ON THE STRIP OVERLAP AND FIELD OF VIEW DESIGN FOR AIRBORNE LIDAR OPERATION

Peter Tian-Yuan Shih Ching-Mei Huang
Department of Civil Engineering
National Chiao-Tung University
1001 Ta-Hsueh Road, Hsinchu, Taiwan
Email:tyshih@mail.nctu.edu.tw
Phone: 886-3-5712121 ext 54940

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ABSTRACT: The system of airborne lidar is equipped with a scanning mechanism which produces a swath of point clouds in each flight strip. The scanning is perpendicular to the direction of flight. The density of point clouds is one of the major quality measures for the data collected with airborne lidar. Point density, shade percentage, and penetration rate, are the major factors considered in the flight design. In practical operation, there are flight missions designed with 5% overlap ratio, as well as missions with 50%. Besides the overlap ratio, field of view is another important parameter of the flight design. An evaluation scheme to assess the overlap ratio between flight strips and the selection of field of view is proposed in this study.

1. INTRODUCTION

The system of airborne lidar, also known as airborne laser scanner, is equipped with a scanning mechanism which produces a swath of point clouds in each flight strip (Ackermann, 1999; Baltsavias, 1999). The scanning is perpendicular to the direction of flight. While the frequency of scanning lines is about 200 lines per second, the repetition rate of the laser subsystem can reach 100K HZ and above. After the raw point clouds are collected, which includes the returns from both terrain and materials above the terrain, such as tree and other vegetations, a filtering and editing process is required to separate the terrain points from the rest to construct Digital Elevation Model (DEM) for topographic mapping. There are applications other than topographic mapping, such as the volume estimation for forestry (Lim, et al., 2003; van Aardt, 2004). But, no matter what applications it may be, the density of point clouds is one of the major quality measures for the data collected with airborne lidar. Point density, shading, and penetration rate, are the major factors considered in the flight design.

Regarding the overlap ratio in the flight design, the completeness of coverage and the density as well as even distribution of points are major concerns. In practical operation, there are flight missions designed with 5% overlap, as well as missions with 50%. If the flying height above terrain can be maintained in a stable manner, 5% overlap could be sufficient for avoiding the gaps between strips. NGS (2003) requires at least 25% overlap for shoreline mapping applications; while NGS (2005) requires at least 50% for airport surveying. The contribution of high overlap ratio is not only reducing the risk of gaps, but also improving the point density. From the block adjustment point of view, higher overlap ratio can strengthen the geometric configuration as well.

Besides the overlap ratio, field of view is another important parameter of the flight design. Although it is well known that the larger the overlap, the higher the density; and the smaller the FOV, the better the penetration rate, the tradeoffs are the longer period of operation and higher financial cost required. An evaluation scheme to assess the overlap ratio between flight strips and the selection of field of view is proposed in this study. The influences of overlap and field of view are also demonstrated with data gathered with a Leica ALS-50 airborne lidar system.

2. SHADE FROM THE OBJECT

Objects on the top of terrain, as well as the undulations of the terrain itself, may cause shade. That is, the laser beam could not reach the area in the other side of the object, that is, the shade. Taking the building as an example, Figure 1 illustrated the relation between the angle of incidence, the height of the building, and the location of the laser origin. The pink area in Figure 1 represents the shade caused by the building.

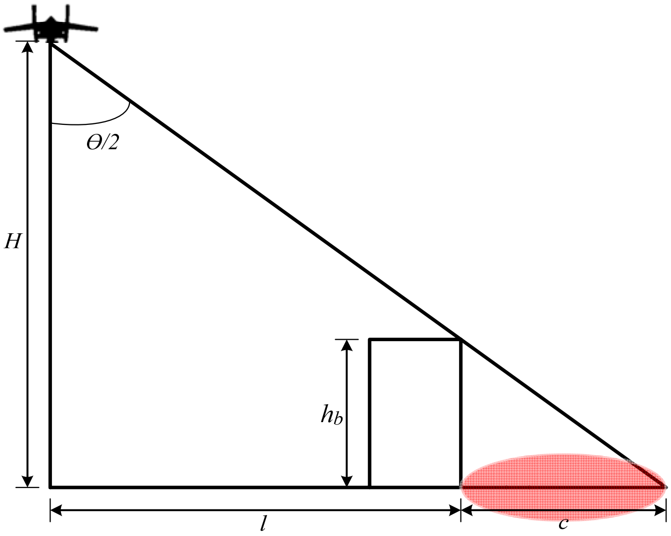

Figure 1: The shade from building

The length of shade is related to several parameters geometrically. This is described with equation (1).

$$c = \frac{h_b l}{H - h_b} \qquad (1)$$

The parameters in Figure 1 represent,

H : flying height above terrain
h_b : the height of the building
c : the length of the shade
l : the horizontal distance between the building and the laser origin

It is apparent that the longer the horizontal distance of the building to the laser origin, the longer the shade. In other words, the larger the incidence angle of the laser beam, the shade length is longer. Certainly, the height of the building is the other positive correlated parameter.

A building located in Erh-Shi-Chang-Li, Hsin-Chu is selected for the evaluation with real data set. Let the FOV be θ, and the width of strip be B, the flying height H can be computed with Equation (2).

$$H = \frac{B}{2}\cot\frac{\theta}{2} \qquad (2)$$

From Equation (2), the following values are obtained.

FOV= 42 degree
B =1110m
H = 1500m

From the measurements made in the lidar point clouds,

$$h_b = 26.21\text{m}$$
$$l = 196\text{m}$$

Following Equation (1), the length of shade c is 3.49m. Comparing with the shade length measured from the point clouds, which is 3.12m, the difference is 0.37m. This may be caused by the uncertainty of the parameters, such as strip width B, which in turned introduced uncertainty to the flying height. The uncertainty from the coordinates of lidar points, both horizontal and vertical, may be a factor of the difference as well.

3. ON THE OVERLAP DESIGN

The strip overlap can not only eliminate gaps between strips, but also can reduce the shade effect. Let the overlap ratio is x, and the distance from the strip center to the non-overlapping area b_n can be computed from Equation (3).

$$b_n = (\frac{1}{2} - x)B \qquad (3)$$

The tolerance of shade is related to the point density required. For the density specification of one point per square meter, there will be no influence if the shade is less than one meter. That is, when $l + 1 < b_n$ and $c > 1$, the shade will affect the completeness of the lidar survey. For most cases of recent airborne lidar survey in Taiwan, the flying height above terrain is 1500 m, FOV(θ) equals $42°$ and overlap ratio (x) is 40%. Therefore, the strip width is 1151.6 m, and the distance from the strip center to the non-overlap area (b_n) is 115.16 m.

When $0m < l < 114.16m$ and $c > 1$, the shade will affect the completeness. These two conditions can be re-written as Equation (4).

$$c = \frac{h_b l}{H - h_b} = \frac{h_b l}{1500 - h_b} > 1 \quad h_b > \frac{1500}{l + 1} \qquad (4)$$

Table 1: h_b and l, from equation (4)

l (m)	20	30	40	50	60	70	80	90	100	114
h_b (m)	71.43	48.39	36.59	29.41	24.59	21.13	18.52	16.48	14.85	13.04

Numerical samples for the relation between h_b and l is listed in Table 1. This demonstrates that for flying height 1500 m, FOV 42 degree, overlap ratio 40%, there could be situations of which the shade is longer than one meter if there are buildings higher than 13 m. On the other hand, 40% overlap is sufficient if no building in the non-overlapping area is higher than 13 m.

4. CONCLUDING REMARKS

This study investigated the relation between the building height, building location, laser incidence angle, overlap ratio, and length of shade. The shade of building occurs in the cross flight direction. The length of the shade is proportionately related to the height of the building, the flying height, and the laser incidence angle. For a single building in a single strip, the length of shade can be computed with $c = \frac{h_b l}{H - h_b}$. For the missions designed for one square meter cell resolution, flying height 1500 m above terrain, FOV 42 degree, overlap ratio 40%, the largest height of building which does not cause shading problem is 13 m for a single building.

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