Research Progress Summary for Florida Citrus Coverage Change Detection

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1. Background

The Florida citrus coverage change detection research project is part of the Florida citrus inventory management and reporting modernization project. To detect changes in citrus acreage, it is necessary to detect not only the land coverage changes between the citrus groves and other land uses, but also the changes in the existing citrus groves, such as tree removal, tree replacement, abandonment or new plantings. There are many change detection techniques applicable if comparable imagery is available. The purpose of this investigation is to find out that if there is a method that can automatically detect the citrus grove growing/planting change based upon the aerial photographs or remote sensing images taken at different dates and times.

2. What Have Been Accomplished

2.1 Evaluated Florida Citrus Data

To perform a systematic change detection study, two data sets prepared at different times are required. What change detection method can be effectively used mainly depends on the data availability and data quality. The ideal imagery data for change detection purposes should be 1) derived from the same sensor with the physical parameters unchanged (This means that all of the following characteristics must be the same; radiometric calibration, image resolution, pixel dynamic range and the spectral coverage); 2) The image is taken during the same season; 3) The weather conditions should be nearly identical; 4) The images should be geo-rectified; 5) The images should be accurately registered under the same map projection (Different map projections will introduce additional errors); and 6) radiometrically corrected. These are general data requirements for change detection.

Therefore, the first evaluation used the existing Florida citrus imagery against these requirements and found the following facts:

a) The Florid citrus aerial imagery acquired in 2004 and 1999 came from different sensors; One was taken with a digital camera while the other was taken with a film camera and then scanned;
b) The image resolutions are different;
c) The image dynamic ranges are different. One is 8-bit while the other is 16-bit;
d) The spectral coverage of the images from different sensors is different, though the number of bands is the same. One image has IR/R/G bands while the other has B/G/R bands;
e) The radiometric calibrations are different;

f) The images are geo-rectified;

g) The images are geo-referenced;

h) Map projection information from one set of images is missing;

i) The weather conditions are not same;

j) The images are not acquired at the same season;

k) The images are registered to one pixel level of error;

l) The images are not radiometric-corrected.

If these findings are compared with the requirements mentioned above, one can easily draw a conclusion: the data is not optimum for change detection, if not impossible. These existing data conditions will dominate which change detection techniques can be used.

2.2 Testing, Data Preparation and Correction

To make the data more feasible for change detection, the following data processing and corrections were successfully conducted:

a) Tested images quantizing using Erdas Imagine;

b) Tested image re-sampling using Erdas Imagine and ArcGIS;

c) Tested adding the missing map-projection information using ArcGIS.

These processes were necessary in preparation for the image differencing techniques.

2.3 Reviewed Existing Change Detection Techniques

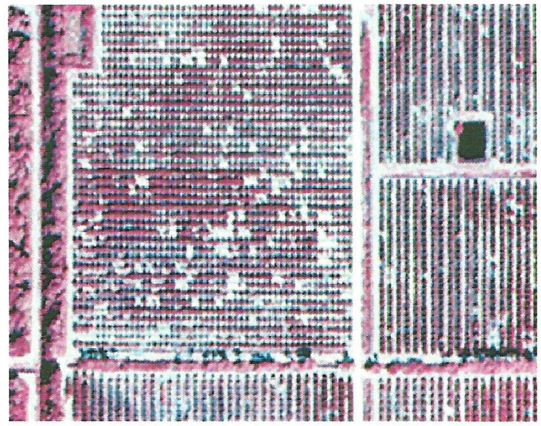
There are many change detection methods that can be used to derive change maps. We reviewed image differencing, change vector analysis, inner product analysis, spectral correlation analysis, image ratioing, vegetation index differencing, normalized image differencing, radiometrically normalized image differencing, albedo differencing, principal component comparison, and post-classification comparison methods. Each of the pros and cons of these methods were analyzed and none were found to be completely suitable for solving the citrus change detection problem.

2.4 Tested Image Differencing Techniques

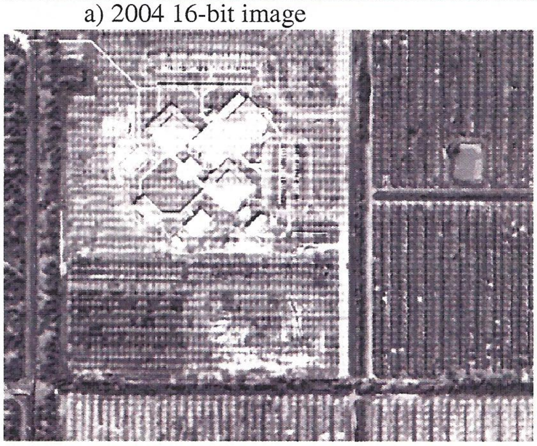
Among the previously mentioned methods, image ratioing, post classification comparison and image differencing are the most widely used ones. The image ratioing method is an easy way of detecting areas of change, but it is not suitable for analysis between different sensors. The post classification comparison methods are good for land coverage type change detection, but it is difficult to use it to detect citrus growth change. Moreover, it requires an experienced analyst to perform the classification and to interpret the results. The third method, image differencing is the most straight forward method. In differencing, the co-registered images from two dates are simply subtracted, pixel by pixel. The result is a difference map (image), which represents the actual image change value between the two dates. However, it requires images from two different dates to have the same spectral coverage, dynamic range, image resolution, and precise co-registration. Obviously, the imagery does not meet these requirements. However, after quantizing and re-sampling, and registration, the image differencing method can be used to validate its performance.

Erdas Imagine has an automated image differencing algorithm already implemented. Two images were tested, one taken in 2004 and the other in 2005. Here are the image differencing results.

a) 2004 16-bit image

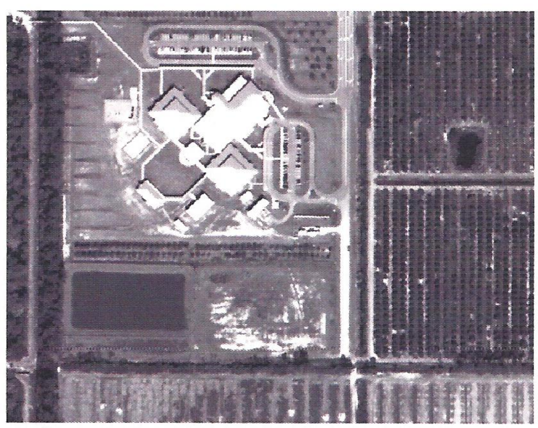


b) 1999 8-bit image



c) difference image with quantizing

d) highlighted difference image



e) difference image without quantizing

Image a) is the original 16-bit image taken in 2004, with 1 meter resolution. Image b) is an 8-bit image taken in 1999, with a resolution of 2 meters. Image b) was re-sampled to 1 meter to match the spatial resolution of image a), while image a) was quantized to an 8-bit image to match image b). Image c) shows the image differencing results between image a) and image b) and the feature changes are highlighted. When the two raw images are compared with each other, it is apparent that there is significant change in the central part and bottom part of the image, but not in the right side of the image. To better visualize the changes in the differencing image, thresholding was applied to highlight the big changes. Image d) is the highlighted difference image, in which the green area indicates 10% increase in radiometric intensity while red area indicates 10% decrease radiometric intensity, i.e., the combined green and red area indicates the area having over 10% change in radiometric intensity. From the difference image, most of the image pixels fall into either the red or green change areas. Specifically, the major structure of the new complex has been detected, but the new roads in the image a) are not well detected. It is interesting that most of the pixels of the citrus areas in the right side and bottom part of images are both detected as significantly changed. When eyeballing the images, it is evident that in the bottom part, the change is significant while on right side of the image, it does not show much change. Of course, the threshold level will affect highlighting the changes in d). However, the radiometric characteristic difference of the images probably plays an even big role in impacting the result of the image differencing. When two images have different radiometric characteristics, and all other imaging conditions and objects are exactly the same, the image subtraction will still show some difference.

The last image e) shows the image differencing results between image a) (16 bit and 1 meter) and image b) (8 bit and 1 meter) but without quantizing image a). From this image, it is observed that the land changes are not clearly detected because of the huge dynamic range difference. In theory, the maximum value of 8-bit image is less than 1%

of the maximum value of the 16-bit image (the ratio is 1/256.) This showcased the impact of the dynamic range difference to the image differencing method for change detection.

2.5 Developed New Algorithm for Change Detection

This data set came from two different sensors, with differences in radiometric, dynamic range, spatial resolution and spectral band coverage. This makes the change detection task very difficult. The spectral signature correlation is one of the spectral based change detection methods that can overcome radiometric and dynamic differences. But it does not solve the resolution difference problem. To overcome spatial resolution differences between images, the spatial information has to be used to provide regional similarity (difference). However, there is no effective method, which can overcome radiometric and dynamic differences and at the same time solve the resolution difference problem. Therefore, a new method is needed that can solve this problem.

After extensive research, a new normalized spatial-spectral cross-correlation method to do the change detection was proposed. This method generalizes both the spatial correlation coefficient and the spectral correlation coefficient into the spatial-spectral domain. It provides a correlation map of the corresponding image pixels that is a measure of the similarity among images pixels. This method inherits the property of invariance to radiometric calibration and dynamic range difference from the normalized spectral correlation method and the capability of detecting the local region similarity from the normalized spatial cross correlation method. Moreover, it grasps both the spectral and spatial signatures. At this moment, the algorithm's theoretical analysis is complete and developing iterative procedures for implementation are underway. In addition, this algorithm has the potential for usage in improving multi-spectral image registration.

2.6 Researched and Selected Implementation Platform

The new algorithm implementation can be performed on different platforms. But which platform should the change detection application be built upon? To answer this question, the Erdas Imagine Developers' Toolkit and ArcGIS's ArcObject library were investigated. The Erdas Imagine Developers' Toolkit provided a C++ library and EML script language for development. A developmental test bed was built, which hooked onto the Erdas Imagine desktop application. It can serve as a framework for further application development. Erdas Imagine has a very strong image processing and analysis capability. But its capability of map handling is weak compared to ArcGIS. Moreover, the documentation for development is very poor. ArcGIS, however, is strong in map handling but very weak in image processing and analysis. It has a very limited image processing and analysis library. Since the Florida citrus imagery is stored in ArcGIS, it is natural to consider using the ArcGIS as a development platform given it has the necessary basic image handling functionality. The language used for development is Microsoft visual C# which is a powerful, simple, managed object oriented programming language targeting for .NET environment. The managed code is executed by the common language runtime environment rather than directly by the operating system. Managed code applications gain common language runtime services such as automatic garbage collection, runtime type checking and security support, and so on. These services help provide uniform platform and language-independent behavior of managed-code applications. Moreover, in the managed language, objects' lifetimes are managed by the common language runtime. The runtime automatically handles object layout and manages references to these objects, releasing them when they are no longer being used. Specifically, it can allocate and release the memory automatically, which will solve a lot of memory-related problem caused by the memory allocation and memory leaking. (JAVA has the same feature, but needs more development effort.) This is the main reason for selecting this language though the Visual Basic is popular in the ArcGIS development community because of its ease of use.

2.7 Implementing New Algorithm

At this stage, the following tasks are complete:

a) Set up the .NET visual studio, C# development environment for ArcGIS development;

b) Designed and implemented a graphic user interface as shown in Figure 1;

c) Implemented image read-in and write-out functionality;

d) Implemented automatic image registration and re-sampling functionality;

e) Implemented image overlapping region calculation;

f) Implementing and debugging the iterative normalized spatial-spectral cross correlation algorithm for change map creation.

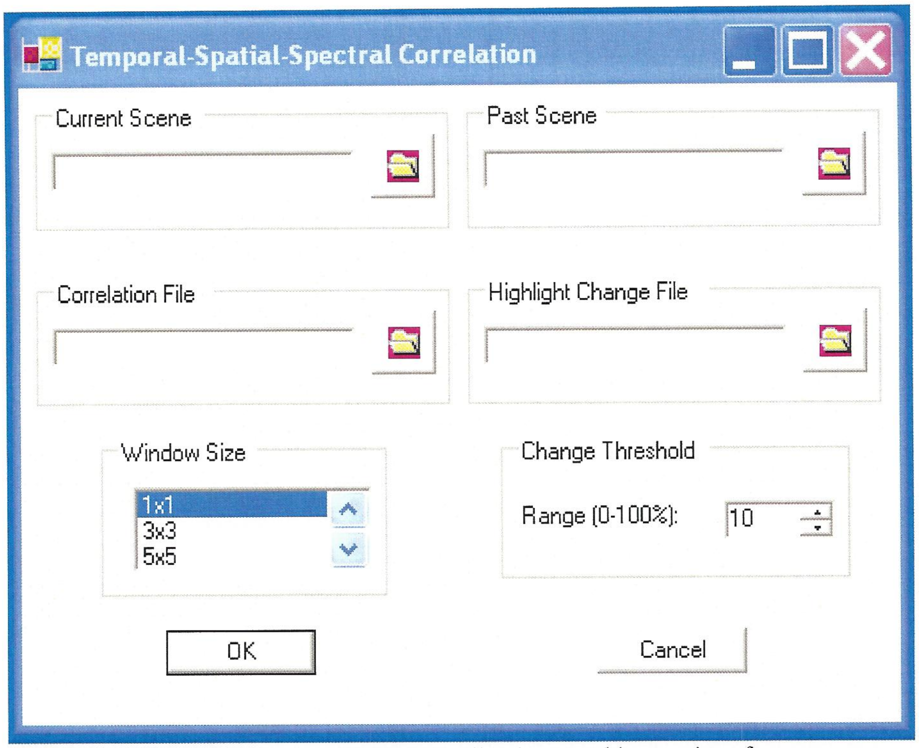


Figure 1. Change detection application graphic user interface

3. What Is Next

Here are tasks that need to be performed next.

a) Finish up the implementation;

b) Test the algorithm against the control dataset;

c) Test the algorithm against the real world data;

d) Compare the results with that of spectral correlation and spatial correlation;

e) Improve the algorithm if possible;

f) Enhance and modify the change detection application if necessary.

g) Deliver the application if it is useful.

h) If not, deliver the research report.

4. Constraints and Possible Risks

This research project could only be pursued in a limited scope with the given time and resource constraint. Therefore, there are some risks that need to be recognized. The possible risks faced right now are three folds:

a) The new algorithm may not work as once hoped. The data comes from different sensors and has different spectral, spatial and temporal variances. These are big hurdles.

b) The user/analyst may not be satisfied with the performance, functionality and the level of automation.

c) There are competing projects in the Spatial Analysis Research Section involving this project and that of the Cropland Data Layer (CDL) modernization project (i.e., re-engineering the digitizing efforts with ArcGIS, image processing/analysis with See5 and regression estimation with SAS.)

5. Future Imaging Potential

It is expected that the State of Florida (Water Management Districts and the Dept of Revenue) and the USDA/National Resources Conservation Service's NAIP program will keep flying aerial high resolution digital ortho-photos annually. The NAIP program will fly 2 meter imagery annually, with every fifth year scheduled for 1 meter (2007) resolution. The NAIP imagery will be acquired during the same time each year from May 1 through June 30. The Florida State Government groups are flying on a three year repetitive cycle (i.e., the Dept of Revenue) and in some cases individual groups (Southwest Florida Water Management District) are flying at resolutions greater than one meter. With this many potential data sources becoming available, getting repeatable consistent data useable for change detection studies is a good possibility for the future.