Z_C-Z_O))} \cdots (5)$$

$$y_c - y_p = -f\frac{(m_{21}(X_C-X_O)+m_{22}(Y_C-Y_O)+m_{23}(Z_A-Z_O))}{(m_{31}(X_C-X_O)+m_{32}(Y_C-Y_O)+m_{33}(Z_C-Z_O))} \cdots (6)$$



基本原理

求解物點物空間坐標

定義

-實際場景中物體的空間坐標

算法：空間前方交會

-已知量：至少兩張照片AB的外方位參數(EOP_A,EOP_B)

-觀測量：兩張照片的共軛點(x_A, y_A),(x_B,y_B)

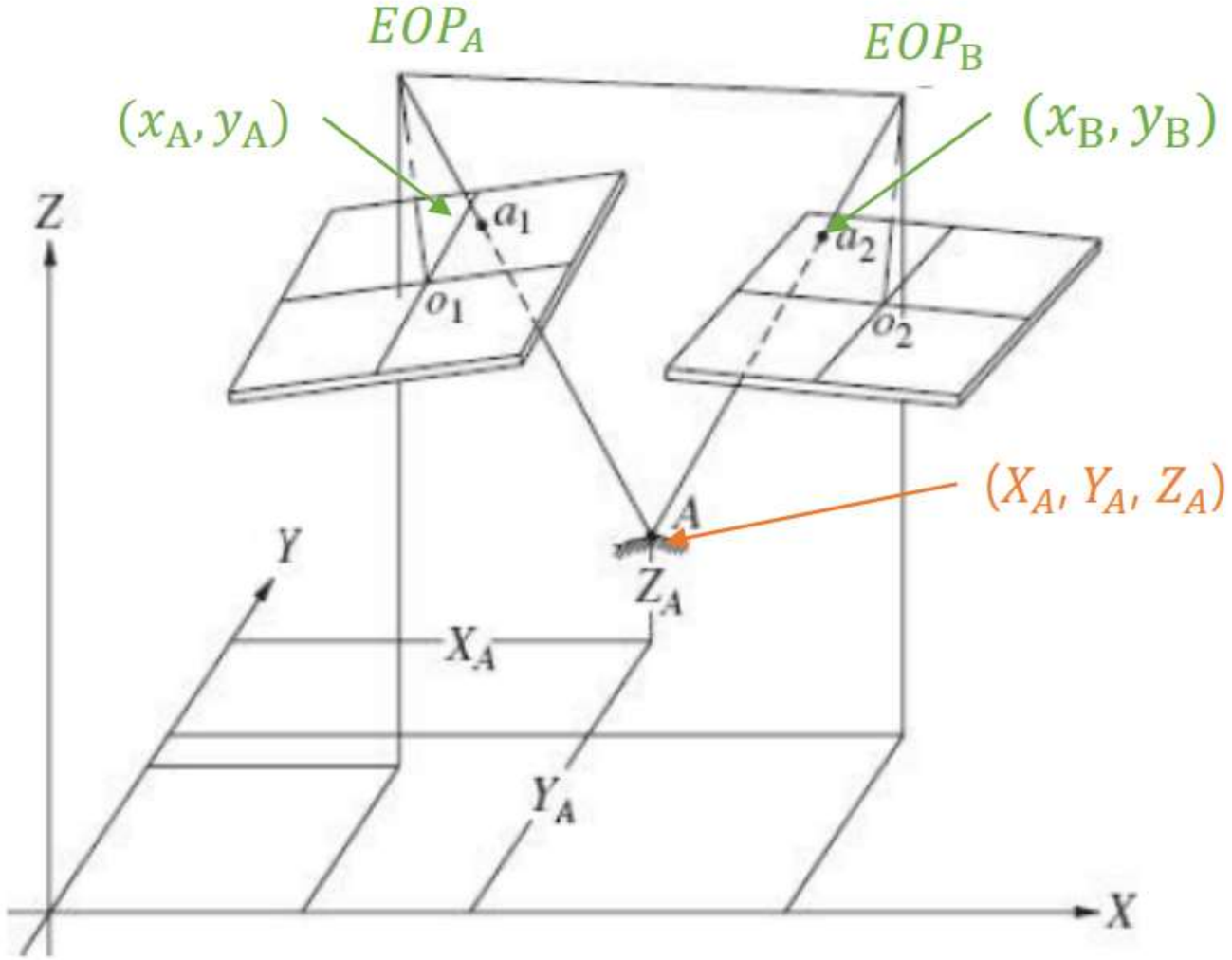
求：A:(X_A, Y_A, Z_A)

$$x_A - x_{p1} = -f\frac{(m_{11}(X_A-X_{O1})+m_{12}(Y_A-Y_{O1})+m_{13}(Z_A-Z_{O1}))}{(m_{31}(X_A-X_{O1})+m_{32}(Y_A-Y_{O1})+m_{33}(Z_A-Z_{O1}))} \cdots (1)$$

$$y_A - y_{p1} = -f\frac{(m_{21}(X_A-X_{O1})+m_{22}(Y_A-Y_{O1})+m_{23}(Z_A-Z_{O1}))}{(m_{31}(X_A-X_{O1})+m_{32}(Y_A-Y_{O1})+m_{33}(Z_A-Z_{O1}))} \cdots (2)$$

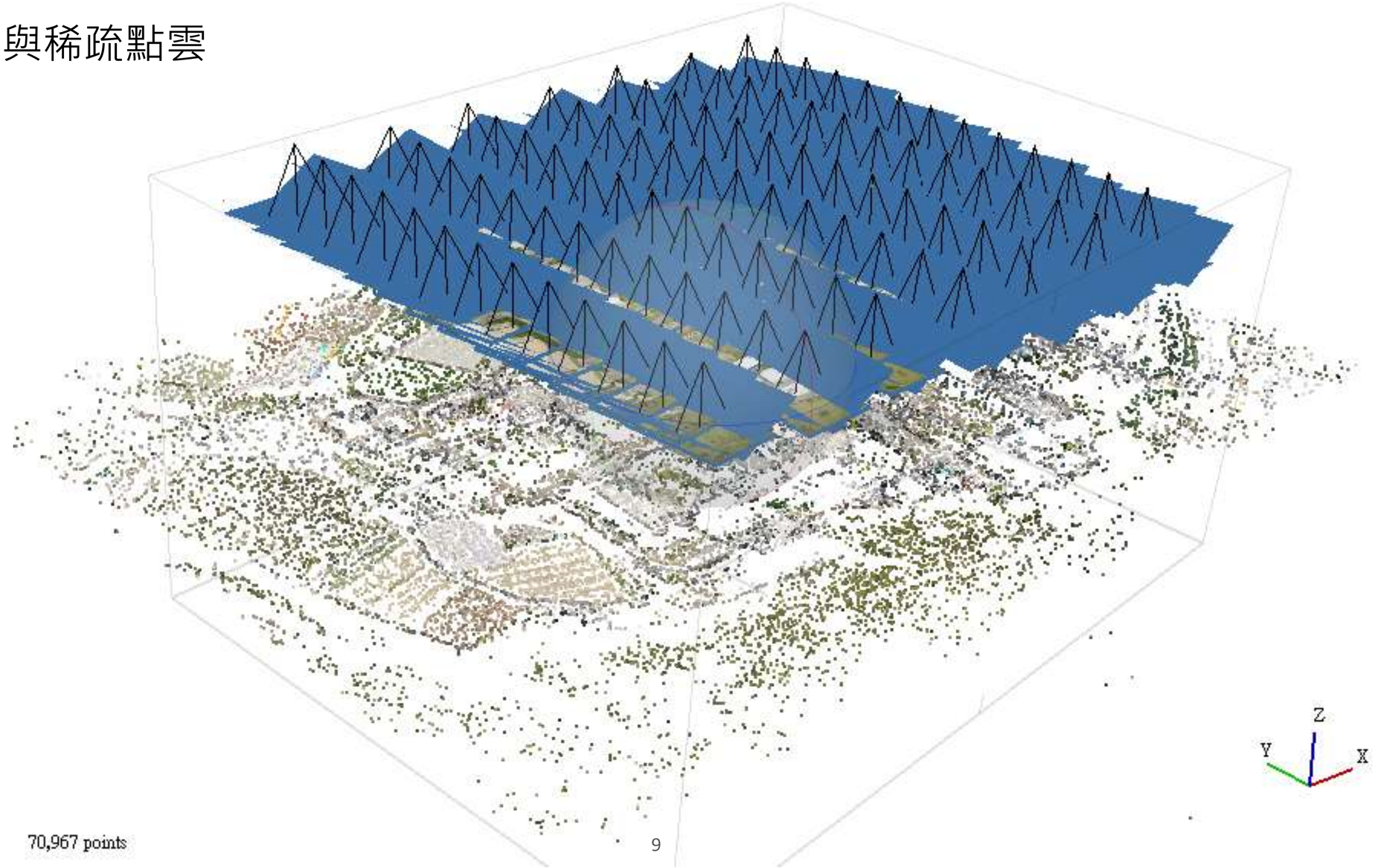
$$x_B - x_{p2} = -f\frac{(m_{11}(X_A-X_{O2})+m_{12}(Y_A-Y_{O2})+m_{13}(Z_A-Z_{O2}))}{(m_{31}(X_A-X_{O2})+m_{32}(Y_A-Y_{O2})+m_{33}(Z_A-Z_{O2}))} \cdots (3)$$

$$y_B - y_{p2} = -f\frac{(m_{21}(X_A-X_{O2})+m_{22}(Y_A-Y_{O2})+m_{23}(Z_A-Z_{O2}))}{(m_{31}(X_A-X_{O2})+m_{32}(Y_A-Y_{O2})+m_{33}(Z_A-Z_{O2}))} \cdots (4)$$



實作成果

影像外方位與稀疏點雲



基本原理

建立影像關係

定義

-兩張影像之間的相對關係

算法：相對方位

-已知量：A照片固定(EOP_A)，兩照片的距離

-觀測量：兩張照片的共軛點若干(x_i, y_i)

$$x_A - x_p = -f\frac{(m_{11}(X_A-X_{L1})+m_{12}(Y_A-Y_{L1})+m_{13}(Z_A-Z_{L1}))}{(m_{31}(X_A-X_{L1})+m_{32}(Y_A-Y_{L1})+m_{33}(Z_A-Z_{L1}))} \cdots (1)$$

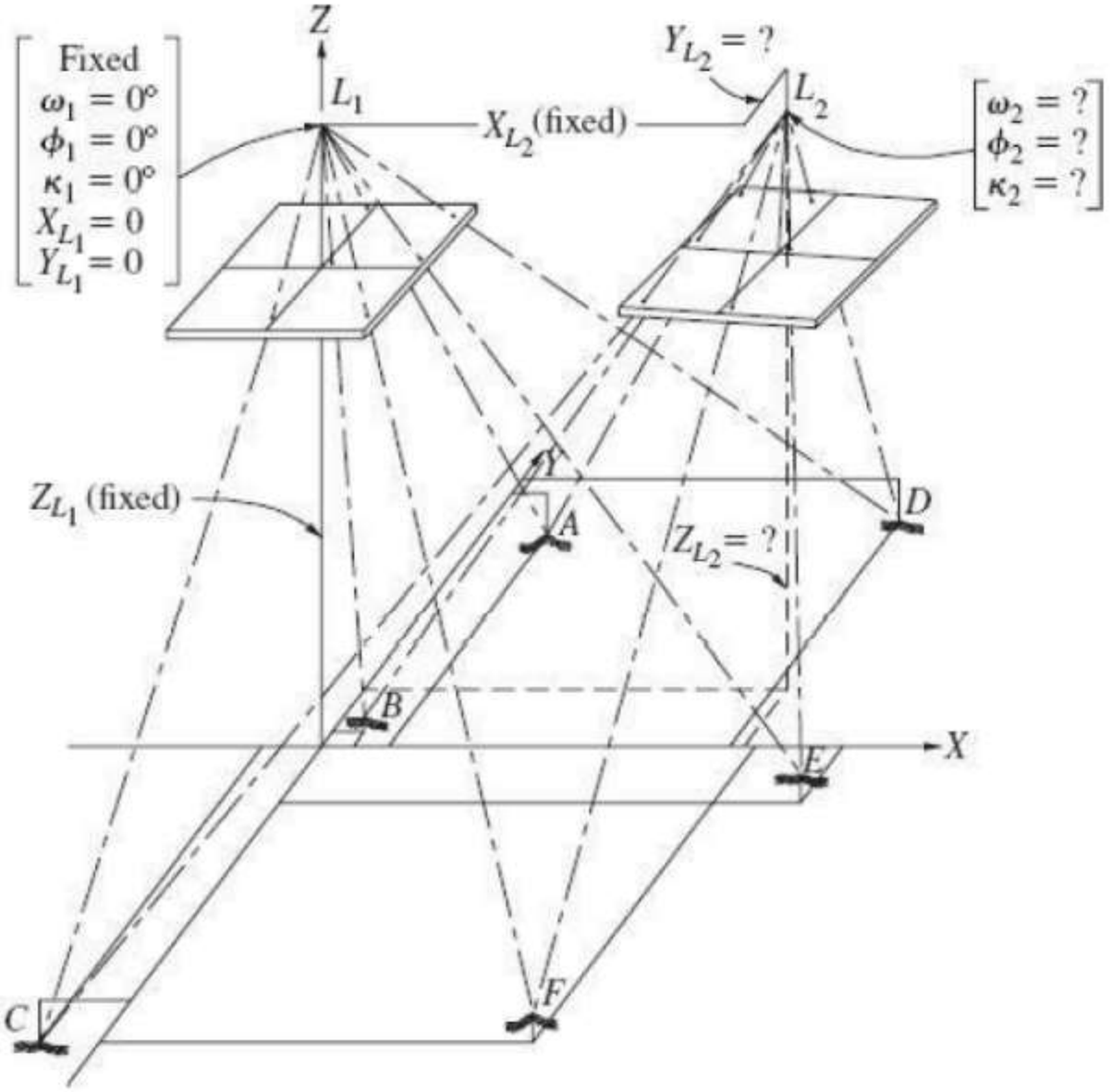
$$y_A - y_p = -f\frac{(m_{21}(X_A-X_{L1})+m_{22}(Y_A-Y_{L1})+m_{23}(Z_A-Z_{L1}))}{(m_{31}(X_A-X_{L1})+m_{32}(Y_A-Y_{L1})+m_{33}(Z_A-Z_{L1}))} \cdots (2)$$

$$x_B - x_p = -f\frac{(m_{11}(X_B-X_{L2})+m_{12}(Y_B-Y_{L2})+m_{13}(Z_B-Z_{L2}))}{(m_{31}(X_B-X_{L2})+m_{32}(Y_B-Y_{L2})+m_{33}(Z_B-Z_{L2}))} \cdots (3)$$

$$y_B - y_p = -f\frac{(m_{21}(X_B-X_{L2})+m_{22}(Y_B-Y_{L2})+m_{23}(Z_B-Z_{L2}))}{(m_{31}(X_B-X_{L2})+m_{32}(Y_B-Y_{L2})+m_{33}(Z_B-Z_{L2}))} \cdots (4)$$

共須5個共軛點合計10條方程聯立

-求：照片B的ω, Φ, κ及2個球坐標自由度



基本原理

測量立體高度

定義

-由位移高差估計建物高度

算法：高差移位

-已知量：H 飛行高度

-觀測量：d 高差移位

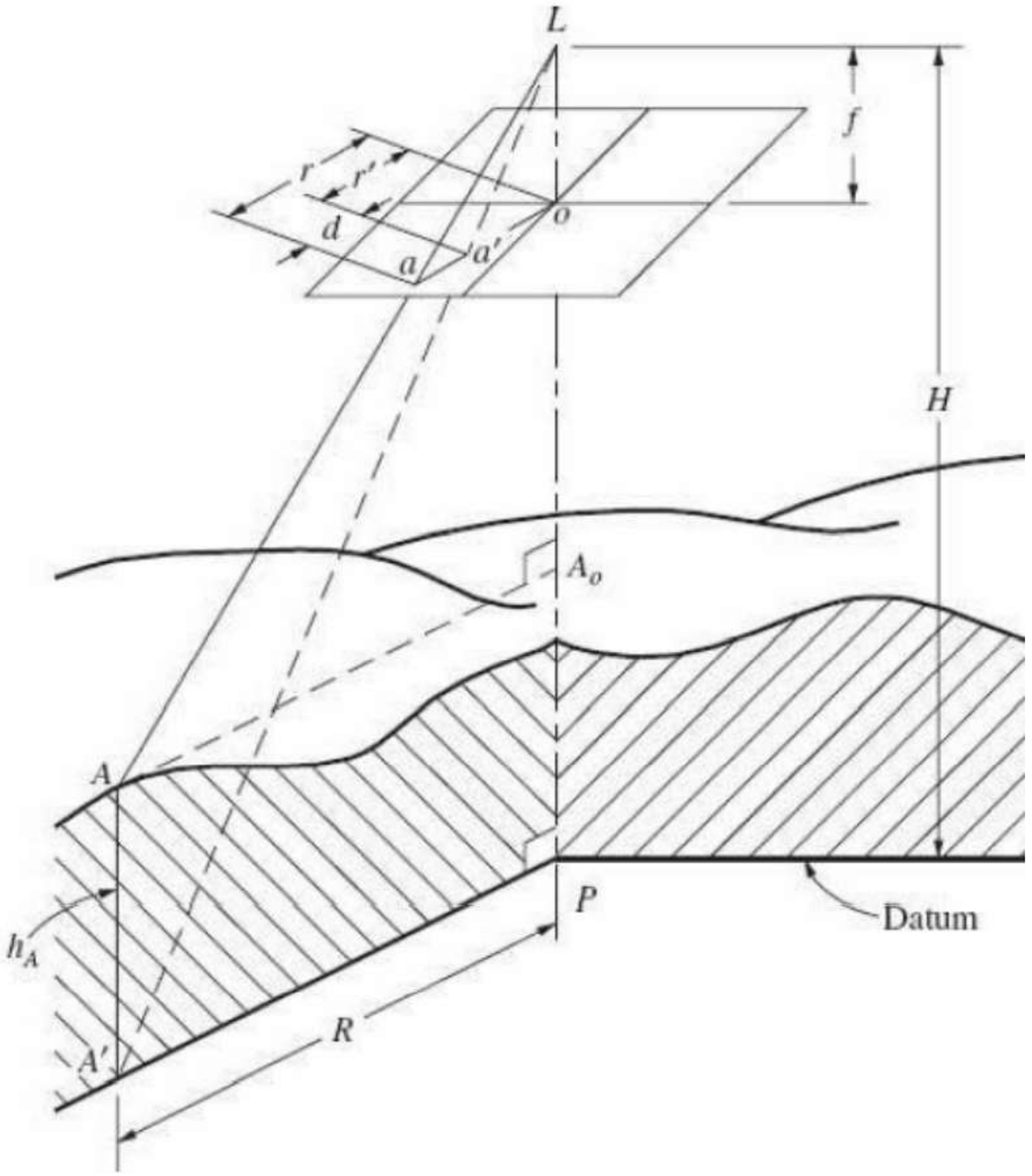
r 建物頂點相對於像主點在影像上的輻射位移

$$\triangle Lao \sim \triangle LAA_O$$
$$R = f : (H - h_A) \Rightarrow r(H - h_A) = R_f \cdots (1)$$
$$\triangle La'o \sim \triangle LA'P$$
$$r' : R = f : H \Rightarrow r'H = Rf \cdots (2)$$

聯立式 (1)(2)

-求：h_A

$$r'H = f : H \Rightarrow rh_A = (r - r')H \Rightarrow h_A = d\frac{H}{r}$$



基本原理

解算所有照片

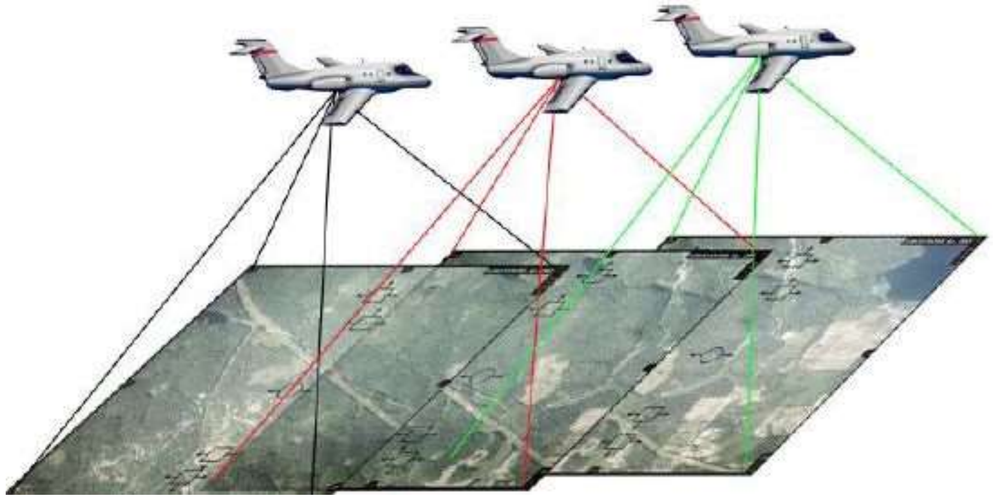
定義

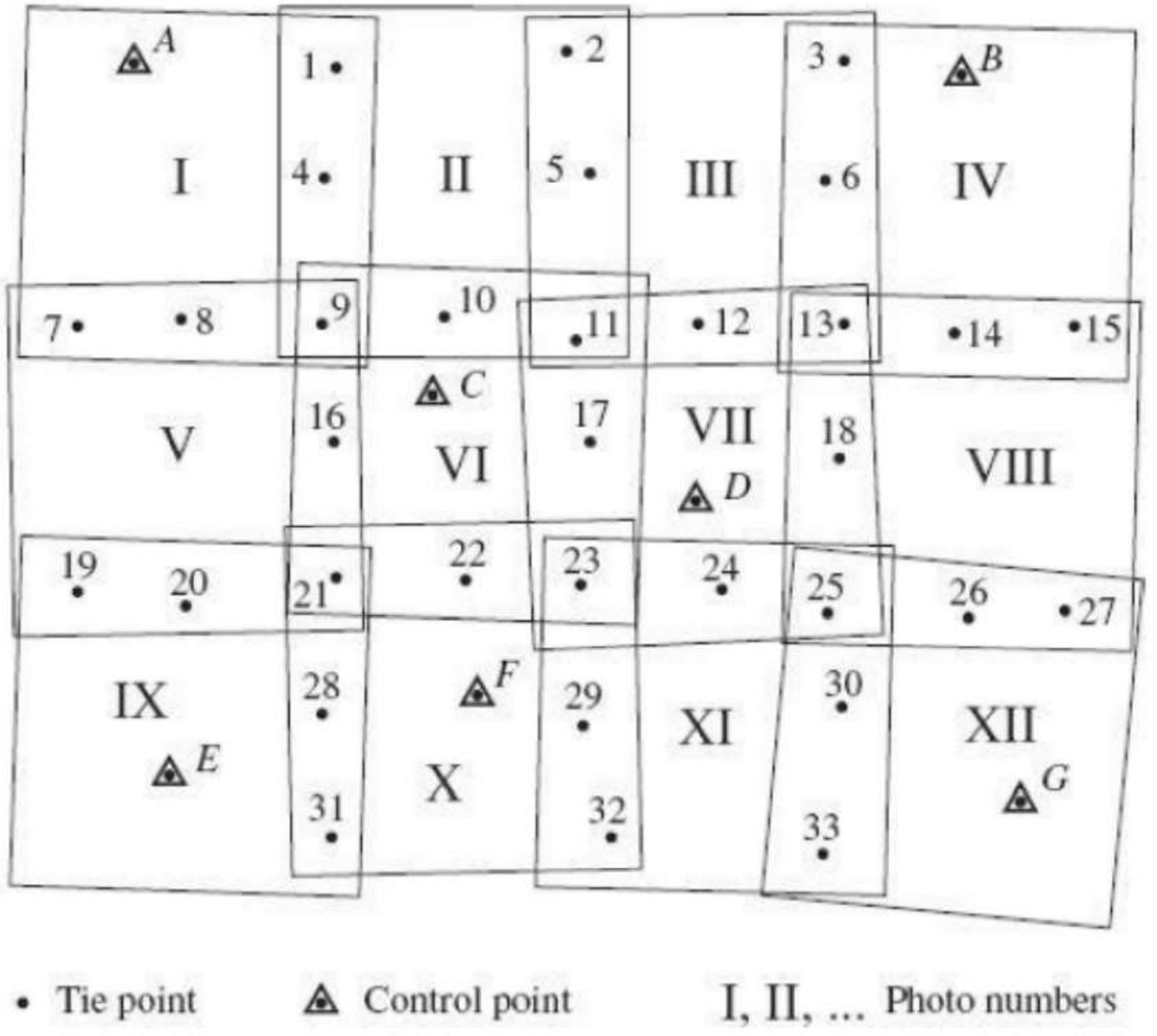
-解算所有照片的外方位參數與所有共軛點的物空間座標

算法：光束法平差

-經由影像匹配尋找不同影像上的共軛點

-經由相對方位建立所有照片的連接





基本原理

相機率定

定義

-共線條件式過於理想，實際照片可能存在偏移

算法：給共線條件式附加參數

-已知量：焦距f, 像主點(x_p,y_p), 輻射畸變(K_1,K_2,K_3), 偏心畸變(P_1,P_2)

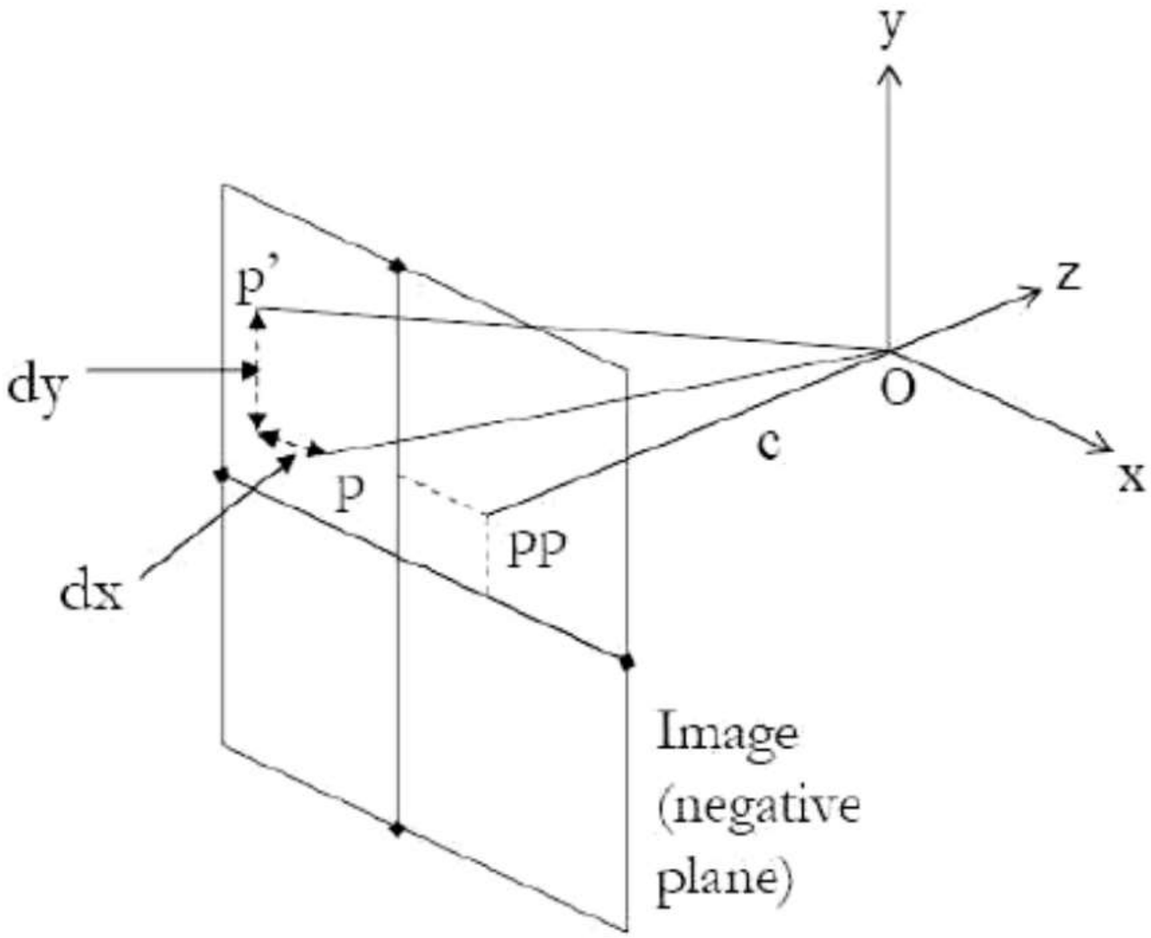
共線條件式　　附加參數

$$\bar{x} = x - x_p = -f\frac{m_{11}(X - X_o) + m_{12}(Y - Y_o) + m_{13}(Z - Z_o)}{m_{31}(X - X_o) + m_{32}(Y - Y_o) + m_{33}(Z - Z_o)} + \Delta x$$

$$\bar{y} = y - y_p = -f\frac{m_{21}(X - X_o) + m_{22}(Y - Y_o) + m_{23}(Z - Z_o)}{m_{31}(X - X_o) + m_{32}(Y - Y_o) + m_{33}(Z - Z_o)} + \Delta y$$

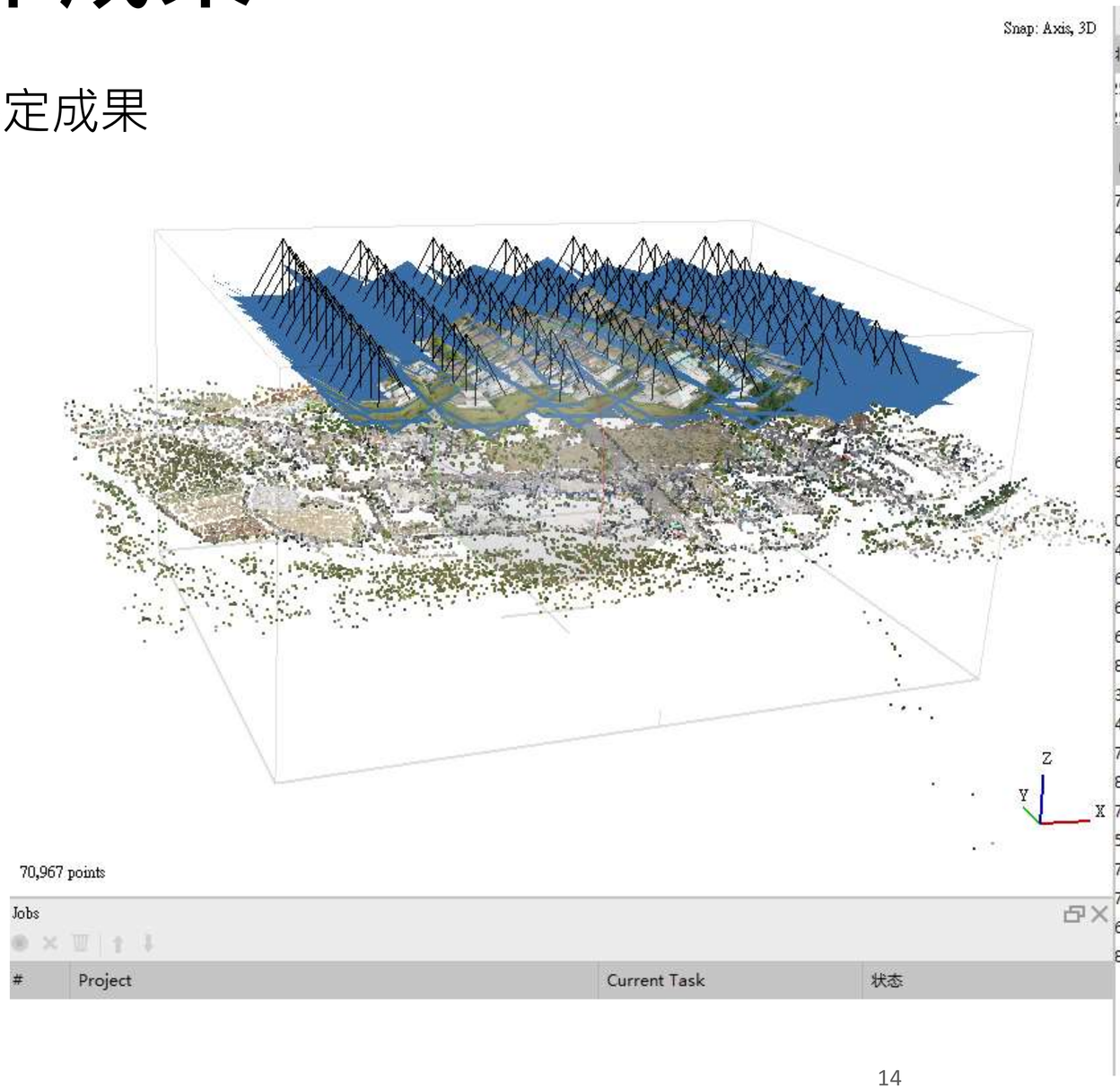
$$\Delta x = (\bar{x})(K_1 r^2 + K_2 r^4 + k_3 r^6) + P_1(r^2 + \bar{x}^2) + 2P_2\bar{x}\bar{y}$$

$$\Delta y = (\bar{y})(K_1 r^2 + K_2 r^4 + k_3 r^6) + P_2(r^2 + \bar{y}^2) + 2P_1\bar{x}\bar{y}$$



實作成果

相機率定成果



北距 (m)	海拔高度 (m)	精度 (m)	Error (m)	横摆 (deg)	间距 (deg)	滚动 (de
2537632.005548	168.972016	10.000000	0.206594			
2537632.005548	168.972016	10.000000	0.453999			

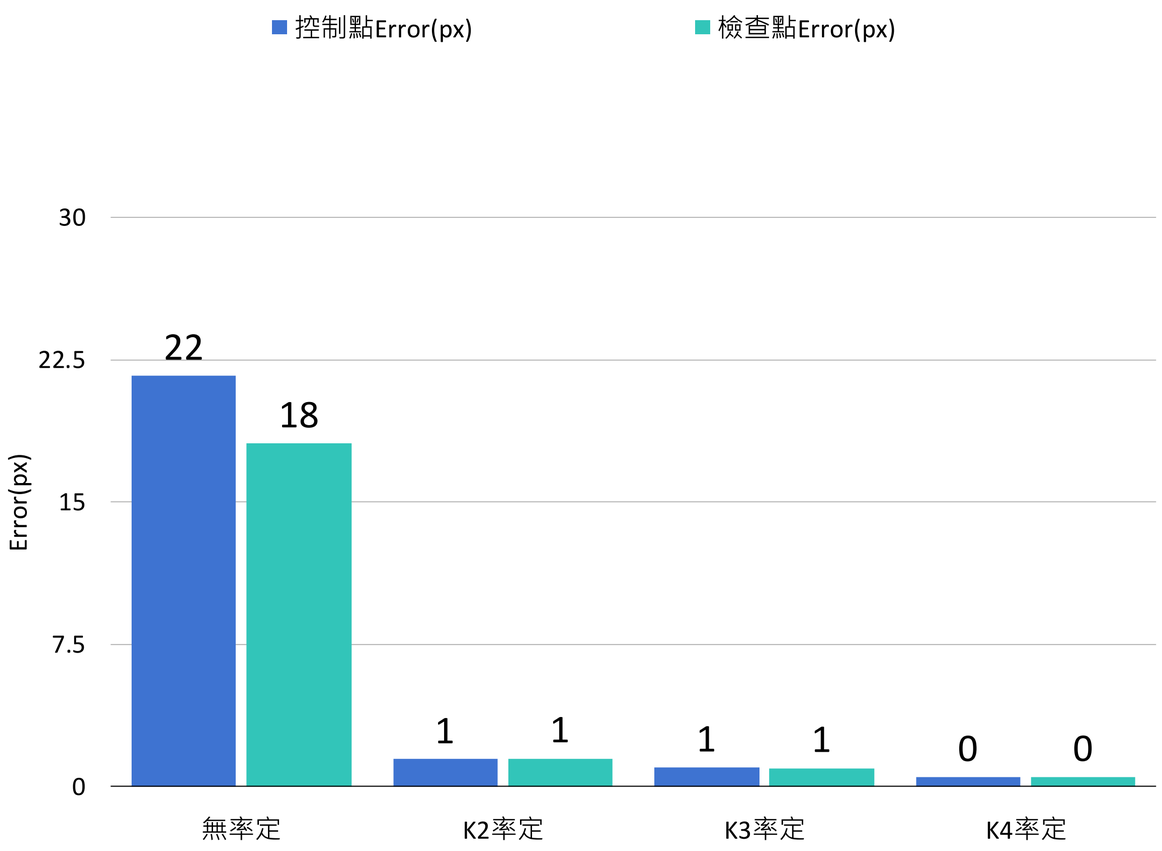
(m)	北距 (m)	海拔高度 (m)	精度 (m)	Error (m)	预测	错误 (像素)
76.521000	2537354.967000	16.274000	0.005000	0.061375	12	0.427
47.954000	2537471.596000	16.438000	0.005000	0.008103	20	0.397
40.653000	2537666.612000	17.290000	0.005000	0.023784	15	0.686
48.591000	2537751.822000	17.978000	0.005000	0.003773	5	0.250
29.338000	2537734.937000	19.704000	0.005000	0.011336	4	0.235
31.457000	2537363.466000	13.918000	0.005000	0.016944	18	0.348
58.965000	2537361.162000	13.935000	0.005000	0.023147	25	0.488
32.226000	2537354.927000	13.954000	0.005000	0.027667	25	0.544
58.009000	2537348.142000	14.509000	0.005000	0.023475	32	0.500
62.082000	2537293.733000	14.422000	0.005000	0.006240	17	0.836
38.323000	2537286.208000	14.361000	**0.005000**	0.023297	7	0.394
02.291000	2537477.853000	13.897000	0.005000	0.007433	20	0.309
41.941000	2537471.868000	14.220000	**0.005000**	0.022068	36	0.462
63.661000	2537463.715000	14.477000	0.005000	0.024733	45	0.508
65.913000	2537512.723000	14.449000	0.005000	0.024366	46	0.393
67.664000	2537546.435000	14.441000	0.005000	0.026139	44	0.358
81.838000	2537621.484000	13.984000	0.005000	0.001290	1	0.258
35.983000	2537597.295000	13.867000	0.005000	0.014365	28	0.432
49.434000	2537587.843000	14.076000	0.005000	0.043843	32	0.353
70.313000	2537589.309000	14.461000	0.005000	0.008583	40	0.393
85.626000	2537581.005000	14.499000	0.005000	0.024655	28	0.450
74.833000	2537675.466000	14.416000	0.005000	0.018006	26	0.639
58.306000	2537668.412000	14.579000	0.005000	0.020548	19	0.844
77.552000	2537727.803000	14.487000	0.005000	0.006993	14	0.393
79.232000	2537762.470000	14.461000	0.005000	0.014742	7	0.522
62.821000	2537750.804000	15.393000	0.005000	0.006216	8	0.635
80.917000	2537801.173000	14.421000	0.005000		1	0.000
				0.015918		0.485
				0.029780		0.487

比較與分析

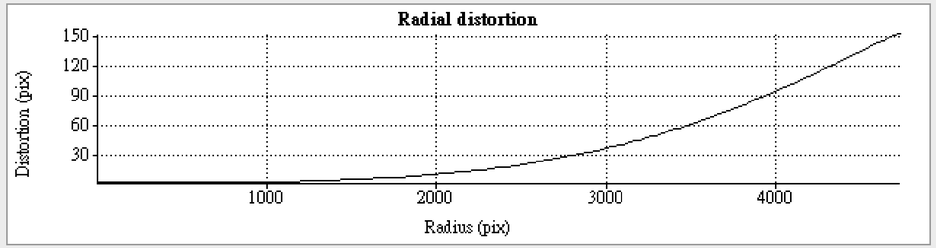
Comparison and Analysis

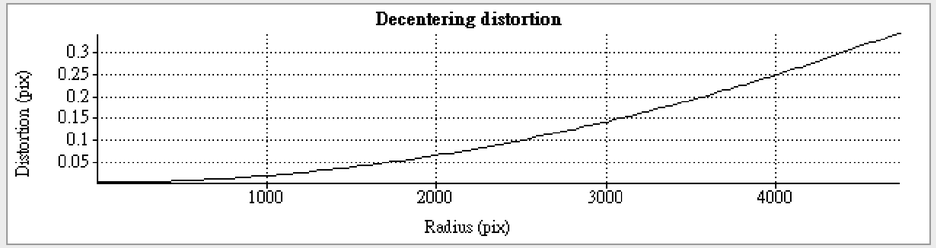
比較與分析

相機率定參數選擇

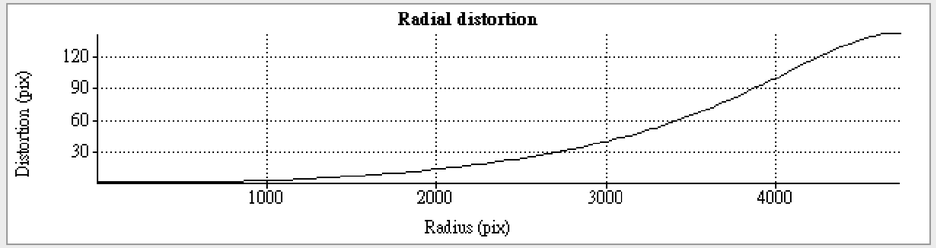


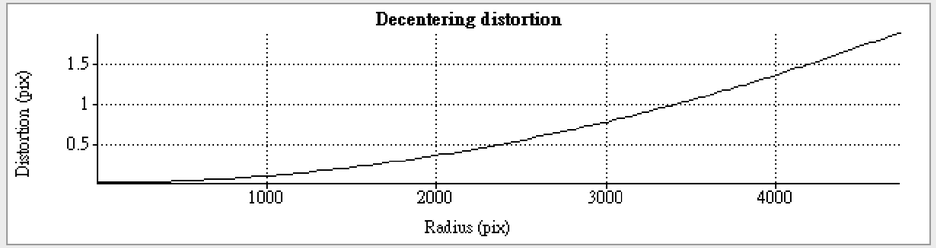
- K3率定





- K4率定





LMR與M 的比較

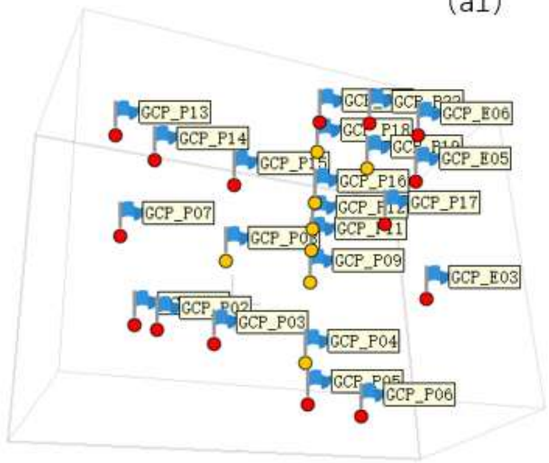
設定參數

- M & LMR 相同的參數
  - 相機焦距：0.004525 mm
  - 座標投影設定
    - 照片方位：WGS84 (EPSG:4326)
    - 控制點座標：TWD 97/TM2 zone 121 (EPSG:3826)

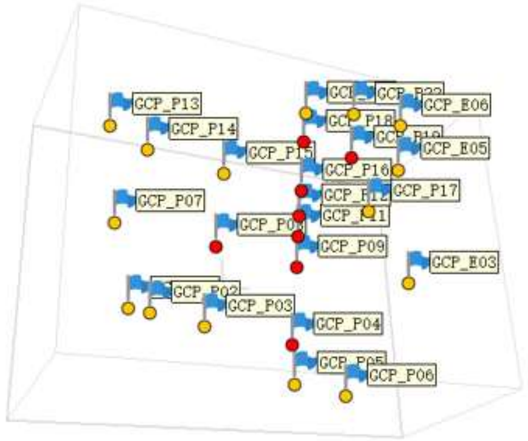
LMR與M 的比較

控制點與檢查點的選擇

(a1)



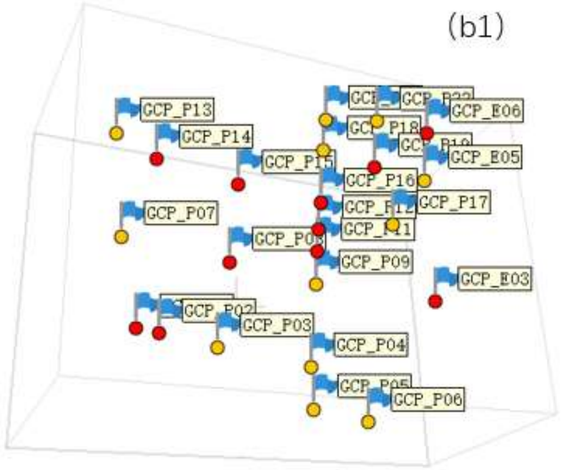
(a2)



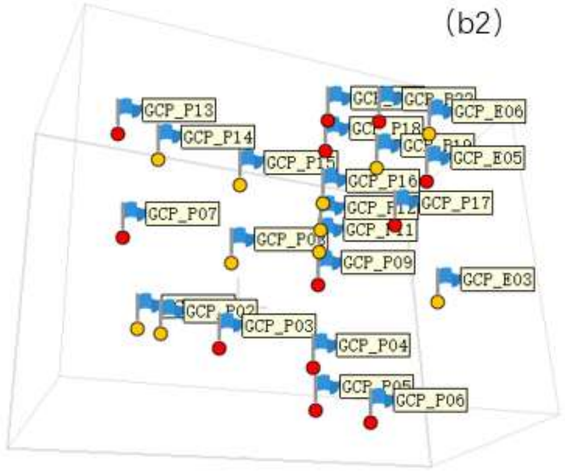
type	Error(m)	Error(pix)
Control	0.016699	0.492
Check	0.028028	0.483

type	Error(m)	Error(pix)
Control	0.016076	0.494
Check	0.037680	0.449

(b1)



(b2)



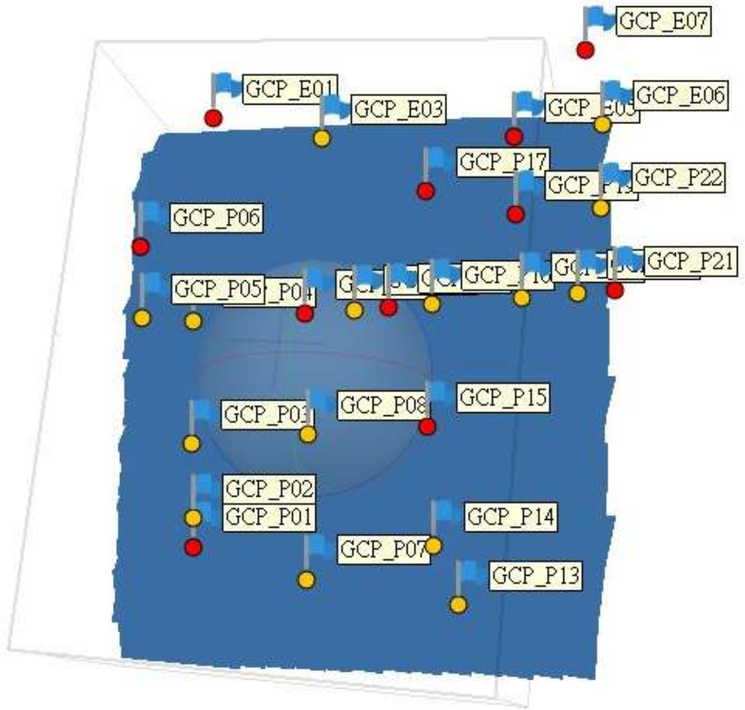
type	Error(m)	Error(pix)
Control	0.014114	0.531
Check	0.024822	0.472

type	Error(m)	Error(pix)
Control	0.012688	0.522
Check	0.037874	0.445

LMR與M 的比較

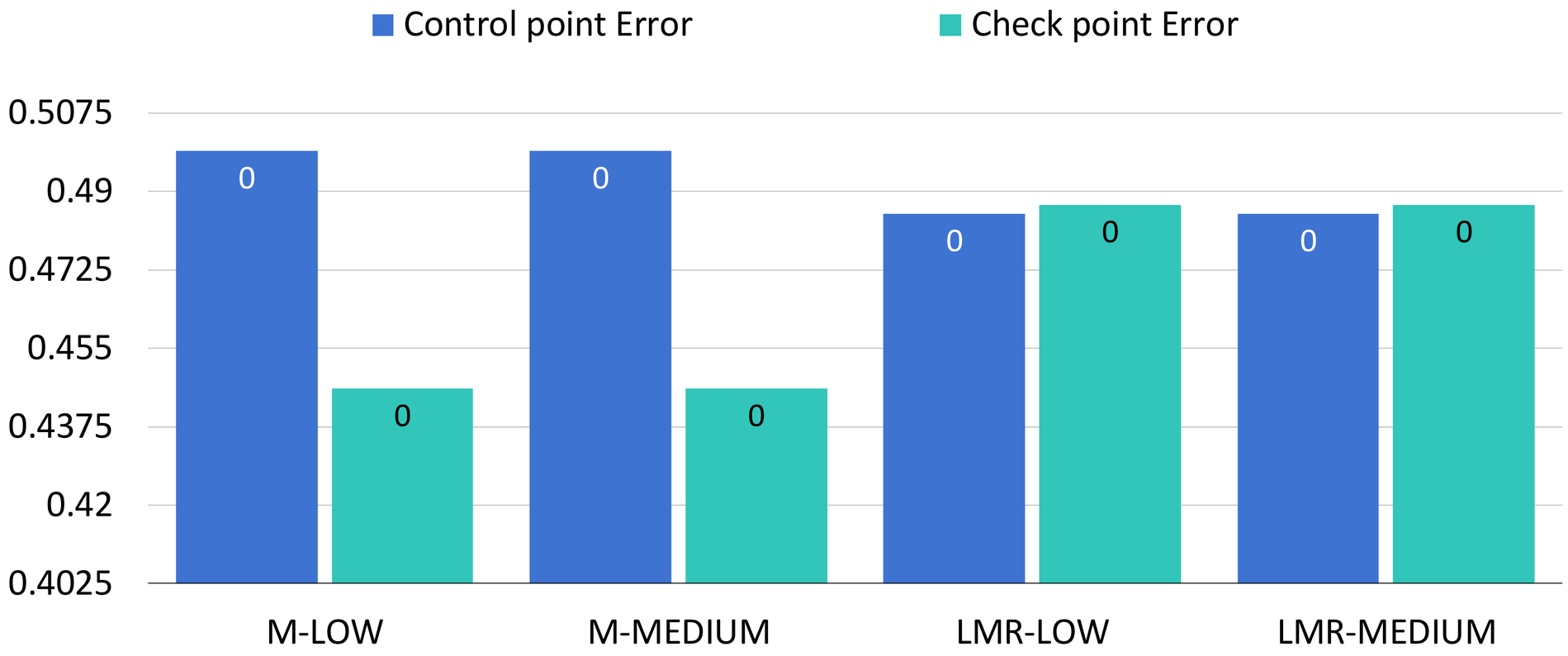
控制點與檢查點的選擇

- M LOW
  - GCP_E01
  - GCP_E05
  - GCP_E07
  - GCP_P01
  - GCP_P06
  - GCP_P09
  - GCP_P12
  - GCP_P15
  - GCP_P17
  - GCP_P19
  - GCP_P21
  - GCP_P23
- M MEDIUM
  - GCP_E01
  - GCP_E05
  - GCP_E07
  - GCP_P01
  - GCP_P06
  - GCP_P09
  - GCP_P12
  - GCP_P15
  - GCP_P17
  - GCP_P19
  - GCP_P21
  - GCP_P23
- LMR LOW
  - GCP_E01
  - GCP_E05
  - GCP_E07
  - GCP_P01
  - GCP_P06
  - GCP_P09
  - GCP_P12
  - GCP_P15
  - GCP_P17
  - GCP_P19
  - GCP_P21
  - GCP_P23
- LMR MEDIUM
  - GCP_E01
  - GCP_E05
  - GCP_E07
  - GCP_P01
  - GCP_P06
  - GCP_P09
  - GCP_P12
  - GCP_P15
  - GCP_P17
  - GCP_P19
  - GCP_P21
  - GCP_P23



LMR與M 的比較

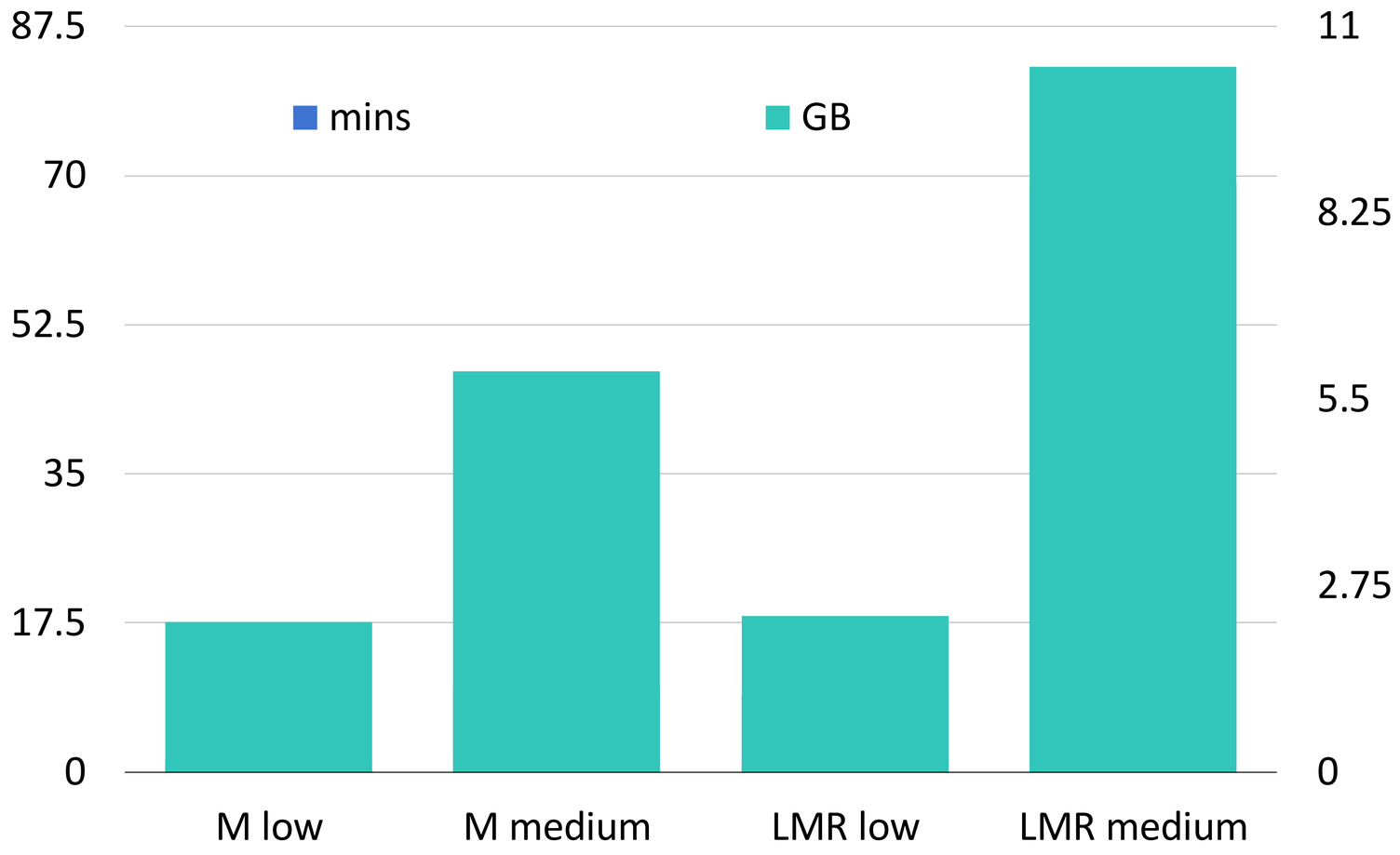
影相匹配成果



LMR與M 的比較

效率—Dense cloud

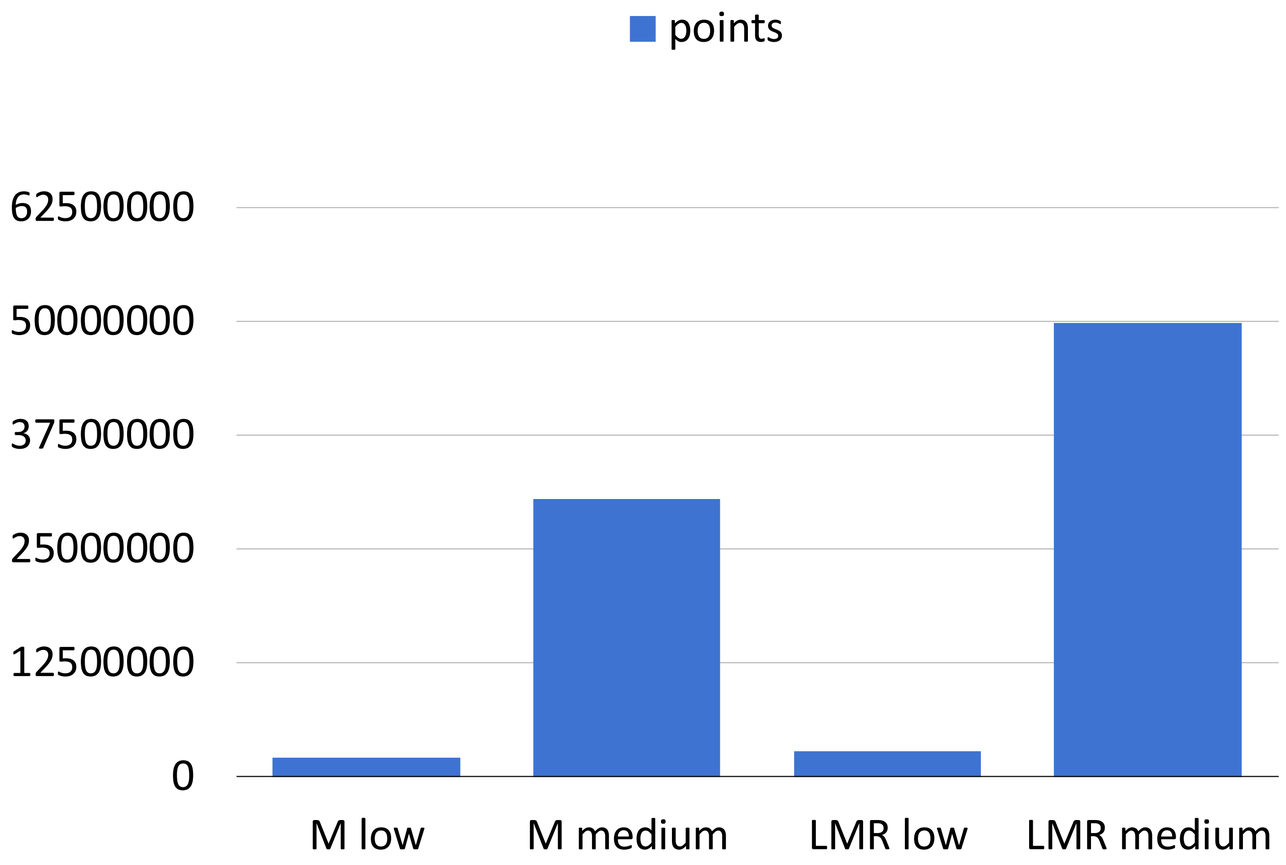
- M
  - low: 1.3 mins / 2.2GB
  - medium: 9 mins / 5.9GB
- LMR
  - low: 10 mins / 2.3GB
  - medium: 69 mins / 10.4GB



LMR與M 的比較

點雲密度

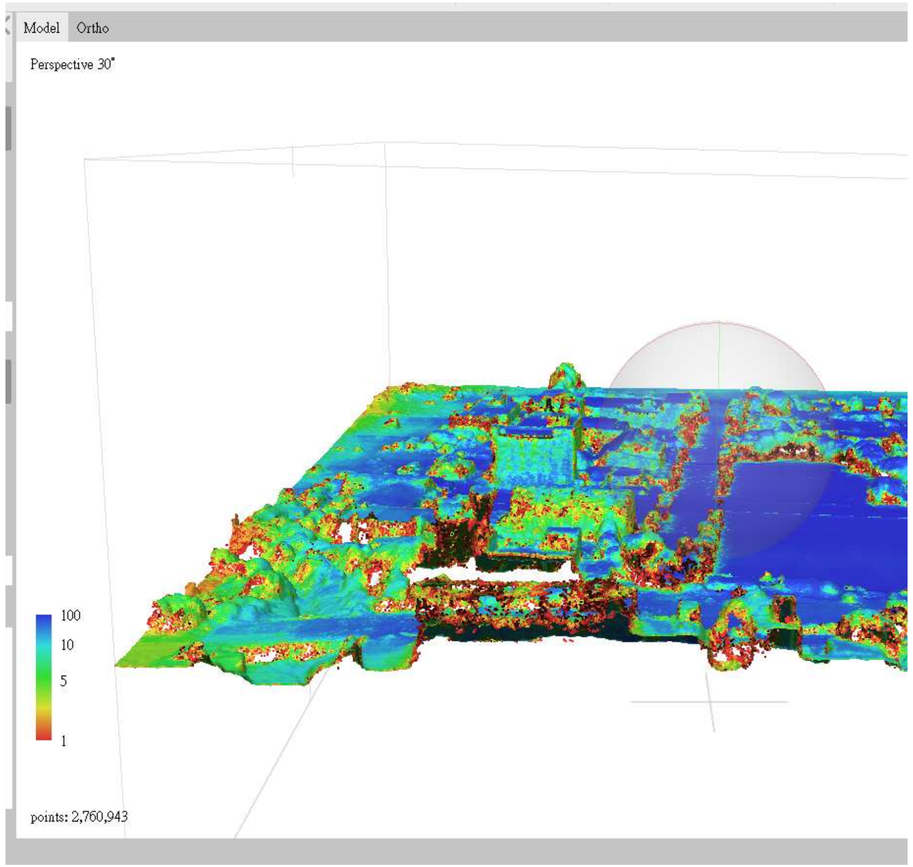
- M
  - low: 2,026,010 points
  - medium: 30,470,374 points
- LMR
  - low: 2,760,943 points
  - medium: 49,754,464 points



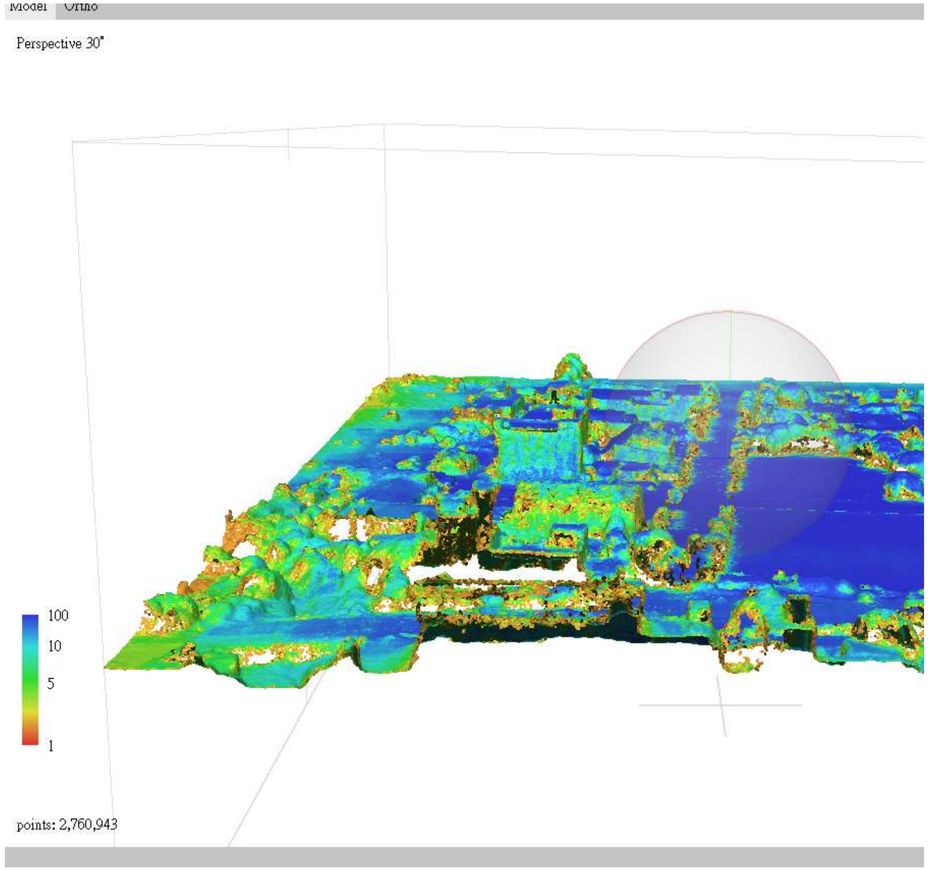
LMR與M 的比較

刪除不可靠點雲

- LMR LOW (0-255)



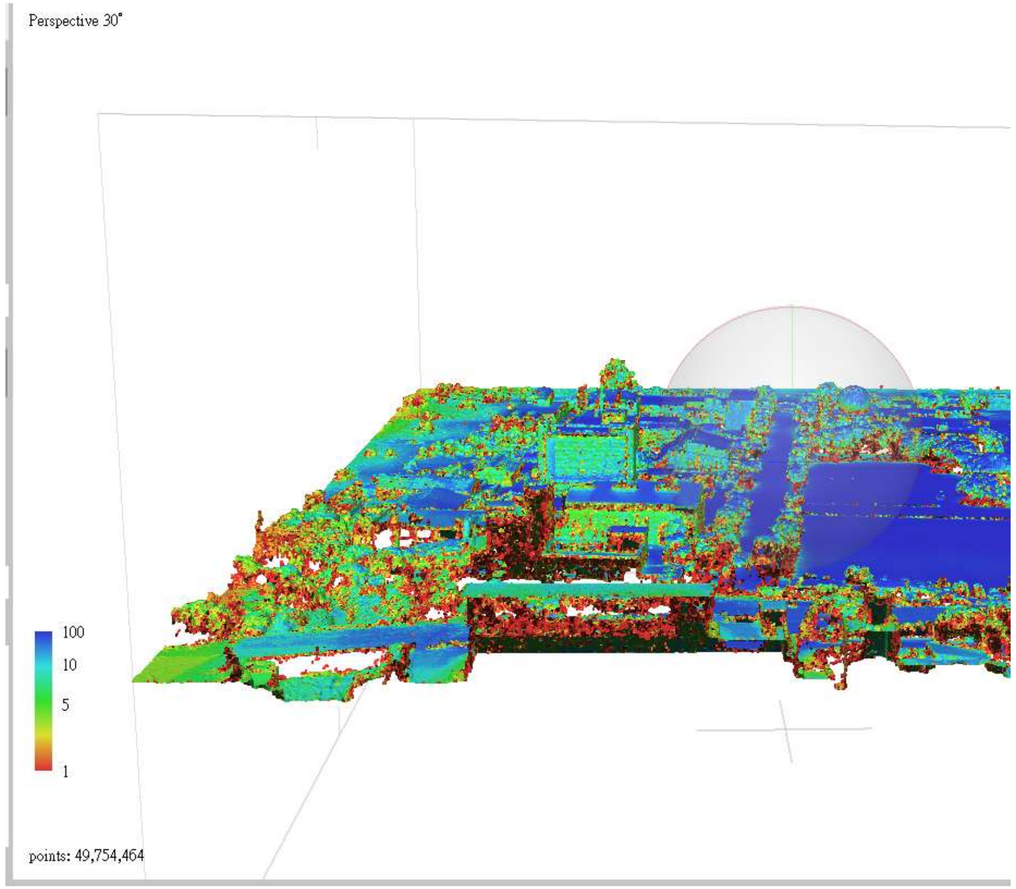
- LMR LOW (2-255)



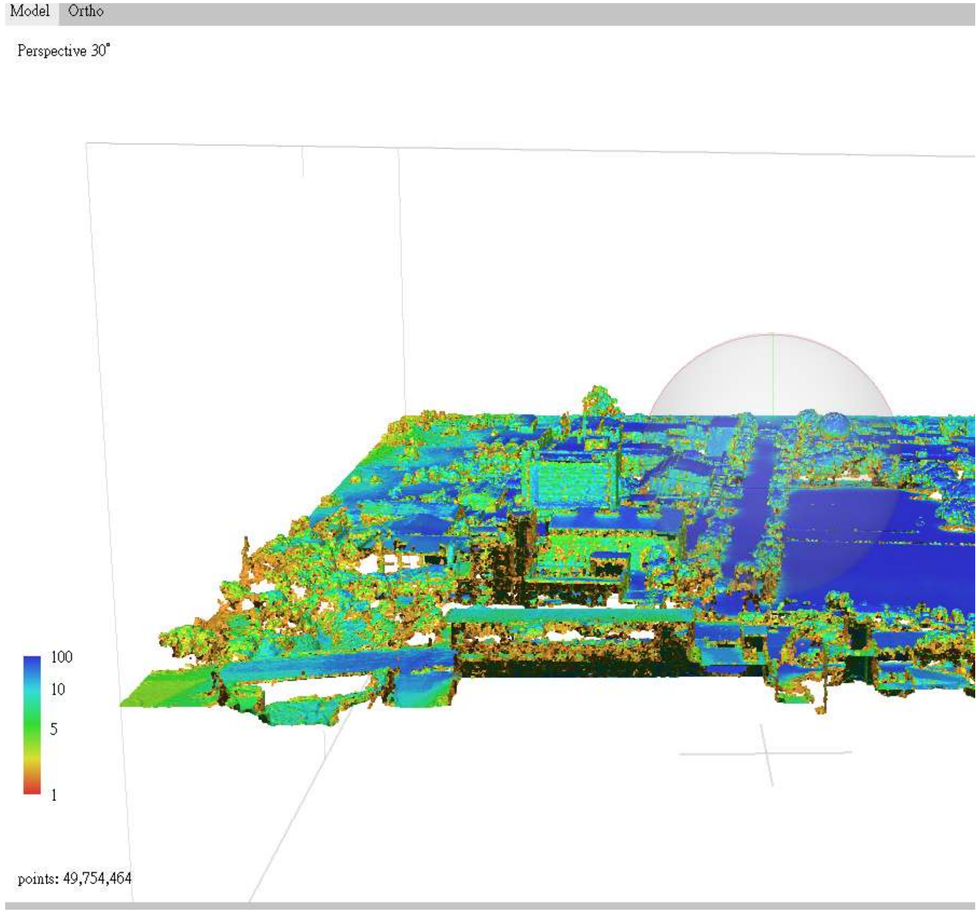
LMR與M 的比較

刪除不可靠點雲

- LMR MEDIUM (0-255)



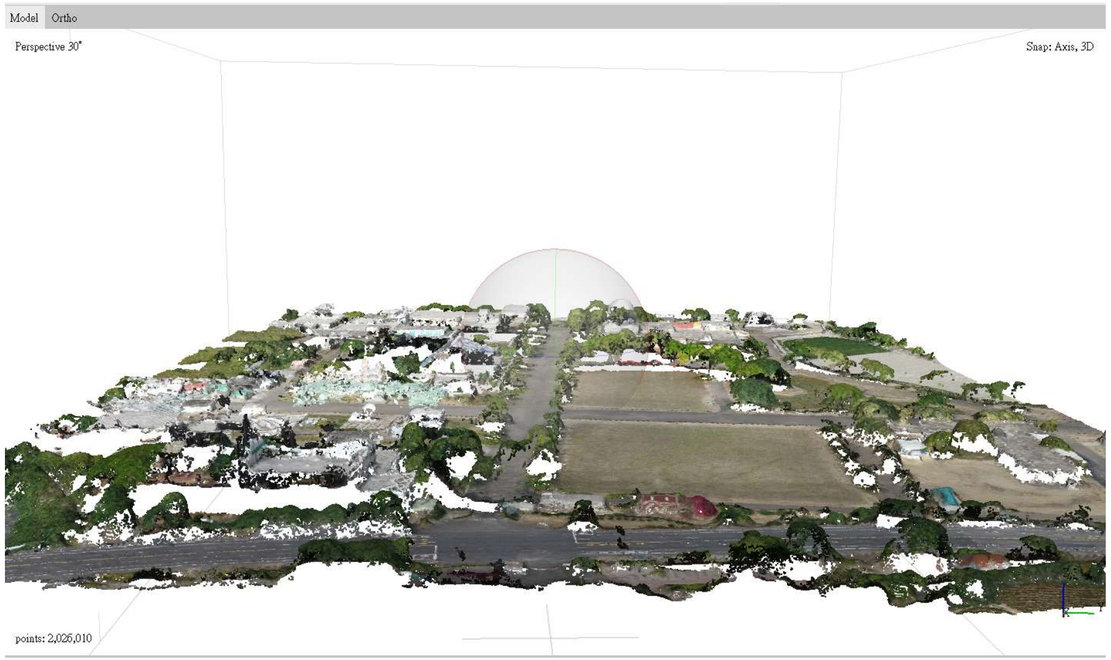
- LMR MEDIUM (2-255)



LMR與M 的比較

點雲完整度

- M LOW



- M MEDIUM

LMR與M 的比較

點雲完整度

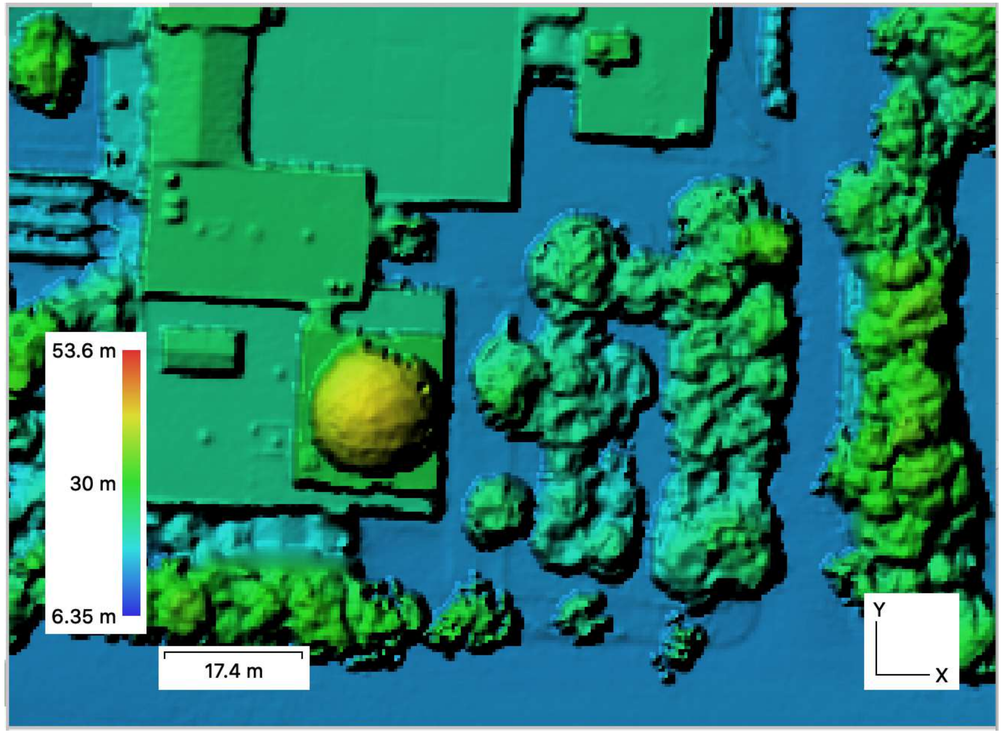
- LMR LOW

- LMR MEDIUM

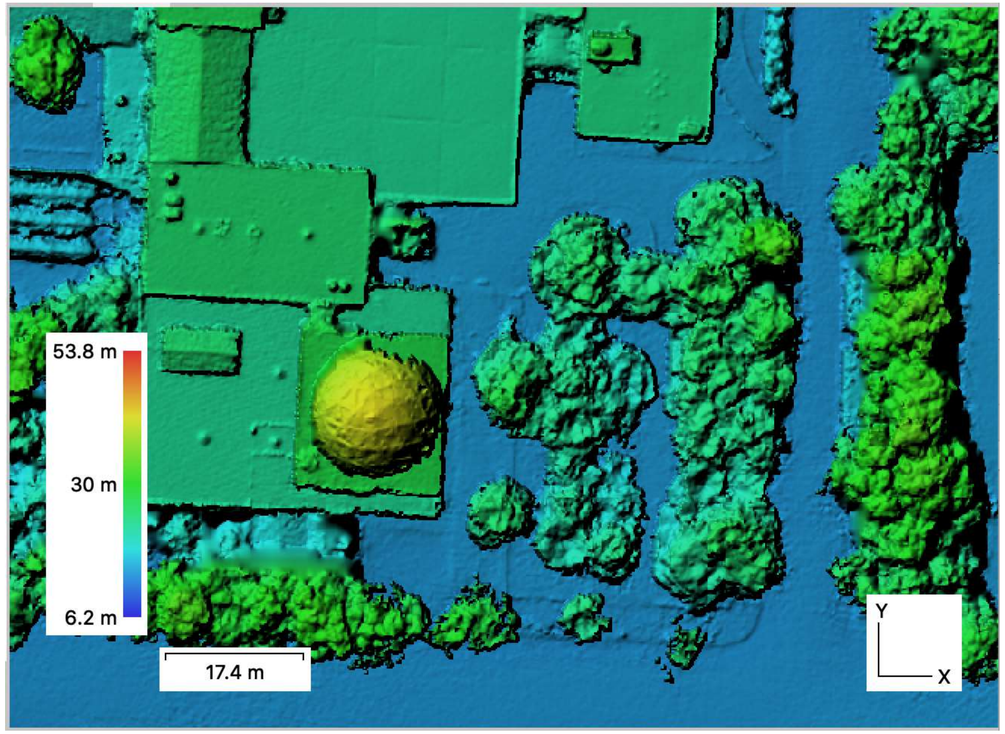
LMR與M 的比較

完整度—DSM

- M LOW



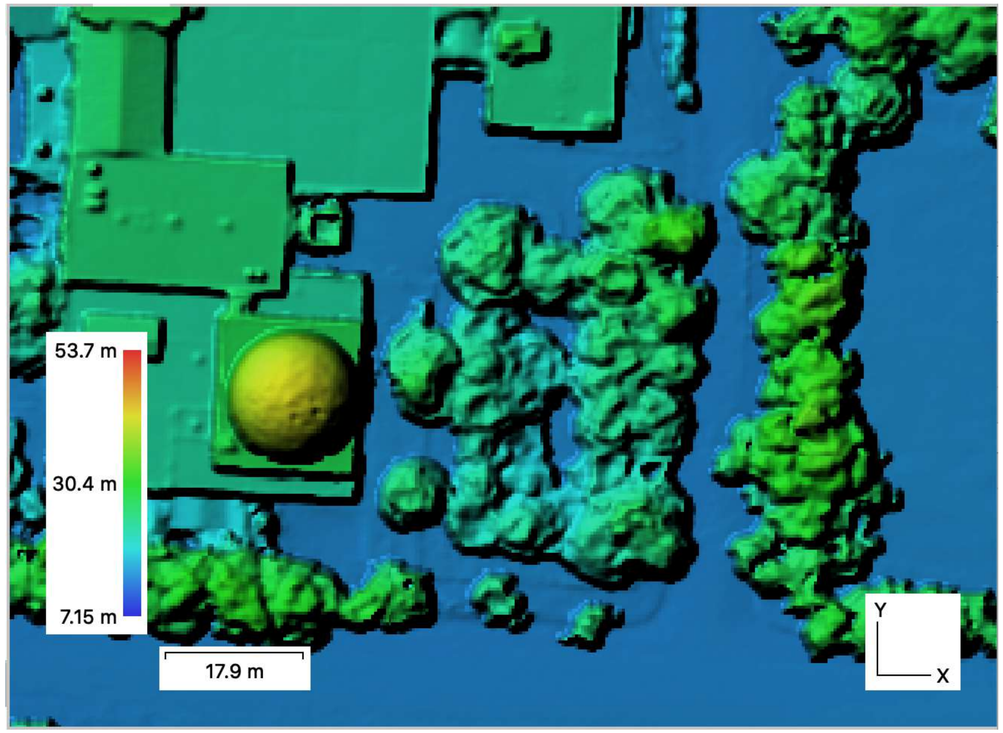
- M MEDIUM



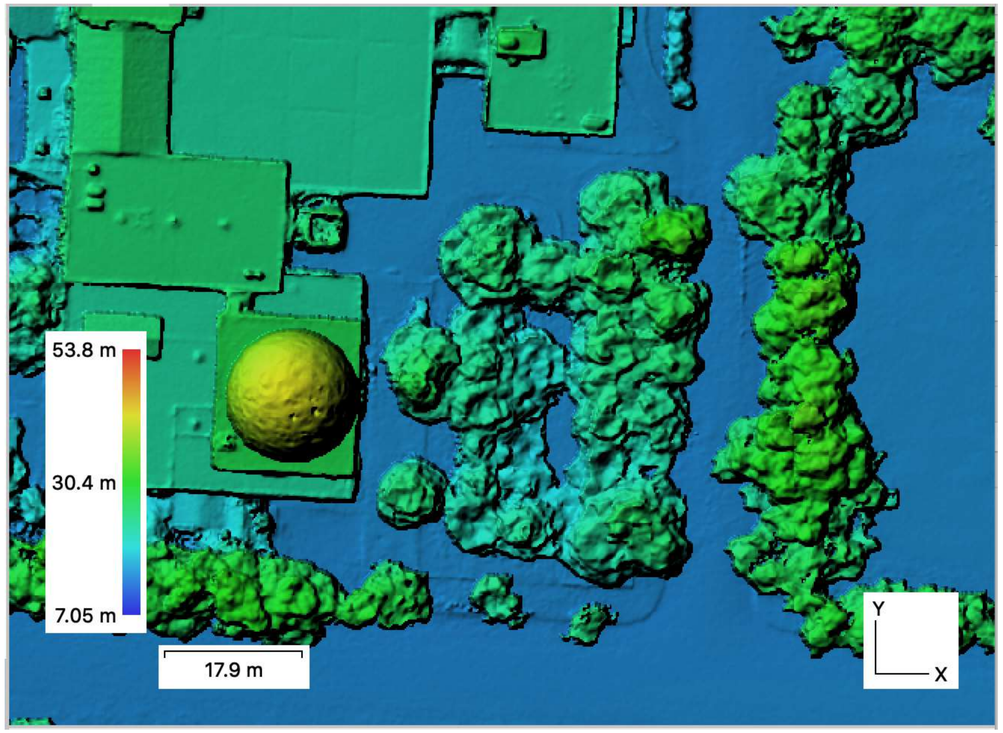
LMR與M 的比較

完整度—DSM

- LMR LOW



- LMR MEDIUM



LMR與M 的比較

完整度—Orthomosaic

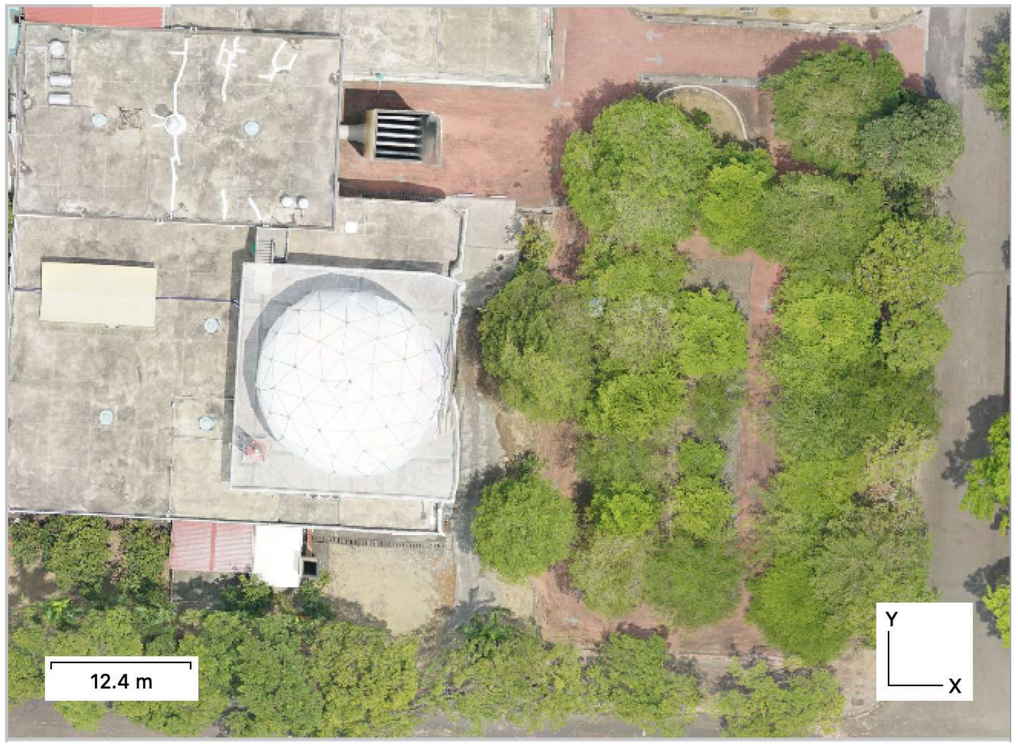
- M LOW

- M MEDIUM

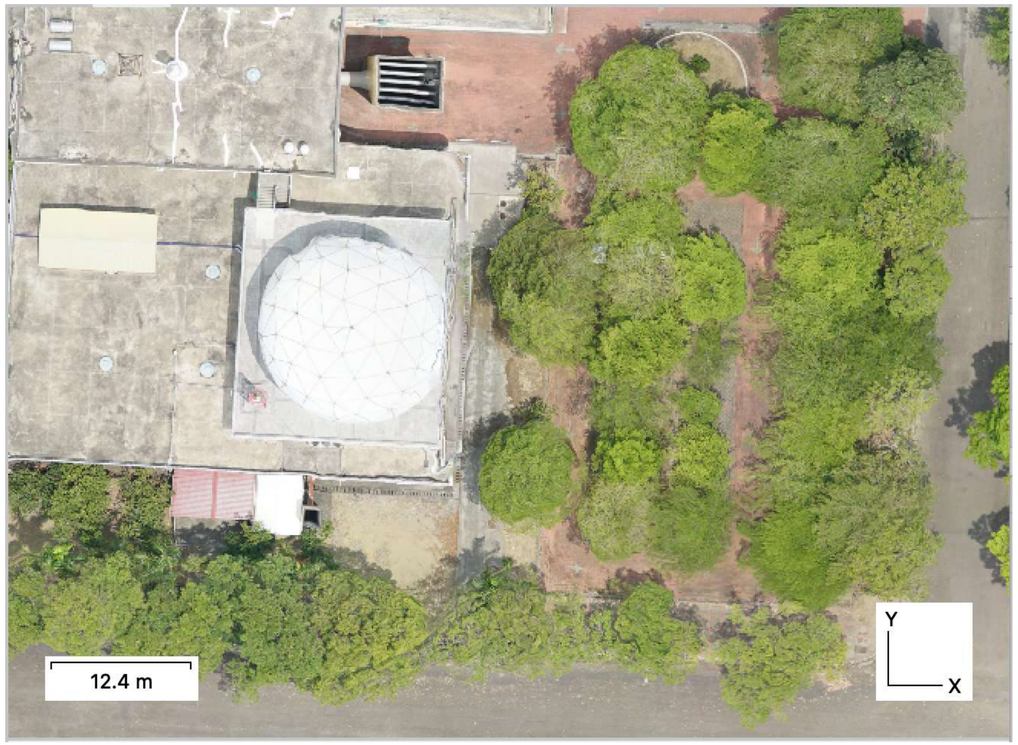
LMR與M 的比較

完整度—Orthomosaic

- LMR LOW



- LMR MEDIUM



實習心得

Experience

心得

- 可以依照自己對模型的精度需求選擇適當的解析度，例如low的模型雖然看起來相對較不清楚，但已經可以看出大致輪廓，且所需時間及產出的檔案也較小。
- 拉控制點拉到眼睛快脫窗了。
- （本來想跑high但）電腦記憶體快爆炸了。
- 如果需要不同精度的DSM的話，要從較高精度的Dense cloud去產生，像low的dense cloud產生的medium和low DSM精度其實差不多。
- 感覺跑建模所需的時間比顯示的還多很多很多。