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Method of Constructing a Space-Time Grid of Variable Size Images and its Application in Image Processing of Landfills

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Abstract: The paper proposes a method of slicing space images into areas of varying sizes to automate the image processing, beginning from the receipt of raw data (download pictures) up to mapping of the underlying surface indices. Indices calculation are based on one image (the surface and the vegetation indices temperature, indices of objects detection on the ground and etc.) and their time series (conducting temporal processing). The downloading of the sources of satellite images algorithm from the sites archives of geodata from the initial data download (the observation area, stage, time period, etc.) is also represented. The procedure of cutting images into segments of varying sizes is described. It allows to use the "contents" of image both in general and for each pixel of the earth's surface to have a whole time series of the spectral brightness coefficients. Examples of time series of geo-referenced source images and the individual indices of the underlying surface are automatically generated by the algorithm method, for specific problems of space debris monitoring (vegetation indices reaction, the degree of soil degradation, detection of indices).

Keywords: Satellite imagery, Image slicing, Sites, Automation, Time series, Temporal processing, Detection, Index of the underlying surface, Landfills, Dumps, Waste disposal facilities.

1 Introduction

The municipal authority is responsible for monitoring waste disposal (or landfill) sites to prevent any potential threats towards natural habitat and public health. Recycling and incineration are two common solutions for waste disposal. Nevertheless, most of wastes are still buried in landfills. Solid waste management and monitoring is a critical issue for the metropolitan authorities of

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developed and developing countries. In many case solid waste disposal sites (WDS) are illegal. So, it is very important to use system for automatic detection of such places using satellite images [1 – 2].

One of the first in US was Jones and Elgy proposed to use remote sensing technology for ground monitoring systems [3]. Early researches utilized historic aerial photography to identify hazardous waste sites based on the size, shape and spectral reflectance of the landfill sites, as well as the texture of surrounding features [4 – 6].

Pope et al. proposed deriving information for characterization of waste disposal sites using multi-temporal aerial images and geographic information system (GIS) [7].

Dewidar used two Landsat TM images and investigated various changes of detection techniques including image differencing, image rationing and postclassification change to determine the landfill areas [8].

In addition to multi-spectral satellite images, remote sensors such as ground penetrating radars (Well et al.; Daniels et al.) and hyperspectral sensors (Slonecker et al.) were used to investigate hazardous waste sites and detect contaminated areas [9 – 11].

One of the peculiarities of aerospace monitoring is manual, automated and automatic nature of the processing of satellite images. In the first case, the image is loaded into the GIS application [12 – 20] and is viewed by a man. This or that problem is interactively solved, for example by using the mouse to highlight the desired areas of disposal sites. In the second case programs applied only to a specific narrow task are developed and implemented, and according to them the operator manually processes images and draws conclusions. Automatic processing methods require minimal operator effort due to the lack of direct data control. The operator starts the processing only by programming conditions. One of the latest research in the area of the dump aerospace monitoring is [21 – 29].

Waste disposal sites have a rather complicated structure and their detection requires the development of special algorithms. Visual detection of dumps [30 – 32] allows solving a wide range of tasks, but it is true only for manual mode, scanning the area of observation and visually distinguishing objects of “dumping” and “not a dump.” Under automated detection specific programs of detection and allocation of landfills are developed [33], their options are assessed [34, 35] on the satellite images, but they narrow the range of tasks in view of imposing additional conditions of deciphering.

2 Problem Statement

To be able to automate the interpretation of ground surface objects (their detection, estimation of parameters, environmental assessment), particularly waste disposal objects (WDO), firstly necessary to automate the download of images.

The procedure automatically download of satellite images to the ftp-server consist from the several steps (Fig. 1). At the entrance of the procedure – image requirements (the territory, time period, type of product downloads and other download options) [36]. At the exit of the procedure – a full array of space images stored in a data store on your computer.

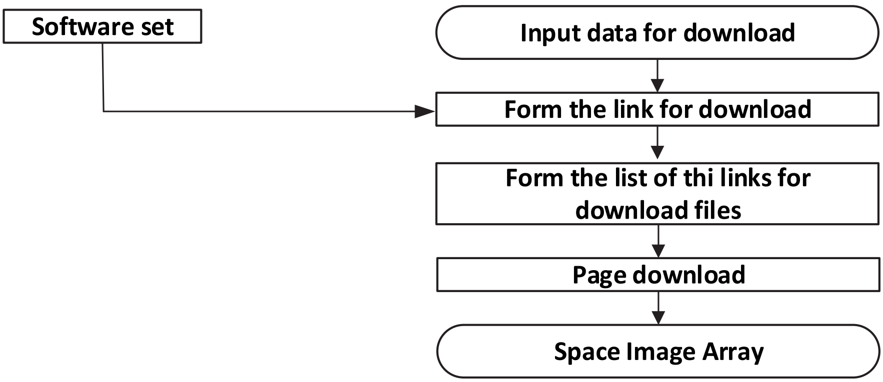


Fig. 1 – *Block diagram of the automatic download satellite images of procedure.*

To successfully download from ftp-server software installation on computer (if it is not found) is required: utility Wget (to start the download procedure in batch mode), Google Earth (for the field of satellite capture, called «tile»), FileZilla (for view the availability of the necessary folders to ftp-server).

First, preparation of input data (reference area, time period and the type of product for download on the site with the images files in the appropriate fields) is performed, resulting in a text file with a list of links to download.

The content of the text file is generated with a single download link received from the site and folder list of addresses to be downloaded from the ftp-server. The resulting set of links is modified as desired depending on the desired time period for the downloaded data. The procedure of downloading of images in batch mode starts in the console command «wget –c –i *input_adress* –o *output_adress*», where the *input_adress* – the full name of a text file with a list of links to download, *output_adress* – the directory to store the downloaded files.

The procedure for the automatic downloading of images to automatically calculate is the image index (II) at each time of shooting (time series of images), such as vegetation indices reactions (VIR) and indices of soil reaction (ISR). [37 – 38].

3 Supplement

ISR on SI (salinity index) [37 – 38] – an indicator of the littering in the same point of the Earth's surface. This is the example of II, the calculation of which can be automated. In [33] the automation method using reference images and geo-referencing is described. If the image is already tied to a common coordinate system, it is possible to apply the method described in the section of automatic processing of satellite images. In this method, each image is cut into a matrix of geo-referenced permanent plots sizes. As a result, it generated many files in the II cards that can look like a "cells" on the "canvas". To avoid this, the image can be cut into sections of different sizes. Consider this method in details.

Input data – satellite images, geo-referenced to the coordinate system Universal Transverse Mercator (UTM) [39], with the presence of the metadata files, such as Landsat 4 – 8 (images of low space resolution). Output data – Image II [39], such as the indices of soil reaction and vegetation reaction (IVR). Look the procedure for Landsat 4 – 8 [39].

In general, the formation of geo-referenced time series, giving the maximum amount of information from the original pictures, is performed according to the scheme:

1. The input - the geographical coordinates of the lower left $A = (X',Y')$ and upper right $B = (X'',Y'')$ in UTM of the rectangle region of interest. X', X'' and Y', Y'' – abscissa and ordinate in the coordinate system UTM (Fig. 2). Points A, B may be any, and cover an area of any size, up to complete coverage of the globe. The rectangle is cut into square sections of constant size with the matrix step h. Step is chosen to commensurate with the operating parameters of the computer system so that in the memory allocated for the image processing program may be stored at the same time 20 matrix size h^2 numeric data type, including 5 – for the regression (see (3)). If we assume that the weight of the pixel is 1 – 2 bytes, as in Landsat 1 – 5, the required bytes are $40h^2$ under the program at $h = 4500$ (half of average side of space image) – 810 MB. If the program can perform distributed computing, it can cope with large matrices. If the program cannot handle, smaller h is assigned, but the best between the number of files and speed.

2. Cells $C = (i,j)$ formed by the grid (Fig. 2) have the coordinates of the lower left $A_{ii} = (X'_i, Y'_j)$ and right upper $B_{ii} = (X''_i, Y''_j)$ peaks:

$$X'_i = X' + i \cdot h \cdot k, \quad X''_i = X' + (i+1)h \cdot k - k, \quad i = 1,\ldots,N_x, \tag{1}$$

$$Y'_j = Y' + i \cdot h \cdot k, \quad Y''_j = Y' + (j+1)h \cdot k - k, \quad j = 1,\ldots,N_y. \tag{2}$$

where k is space resolution, N_x and N_y are numbers of cells on the x and y axis.

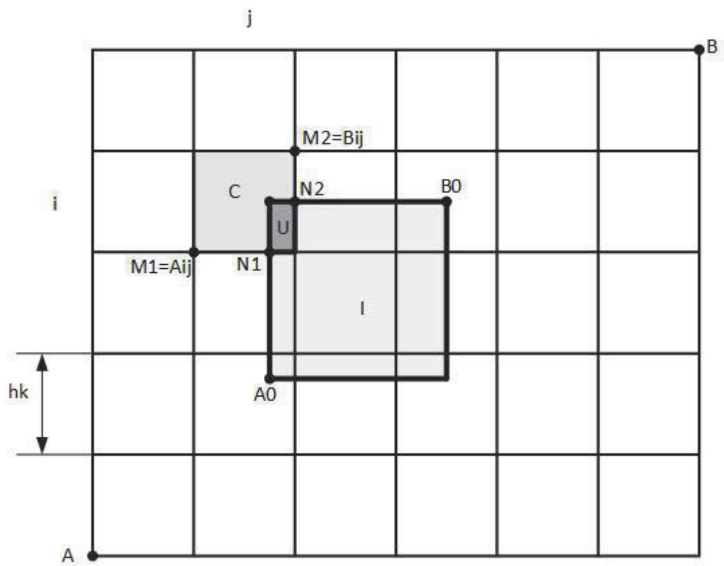


Fig. 2 – *Slicing scheme on image portions of varying sizes.*

3. Because of the metadata of the current image I it is retrieved: $A_0 = (X'_0, Y'_0)$ – the geographical coordinates of the lower left vertex, (s_x, s_y) – image size, T – time coordinate of the image (day of month, day of year, month, year). Coordinates $B_0 = (X''_0, Y''_0)$ of the upper right vertex:

$$X''_0 = X'_0 + (s_x - 1) \cdot k, \quad Y''_0 = Y'_0 + (s_y - 1) \cdot k. \tag{3}$$

4. Find numbers (i, j) of cells, for witch:

$$(X'_i < X'_0 \vee X''_i > X'_0) \wedge (X'_i < X''_0 \vee X''_i > X''_0), \tag{4}$$

$$(Y'_j < Y'_0 \vee Y''_j > Y'_0) \wedge (Y'_j < Y''_0 \vee Y''_j > Y''_0). \tag{5}$$

Condition (4 – 5) means that the image I overlaps with cell C.

5. For each cell $C = (i, j)$ – coordinates of lower left $M_1 = (X_1, Y_1)$ and the right upper $M_1 = (X_2, Y_2)$ vertices, $X_1 = X'_I$, $Y_1 = Y'_j$, $X_2 = X''_i$, $Y_2 = Y''_j$. Then – the coordinates of the lower left matrix $N_1 = (x_1, y_1)$ and the upper right $N_2 = (x_2, y_2)$ on an area $U = I \cap C$, intercept the cell C (see Fig. 2):

$$x_1 = \left[\frac{X_{\min} - X_1}{k}\right] + 1, \quad x_2 = \left[\frac{X_{\max} - X_1}{k}\right] + 1, \tag{6}$$

$$y_1 = \left[\frac{Y_2 - Y_{\min}}{k}\right], \quad y_2 = \left[\frac{Y_2 - Y_{\max}}{k}\right] + 1, \tag{7}$$

$$X_{\min} = \max(X_1, X'_0), \quad X_{\max} = \min(X_2, X''_0),$$
$$Y_{\min} = \max(Y_1, Y'_0), \quad Y_{\max} = \min(Y_2, Y''_0).$$

$[\cdot]$ – extracts the integer part.

Similarly, the coordinates matrix ***U*** section of the image:

$$x'_1 = \left[\frac{X_{\min} - X'_1}{k}\right] + 1, \quad x'_2 = \left[\frac{X_{\max} - X'_2}{k}\right], \tag{8}$$

$$y'_1 = \left[\frac{Y'_1 - Y_{\min}}{k}\right], \quad y'_2 = \left[\frac{Y'_2 - Y_{\max}}{k}\right] + 1. \tag{9}$$

Thus image *I* is cut into generally different size areas with parameters $\{x_1, y_1 x_2, y_2, x'_1, y'_1 x'_2, y'_2, n, b, i, j\}$, where *n* is the image number (set time position), and *b* is the channel number. The area is identified by a set of $[n\, b\, I\;\; j]$ and is set by the coordinates of the vertices (x_1, y_1) and (x_2, y_2) of the cell (i, j).

A continuous stream of images I provides time series of images on the cells (i, j) on the channel *b*, having *n* – that shows the report time. The output images can be stored in the same folder as the image names $[i\; j\, n\, b]$ or different generated folders with the names $[i\;\; j]$ and image names $[n\, b]$. In the first case, the text is bound to the location data file *n*, *i*, *j*, x_1, y_1, x_2, y_2. In the second case, it is attached to folders text files with data *n*, x_1, y_1, x_2, y_2. For time data a text file with the data *n*, *T* is generated (or text files that are attached to folders). Thus, based cloud masks and emptiness, all the information is extracted from the images.

A special case of a grid is one cell. Then, from the images corresponding to the condition (4 – 5), it is cut the time series sites of channels for this cell.

A text file is created with the data n, x_1, y_1, x_2, y_2, n. When forming the time series PRODUCT_TYPE (or its synonym DATA_TYPE) should be considered, which should be equal to L1T.

4 Results

Procedure for automatic downloading and cut into segments of varying sizes was obtained by the structure of space images, identified the parameters given in **Table 1** [44 – 46].

Table 1
Parameters of cutting space images.

Parameter	Value
Type of images	Landsat4, 5 TM (historical photos)
Field observations	Moscow in the Near East
The period of observation $[t_1, t_2]$	1983-2011
Grid boundaries, AB	X' = 423965, Y' = 6166835, X'' = 443965, Y''= 6186835 [m, UTM]
Cutting scheme, N_x, N_y	$N_x = 1$, $N_y = 1$

Fig. 3 shows a portion of the cutting. The file names consist of the picture numbers from which the portion is cut, and the number of its channel. Files cloud masks and “emptiness” is referred to as a single number. Different pictures generally give areas of different sizes.

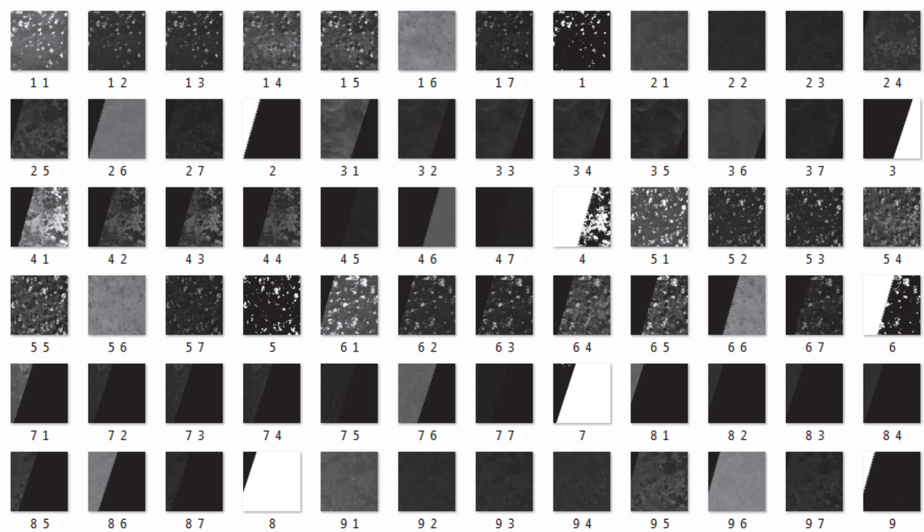
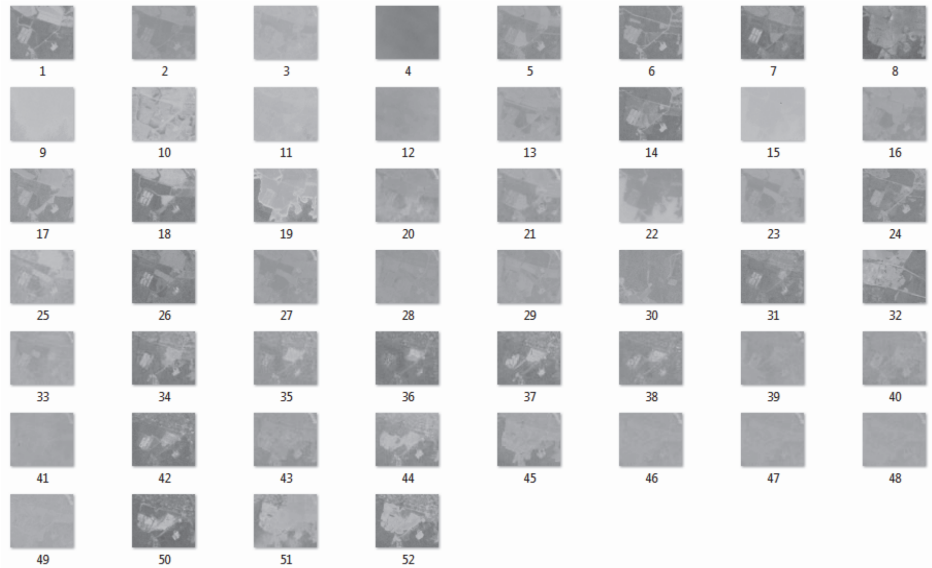


Fig. 3 – *Fragment of the image cut on the variable-size plots.*

The time series data of many II have been obtained for different WDO [46]. Fig. 4 shows 2 II (IVR and ISR) as an example for landfill Torbeevo.

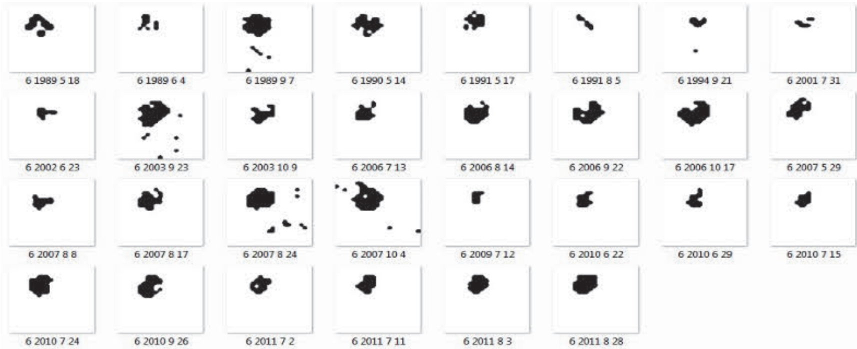
An example of II – detection index (DI) of an object, showing the presence or absence of the detection object at a given point (for a given pixel).



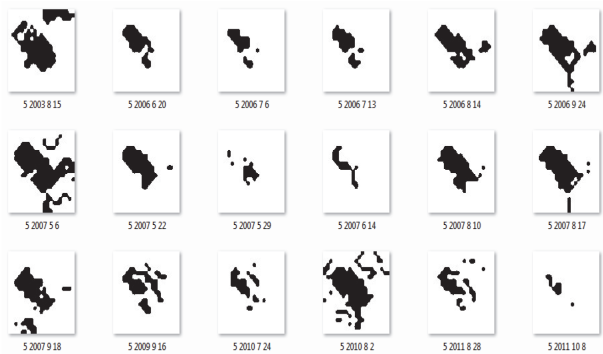
(a)

(b)

Fig. 4 – *Fragment of image time series for: a) vegetation reaction index (VRI), b) soil degradation degree (SDD) landfill Torbeevo.*



(a)



(b)

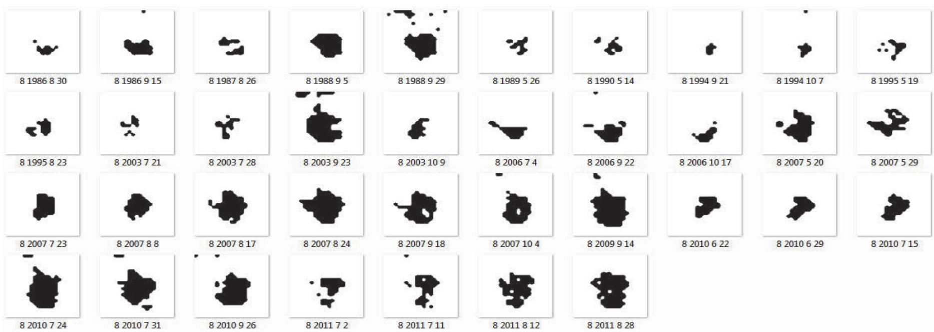


Fig. 5 – *Time series image of the landfill detection:*
a) Dubna Pravoberezhnaya; b) Zhiroshkino; c) Nepeyno (Moscow district).

DI can be defined as: 1) a logical value (DI = 1 – the presence, DI = 0 – absence of the object); 2) continuous values (DI – the probability of the presence of the object). If you know the object detection algorithm for cutting, depending on the time of shooting time t, then the time series of images of the

DI of the object detection can be obtained. Fig. 5 shows the examples of the time series of images DI [45 – 47] for 3 WDO (the landfills in the Moscow region), based on other cut. The files are named in the format «a b c d», where a – number of WDO, b – year, c – month, d – day of the month.

5 Conclusion

It is developed and proposed a technique for the automatic processing of space images by cutting the image into sections of variable sizes to obtain image indices. The technique is based on method of temporal processing, regression analysis methods (calculation of regression lines, calculation of periodic and trend components of time series of temperatures), threshold filtering.

For a given observation area (Moscow region), a structural time series of georeferenced images of the earth's surface is constructed on different channels. In the process of automatic downloading of snapshots in a batch mode, their geographic binding and cutting into sections of variable sizes, indices of the vegetation response (one space image) and the degree of soil degradation (according to the time series of georeferenced space images) in the vicinity of the Torbeevo solid waste landfill are calculated. The results of the automatic processing using the example of recognition of waste disposal facilities are shown. Time series of waste disposal objects areas (landfills Dubna Pravoberezhnaya, Nepeyno and Zhiroshkino ranges of the Moscow region) are given.

The use of the automatic downloading of images and automatic cutting procedure makes it easier to satellite images processing and to reduce processing to full automation. These procedures can be programmed in a variety of software tools that allows solving a wide range of image processing tasks, going beyond the limitations of interactive programs.

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