# Change Detection Analysis of Forest Areas Using Satellite Stereo Data

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**Abstract:** Tree height is a fundamental parameter for describing the forest situation which can be determined by different means. In this paper a novel region based forest change detection method is proposed using panchromatic CARTO-SAT-1 stereo imagery. In the first step, DSMs from two dates are generated based on a new dense matching methodology called semi-global matching. To achieve reliable change detection a multi-step procedure has been developed using a combination of image data and DSMs. After 3D co-registration of the two DSMs, the othorectificated images are generated based on these DEMs. Mean-shift segmentation is applied to the ortho-images to get the initial regions. Following, the height change is extracted as well as grey value changes based on a region based level. The fusion of the several kinds of change sources are performed under the Dempster-Shafer statistical theory. To further improve the change detection result, texture measures called Grey Level Co-occurrence Matrix (GLCM) features are derived with changing window size and displacements and are analysed to extract the real forest change area. The test data are acquired over a forest area close to Freising, Germany, which consist of two pairs of stereo data from the year 2008 and 2009. Evaluation of the proposed approach proves its efficiency and accuracy.

## 1. Introduction

Forest management and observation is an important and time-consuming task. Besides in-situ inspection, in the last years, numerous change detection methods using remote sensing with different kinds of images have been used for forest monitoring [Lu04]. However these methods are not practicable for Cartosat-1 imagery, which was launched by the Indian Space Research Organisation in 2005, acquiring 2.5 meter spatial resolution stereo images but exhibiting relatively low spectral information since only one panchromatic channel is available. Until now the research on using Cartosat-1 image for automatic and semi-automatic change detection are rare. But, according to literature on Digital Surface Model (DSM) generation [DMK08] Cartosat-1 imagery is well suited for DSM generation. This offers further possibilities for Cartosat-1 image analysis and applications. Therefore, we propose a two steps region based change detection method for

forest change monitoring which combines the use of Cartosat-1 images and the digital surface models generated from the stereo pairs.

## 2. DSM generation

Cartosat-1 stereo scenes are provided with rational polynomial coefficients (RPC) sensor model, as described by Grodecki et al. [GDL04], derived from orbit and attitude information. The RPC have a much lower absolute accuracy than the ground resolution of approximately 2.5m. Subpixel accurate ground control points (GCP) were used in previous studies to estimate bias or affine RPC correction parameters required for high quality geolocation. As such GCPs were not available for the study areas we used the Shuttle Radar Topography Mission (SRTM) DSM as geolocation reference [DMK08].

Digital surface models with a resolution of 5 m are derived from dense stereo matching, forward intersection, and subsequent interpolation into a regular grid. First, quasi epipolar images are generated to restrict the search range for the dense stereo matching into one dimension. The Semi Global Matching (SGM) algorithm by [Hi08] is used to perform dense and reliable stereo matching. SGM avoids using matching windows, and is thus able to reconstruct sharp object boundaries, that appear washed out when using window-based correlation methods. Instead of strong local constraints in a window, a (semi-) global energy function is minimized for all disparities (local shifts between the stereo pair). This energy function consists of a data term, measuring the similarity of possibly corresponding pixels in the two images, and a regularisation term, which favours similar disparities for neighbouring pixels, but also allows large jumps at discontinuities. Both the Mutual Information as well as the Census cost function are used in this paper. To eliminate gross outliers, a check against the SRTM DSM is performed. All points whose height deviates more than 100m from the SRTM DSM are removed. The resulting DSM contains holes in occluded areas and regions where the matching failed or outliers were removed. These holes are filled with SRTM data using the delta surface fill method by Grohman et al. [GKS06].

## 3. Change detection

### 3.1 Data preparation

A further 3D-registration [TLK11] between the two resulting DSMs has been done to remove any shift in three dimensions that might exist between the two DSMs. After that, the Cartosat-1 images are then orthorectified using the filled DSMs from chapter 2. In this research, the objective of segmentation is to get small units that have difference spectral characteristics from the areas nearby. The Mean Shift [CM02] method is adopted to get the initial regions. Two segmentation results are achieved from the two dataset. An intersection of the two segments is done to get all of the possible change regions.

### 3.2 First step change map generation

In the investigated region, the main forest species is spruce trees (Picea abies), a common and important forest type in Europe [SGH08], which appears in the panchromatic images with lower grey values than deciduous trees and grass land. We get a first rough estimation of the spruce tree cover map by giving a threshold for the panchromatic images, then this feature is combined with height information from DSM by using Dempster-Shafer (DS) theory [RTC05]. The function of each indicator is calculated by using cubic parabola with horizontal tangents that is also promoted in the paper [RTC05] to get a smooth transition for the middle values. The regions with higher possibility to be forest are kept as forest change candidate after this step.

### 3.3 Second step change map generation

To overcome the lack of spectral information, texture features have been promoted and adopted by many studies. One of the most efficient textures for forest change detection is GLCM, which was first introduced by [HSD73]. Due to similar texture of forest and crop area using a GSD of 2.5 m, texture information is not very helpful if using the whole image. However after the first step process, all of the change candidates are in or close to the forest area. The remaining main false change alarms are located in grassland areas around or in the middle of the forest, which exhibit different texture characteristics in comparison to trees. In this step, the contrast and homogeneity of the GLCM are adopted to separate forest and grassland.

## 4. Experiments results and discussion

The study site is located in a northeast forest area of Freising, Germany. it exhibits a region of approximately 5×5 km² in a hilly area with an overall height difference of 20 m. The Cartosat-1 images have one year time difference, one is from May 2008 and the other is from May 2009. A further orthorectification is done after generating the DSM for the subsequent feature extraction. The test area is quite complex because many change areas are quite small with irregular shapes. However, the result of our region based change detection approach gives relatively good results in most of the test areas (Shown in figure 1). To evaluate the effectiveness of the proposed method, we manually extracted the reference data for the deforestation area directly from the images. The Kappa accuracy in the 3 test area can reach 0.624, 0.643 and 0.854 respectively.

The experiments are performed to evaluate a new approach for forest change detection using Cartosat-1 images. The proposed two steps region based change detection method is well suited for forest areas. As a decision fusion method the Dempster-Shafer method is much faster than normal cluster methods, and produces reliable results. Further more, GLCM texture parameters as an additional step works well in forest change refinement. The results achieved are quite promising, although some parts of the DSMs generated by stereo matching exhibit low quality height values. However by a combination with the original images and texture measures, efficient and robust forest change detection can be

performed, even to detect small changes at forest borders. In this paper, the thresholds for contrast and homogeneity are manually chosen in the test procedure, more automatic refinement methods have to be developed in further investigations. Also more texture features will be tested in the future work.
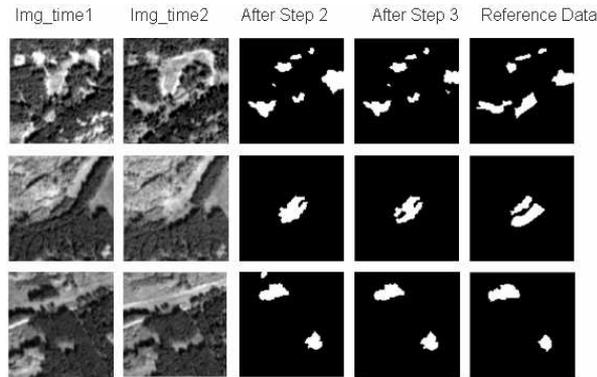


Figure 1.Comparison of change detection result and reference data

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