

Technical Note on:

## Intensity

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Latest Revision:

## 1 Introduction

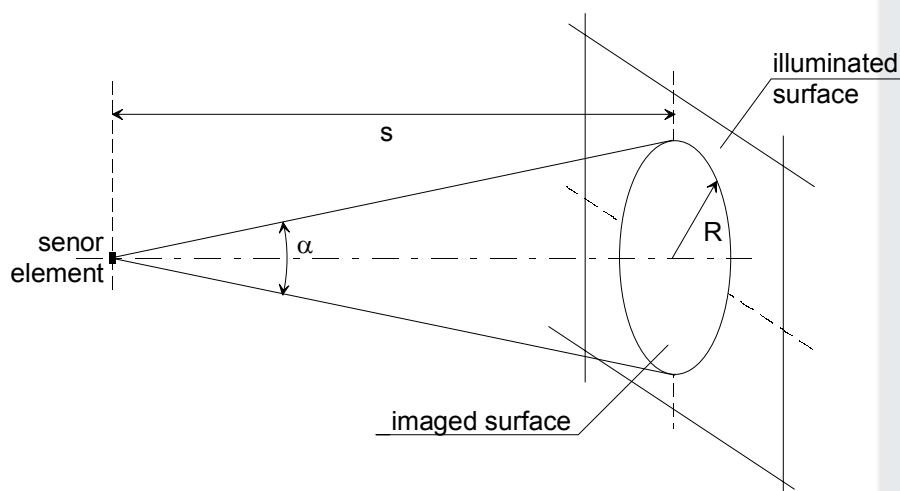
For airborne laser-scanning the measurement of the strength or the intensity of the returned echo has become a reasonable mean for distinguishing between different surfaces. But intensity of a laser echo means somewhat different than what is understood by the remote sensing community.

This note shall outline the commonalities but also the differences and shall give hints where intensity of the laser echo can aid the interpretation and where it has to be used with extreme care.

## 2 Basics

### 2.1 Passive Sensors

In most cases it is assumed that a surface is illuminated (e.g. by the sun) and reflects the energy which is measured by a passive sensor. Measured intensity ( $I_m$ ) is then that part of the reflection (or emission)  $I_r$  falling into the viewing angle of an individual sensor element (section of a film, element of an electro optical device, etc.).



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For simplicity it is assumed that an individual sensor element images a circular area of a homogenously illuminated surface. Assuming further that the viewing cone is narrow, we can write

$$R = s \cdot \alpha / 2$$

Without going into details about light flux, power and intensity we can state that

$$I_m \approx I_r \cdot R / s$$

$$I_m \approx I_r \cdot \hat{\alpha} = I_0 \cdot r \cdot \hat{\alpha} \quad (2-1)$$

where  $r$  is the reflectivity of the illuminated surface and  $I_0$  illumination intensity.

This means that the measured intensity  $I_m$  of a reflecting surface (illuminated by an external source) depends on the instantaneous viewing angle and the reflectivity  $r$  but not on the measurement distance. For simplicity atmospheric attenuation, diffraction, etc are ignored.

## 2.2 Active Sensors

A number of active sensors provide their own "illumination". For these sensors other illumination sources are considered as "background noise", which might cause detection problems for very long distances.

A LIDAR emits all its power  $P_e$  into a small angle and illuminates a respective surface. Assuming a homogenous surface reflecting this energy (or light), then the reflected intensity is proportional to the emitted power divided by the illuminated area and multiplied by the reflectivity of this surface.

$$I_r \approx \frac{P_e}{A} \cdot r \quad (2-2)$$

As the illuminated area is proportional to the squared distance  $s$  and the illumination cone  $\alpha$

$$A \approx 2\pi R^2 \approx s^2 \cdot \hat{\alpha}$$

the reflected illumination becomes

$$I_r \approx \frac{P_e}{s^2 \cdot \hat{\alpha}} \cdot r$$

Taking equation (2-1) the measured intensity becomes

$$I_m \approx \frac{P_e}{s^2} \cdot r \quad (2-3)$$

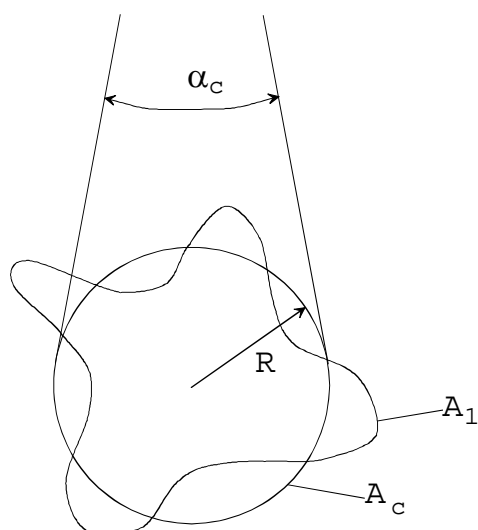
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The measured intensity is proportional to the emitted power divided by the squared distance. This effect is well known from practical life. A white wall illuminated by a street light is visible over a larger distance than the same wall illuminated by a pocket light (as bright as the street light) carried by the observer.

One surface illuminated and observed by an active sensor from different distances will result in different measured intensities. So intensity measurements need to be normalized to an average distance to become comparable.

### 3 Partial Reflections

In the previous section we assumed that all energy emitted gets reflected (losses neglected). In some cases we have to consider, that the reflecting body (or surface) is smaller than the illuminated area and that only parts of the emitted energy can be reflected.



The laser beam radiates into a space-angle  $\alpha$  illuminating the area  $A$  (circle or spherical segment). The laser light might illuminate an irregular shaped area  $A_1$  which is smaller than the illuminated area  $A$ .

The equivalent space-angle of such an area  $A_1$  is defined as that angle  $\alpha_c$  spanning a circle (or spherical segment) having the space  $A_c = A_1$ .

The measured intensity reflected from this area becomes

$$I_{m1} \approx \frac{P_e}{s^2} \cdot \frac{r_1}{\alpha_c}$$

The measured intensity depends not only from the known distance but also from the ratio of the unknown reflectivity and the unknown size of the reflecting surface.

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### 4 Multiple Echoes

Multiple echoes mean that the laser light “traveling” to the ground hits several distant surfaces reflecting parts of the laser light, each of them causing the detection of an echo (if the return signal is strong enough to be detected).

Lets assume three surfaces which add up to the complete illuminated surface then the total measured intensity becomes

$$I_m = I_{m1} + I_{m2} + I_{m3} = P_e \left( \frac{1}{s_1^2} \frac{r_1}{\alpha_1} + \frac{1}{s_2^2} \frac{r_2}{\alpha_2} + \frac{1}{s_3^2} \frac{r_3}{\alpha_3} \right).$$

If each of the three intensities would have been measured separately, it is impossible to deduce any information on the reflectivity of each of the three surfaces.

Furthermore one needs to regard, that not all reflected light might have been strong enough to cause the detection of an echo and to measure the related intensity. So even the sum of all measured intensities would not represent the total illuminated surface.

### 5 Conclusions

For flat, unobstructed surfaces the measured intensity provide a reasonable mean for the reflectivity, if the measured intensity is corrected by the known distance

$$r \approx \frac{I_m}{P_e} \cdot s^2$$

In areas with only minor differences in elevation the elevation data set provides only rare chances for lateral orientation. Here the intensity information can aid the local analysis of the data to a far extend.

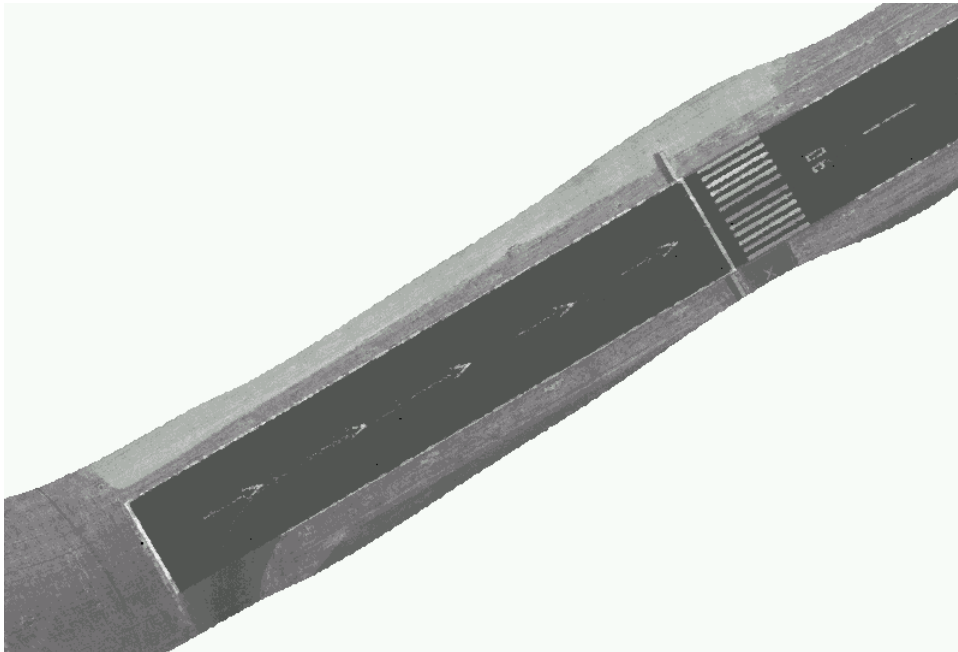
The intensity-image on the next page shows the run-way of a regional airport. One can clearly distinguish the runway and its marking, the taxi-way and the surrounding vegetation.

The second image is much more complex, showing a road intersection, o road crossing over a second road, a parking lot, a pleasure.ground, a small creek and the like. In combination with the elevation model, this will lead to a much better (still manual) interpretation of the complete situation, even if the intensity of multiple reflections is discarded or at least taken with care.

Intensity-values resulting from multiple reflections are indicated within the TopoSys software.

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Intensity Image of Runway



Intensity Image of Roads, intersections, pleasure-grounds, etc.