MONITORING POWERLINE CORRIDORS WITH STEREO SATELLITE IMAGERY

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ABSTRACT

Power-line corridors are very sensitive for higher vegetation which might interfere with the conductor. Such an event may lead to massive damage of the conductor by shortening and as a consequence to economic losses in large areas. The energy supplying companies are responsible for the maintenance of the corridors and they have developed several methods for the inspection. All methods used so far are either time consuming or inaccurate, some are very expansive. This paper discusses a new method based on the analysis of multi-spectral and stereoscopic very high resolution satellite imagery. This approach should be realized in a three step workflow. After pre-processing of the data and pan-sharpening, the tall vegetation will be extracted from the multi-spectral bands first, vegetation height will then be evaluated from the stereo images and finally that vegetation with a potential interference will be mapped. So far the workflow has been realized only for the first step, the vegetation mapping. The vegetation analysis has been performed with an object based approach and results will be presented.

INTRODUCTION

Power-line corridors are maintained by power and energy supplying companies in the U.S. and in Europe as well. They have to make sure that energy can be provided to the customers in a save and reliable way. Failure or disturbances have to be minimized because those will cause huge economic costs. Therefore the power-line corridors have to be cleared of everything interfering with the power-lines. The lines themselves may be affected directly by falling vegetation and so bringing down the lines. Power-lines are mainly made of copper, a highly extendable metal and as a consequence power-lines permanently change their length depending on the actual temperature. This special behavior of the lines can be modeled in a CAD or GIS environment with a security envelope surrounding the lines (fig. 1).

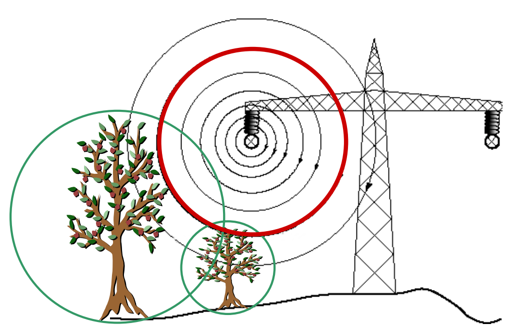


Figure 1. Vegetation, potentially interfering with the power-line security envelope.

Vegetation may never interfere with the power-line security envelope; several methods are used by power-line operators to guarantee a functional power providing network. These methods are proofed so far for the monitoring of power-line corridors:

Table 1. Methods for the monitoring of power-line corridors

	accuracy	time	costs
field survey	***	*****	***
survey by helicopter	****	***	*****
aerial image analysis	*****	****	****
LIDAR analysis	*****	***	*****

ranking: ***** - very high, **** - high, *** - moderate, ** - low, * - very low

None of these methods provides a satisfying way for an efficient monitoring. One is too much time consuming like the field survey by a human analyst and it also lacks of accuracy. LIDAR image analysis may provide very accurate results, but the relatively new technique is still expansive and not available for an arbitrary working basis. None of the methods does enable the exact mapping of vegetated objects and their heights for a large area at one time. Therefore satellite imagery with a very high spatial ground resolution and stereoscopic capability should provide best possibilities for a synoptical analysis.

The approach discussed in this paper will make advantage of those satellite images and it will take the high spatial resolution as well as the multi-spectral and the stereoscopic capabilities into account.

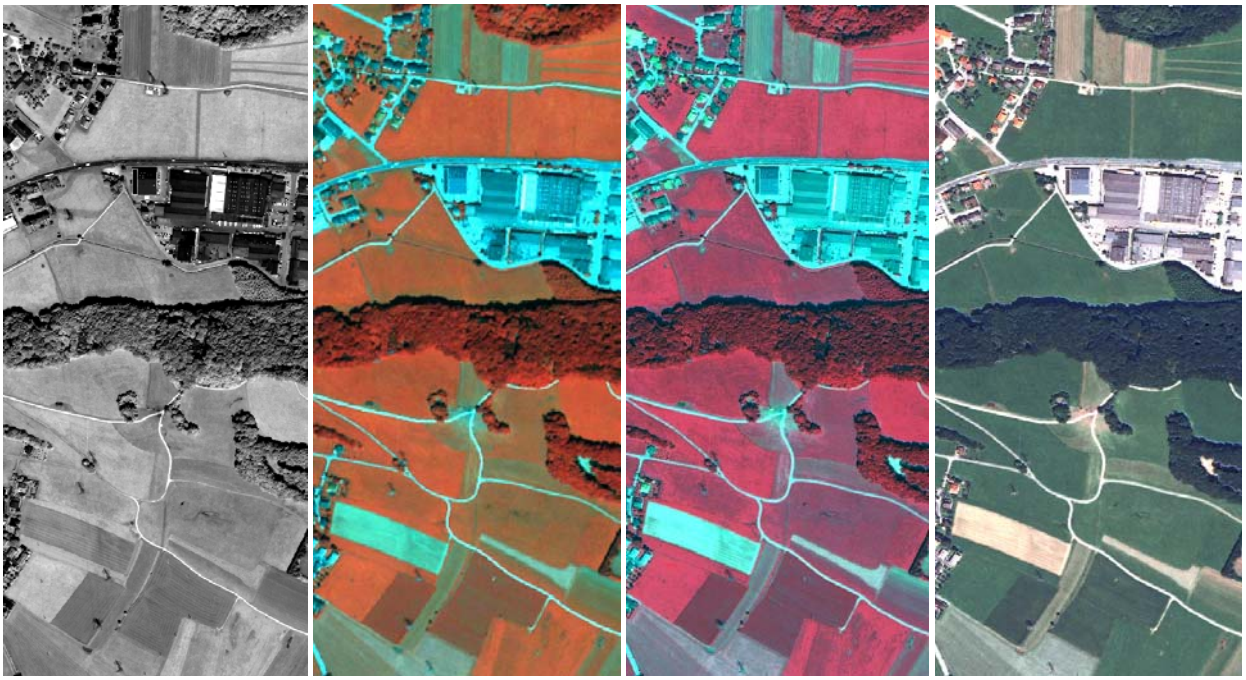
VERY HIGH RESOLUTION SATELLITE IMAGERY

Very high resolution satellite imagery is acquired mainly by three operational commercial optical satellite systems: Ikonos (GeoEye), Orbview (GeoEye) and Quickbird (DigitalGlobe) (see table 2).

Table 2. Very high resolution satellite systems

operator	DigitalGlobe	GeoEye	GeoEye
sensors name	QuickBird	IKONOS	OrbView-3
launch	18th October 2001	24th September 1999	26th June 2003
orbit height	450 km	681 km	470 km
inclination	98°, sun-synchronous inclination	98.1°	97.24°
equator crossing	~ 10:30 a.m.	10:30 a.m.	10:30 a.m.
repetition cycle	~ 1-3.5 days dep. latitude	3 days	3 days
radiometric features	11-bits	11- bits	11- bits
ground resolution pan	0.6 meter GSD at nadir	1 m	1 m
ground resolution multi-spectral bands	2.4-meter GSD at nadir	4 m	4 m

This study used Quickbird satellite imagery for the multi-spectral analysis of vegetation. The imagery has been recorded June 21st 2005 and covers the city of Salzburg, Austria. A subset of this scene with some different types of power-lines and pylons can be seen in fig. 2 and 3. The satellite data has been ortho-rectified first and atmospheric influences were eliminated by applying an atmospheric correction tool (ATCOR). The imagery has been pan-sharpened using the IHS pan-sharpening algorithm described by Jensen (2004). The result of the fused images can be seen in fig. 2c+d.



a) pan original b) cir ms original c) cir pan-sharpened d) true color pan-sharpened
extend: 580 m * 1260 m

Figure 2. Test site located north of Salzburg, Austria

The conductor itself can be detected by the observer's eye in the pan original image against the bright background, because the contrast is relatively high (fig. 3). The pylons basis is also clearly identifiable from the pan image. However, the power-line operator provides GIS data for the base of each pylon as a x, y, z coordinate.

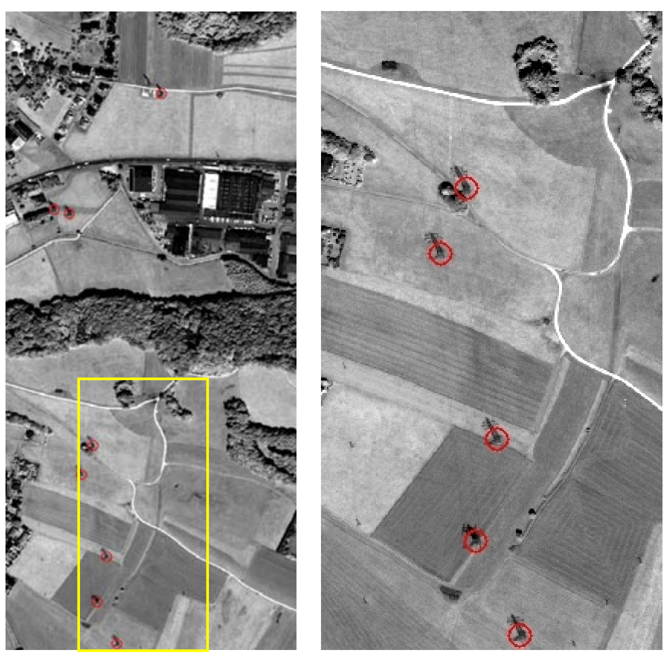


Figure 3. Pylons and power-line as seen in the pan image
red circles indicate pylons base points; yellow box (left image)
indicates the enlarged area in the right image

Workflow for the Analysis of Vegetation Heights

The overall workflow for the analysis of the satellite data can be differentiated into three steps. First the tall vegetation has to be separated by a spectral analysis of the pixel values. In a second step the height for the extracted vegetation objects has to be calculated. Finally the height values of the vegetation objects have to be compared with the height of the power-line security envelope. Actually this project is in the stage, that an arbitrary approach for the identification of vegetation has been established. Steps two and three will follow once a stereo image has been recorded for the study site.

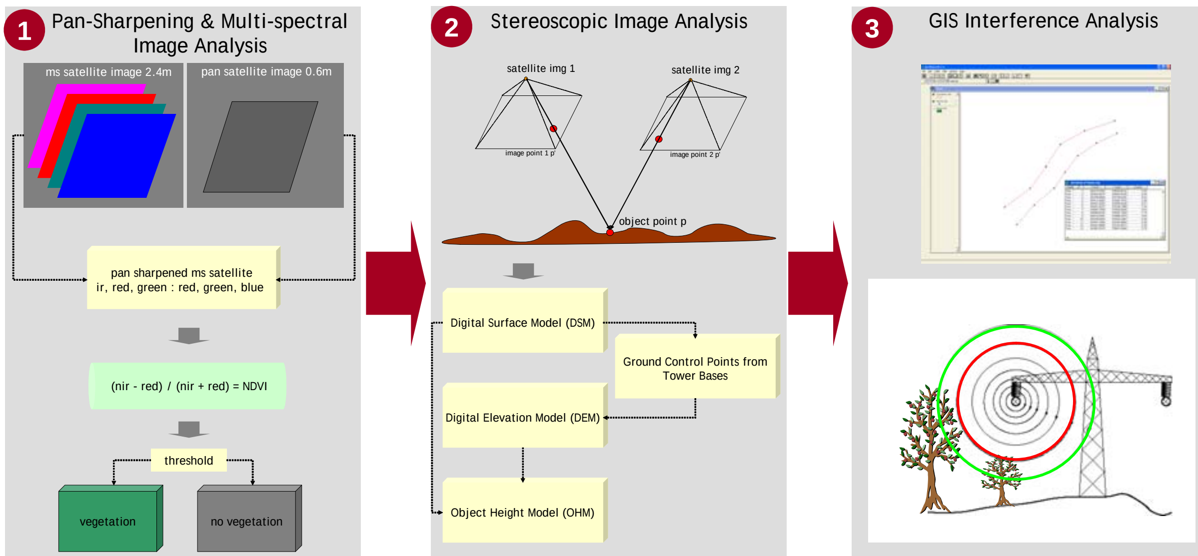


Figure 4. Project workflow

Analyzing Higher Vegetation

For the detection of tall vegetation an object based image analysis approach was used (this approach is explained in detail by Blaschke et al. 2000). This new process oriented algorithm is introduced with the software package Definiens prof. vers. 5 (Tiede and Hoffmann 2006, Tiede et al. 2006). Applying just a vegetation index calculated from the red and infrared spectral bands with a specific threshold value is the most common way to differentiate vegetation from non vegetated areas (Jensen 2004). This vegetation index alone would not be helpful to differentiate between surface vegetation, which does not affect power-lines, and tall vegetation.

First we calculated a chessboard grid pattern with a 12 m * 12 m cell size. In a second step the texture has been computed and the chess board cells were classified. The following second classification step was only applied on those grid cells meeting the texture expression. This classification was based on the NDVI (normalized differenced vegetation index). The resulting classification can be seen in fig. 5c. It only represents tall vegetation (e.g. trees and tall bushes) with a reliable accuracy.

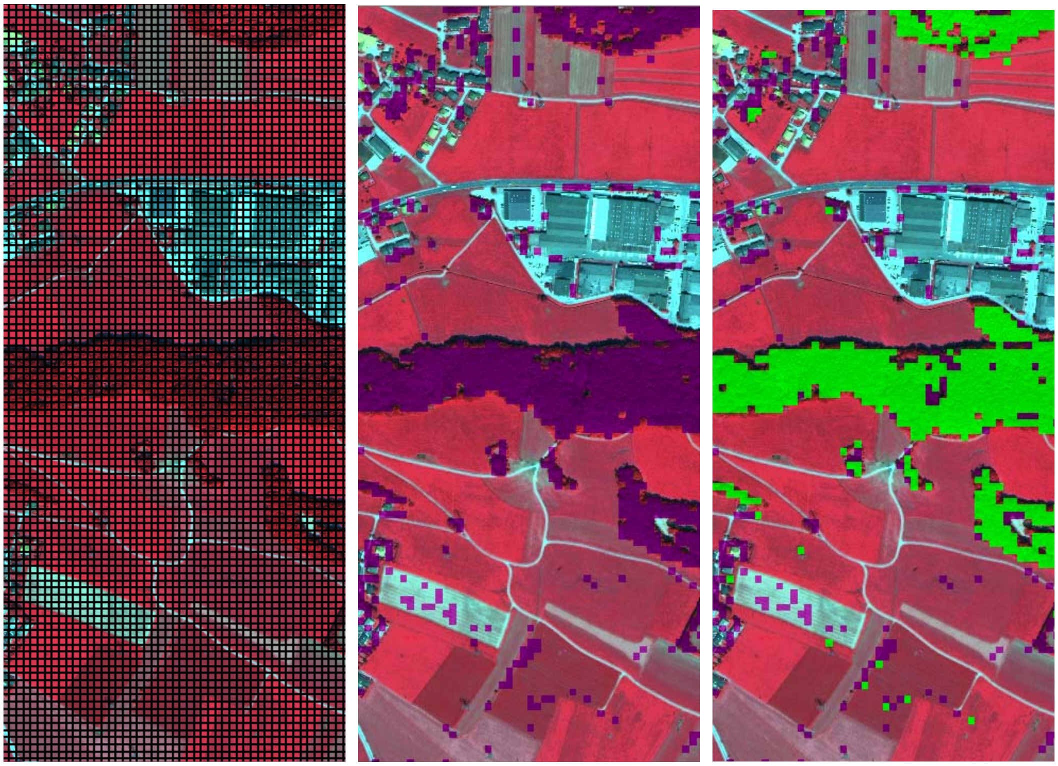


Figure 5. Classification of the pan sharpened subset

Table 3. Process tree for the classification of tall vegetation

step	action	parameter
1	segmentation	size: 20 * 20 pixels
2	texture classification	GLMC Homogeneity 0 – 0.1
3	vegetation classification	NDVI > 0.7

IMAGE STEREOSCOPY

Unfortunately we could not record/acquire a stereo satellite scene for our study site so far due to weather limitations. However, the acquisition is planned for the next future and is on its way. As a substitute we used a digital surface model (DSM) computed from an Ikonos scene for our testing purposes.

The Ikonos satellite data set is available for test purposes and free for download from the GeoEye catalogue website (http://carterraonline.spaceimaging.com/). This scene is recorded over the city of San Diego, CA and consists of the panchromatic, multispectral and stereo data sets. The stereo data is associated with a rpc (rational polynomial coefficient) file, which provides specific sensor parameters, meta data and additional information about scene acquisition. The stereo data set has been analyzed with appropriate orthophoto software, a 3D DSM could be derived (fig. 6) and just a visual inspection has been performed for the height of vegetation.

Figure 6. CIR and DSM of the Ikonos stereo test scene
extend of the subset: about 900 m * 900 m, location San Diego, CA

NEXT STEPS TOWARDS AN ARBITRARY WORKFLOW AND FUTURE OUTLOOK

In a next step we will obtain a stereo pair of satellite images covering our test area in Salzburg. We will then verify and measure the differences of height in the satellite stereo image and will compare the values to the infield measurements. The outcome of this test will be essential for the methodological progress of the project. However, we are optimistic. If the results of the height measurement with the 0.6 m Quickbird are not sufficient, we will make advantage of the next generation high resolution satellite imagery with a 0.5 m spatial resolution. Those are announced for early 2007 from GeoEye. The high resolution SAR sensor from the TerraSAR-X mission will also provide a DSM product from SAR image interferometry. After resolving step number two and three it is finally planned to integrate the different steps into one arbitrary workflow. This workflow will be handled as one process under a user friendly GUI and it will connect all programs under one shell.

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