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Environmental Change Detection and Visualization by Differential Computing for Satellite Images with 5D World Map System

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Abstract

This paper presents a differential computing system for satellite images called SIDE, which automatically extracts areas, boundaries and lines on earth from any type of general images using image processing technology. Unlike other general GIS software, SIDE can process any type of images without geo information (lat, long) as input and convert to geo information with template. The feature of SIDE is that it enables users to extract the differences between images using color information of areas on earth such as forest, ice, ocean, river, soil and desert, and compare the differences in time-series analysis. Also, SIDE provides a function to modify the position, size and angle of detected area, border and lines, and adjust the positions to geo information to overlap output images onto the base-map such as Google Maps or ArcGIS maps. By using this system with a multimedia sharing system called 5D World Map System, users can analyze the impacts of environmental change to the other phenomena by global viewpoints with other related multimedia.

Keywords: Multimedia, Image Processing, Environmental Studies,

1. Introduction

For analyzing environmental change, it is important to compare not only the features of environmental phenomena in different areas but also the time-series change of the features of same area. For this purpose, any type of multimedia such as image, text, video, sound, statistics and sensor data should be utilized for the analysis of the features. Based on these assumption and objective, this paper presents a differential computing system for satellite images called SIDE for the detection and visualization of environmental change. The proposed system detects and visualizes the distinct differences among image groups of land, especially satellite images, aggregated by the time, and provides "difference-images" for users to grasp the notable changes in environment. The objective of this research is to realize a new analyzer for computing differences in environmental images for discovering new knowledge based on actual aspects and contexts, based on the concept and approach of Differential Computing [3]. The main feature of this system is that it enables to extract the differences between images using color information of areas of land such as forest, ice, ocean, river, soil, desert, mountain, city and road, and compare the differences in time-series analysis. In addition, how the change of geographical area makes impacts on to other phenomena can be also analyzed by mapping the results to a multimedia sharing system called 5D World Map system.

2. Overview of 5D World Map System

The analyzed results by the differential computing system for satellite images are supposed to be mapped onto a multimedia sharing system called 5D World Map System for collaborative knowledge creation on environmental studies.

5D World Map System enables semantic, temporal and spatial analysis of multimedia, integrates and visualizes the analyzed results as a 5-dimentional dynamic historical atlas [1][2][3]. The main feature of this system is to create various context-dependent patterns of environmental/historical/cultural stories according to a user's viewpoint dynamically. This system provides a platform and a common framework to share the research results of joint research activities, and generates multiple views of semantic and temporal-spatial relationships among multimedia of the cross-cutting issues with high visibility of semantic correlations between multimedia in time series variation with multi-geographical spaces. The objective to create this system is to combine real and cyber spaces to share knowledge not only in technological systems/mechanisms but also social rules/phenomena in the field of environmental research.

The latest 5D World Map System consists of five main functions [4][5]: (1) Cross-topic multimedia search by semantic similarity calculation (Figure 1), (2) Multimedia database overview by spatiotemporal information, (3) Media data uploader for multi users, (4) Differential computing for spatiotemporal data, and (5) Historical-geographical information visualization (Figure2).

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3. Differential Computing System for Satellite Images

In this section, we introduce a differential computing system for satellite images named SIDE (Satellite-Image Difference Extraction system). SIDE automatically extracts the area, boundary, lines of lands from any type of general images (.jpg, .png., .tiff etc.) using image

Figure 1. Multimedia Search UI in 5D World Map System [4][5]

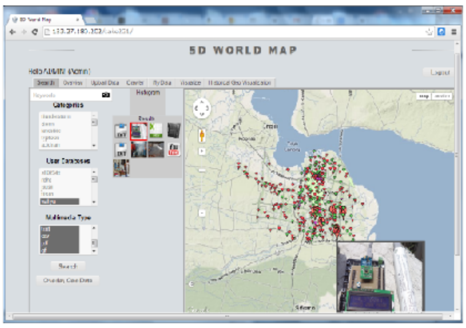

Figure 2. 5D World Map System: Historical-geographical Information Visualization [4][5]

processing technology. Unlike other general GIS software, the input can be any type of images without geo information (lat, long). The feature of SIDE is that it enables to extract the differences between images using color information of areas of land such as forest, ice, ocean, river, soil, desert, mountain, city and road, and compare the differences in time-series analysis. Also, SIDE provides a function to modify the position, size and angle of detected area, border and lines, adjust the position to overlap to the base-map such as Google Maps or ArcGIS maps.

By using SIDE system, users can extract specific geographical area (glacier, forest, desert, etc.) from any images, especially from satellite images, and create difference images for time-series analysis of environmental change. Furthermore, using template images, the correspondence between geographical location (lat, long) and the position on the map image can be specified and output as geo data file.

The output images of difference-images or difference geo data files can be mapped onto a multimedia database system such as 5D World Map and shared by any remote users. In addition, the users can analyze how change of geographical area have been making impacts on to other phenomena by displaying with the other multimedia data (document, image, music and video) on 5D World Map system.

3.1. System Structure

Figure 4 shows the system structure of SIDE that consists of two main functions as follows:

- Function F_{diff} reads a set of satellite images, and extracts the color-difference among them. As sub-functions, it includes image-color clustering, difference calculation and difference-image creation.
- Function $F_{diff2kml}$ transforms the difference-images of out of F_{diff} to geo information, and outputs as a format of KML. Using position template files, it transforms the position (x, y) of an image to geo information (lat, long) on a world map.

In this paper, we focus on the first function F_{diff} to examine the functionality of SIDE as a tool to analyze the real environmental issues.

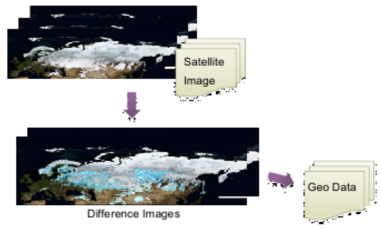

Figure 3 Overview of our differential computing system for satellite images (SIDE)

3.2 Image-Color Clustering

As a sub-function of F_{diff}, Image-Color Clustering function reads satellite image files and automatically splits the regions from the images by color information. The processing is shown in Figure 5. First, this function segments pixels in a satellite image into groups. In this colored-area segmentation, the pixels close in space and color are joined. Next, the pixels are divided into specified number of groups by color clustering. This function enables to extract specific geographical area (glacier, forest, desert, etc.) from satellite images.

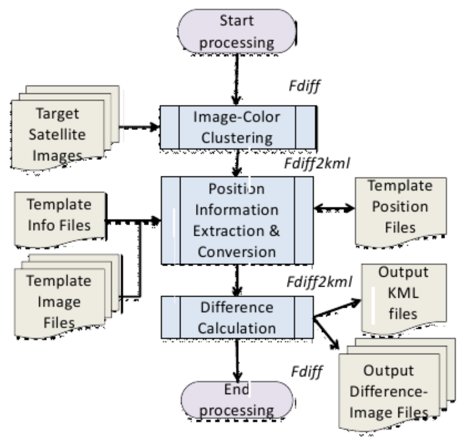

Figure 4. System structure of SIDE

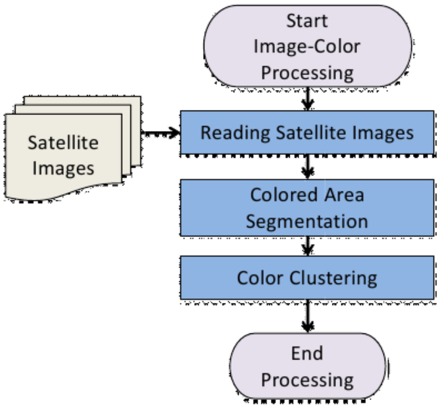

Figure 5. Processing flow of Image-Color Clustering

For the colored-area segmentation, the function segments pixels in a satellite image into several groups by color using Mean-Shift method (Figure 6). The pixels are grouped by color, by setting average color as a color of each pixel in neighborhood. Users can select option to set a spatial window radius, color window radius, and max level of image pyramid used for segmentation. If the spatial window radius increases, area of neighborhood increases. If color window radius increases, color range of same group increases.

For the color clustering, the function divides the pixels in input image into specified number of groups by K-means algorithm (Figure 7). K-means algorithm finds the centers of clusters, and groups the pixels by color. The Number of groups (clusters) can be specified by users.

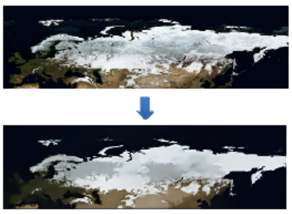

Figure 6 Colored-Area Segmentation

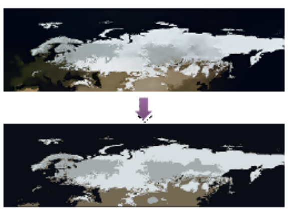

Figure 7 Color Clustering (cluster no. = 4)

3.3 Difference Calculation

As a sub-function of F_{diff}, Difference Calculation function creates difference-images from the result images of color clustering (Figure8). First, from the result images of color clustering, the function extracts the specified colored-area for extracting difference area. Next, by comparing the extracted area of two images, the function obtains common, advanced(increasing) and retreated(decreasing) area (difference area). Drawing each area by specified color, the function creates difference-images. In addition, the function extracts the border lines from each area (Figure 9).

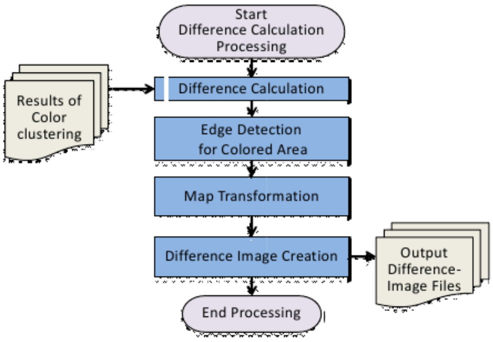

Figure 8. Processing flow of Difference Calculation

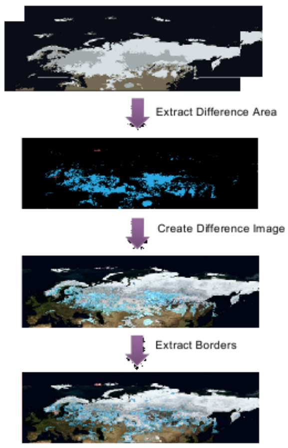

Figure 9. Difference Calculation and Difference-Image Creation

Users can set the difference-images creation options, such as the number and color of extracted area, the color for visualizing advanced/increasing and retreated/decreasing area, the opacity (transparency) of extracted area, the dot size of noise, kernel size for blurring edge, the vertex number for removing small borders, and max distance between edge lines for reducing border vertex.

4. Prototype Implementation

We have implemented a prototype system as a software package with a graphical user interface for seeking the high applicability, usability and user-friendliness. Figure 10 shows the GUI for Image-Color Clustering and Table 1 shows the options for colored-area segmentation and cluster settings that are available for users to set.

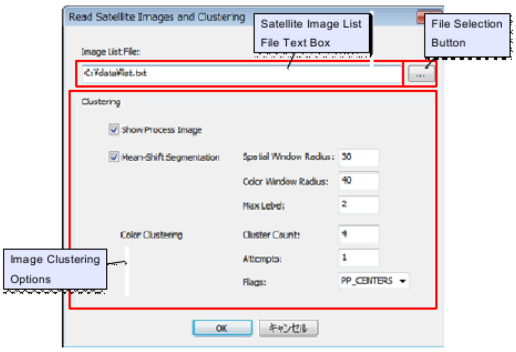

Figure 10. GUI for reading images and setting options for colored-area segmentation and color clustering in Image-Color Clustering

Table 1. Options for colored-area segmentation and cluster settings that are available for users to set.

Option Name	Settings	Value	Description
Show Process Image	Check to view the results of the image processing		
Mean shift Segmentation	Check to split regions from the map image by color		
	Spatial Window Radius	0 < value	Space Search Radius
	Color Window Radius	0 < value	Color Search Radius
	Max Level	0 <= value	Maximum level of the image pyramid used for segmentation
Color Clustering	Setting of color clustering		
	Cluster Count	2 to 10	Number of color clusters
	Attempts	1 to 4	Number of times the algorithm is executed using different initial labelings.
	Flags		Selection method of initial centers: ･RANDOM_CENTERS: Select random initial centers in each attempt. ･PP_CENTERS: Use kmeans++ center initialization by Arthur and Vassilvitskii.

Figure 11 shows the GUI for Difference Calculation and Difference-image Creation and Table 2 shows the options for Difference Calculation and Difference-image Creation (especially for extracting borders).

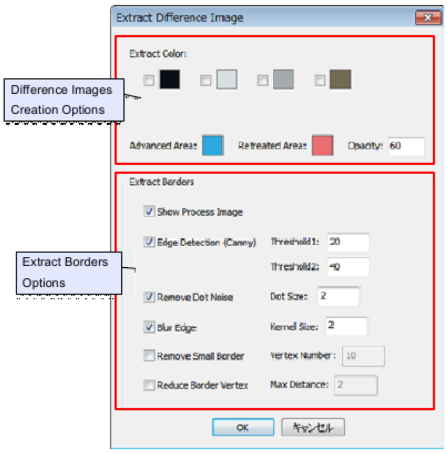

Figure 11. GUI for Difference Calculation and Difference-image Creation

Table 2. Options for Difference Calculation and Difference-image Creation (especially for extracting borders)

Option	Setting	Value	Description
Show Process Image	Check to view the results of the image processing		
Edge Detection (Canny)	Check to extract edges before extracting borders		
	Threshold1	1 <= value	First Threshold[1]
	Threshold2	1 <= value	Second Threshold[1]
Remove Dot Noise	Removing small independent noise		
	Dot Size	1 or 2	Size of the dot noise to be removed
Blur Edge	Check to apply smoothing		
	Kernel Size	1 <= value	Smoothing kernel size
Remove Small Border	Check to remove borders with small amount of vertices		
	Vertex Number	1 <= value	Minimum number of vertices on borders you wish to keep
Reduce Border Vertex	To reduce number of vertices on borders, check this		
	Max Distance	0 < value	Maximum distance after reducing vertices

5. Experiments

5.1 Case 1: Visualization of a set of Global Map

To examine the functionality of our differential computing system for satellite images SIDE, we performed a preliminary experiment using a pre-processed and digitized satellite-image data-set selected from Visible Earth provided by NASA [6]. We selected 12 images of Blue Marble from Jan. – Dec. 2004 shown in Table 3. The features of this image-set is that the cloud-contaminated and other noises are removed in advance manually, which provides great details in darker regions without washing out brighter regions.

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In this case, we set the number of color clustering as 5 so that we got extracted colors as dark-blue, white, gray, dark-green and brown. Then, we selected white and gray colors as focused color to detect the time-series change of area ratio of ice-melting on the globe.

Table 4 shows the results of difference extraction. The decreasing part of ice (white and gray) on a month-by-month basis is visualized by red color, and the increasing part is visualized by blue color. By these results, we can see that our difference extraction method and difference-image creation function work reasonably, though the result of time-series change itself is only to be expected because the phenomenon of ice-melting happens according to the change of seasons.

Table 3. Original images from Visible Earth by NASA

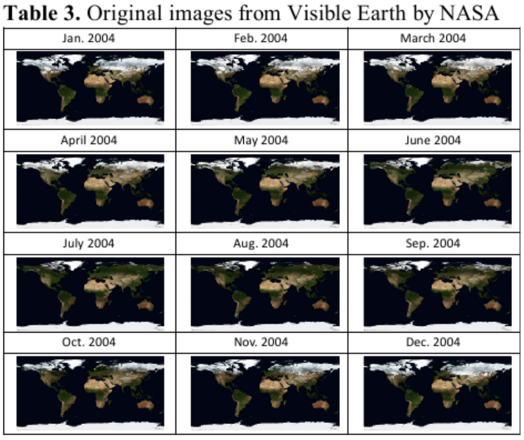
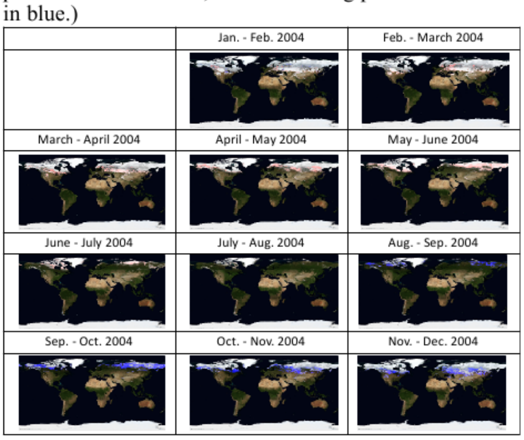


Table 4. Results of difference extraction and difference-image creation (Focused colors are white and gray, which mean ice part of globe. Increasing parts are shown in red, and Decreasing parts are shown in blue.)



5.2 Case 2: Deforestation in Northern Thailand (Mae Wong)

To examine the effectiveness and usefulness of our system to analyze the real environmental change, we performed an experiment with Landsat satellite images selected from U.S. Geological Survey (USGS) [7]. We selected four national parks in Thailand as target areas for analyzing deforestation in Thailand (Figure 12).

It is pointed out that forest cover in Thailand declined from 61% to 34% of the country's land area between 1945 and 1975, and Thailand lost close to 28% of all of its remaining forests over the next 11 years [8]. During the 20th century, deforestation in Thailand was driven primarily by agricultural expansion [9], and Thailand's recent economic improvement is attributed to increased agricultural production for export. From 1989, after assessing the extent of the damage, the Thai government is beginning to emphasize forest restoration.

As an example in this case, we show the time-series difference extraction results on deforestation in Mae Wong National Park, where the deforestation was heavily done previously and currently large-scale of restoration is deployed.

Figure 12. Four important national parks to analyze deforestation in Thailand

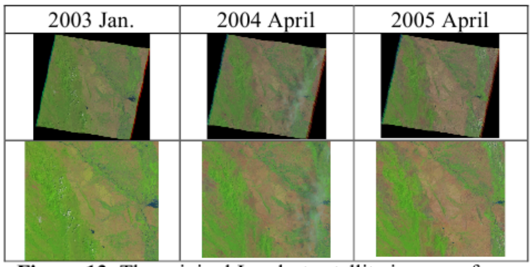


Figure 13. The original Landsat satellite images of Mae Wong from Jan. 2003 to April 2005 (upper line), and the pre-processed images of them (lower line)

Figure 13 shows the original Landsat satellite images of Mae Wong from Jan. 2003 to April 2005 and the pre-processed images of them. The pre-processing for the original images starts from rotating, via position adjustment, trimming, and ends by color-contrast adjustment. Figure 14 shows the difference extraction results. The results show that the retreated area of green increased much from 2003 to 2004, but not so much from 2004 to 2005. The advanced area of green seems to increase from 2004 to 2005. We need to examine the detail more and check with more images

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to judge if these results mean the speed of deforestation is reduced year by year.

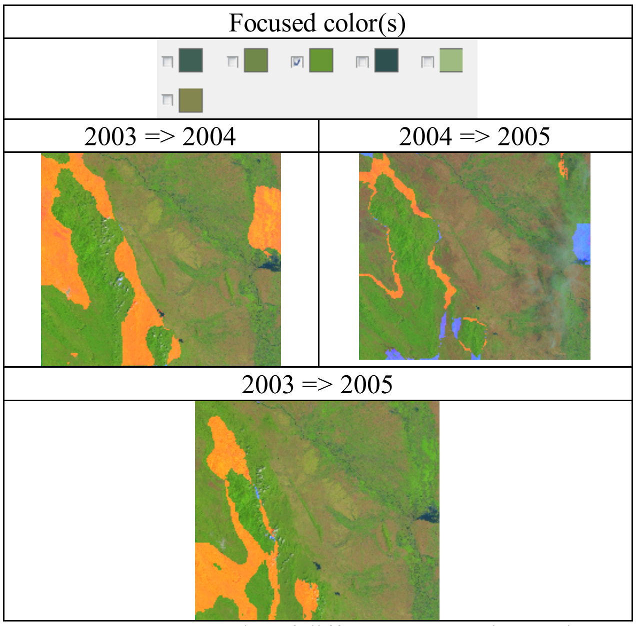

Figure 14. Results of difference extraction and difference-image creation (Focused color is bright-green, which means forest area. Increasing parts are shown in orange, and decreasing parts are shown in blue.)

5.3 Mapping to 5D World Map

As shown in Figure 15, Figure 17 and Figure 18, the original satellite images with geo information and the difference-images extracted by SIDE can be mapped onto 5D World Map, and visualized with other data such as sensor data of weather and statistical data about deforestation around the world. This visualization enables users to understand the complicated relations among various environmental phenomena intuitively.

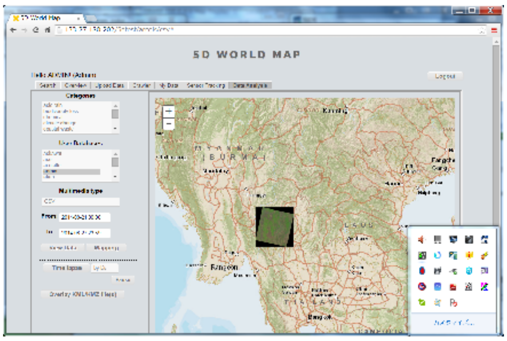

Figure 15. Mapping of an original satellite image with geo information converted as a KML file

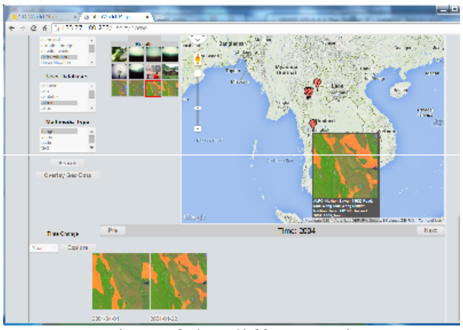

Figure 16. Mapping of the difference-images extracted by SIDE onto Mae Wong area

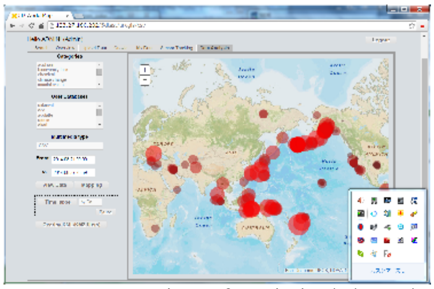

Figure 17. Mapping of statistical data about deforestation around the world

6. Conclusion

This paper has been presented a differential computing system for satellite images called SIDE, which automatically extracts areas, boundaries and lines on earth from any type of general images, and the differences between images using color information of areas on earth such as forest, ice, ocean, river, soil and desert, and compare the differences in time-series analysis. We examined the feasibility, applicability and effectiveness for environmental change analysis with several experiments.

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