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### **Thematic elaborations in the field of digital analysis of satellite images**

**Abstract.** Digital analysis of remote sensing data aims at realization of thematic elaborations for different scientific and technical branches. It is performed by utilizing specialistic computer systems.

Presented in this paper are thematic elaborations performed by the staff of the Polish Remote Sensing Centre (OPOLiS) within the Institute of Geodesy and Cartography in Warsaw, with the use of the LARSYS computer system (West Lafayette, Indiana, USA) and the 2 PAAC System (at OPOLiS laboratories). Besides, the method for performing digital rasters of images, which substitutes the optical method is also discussed.

#### **1. Introduction**

Remote sensing data, acquired by devices installed on boards of airplanes and satellites, is analysed and processed by different ways and methods. Two basic types of analysis of remote sensing data can be distinguished: the analog and the digital analysis. The analog analysis includes visual data interpretation, performed by the user and realized with utilization of optical equipment (different colour viewers, stereoscopes, interpretoscopes) and analog-and-electronic (analog-and-electronic converters equipped with colour television monitors). Optical devices allow to determine the characteristic features of processed images by method of optical interpretation of remote sensing data registered on light sensitive materials. The analog-and-electronic converters enable to perform series of functions for changing the scale of images, contrast, performing density slicing, determining the size of areas of equal density levels, etc. The results of the analog elaboration of remote sensing data are usually presented in the form of thematic maps and overlays or colour photographs of images created on screens and monitors of devices, meant for data processing.

Digital analysis of remote sensing data is another type of analysis. It is performed with the utilization of specialized computer systems, allowing for objective analysis and processing of data, with the possibility of performing function which improve the quality of remote sensing information, and therefore, increase the accuracy of performed analysis, as well as to withdraw the data and results to different peripheral de-

vices, which are the components of the system. In effect of the digital analysis a thematic elaboration is created which is supplemented with statistical computations. It can be registered at the data base, visualized on the interactive colour television screen or printed on a line printer by alphanumeric symbols of fortuitous choice.

### *1.1. Digital analysis of remote sensing data*

The digital analysis of data, due to its nature, is a means of quick procurement of current information concerning investigated objects and phenomena, with the possibility of observation and registration of their changes in time. At present the digital methods of remote sensing data are applied in: agriculture, forestry, hydrology, geology, meteorology, water economy, land use investigation and in the protection of natural environment.

The system utilizes source data, unprocessed, registered on transparent materials (negatives or diapositives) or opaque materials (black-and-white prints, colour composites) as well as processed data in a similar form or in the form of computer print-outs, being thematic overlays and maps. Digital data, resulting from elaborations is utilized as ancillary, supporting data, while for statistical purposes it is of basic information.

The digital analysis methods of remote sensing data are very important for land use research, allowing to observe the structure of the land use and occurring changes. The digital analysis of data, aiming at determining methods and the structure of the land use can be performed by means of two basic methods: the non-supervised and the supervised analysis. The difference between these two types of digital analyses consists of the utilization of terrain data in analysis in the case of supervised analysis, and in the case of non-supervised analysis only spectral characteristics of objects are utilized, without introduction of ancillary data.

### *1.2. The 2 PAAC System for digital analysis of data*

The 2 PAAC System produced by the OVAAC8 in Toronto was installed at the Polish Remote Sensing Centre (OPOLiS) at the Institute of Geodesy and Cartography in July, 1980. This system performs processing and digital analysis of multispectral data. It enables to carry out digital analysis of pictorial remote sensing data, as well as other image files recorded in the data base of the system.

The central processor of the system is the DEC PDP 11/34 mini-computer with 64K bytes memory capacity. Several input/output devices are connected with the central unit; the most important of them are: the colour interactive TV monitor ICT (Intelligent Colour Terminal) of size 256×256 pixels, supported by the specialized processor, as well as

magnetic tape units and magnetic disks with exchangeable disks. Due to the possibility of making thematic overlays and thematic maps, the important peripheral devices in the system are: the line printer, the electrostatic printer plotter and the digital-to-graphical converter. The line printer enables to obtain the print-out of source data as well as of results of processing, by means of alphanumeric symbols; the electrostatic printer/plotter — by means of pictorial symbols, and the digital-to-graphical converter allows to output the data on photographic materials in the form of tonal imagery. The Summagraphics digitizer is a very important input device allowing to combine the map's coordinate system with the image coordinate system (lines and columns) through the digitizer's system on the base of identification of corresponding points.

The main source of information utilized by the 2 PAAC System are the Landsat imageries registered on magnetic tapes. Poland utilizes imageries acquired by the Italian receiving station at Fucino. Another source of information for the system can be, for example: aerial multi-spectral scanner images, colour composites registered on photographic materials, photographs taken with photographic cameras. The data mentioned above is also entered to the system from magnetic tapes after the previous suitable preparation process.

The 2 PAAC System performs three basic functions. The first function of the system is realized by programmes utilized to transfer remote sensing data and ancillary data between the input/output devices. The second function in general can be determined as the improvement of quality of the analysed image, including filtration, contrast enhancement, decrease of information capacity by means of principal component analysis, edge enhancement, etc. The third function of the 2 PAAC System is performed by programmes allowing to analyse remote sensing data by means of various methods, resulting in obtaining the classification or improved source data, theoretically having the possibility of maximum 50 class-choice. Two basic methods of digital image analysis can be performed by the 2 PAAC System, namely the parallelepiped and the maximum likelihood methods.

It is possible to distinguish a single class or a determined number of classes at one time, so one or many cover types can be distinguished in this way. All programmes covered by the 2 PAAC System, serving the digital data analysis perform the classification supervised by the user of the system, by means of a colour interactive ICT monitor.

## **2. Thematic elaborations in the field of digital analysis of data**

Below are presented examples in the field of computer cartography, performed by specialists from the Polish Remote Sensing Centre of the Institute of Geodesy and Cartography. Besides these elaborations, the

system for digital image analysis is applied in order to solve particular requirements of the users in different branches of science and technology.

### *2.1. Elaborations performed on the computer LARSYS System at LARS (Laboratory for Applications of Remote Sensing)*

The land use map for the vicinities of Warsaw, performed at the Laboratory for Applications of Remote Sensing (LARS), Purdue University, West Lafayette, Indiana, USA in 1977 is an example of non-supervised classification of satellite data and at the same time the first elaboration of this type, realized by the OPOLiS-IGiK staff.

Multispectral satellite data, acquired by the Landsat satellite on June 26, 1975 covering central Poland, was utilized for this analysis. Approximately one-fourth of the Landsat frame, covering the Nizina Mazowiecka, was chosen for the elaboration. Further, detailed analysis was performed for the area of Warszawa covering approximately 1400 square kilometres. During the analysis, on the investigated area 9 distinguishable classes were separated, belonging to 5 land use categories:

#### I. Forested areas

1. Coniferous forests (1), 2. Deciduous forests (2), 3. Mixed forests and parks (3),

#### II. Water areas

1. The Vistula River, ponds and lakes (4),

#### III. Urban areas (5)

#### IV. Green areas (6)

1. Meadows (7), 2. Pastures (8),

#### V. Rural areas

1. Agricultural fields (9).

The final result of this elaboration was a colourful land use map at the scale of 1 : 100 000 in the UTM projection, obtained by the laser graphical-digital converter. This map, at the scale of 1 : 50 000, including names of towns, settlements and districts and the network of squares, was printed in Poland.

The second example of the digital classification of data, registered by the Landsat satellite on the same frame, was the elaboration of a land use map for the vicinity of Puławy, covering approximately 1900 square kilometres, also performed at LARS, West Lafayette, Indiana, USA. This elaboration was performed in two stages: the non-supervised analysis, and, for the first time for the Polish area, the supervised classification. Prior to the analysis information was collected concerning the location and types of yields on the chosen test fields.

This data was utilized for „training” of the computer system in the sphere of recognizing the type of yields. During the first stage, the non-supervised classification of the test fields was carried out on the basis

of the spectral characteristics and statistical data of the investigated objects, connected with the possibility for distinguishing particular classes. The supervised analysis was started by determining the location of the test fields, which was compressed in terrain data. Spectral and statistical characteristics were determined from these fields, which were entered into the memory of the computer and they served as standards for particular classes. The classification of particular image elements was performed on the basis of the principle of maximum likelihood and the nearest neighbourhood. Investigated were also the possibilities of such a distinction of classes or groups of classes as to maximally increase the accuracy of obtained results. In effect, 14 classes belonging to 5 land use categories were distinguished:

I. Forested areas

1. Coniferous forests (1), 2. Deciduous forests (2), 3. Mixed forests (3),

II. Water areas

1. Water (rivers, lakes, ponds) (4),

III. Urban areas

1. Town areas (5), 2. Industrial areas (6),

IV. Green areas

1. Tree/grass (7), 2. Open areas (8), 3. Grasses (9),

V. Agricultural areas

1. Gramineous/leguminous crops (10), 2. Root crops A (11), 3. Root crops B (12), 4. Cereals (13), 5. Mixed crops (14).

The final result was a colourful thematic map at the scale of 1 : 100 000 in the UTM projection, obtained by the laser converter.

The two discussed works were the first elaborations of computer maps for the territory of Poland. The works allow to determine the usefulness of Landsat satellite imageries for the requirements of land use investigations in the Polish conditions.

## *2.2. Elaborations performed by means of the 2 PAAC System*

The first work carried out at the OPOLiS-IGiK laboratories with the use of the installed 2 PAAC System, was the elaboration of a method for obtaining monothematic maps of chosen types of vegetation growth. An example of such an elaboration was the determination of the size of the forested areas in Poland considering the administrative division of the country. In order to carry out the discussed problem, a technology was elaborated determining the surface of chosen classes, for example the types of land use within determined borders, which could be the borders of the administrative units of the country. Due to the lack at the OPOLiS library of full cover of the area of Poland with satellite imageries, registered on magnetic tapes, another technology allowing

for digital analysis of data registered on colour composites of the photographic materials was elaborated.

The discussed work was performed in two stages. The first stage covered the plotting of administrative borders, for which the surface of the forested areas was to be determined. This stage was carried out with the use of the digitizer and the colour ICT monitor, on which successive Landsat frames were displayed. The borders of particular voivodships were plotted on the basis of the Administrative Map of Poland at the scale of 1 : 500 000. The areas of particular voivodships or parts of them were distinguished from the registered satellite frames, creating classification areas, performed during the second stage of the elaboration. Before classifying the data, test fields were chosen for each voivodship, which corresponded to the forested areas of a given voivodship. On the basis of the location of the test fields on the image, spectral and statistical characteristics of forested areas were computed, which in turn allowed to perform the digital classification of the data. The result of the discussed topic was the measurement of the surface of the forested areas within each of the 49 voivodships in Poland, and the whole area of each voivodship. The computational results were presented in the form of a tabular specifications containing the name and the number of the voivodship, calculated and rectified areas of voivodships (in hectares) and the percentage error of the surface of each voivodship. The fragments of the Landsat multispectral imageries and the classified imageries including distinguished forested areas, being particular parts of/or the entire voivodships, were registered on magnetic tapes. In this way a digital satellite data bank for Polish voivodships was created. Information from the data bank can be utilized among others for investigations of changes in time occurring within the forested areas in Poland. The result of the elaboration was also presented in the form of a computer prin-out for the area of the voivodship, by means of a line printer with chosen alphanumeric symbols which correspond to the types of vegetation growth in the form of a thematic overlay for forests occurring in the territory of the voivodship. Due to economic reasons, the discussed work accepted as the smallest analysed unit the areas of approximately 50 hectares. Considering the full resolution of Landsat images, approximately 0.5 hectares, would cause the elaboration to extend in time, which in turn would increase the costs. The presented elaboration was carried out for the Main Statistical Office. However, the applied methods and technology could also be utilized in different branches of the economy.

### 3. Digital rasters of images

The other problem occurring during the digital analysis of remote sensing data, is the preparation of results in such a way, which would enable direct reproduction, without the necessity of an additional process. The possibility of utilizing the computer technique for cartographic reproduction, will be discussed below.

As it is known, the tonal image, as well as the satellite image, registered on photographic material or on magnetic tape, can be reproduced only after previous change into a raster image, that is, the image consists of groups of black-and-white dots. Within traditional reproduction methods raster images are obtained by taking photographs of the original image by the raster. However, such optical operations decrease the accuracy of the digital image, which is characterized by a very high accuracy in comparison to photographic images. This fact was the reason of elaborating such a method, allowing to substitute this stage of photographic processing with the digital image rasters. The image registered in digital form can be visualized on photographic material with the utilization of the graphical-to-digital converter. In effect of the visualization on the photographic material, the tonal image is created, where the input elements are represented by corresponding optical density values. The method of digital rasters, elaborated at OPOLiS-IGiK allows to substitute the values of particular elements of the input image by the corresponding configuration of black-and-white dots, differentiating in effect the obtained raster image. Not only the results of digital analysis, but the source images, registered in digital form, can be rastered. During the digital rastering, also the contrast of the image can be changed, determining the number and range of gray levels obtained on the raster image. It is also possible to change the scale of the image by changing the size of black-and-white dots. The resulting image processed on the graphical-to-digital converter, can be exposed with the use of colour filters, obtaining in this way colour separations. For each of them, another configuration of black-and-white dots can be applied during the digital raster process. The overlay of such colour separations allows to obtain colour copies during the reproduction process. It is carried out within conventional methods by the utilization of raster rotation, where the angle of rotation is determined for particular constituent colours. In order to fit in colour separations rastered digitally, additional marks are introduced to facilitate at the same time the overlay of images. The colour ICT monitor which is an element of the 2 PAAC System, makes the process of digital rastering easier. The process of digital rastering can be directly observed on the ICT screen. Through its use the configuration of the digital raster can be changed in order to choose the most convenient one. Raster images obtained by means of the above discussed

method are suitable for making reproduction copies, thanks to which the process of photographic preparation of rasters is excluded. In this way the process of reproduction is speeded up.

#### 4. Final remarks

The elaborations in the field of digital image analysis and processing of remote sensing data, discussed in this paper, carried out by the OPOLiS-IGiK staff show the possibility of utilizing the satellite Landsat data for preparation of small- and medium-scale land use maps of Poland. It is forecasted, that with the increase of the resolution of the scanner images, the elaborations of large-scale thematic maps will be also possible.

#### L I T E R A T U R E

- [1] Bochenek Z., Madej W.: *Land use classification of the Warsaw, Poland area by digital analysis of Landsat data*. LARS Technical Report 090777, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana, USA, 1977.
- [2] Domański J.: *Application of digital rasters for computer image analysis*. Proceedings of the Institute of Geodesy and Cartography, 2/68, 1981.
- [3] Domański J., Morawski S.: *Land cover study for the Puławy region, Poland by digital analysis of Landsat data*. LARS Technical Report 112378, Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana, USA, 1978.
- [4] Kowalski H.: *Production of large- and medium-scale maps in Poland; at present and in the future*. International Cartographic Association, Commission III Computer-assisted cartography, Seminar, 6—11 November 1978, Nairobi, Kenya.
- [5] Lady Drużycka K., Domański J.: *The 2PAAC specialized computer system implemented at the Polish Remote Sensing Centre of the Institute of Geodesy and Cartography*. Bulletin of the Institute of Geodesy and Cartography, supplement to the Geodetical Review, No. 9 1981.

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#### ELABORATIONS THÉMATIQUES DU DOMAINE DE L'ANALYSE NUMÉRIQUE DES IMAGES DE SATELLITE

#### Résumé

L'analyse numérique des données de télédétection est réalisée à l'aide de systèmes spécialisés d'ordinateur. Ces systèmes permettent aussi bien le traitement que l'analyse des images. En résultat de l'analyse numérique on obtient des élaborations

рации тематических аниси que des calculs statistiques concernant les phénomènes et les objectifs étudiés.

Le Centre de Traitement des Images Aériennes et de Satellite (OPOLiS) qui fonctionne dans le cadre de l'Institut de Géodésie et de Cartographie est, un organisme central dans le domaine de l'analyse numérique des données de télédétection en Pologne.

Dans ce Centre a été installé un système spécialisé d'ordinateur 2 PAAC mis au point par la société canadienne OVAAC 8 de Toronto. Grâce à ce système il est possible d'exécuter des traitements et d'effectuer des analyses de données. Les images du satellite LANDSAT enregistrées sur des bandes magnétiques constituent la source principale d'informations pour le système 2 PAAC qui accomplit les trois fonctions fondamentales permettant la transmission des données entre les unités „entrée”—„sortie”, la correction de la qualité de l'image analysée et la réalisation de l'analyse des données par les méthodes différentes.

Dans le cadre des travaux effectués par l'équipe d'OPOLiS dans le domaine de l'analyse numérique des données de télédétection ont été élaborées les cartes thématiques d'exploitation de la Terre. Pour l'établissement de ces cartes on a utilisé une classification non-surveillée et surveillée des données enregistrées par le satellite LANDSAT. A l'OPOLiS a été élaborée une méthode d'établissement des cartes monothématiques pour les types de recouvrement de terrain choisis. Comme exemple d'une telle élaboration on peut citer l'élaboration de la séparation et du calcul de surfaces des terrains boisés en tenant compte des limites des unités administratives.

En vue de permettre la reproduction cartographique des données originales ou transformées enregistrées sous forme numérique on a élaboré à l'OPOLiS une méthode d'ordinateur de tramer des images. Cette méthode remplace une méthode optique de tramer les images à l'aide du traitement numérique direct.

Outre les élaborations présentées à l'OPOLiS on réalise aussi d'autres travaux du domaine de l'analyse numérique des images tenant compte des besoins concrets des utilisateurs de différentes disciplines de la science et de la technique.

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КРЫСТЫНА ЛЯДЫ ДРУЖЫЦКА  
ЯЦЕК ДОМАНЬСКИ

## ТЕМАТИЧЕСКИЕ РАБОТЫ ИЗ ОБЛАСТИ ЦИФРОВОГО АНАЛИЗА КОСМИЧЕСКИХ СНИМКОВ

### Резюме

Цифровой анализ данных дистанционного зондирования осуществляется путем использования специализированных компьютерных систем. Эти системы дают возможность как преобразовывать, так и анализировать изображения. В результате цифрового анализа получают тематические разработки, а также статистические вычисления, касающиеся исследуемых явлений и объектов.

Ведущей единицей в Польше в области цифрового анализа данных дистанционного зондирования является Центр Обработки Аэрокосмической Информации (OPOLiS), который действует в Институте геодезии и картографии. В этом

Центре установлена специализированная компьютерная система 2 ПААС, разработанная в канадской фирме OVAAC 8 в Торонто, которая дает возможность преобразовывать данные и производить их анализ. Главным источником информации для системы 2 ПААС являются изображения со спутника LANDSAT, зарегистрированные на магнитных лентах. Система 2 ПААС выполняет три основные функции, дающие возможность передачи данных между устройствами ввода-вывода, поправки качества анализируемого изображения и проведения анализа данных разными методами.

В рамках работ осуществляемых работниками в OPOLiS в области цифрового анализа данных дистанционного зондирования были созданы тематические карты землепользования. Эти карты были составлены на основе неконтролируемой и контролируемой классификации данных, зарегистрированных спутником LANDSAT.

В OPOLiS разработан метод получения монотематических карт для избранных типов покрытия местности. Примером такой разработки является выделение и вычисление поверхности лесных пространств с учетом границ единиц административного деления страны.

С целью осуществления картографического воспроизводства оригинальных или преобразованных данных, зарегистрированных в цифровом виде, в OPOLiS был разработан метод компьютерного растривания изображений. Этот метод заменяет оптическое растривание изображений непосредственным цифровым преобразованием.

Кроме представленных разработок в OPOLiS осуществляются также другие работы из области цифрового анализа изображений, учитывающие конкретные нужды потребителей, представляющих разные области науки и техники.

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## OPRACOWANIA TEMATYCZNE Z ZAKRESU ANALIZY CYFROWEJ OBRAZÓW SATELITARNYCH

### Streszczenie

Cyfrowa analiza danych teledetekcyjnych jest realizowana z wykorzystaniem wyspecjalizowanych systemów komputerowych. Systemy te umożliwiają zarówno przetwarzanie, jak i analizę obrazów. W wyniku analizy cyfrowej otrzymuje się opracowania tematyczne, a także obliczenia statystyczne dotyczące badanych zjawisk i obiektów.

Wiodącą jednostką w zakresie cyfrowej analizy danych teledetekcyjnych w Polsce jest Ośrodek Przetwarzania Obrazów Lotniczych i Satelitarnych (OPOLiS), który działa w Instytucie Geodezji i Kartografii. W Ośrodku tym zainstalowany jest specjalistyczny system komputerowy 2PAAC opracowany w kanadyjskiej firmie OVAAC8 w Toronto, który umożliwia wykonanie przetworzeń i przeprowadzenie analizy danych. Głównym źródłem informacji dla systemu 2PAAC są obrazy z satelity LANDSAT zarejestrowane na taśmach magnetycznych. System 2PAAC speł-

nia trzy podstawowe funkcje umożliwiające przesłania danych między urządzeniami wejścia-wyjścia, poprawianie jakości analizowanego obrazu oraz przeprowadzanie różnymi metodami analizy danych.

W ramach prac realizowanych przez pracowników OPOLiS z zakresu cyfrowej analizy danych teledetekcyjnych zostały opracowane mapy tematyczne użytkowania Ziemi. Mapy te sporządzono na podstawie nienadzorowanej i nadzorowanej klasyfikacji danych zarejestrowanych przez satelitę LANDSAT. W OPOLiS opracowano metodę otrzymywania map monotematycznych dla wybranych typów pokrycia terenu. Przykładem takiego opracowania było wydzielenie i obliczenie powierzchni terenów zalesionych z uwzględnieniem granic jednostek administracyjnego podziału kraju.

W celu umożliwienia kartograficznej reprodukcji oryginalnych bądź przetworzonych danych zarejestrowanych w postaci cyfrowej, w OPOLiS opracowano metodę komputerowego rastrowania obrazów. Metoda ta zastępuje optyczne rastrowanie obrazów bezpośrednim przetwarzaniem cyfrowym.

Oprócz prezentowanych opracowań w OPOLiS realizowane są także inne prace z zakresu cyfrowej analizy obrazów uwzględniające konkretne potrzeby użytkowników reprezentujących różne dziedziny nauki i techniki.

