

Technical Note on:

Image Scale and Resolution

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Date: July 7, 2004

Last Revision:

1 Introduction

One basic source for mapping are aerial images rectified to ortho-projection and mosaiked covering homogenously large areas. Images are taken by airborne cameras, developed, digitized or scanned, rectified and combined to form an image-map. In this context three terms are mostly used for defining the image quality and usability

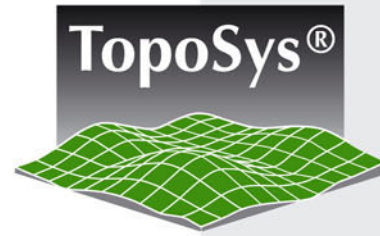
- Image scale
- Map scale
- Resolution

These terms are not used consistently and often cause misunderstandings.

Conventional aerial images are dominantly characterized by the term image scale which defines the area covered by one image and the details recognizable within the image.

The term image scale can not be simply transferred to digital push-broom scanners. This technical note shall outline the differences between conventional aerial images and image maps resulting from the image acquisition by push-broom scanners and shall give some hints on how to interpret the different terms.

Technical Note on: Image Scale and Resolution



2 Conventional Film

2.1 Image Acquisition

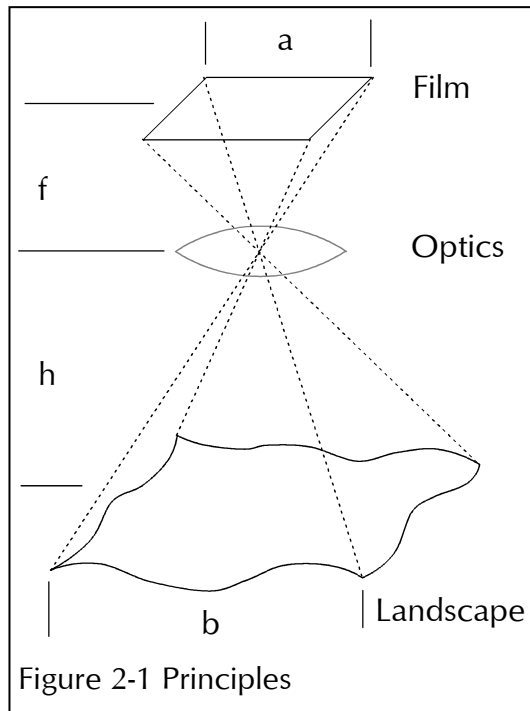


Figure 2-1 shows the general relations between image (on film) and imaged area. The basic terms are defined below:

a = active film size (usually 20 cm)

b = width of imaged area

f = focal length of camera

h = flight height above ground

m_b = image scale

$$m_b = \frac{a}{b} = \frac{f}{h}$$

The minimum size of detectable objects depends not only on the image scale but from the film resolution which varies with the type of film used (panchromatic, color, infra-red) and the film's sensitivity or the film speed.

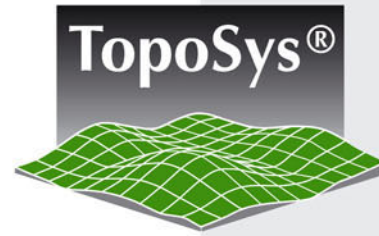
High resolution: fine grained film and high exposure time

Low resolution: coarse grained film and short exposure time

For color films one can expect 50 to 100 line-pairs per mm at a high contrast ratio, supposed the exposure time was properly adjusted to the illumination conditions and the flight speed and the chemical development process was handled in accordance with the film specifications.

In the best case the resolution will be 5 μm at 100 line pairs per mm. Under standard conditions one can expect a resolution of about 10 μm to 20 μm . At an image scale of 1:10,000 ($h=1350\text{m}$, $f=135\text{mm}$) this corresponds to a ground resolution of 10 cm to 20 cm.

Technical Note on: Image Scale and Resolution



2.2 Ortho Images

Standard images are today ortho-images rectified by applying a digital terrain model. The usual process – very simplified – is to scan the film, to do aerial triangulation digitally, calculate the ortho projection and to match adjacent images.

Scanning of the film is mostly done at resolutions of 10 μm to 20 μm . Scanning at 20 μm is preferred because of two reasons:

- Firstly it does not provide any advantage scanning at a resolution better than the film quality.
- Secondly scanning at 20 μm is about 4-times faster than scanning at 10 μm . In addition this produces only one quarter of data and thus the subsequent processing is much faster. Last but not least it is less expensive.

The final images are usually north-south oriented at a rectangular map projection. All the processing steps mean a complete re-sampling of the scanned image pixels. The re-sampling might be done in one or several steps applying simple methods as “nearest neighbor” or more sophisticated algorithms as “weighted average” or “bilinear cubic interpolation”.

The resolution of the final image corresponds to the poorest resolution applied throughout the complete process. Scanning a 20 μm film at 10 μm creates smaller pixels but does not increase the usable resolution. On the other side scanning a 10 μm film at 20 μm will degrade the data and the final image will correspond to the scanning resolution.

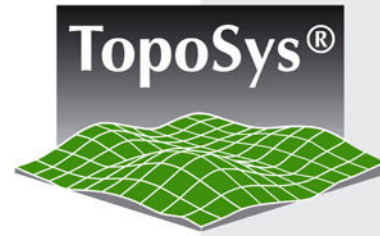
One major disadvantage of this type of ortho-image is the correction by applying the terrain model. Thus elevated objects are not corrected properly, so the roof of buildings are always displaced. This displacement increases with the distance from the film’s center.



Figure 2-2: Ortho-Image of City

Figure 2-2 shows as example a small area of a city, where the roof displacement hides half of the streets. The image has a resolution of 0.1 m and is reproduced here at a scale of 1:2,000.

Technical Note on: Image Scale and Resolution



3 Framing Cameras

Framing cameras rarely differ from film. The chemical development of a film is avoided and the scanning (or digitizing) of the film is done already by the camera.

4 Push-Broom Scanner

4.1 Data Acquisition

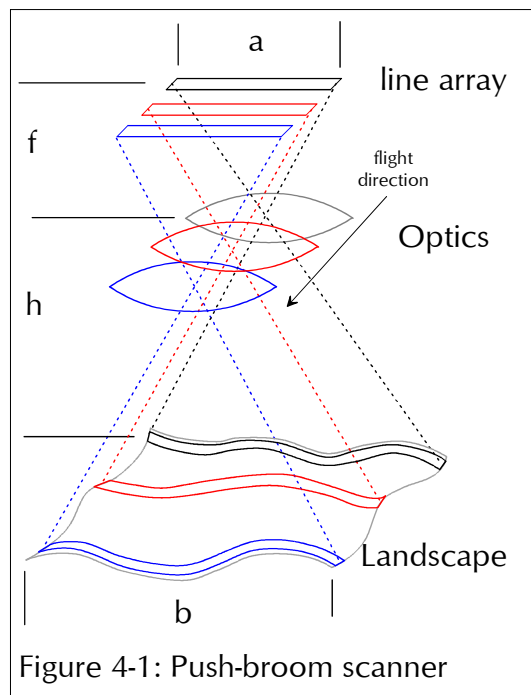


Figure 4-1: Push-broom scanner

Push-broom scanners acquire data line by line as indicated in figure 4.1 by the black, red and blue areas. The term image scale applies properly only in the direction of the array and is the same as for film

$$m_b = \frac{a}{b} = \frac{f}{h}$$

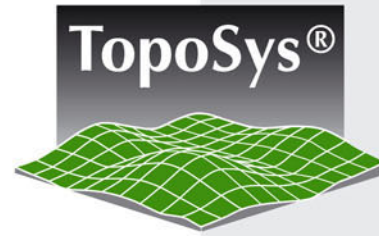
In the flight direction this term applies only to the individual pixels. At an image scale of 1:10,000 a 10 μm pixel corresponds to a 10 cm area on ground. But subsequent lines are not regularly separated by 10 μm . The line separation depends on flight speed and line rate or exposure time, which might vary from line to line, depending on illumination conditions and brightness of the imaged area.

4.2 Ortho Images

4.2.1 Aircraft motion

The forward motion of the aircraft causes that subsequent lines cover different areas on ground. Assembling these lines side by side gives an image. But an aircraft is not as stable as a spacecraft and thus one has to correct for all attitude changes during image acquisition.

Technical Note on: Image Scale and Resolution



The two images presented in figure 4-2 show to the left the image lines assembled without caring for the sensor attitude and without any radiometric correction. The right image shows the data after correction of attitude and flight speed and after radiometric adjustment of the spectral channels.

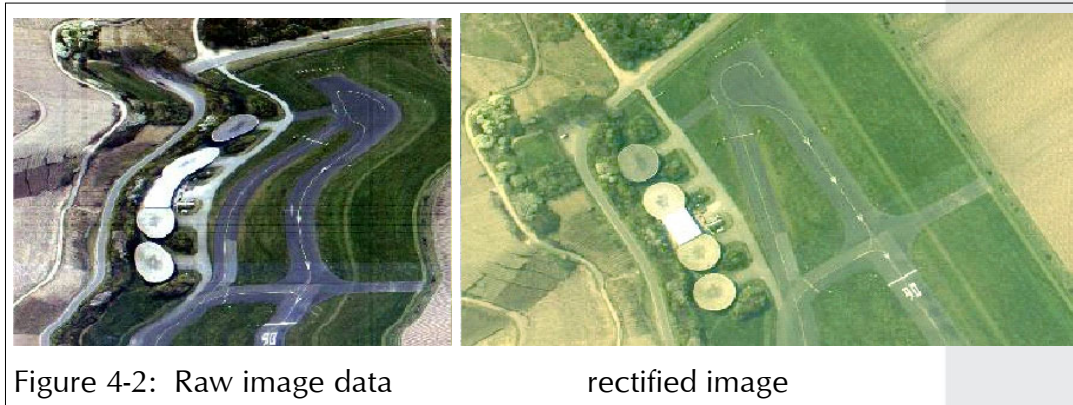


Figure 4-2: Raw image data

rectified image

4.2.2 Over DTM

Each pixel of the array is projected according to its individual line of sight onto the digital terrain model and then transferred to the final orthogonal map projection. Due to the fact that the scans are not precisely in north-south or east-west direction these processing steps cause a bidirectional re-sampling as for film or digital cameras.

The resulting ortho-image still includes oblique views of buildings. If the scanner looks perpendicular to ground then the oblique view is only to the left and right of the flight direction but not in flight direction. Should the scanner look forward or backwards then the oblique view is given also in flight direction and is associated by large shadowing in the opposite direction.

4.2.3 Over special DSM

TopoSys has selected a very specific approach by having a push-broom scanner looking the same direction than the laser scanner. For standard surveying purposes the sensors are mounted looking perpendicular down. The sensor can be mounted in any viewing direction to fulfill the needs of for very specific applications.

From the distance data a very specific digital surface model is calculated, best representing the visible surface. A leafless tree provides echoes from its branches but the road beneath is visible. So the image data have to be rectified by using the elevation of the road but not the tree.

Technical Note on: Image Scale and Resolution

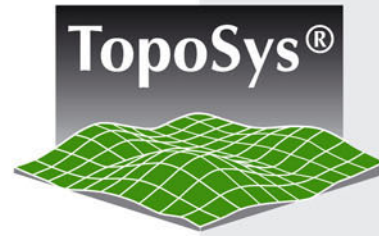


Figure 4-3 shows the same area than figure 2-2 but four years later, acquired by FALCON and rectified on a special DSM.



Figure 4-3: True-Ortho-Image of City

The resolution is 0.25 m and the image is printed at a scale of 1:2.000.

The direct combination of a laser scanner and an optical scanner provides elevation and visible data at the same time. Ortho correction thus can be made even for transportable objects.

The major advantage of this sensor combination is the correction based on surface elevation providing among others a complete view into streets. This is of specific interest in cities having narrow streets, which remain invisible applying

conventional ortho-photos rectified by a terrain model.

5 Image-Map Scale

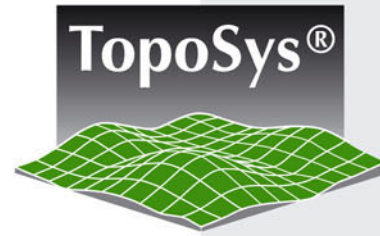
Following the above explanations, the scale of the final image after all rectification and re-sampling is the parameter dominating the usability of this final image or image-map. The size of recognizable objects and the scale are linked by a readable resolution.

For black drawings on white paper the thinnest line being recognizable and reproducible is specified as being 0.1 mm thick. In typographical terms this corresponds to about ¼ point or about 280 dpi. For printing images a pixel size of one typographical point provides excellent images, which means that a pixel size of 0.25 mm fulfills most needs.

Applying this also to printed images then the minimum pixel size is linked to the map scale as follows:

Image-map scale	pixel size on ground	
	at 0.1 mm	at 0.25 mm
1 : 500	5 cm	12.5 cm
1 : 1,000	10 cm	25 cm
1 : 2,000	20 cm	50 cm
1 : 2,500	25 cm	62.5 cm
1 : 5.000	50 cm	125 cm

**Technical Note on:
Image Scale and Resolution**



6 Technical Parameters of FALCON II

Line-scanner:

Pixels per channel	682
Pixel size	14 μm
Viewing angle	21.6°
Resolution across track	0.5 mrad
Focal length	75 mm
“Image scale”	$m_b = 0.075\text{m} / h$
	at $h = 1500\text{ m}$ the image scale becomes 1:20,000

After all processing as line assembling and rectification the image resolution becomes about:

Flight height m	Resolution on ground	respective map scales
1,500	0.50 m	1 : 2,000 to 1 : 5,000
750	0.25 m	1 : 1,000 to 1 : 2,500
300	0.10 m	1 : 500 to 1 : 1,000