Use of airborne small-format digital cameras as tools for collecting ground truth

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Abstract - Satellite based mapping of land cover is the first milestone in the SatNat program, a collaboration between the Norwegian Directorate for Nature Management (DN) and the Norwegian Space Centre (NRS). The land cover map will be made from satellite images, automatically classified by hyperclustring. A large number of ground truth is necessary, which will be collected from aerial photos. An airplane equipped with digital video cameras and two different digital cameras have been assessed. 24,000 georeferenced images and 20 hours of videotape were acquired through 10 days of flying in three regions of Norway. The aerial images are georeferenced by aerial triangulation or by using the camera orientation elements directly. Relevant nature types are identified in the field from a representative extraction of the images. These field samples are used to make a vegetation key. Vegetation samples will then be collected from the aerial images in a GIS program.

1 Introduction

The SatNat program is a collaboration between the Norwegian Directorate for Nature Management (DN) and the Norwegian Space Centre (NRS). The goal for DN is to obtain easy and swift access to spatial information about biological values. Norway lacks a national and updated landcover at 1 : 50 000 scale. Satellite based mapping of land cover is the first milestone in the SatNat program, as a basis for vertebrate habitat mapping and GAP-analysis. The land cover map should be directly implemented into area planning and management from a local to a national level.

The lack of a sufficient number of ground truth sites is often a limiting factor in the classification of satellite images as well as a proper validation of that classification. Field visits to these sites are time consuming and often limited due to accessibility. Capturing detailed information of the landscape from an airplane is an alternative approach to collecting ground truth (Slaymaker et. al 1996).

Digital video cameras carried in small airplanes combined with GPS-information and plane orientation data (INS) have been used for identifying points on ground. However, the quality of the images, both in resolution and dynamic range, is limited in the video formats. The digital cameras available today have much better image quality and cover larger areas at similar or higher resolution than video. Four band aerial digital camera systems that match the spectral response of Landsat or SPOT data image layers have also been developed. The use of these cameras open new possibilities for utilising satellite classification techniques based upon a large sample of ground truth.

2 Data sources and equipment

Optical satellite images with a spatial resolution from 5 to 30 meters are used for classification. The Landsat 7 and IRS-1C/D have been used so far, but the coming SPOT 5 will also be used when available. Images from spring, summer and autumn will be used to make a multitemporal classification.

In this study we examined two digital cameras and compared them with a digital video. We used a Kodak DCS 760 camera with a 12 bit dynamic range and CCD resolution of 3032x2008 (6,1 mill. pixels) and a DuncanTech MS 3100 four channel camera with an 8-bit dynamic range and a CCD resolution of 1024x1280 (1,3 mill. pixels). During August 2001 we flew a set of flightlines in three areas of Norway in grids separated by 5 to 15 km. In total we captured more than 6000 Kodak pictures and 18000 pictures from the Duncan camera. We flew 600 meters (2000 feet) above ground, which gave a ground pixel resolution at about 20 cm for both camera systems.



Figure 1. Camera configuration video/DuncanTech/Kodak

The aircraft was supplied with a Garmin real-time differential GPS receiver and aircraft attitude was handled by a Watson Industries Attitude and Heading Reference System. Differential GPS accuracy and time code logging (link between GPS and images) should be handled with special care. The Kodak camera has a GPS input port, and can label each exposure with the most recent GPS record, but we were unable to maintain a stable connection with either of the Kodak cameras we had or any of the serial port cable Kodak had sold us. Instead we logged GPS and Kodak images on the same computer. This creates a possible time delay and position inaccuracy.

Images captured with the Kodak camera are handled easily by the accompanying DCS Photo Desk software. Visual checks (overlap, clouds) and image commands like rotation of the images helps the user to manage the large number of images. Unfortunately, the software had no option to export information like the time code of the images. This made the linking to GPS positions time-consuming. The DuncanTech images were handled by Video Savant software, GPS and INS data were linked automatically and a file that could be imported in Erdas OrthoBase was created.

3 GEOREFERENCING OF AERIAL PHOTOS

Since we captured the frames at a 60% or greater overlap, along with logged GPS and INS data, we could triangulate them into long georeferenced strips using ERDAS OrthoBase. With a 5 meter terrain model and 2 meter accuracy ground control points we made fairly accurate mosaics. Mosaics of up to 400 Kodak images were made this way. Individual stereo pairs of the ERDAS block file can be viewed in ERDAS Stereo Analyst and 3D measurements are possible.

Due to the vast number of images, a less time consuming method of automatically generating world files to each image from GPS/INS data and view them in ArcView proved more cost efficient. This method proved to be the preferable for referencing DuncanTech. Flightlines were east/west or north/south and images were rotated respectively. The small extent of each image on the ground (300 – 500 meters) gave minimal radial distortion in the images. Quite a few of the referenced images had gross position errors (50 – 200 meters) and had to be corrected manually. By using a IRS-1C/1D satellite image underneath, errors could be located and corrected. An operator can check and correct some 500 images each day this way. A more accurate and automated method by use of area-based matching would be preferable. This is described by Abd-Elrahman et al., 2001.

The video tapes from the zoom and wide angle cameras are converted to a MOV-data format. Then processed with a program (MOSAIKER) developed by the computer Science department of the University of Massachusetts that automatically generates a stereo pair of image strip mosaics that can be viewed in 3D. The strips are georeferenced by use of ground control points.

4 COLLECTION OF GROUND TRUTH

Procedures were developed for identifying vegetation classes using an image catalogue showing the different vegetation types. Ground visits are necessary to identify vegetation types (Fremstad 1997) not easily recognisable in the photos. Having this catalogue we could identify vegetation classes down to a phenological level.

Stereo view of aerial images is preferred by many field inventors. This is possible in ERDAS Stereo Analyst or by using paper prints. Both ways increased our ability to identify vegetation. Superimposing the georeferenced strips directly over the satellite images also made it easier to identify pixels of similar vegetation type than by inspection of the digital images alone. Colour balancing makes the mosaics prettier, but often less convenient to interpret. The Kodak images are similar to standard analog colour images, except for their 12-bit radiometric range. Areas obscured by shadows can be histogram stretched and becomes interpretable.

ArcView was used for digitising vegetation type samples in the DuncanTech images. One photo could add some 25 ground truth samples to the classification. By viewing aerial photo and satellite

image simultaneously, sample location error could be controlled. DuncanTech images in infrared colour combination were used for field check and digitising.

Airborne videography for collecting ground truth were used in several earlier studies (Graham 1993, Slaymaker et. al. 1996) and the method is well described (Slaymaker 2002).

5 TEST OF GROUND TRUTH SAMPLING ACCURACY

One half of the field checked image prints were used for collecting vegetation sample points and establishing a vegetation key. The other half of the field image prints were put aside and their digital versions were used to pick new samples without checking the field annotations. When compared afterwards, the accuracy of these observations could be calculated. The results are under evaluation.

6 HYPERCLUSTRING AND DECISION RULES

Satellite data are segmented into a number of clusters (~250) after a modified ISODATA method (Myers 1999 a and b). Images from different seasons will be used to make one cluster image. By using the phenological changes that occurs throughout the growing season, we increase the possibility to differ vegetation types. Kinds of deciduous forest for instance, will appear differently.

Terrain information like slope and aspect and vegetation ecological regions (Moen 1998) will also be taken into account. Norway is a country with large variations in topography and climate. A single Landsat scene can contain boreonemoral, boreal and alpine zones and each of these zones can differ from a highly oceanic to a slightly continental section.

In a landscape this dissected, the spectral signatures in an unsupervised classification of satellite imagery will have been affected by topography, elevation, ecological zone and a host of ancillary factors other than the ground cover they reflect. In this situation, the relationship between spectral classes and vegetation types will rarely be straightforward. Most vegetation types will be mixtures of spectral signatures in associations that shift within the context of the image as a function of these other factors that affect reflection. Therefore, a great many sample points are necessary for each spectral class to model all these variations and generate sets of inference rules that relabeled each pixel in an unsupervised classification to its most probable vegetation class for a specific slope and set of neighborhood conditions. This, in essence, is the purpose of the aerial video and digital grid coverage, to collect a small but well distributed percentage of the region covered by the satellite image that can be interpreted at a very large scale. The thousands of ground reference points and polygons that can be efficiently collected by this method create a sufficient sample population of each spectral class under each set of ancillary factors.

7 COMPARISON OF THE DIFFERENT CAMERAS

There are several advantages of using digital cameras instead of analog ones. Reduced costs (film, development and scanning), faster availability (data can be processed the same day as capture), spectral resolution (more than just visible bands) and radiometric resolution (more than 8 bit data range). In total, this will compensate for lower image resolution.

Advantages and disadvantages of the different cameras are listed below, as we found them in practical use.

Kodak DCS-760

+ can be used to make orthomosaics (stripes and blocks)
+ 12 bit data compensate for shadows
+ colourful, representative appearance
+ standard camera, good value, useful software
+ automatic exposure control
- software lacks possibility to extract time code
- poorly designed and non-functioning GPS port
- high radial distortion (18 mm lens)

DuncanTech MS-3100

+ four band representation
+ IR colour combination very useful
+ software links time code, GPS and INS data
+ timesaving semiautomatic georeferencing
+ low radial distortion
- low contrast in shadows
- manual exposure control
- low CCD resolution

Zoom/wide angle video cameras

+ software can produce semiautomatic 3D orthomosaics
- low radiometric resolution

8 CONCLUSIONS

By using small format airborne cameras like DuncanTech MS-3100 we can collect large amounts of field samples for classification. The vegetation can be identified down to a floristic level (community level) and we can choose between identifying areas of similar vegetation type (polygons) or by identifying points at a more individual trees/shrub level.

The Kodak DCS-760 camera have proven useful for making orthophotos for surveillance of river deltas, power lines, roads and other features.

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