Automated Detection of Forest Cover Changes

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1. Introduction: the importance of forest cover change detection

Being able to detect changes in forest cover is of critical importance for both economic and scientific reasons, e.g., using forests for economic carbon sink management and studying natural and anthropogenic impacts on ecosystems. The contribution of greenhouse gases from deforestation is one of the most uncertain elements of the global carbon cycle and without information about global deforestation patterns and fluxes, it is difficult to balance the present-day carbon budget and predict the effects of climate change [5]. Recent research [4] suggests that the role forests play in regulating global climate is larger than previously thought and will likely become even more important as alternative carbon sinks become saturated while forests continue to act as sinks throughout a century of climate change. In fact, changes in forests account for as much as 20% of the greenhouse gas emissions in the atmosphere, an amount second only to fossil fuel emissions. Thus, for carbon management and many other tasks, the need to assess the state of forest ecosystems and how they are changing has become increasingly urgent. This abstract describes change detection algorithms which dramatically advance the state-of-the-art in this area.

2. change detection: time series versus image analysis

Global change detection studies using remotely sensed images are challenging because of the need to balance data set size with the high spatial and temporal resolutions required to describe fine scale landscape changes with high temporal precision. For example, a global image library based on five years of bi-weekly 1 km MODIS images would require the storage and processing of over 130 images having 125 million pixels each. Most prior work in change detection has been performed by comparing two or more images of different dates, or "snapshots," to determine the land cover differences between them, which make them inherently unsuitable for global analysis. Hence, most studies have focused on relatively small areas or described changes in specific categories of interest [2, 3, 6, 7] because they are unsuitable for global analysis.

We recently developed a time series based algorithm that can handle massive global data and take advantage of the seasonality and spatio-temporal information in the data [1]. Time series based change detection has significant advantages over the comparison of snapshot images of selected dates since it takes into account information about the temporal dynamics of landscape changes. Detection of changes is based on the pattern of spectral response of the landscape over time rather than the differences between two or more images collected on different dates. Therefore additional parameters such as the rate of the change or the extent, speed, and pattern of regrowth can be derived and used for change detection and characterization.

The general problem of change detection in time series data has been extensively studied in the fields of statistics, signal processing and control theory. However, most of the previous work in time series change detection is not suitable for the land cover change detection problem because these techniques do not take advantage of the inherent structure present in Earth Science data. There has been some work in time series-based land cover change detection, but this work has had limited success. For example, the change detection algorithm used to generate the Burned Area Product (a well-known MODIS data set) performs very poorly in parts of North America such as California. In addition, such algorithms and products are geared towards specific kinds of changes (such as fires), and are not capable of detecting the broad set of changes that we seek to address (such as those due to deforestation, floods, droughts and insect infestations).

3. Results: a global history of forest changes

Using our change detection algorithm, we have produced a global 10 year history of major forest changes using MODIS data. This history consists of approximately 25 thousand high quality change points at 4km resolution. The points have been detected using quality-filtered FPAR data from March 2000 through February 2009. The analysis includes forests around the globe using a 4km MODIS forest cover map from Boston University. The output will be available through the Planetary Skin Institutes (PSI) disturbance viewer.

To ensure the algorithm produces trustworthy results, we conducted extensive validation using ground truth data wherever possible. Currently, independent ground truth data is currently available for the following regions:

- California – entire state from 2000 to 2008
- Canada – the following provinces and corresponding time periods
    - Alberta – 2000 to 2008
    - British Columbia – 2000 to 2008
    - Northwest Territories – 2000 to 2006
    - Saskatchewan – 2000 to 2007
    - Yukon – 2000 to 2008
- Amazon – PRODES data from 2003 to 2007
- Greece – 2000 to 2008

We applied the algorithm on a global scale using 4km x 4km FPAR data over land areas classified as forest detected major forest fires worldwide (see Figure 1) as well as large-scale deforestation (in the Amazon) and vegetation disturbances due to large-scale floods. This work is unique because it is among the first high temporal resolution schemes for land cover change detection and because of the high accuracy with which changes are detected. We also applied our algorithm to for 250m x 250m EVI data and detected a number of interesting land cover changes in California including logging (Figure 2), forest fires, and conversion from desert to farmland [1].

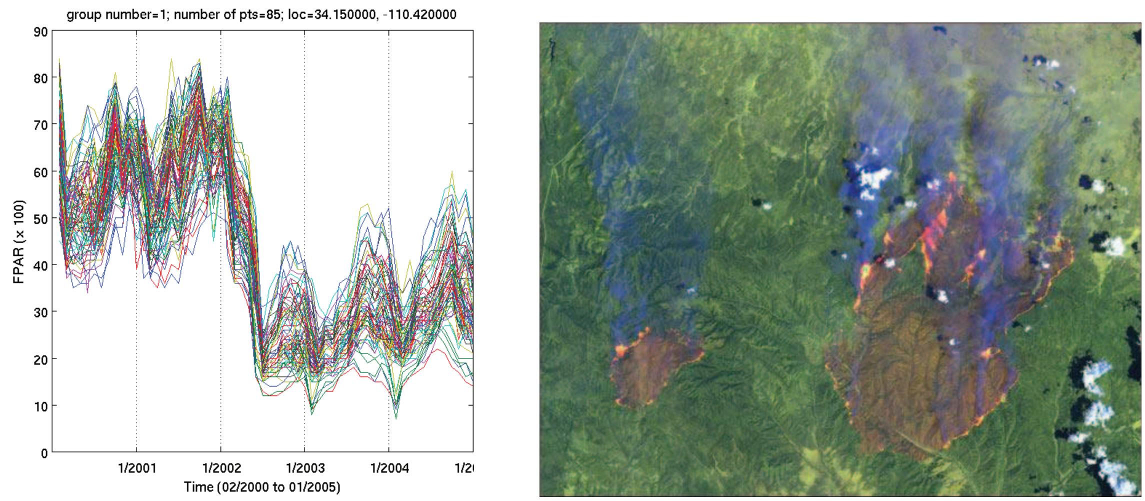

Figure 1: The collection of time series (left) identified by our change detection algorithm show a dramatic drop in vegetation index (FPAR) around the summer of 2002. These time series correspond to a forested area near Phoenix. Satellite imagery (right) for this location from June 2002 shows a large scale forest fire in progress – the well-documented Rodeo Fire. (Figure best seen in color.)

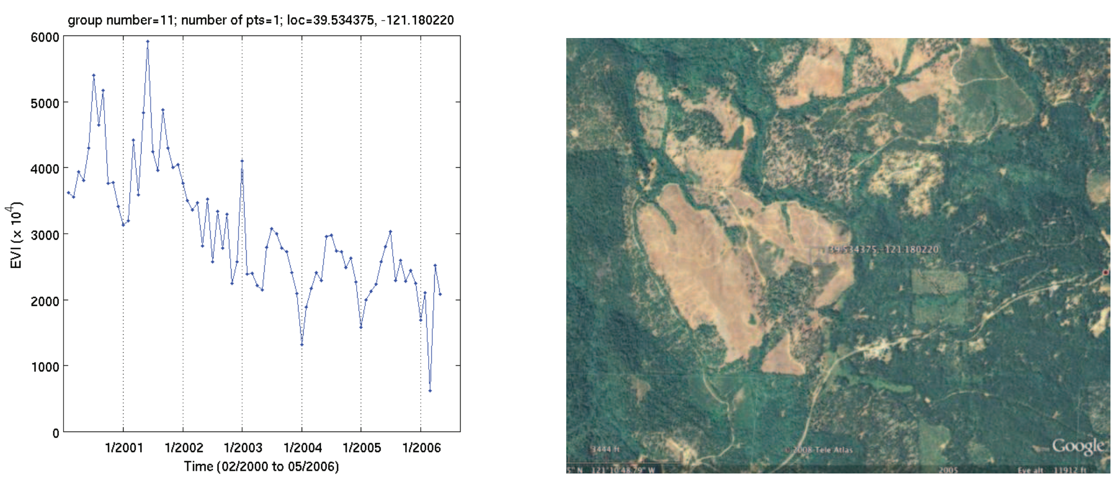

Figure 2: Vegetation time series (left) identified by our change detection algorithm shows a sustained decrease in vegetation. The corresponding satellite image from Google Earth (right) shows that logging has indeed occurred in this forested area. (Figure best seen in color.)

4. References

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