

AN ADAPTIVE FILTERING ALGORITHM FOR BUILDING DETECTION FROM LIDAR DATA

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ABSTRACT

Research on lidar data filtering for building detection has continued to flourish in recent years due to the increasing need for 3-dimensional data in urban development and planning. Over the last decade, many filtering algorithms have been developed to classify lidar point clouds. As a result, interpolation-based filters, slope-based filters and morphological filters were widely accepted. Most of the filtering algorithms require 'raw' lidar data to be rasterised i.e. interpolated into grid images. However, rasterisation often causes a significant loss of information after data processing. To overcome the information loss, we developed an adaptive filtering algorithm that classifies lidar data effectively and efficiently into ground and non-ground for the building detection purposes. The digital elevation model generated from the filtered ground was used to detect man-made objects e.g. buildings. The results show that, by using an adaptive window size indicator, the proposed algorithm can effectively classify lidar data at a high accuracy.

Keywords: Lidar, Ground Filtering Algorithm, Building Detection, Adaptive Window Size, Mathematical Morphology

ANALYSIS OF THE PHOTOGRAMMETRIC DATA OBTAINED FROM ULTRALIGHT MEASURING PLATFORM MOUNTED ON GYROCOPTER

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ABSTRACT

Obtaining photogrammetric data such as digital images or laser point clouds using a plane or a helicopter is already very common. These methods are used in case of large surface areas. For several years, experiments using a variety of unmanned aerial vehicles (UAV) for measurements have also been carried out. However, the UAVs are capable of imaging very small objects (point object) with the use of non-metric cameras, while gyrocopters, compared with currently used aircraft are characterized by: high maneuverability and low minimum speed-through, much lower costs of purchase and use, and ease of transport. Therefore, they are used wherever the use of both plane, and helicopter, as well as ground-based measurements is uneconomical.

This article presents an initial attempt to assess the quality of the photogrammetric data obtained from gyrocopter. GPS/INS data, images from digital camera and point clouds from airborne laser scanner are analyzed considering the stability of the flight of gyrocopter and hence the quality of the obtained data, and their usefulness in generating further products, such as digital terrain models, orthophotomaps, or 3D buildings models. The results provide information necessary at the stage of planning photogrammetric mission with the use of gyrocopter.

Keywords: gyrocopter, airborne laser scanning,

ASPECTS ON DIGITAL CADASTRAL MAP OF IASI CITY CREATED BY MEANS OF DIGITAL PHOTOGRAMMETRY TECHNIQUE

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ABSTRACT

The purpose of this article is to present some aspects related to the stages of digital cadastral mapping process for Iasi city created at a scale of 1:500 and based on the digital photogrammetry technique, and to the accuracy of results. The photogrammetric works carried out for the digital cadastral map of Iasi have consisted in: schedule the flight of the photogrammetric unmanned aircraft, taking aerial photos, georeferencing, aerial triangulation and digital stereophotogrammetry, taking up the digital imaging, data processing and deliver of final result.

The cutting-edge photogrammetry technologies have enabled the elaboration of the digital cadastral mapping of Iasi by orthophotomap on which geographic elements such as property boundaries, road infrastructure, woods, rivers, etc. have been vectorized. The mapping content of the cadastral map has therefore been ensured.

Currently the specialists are increasingly using the digital photogrammetry to elaborate and update the digital cadastral maps at various scales. The progress the computer science has made in the automation of aerial imaging acquisition, storage and processing has led to the development of the geomapping photogrammetry technologies.

Keywords: digital photogrammetry, digital cadastral map, aerial photography, orthophotomap, vectorization.

ASSESSING THE PERFORMANCE OF RELATIVE RADIOMETRIC NORMALIZATION METHODS FOR SOME VEGETATION INDICES

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ABSTRACT

Using the time series of satellite images in studies on vegetation indices involves absolute or relative radiometric normalization (RRN). In this study we used two Landsat Thematic Mapper 5 images acquired in 2007 and 2011, the first representing the subject image and the second the reference image. Five methods of RRN have been applied to the subject image acquired in 2007 for evaluating their performance in relation with vegetation indices. These methods include simple regression (SR), pseudo-invariant features (PIF), no-change set determined from scattergrams (NC), histogram matching (HM), and radiometric control set (RCS). They were compared in terms of their statistical robustness and capability to improve visual image quality. The focus was on the manner in which each different RRN method influences the results of extracting information about vegetation indices. It was found that each vegetation index after RRN differs in comparison with the same vegetation index before RRN. We also identified the factors which affect the performance of RRN in the case of the analyzed vegetation indices.

Keywords: relative radiometric normalization, vegetation indices, simple regression, pseudo-invariant features, histogram matching, satellite images.

ASSESSMENT OF THE ACCURACY AND PRECISION OF A NEAR-REAL-TIME PROCESSING METHOD OF LASER SCAN DATA APPLIED ON CONCRETE STRUCTURES

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ABSTRACT

By now, the use of terrestrial laser scanning for deformation measurements of large concrete structures is well established. To tackle the time consuming processing of the large amounts of data that are the result of the scanning process, a ‘Quick and Dirty Method’ (QDM) was developed and documented. In order to quickly derive a certain number of cross sections at predefined locations, this QDM implies no cleaning up of the point clouds and no registration, but only primitive modeling of parts of the structure. This allows a near-real-time processing of the data, with resulting deformation values that are similar to the values obtained by total station measurements. The principle idea was to assess the possibility of using laser scanning in time critical situations for which until now, only conventional total station measurements are used. The potential of the QDM was demonstrated with a specific test case: namely the monitoring project of a sewage purification plant. Furthermore, the degree of detail that can be reached by using laser scanning surpasses the possibilities of total stations. Moreover, the visualization of deformations by the QDM is much more comprehensive than the results that can be obtained by using a total station.

However, the previous method was only tested in one particular case study of a sewage purification plant. In a real-time situation, it is not possible to obtain the number of measurements needed to produce statistically correct statements on the quality of the data. Consequently, a thorough assessment of the accuracy and precision was impossible. Besides, as the range errors depend on the measured distance, the incidence angle of the laser beam, the material characteristics of the object and the type of laser scanner, these parameters have to be taken into account to assess the conditions in which the QDM can be used and to quantify its performance.

In the more advanced research at hand, a concrete test specimen was scanned from six different distances from the scanner. In order to assess the influence of the incidence angle on the point cloud, the specimen was also rotated over five different angles and then translated over about one centimeter (measured with a dial gauge). For each position of the test specimen, 120 scans were performed with a point spacing of 2 mm by 2 mm. This resulted in approximately 720 scans for each scanner to object distance.

This paper elaborates on some of the most important results for the Leica ScanStation C10.

ASSESSMENT OF THE INFLUENCE OF AERIAL IMAGE RADIOMETRY ON THE QUALITY OF POINT CLOUDS GENERATED BY SEMI-GLOBAL MATCHING

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ABSTRACT

This paper presents the results of the research concerning the influence of aerial image radiometry on the quality of the point cloud generated by semi-global matching. The research involved the examination of several issues related to image radiometry such as spectral band, histogram stretching, bit depth and lossy compression. A selected pair of images acquired with the use of Intergraph DMCI230 aerial camera have been subjected to semi-global matching. This step was carried out using images resulting from different radiometric processing scenarios. The quality of the resulting point clouds was evaluated by analyzing statistical parameters on flat parts of terrain surface. For the purpose of the evaluation 6 control planes were defined. An additional visual assessment of point clouds was carried out consisting mainly of point clouds profile analysis. The results enabled to formulate the conclusions concerning the influence of image radiometric parameters on the semi-global matching. Some recommendations concerning the radiometric processing of aerial images for optimal results of semi-global matching are made.

Keywords: Matching, Image, Point Cloud, Radiometry, Quality

AUTOMATIC CLASSIFICATION OF FOREST STAND BOUNDARIES BASED ON RESULTS OF AERIAL PHOTOGRAMMETRY

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ABSTRACT

This paper deals with an assessment of accuracy of the automatic object-oriented classification of margins and internal subdivisions of forest stands using different orthophotos. For elaboration, we used outputs of digital photogrammetry - the traditional and true orthophotos made by large format digital camera UltraCam Xp with a final spatial resolution of 10 cm and outputs of small-scale imaging using UAV Gatewing X100 with a spatial resolution of 10 cm. The paper also evaluated the accuracy of aerotriangulation performed during the processing of particular materials, according to the amount of ground control points used. A skilled operator determined the correct boundaries (reference standard) by stereoscopic evaluation, from which a comparative TTA mask was created. The classification accuracy was evaluated with the KHAT index calculated on the basis of the created TTA mask. Our results have shown that in case of using the object-oriented classification for identifying the boundaries of forest stands from orthophotos we have achieved satisfactory results not only in terms of accuracy, but also in terms of efficiency and time demands. The best classification accuracy can be achieved if true orthophotos are used. The research site was located in the territory of the University Forest Enterprise at the Technical University in Zvolen, in the central part of Slovakia. The selected sample area (possibility of using UAVs was taken into account) is situated in a slightly hilly terrain with forests and herbal vegetation cover. The area consists of compact forest stands, forests vertically subdivided by anthropogenic interactions according to forest management rules of silviculture, as well as a significant boundary between forest and the agricultural land.

Keywords: object oriented classification, aerial digital photogrammetry, aerotriangulation, identification of forest stand

**AUTOMATIC TEMPLATE GENERATION FOR INDIVIDUAL TREE
IDENTIFICATION IN REMOTE SENSING DATA USING (1+1)
EVOLUTIONARY ALGORITHM**

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ABSTRACT

Accuracy and computational speed of the template matching procedure for individual tree identification depends on the choice of templates representing tree crowns. The aim of this paper is to present a novel approach for optimal template generation using an evolutionary algorithm. Suggested methodology enables automatic generation of the templates by minimizing the commission and omission errors of tree identification according to the reference set with selected tree crown areas. Template matching procedure with automatically generated templates for the study site achieved 74% accuracy (205 of 277 trees) with 27 false positive records, while manually selected templates from the same image resulted in 53 % accuracy (147 of 277 trees) and 25 false positive records.

Keywords: template matching, automatic template generation, (1+1) evolutionary algorithm, individual tree identification, high resolution remote sensing data

BUILDING EXTRACTION FROM HIGH RESOLUTION SATELLITE IMAGES USING MATLAB SOFTWARE

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ABSTRACT

Now-a-days, automatic building extraction from high resolution satellite images is a very active field of research. During the past decade, a considerable research has been done for automatic extraction of buildings from satellite images. In India, building extraction for satellite images is a difficult task because the building doesn't follow a specific pattern and the individual building covers a very small area on the ground. In addition, the reflectance of buildings and roads is almost similar on satellite images for many regions which results in error in traditional digital classification. In such cases, differentiation between buildings and roads by traditional digital classification of satellite image becomes a difficult task. In this paper, an algorithm has been proposed to extract the urban buildings from high-resolution multispectral IKONOS image. In the proposed method, an IKONOS image of Dehradun City, Uttarakhand, India has been used. For the accurate extraction of buildings, a program is developed in Matlab. In the first step, an image enhancement method is applied on the multispectral IKONOS image. Then NDVI is applied individually on all bands of enhanced image to remove the vegetation cover. After removing the vegetation, all the bands are stacked, and the image is converted from RGB color space to L*a*b* color space. The colors in 'a*b*' space are classified using K-Means Clustering. Using the results from K-Means, all the pixels in the image are labeled, and thereafter the segmentation is done. In next step, morphological operators – erode and dilate are applied. The small holes of other objects present in the buildings segments are filled up. Later, the segments of our interest are filtered out on the basis of area and shape. At the end, some cleanup operators, like smoothness and orthogonality are applied on the image. The buildings present in the IKONOS image are also manually digitized using ArcMap 10. The buildings extracted from the proposed method are compared with the manually digitized buildings to carry out the accuracy assessment.

Keywords: Building extraction, Segmentation, Clustering, Morphological operators, Matlab

BUILDING THE EVAPOTRANSPIRATION MAP OF THE BULGARIAN TERRITORY WITH MODIS TOOLBOX AND ARCGIS

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ABSTRACT

Demand for the world's increasingly water supply is rising rapidly, challenging its availability for food production and putting global food security at risk. This aspect combined with climate change determine people to focus on all possibilities to obtain and preserve fresh water resources.

In this context, data regarding evapotranspiration on earth, as significant part of water cycle in nature, are extremely valuable and important to know.

This paper presents a way to create evapotranspiration maps for large territories, using remote sensed data collected by satellite, analyzed and processed with an improved algorithm, by a specialized toolbox, capable to be integrated in ArcGIS. The theoretically approach and results of the methodology are illustrated using the generation of Bulgarian evapotranspiration map as example.

Keywords: evapotranspiration, remote sensing, MOODIS, ArcGIS.

CAPABILITIES OF A SMARTPHONE FOR GEOREFERENCED 3D MODEL CREATION: AN EVALUATION

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ABSTRACT

This paper focuses on assessing capabilities of a smartphone for performing a specific close-range photogrammetry task: creating a georeferenced 3D model. One of the subjects discussed in this paper was the application of non-metric camera and location sensors' usefulness in photogrammetric data processing. The calibration of the camera was carried out on the basis of measurements in a three-dimensional test field. Another piece of research was carried out to evaluate the quality of angular sensors and GNSS antenna which are embedded in the tested device. Data collected in these experiments was used for image geometric correction and weighting the equations in the adjustment process.

In a further experiment, an evaluation of smartphones capabilities for creating a georeferenced 3D model was made by a creating model of an Old Town wall fragment located in Warsaw. During several bundle adjustments with different options it was proved that initial values of exterior orientation can increase the accuracy of photogrammetric post processing with a low number of control points. Application of integrated sensors in smartphones is definitely useful for low-cost 3D modelling and it can be a good solution for achieving accuracy of decimeters in creating a model of an object. However, accuracy of centimeters required in close-range photogrammetry cannot be guaranteed by using only a smartphone without considering an application of at least 3 control points.

Keywords: smartphone, 3D model, calibration, GNSS, bundle adjustment

**CERTAIN RESULTS OF THE REMOTE SENSING TECHNIQUES
APPLICATIONS FOR THE COASTAL ENVIRONMENT QUALITY
MONITORING AND ROMANIAN ICZM PROCESS IMPLEMENTATION**

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ABSTRACT

Applications of the remote sensing to the coastal environmental monitoring as a main tool of an Integrate coastal management includes certain types of imagery on the coastal ecosystem/habitats changes, as well synoptic data on sea water, temperature, salinity, and components for a better understanding of the chlorophyll/plankton and fish/invertebrate distributions, as well as marine modeling forecast data.

A system of RS&GIS techniques can be a dynamic tool for the coastal managers and decision makers. Such system is one of the main results of recent/ongoing national projects, and certain results of it will be presented in relation with several data and information evaluation activities [3].

Also, the work presents several approaches and results on coastal remote sensing and spatial analysis techniques implementation in a certain case studies, towards an erosion and coastal waters quality control. The coastal variability at the sea-land interface, for a period of several decades, has been revisited on the basis of the historical remote sensing images/maps, and obtained results were the base of an online Coastal Atlas for the Romanian Black Sea Coast.

Keywords: Remote sensing, coastal GIS, Romanian coastal zone, erosion/accretion processes, vulnerable areas, ICZM (Integrated Coastal Zone Management).

COMPARISON AND ANALYSIS OF SOFTWARE SOLUTIONS FOR CREATION OF A DIGITAL TERRAIN MODEL USING UNMANNED AERIAL VEHICLES

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ABSTRACT

Development of Unmanned Aerial Vehicles (UAV) as mapping systems is gaining more attention in recent years. The need for "real-time" spatial data acquisitions in a more efficient and economical way is the reason why UAV is presented as one of the most promising acquisition techniques today. That is most evident in areas where human life could be endangered which are therefore very difficult for survey using conventional methods. Thus, analyzing the capabilities of this technology and discovering the extents of its usefulness for geodetic survey needs to be conducted. The paper presents an overview of UAV systems and their applications. This overview describes different UAV systems, their characteristics and capabilities. The main objective of this paper is focused on comparison of different software solutions for processing images and analysis of their influence on the quality of Digital Terrain Models. Software packages used in this comparison are 3DM Analyst Mine Mapping Suite and Pix4D mapper.

Keywords: Unamanned Aerial Vehicle, DTM, 3DM Analyst Mine Mapping Suite, Pix4D mapper,

**CONTRIBUTIONS TO THE METHODOLOGY
OF THE USE OF SATELLITE REMOTE SENSING METHODS
IN STUDIES ON GEOTHERMAL ANOMALIES**

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ABSTRACT

In studies on the geological environment, besides the traditional geophysical measurement techniques, remote sensing data is used. The optical multispectral data is still the first and most commonly used. The importance of radar data has recently increased due to the development of this type of satellite imaging systems. The use of thermal data, namely, the data registered in the so-called long-wave infrared is still relatively limited. The reason may be the relatively small number of satellite sources of this type of imaging data (limited to missions of Landsat and Terra/Aster systems), and the relatively low spatial resolution of the data, making its interpretation difficult.

The presented methodological aspects of satellite data use are supported by tests and experience gained within three independent research experiments related to various types of geothermal anomalies. In each case different configuration of various factors occurred, i.e. the topographic characteristics of the area, the set of imaging data (sources and quantity of data, registration season of a year), identification of location (spatial range) and description of geothermal anomalies by means of geophysical methods. The difficulty of remote sensing method application was also associated with the fact that in each of the cases studied the difference in temperature observed in soil layers close to the surface at the area of the anomaly and in its surroundings reached only several degrees.

The untypical nature of each of the experiments enforced the answer to the following questions:

- to what extent it is possible to use optical multispectral data as complementary to thermal data?
- how the selection of data sets can be made and within the data selected – which channels should be used, what are the factors determining their usefulness, which techniques of multispectral image processing are effective?
- how to eliminate, restrict or consider the factors influencing on temperature in calculations, such as insolation or the diversified land cover and landuse, canopy, etc.?
- which solutions should be used to enable the generalisation of the result in the dynamically changing local spatial conditions?
- which solution should be used in case well-known anomalies are confirmed, and which solution should be used to detect the potential places of their occurrence?

In the article, variants of methodical solutions adjusted to the specific nature of individual research problems are presented. The studies have shown that:

- reliance on the available satellite data registered in the thermal band, such as Landsat and Terra/Aster, while maintaining the relevant methodical solutions enables to confirm the occurrence of geothermal anomalies;
- the remote sensing methods may provide support for defining the range of the geological structures associated with the occurrence of the geothermal anomalies.

Keywords: thermal remote sensing, geothermal anomalies, LANDSAT, ASTER

**CREATION OF LARGE SIZE BORE-SIGHT CALIBRATION FIELD FOR
PROFILE LASER SCANNER WITHIN AUTONOMOUS MAPPING AIRSHIP
PROJECT**

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ABSTRACT

The determination method of a large size permanent exterior spatial calibration/test field and its parameters are described in the paper. The calibration field consists of planar surfaces with diverse spatial orientation and is represented by various urban elements such as sloping and horizontal roofs, walls, parts of pavements and roads etc. The calibration field purpose is the determination or verification of laser scanner bore-sight calibration within the Autonomous Mapping Airship project (AMA, see [7], [8], [6] and [9]). The calibration field was measured by terrestrial laser scanning technology.

Keywords: Bore-sight, Calibration, Laser Scanning, Airship

DATA FUSION AND SUPERVISED CLASSIFICATIONS WITH LIDAR DATA AND MULTISPECTRAL IMAGERY

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ABSTRACT

The proposed research aims to amalgamate a lidar point cloud and a multispectral image in order to classify the surveyed area into chosen categories by using a supervised classification algorithm. An airborne lidar point cloud and a QuickBird satellite image of Red, Green, Blue, and Near-Infrared bands over a city of Strasbourg, France, were processed to achieve the data fusion and estimate the accuracy of the proposed method. Firstly, the multispectral image was used to create three raster images representing Normalised Difference Vegetation Index (NDVI), Soil-Adjusted Vegetation Index (SAVI), and Global Environment Monitoring Index (GEMI), respectively. Secondly, the lidar point cloud was used to calculate the height of the features above ground and the 3-dimensional information was converted to a raster image. In total, seven different rasters were created by combining the aforementioned four rasters and tested to determine the best combination. A supervised classification method known as the Support Vector Machine (SVM) algorithm was applied to the rasters to classify them into three categories: ground, vegetation, and artificial objects. Confusion matrices of the classification results indicate that the overall accuracy of the classification improves when the lidar data is integrated rather than the multispectral imagery is used alone.

Keywords: Lidar, multispectral image, supervised classification, support vector machine, data fusion.

DETAILED MAPPING OF ANTHROPOGENIC AND NATURAL MICRO-RELIEF FORMS IN FOREST STANDS

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ABSTRACT

The identification and mapping of historical anthropogenic and natural relief forms in forest stands by laser scanning and gaining the large-scale aerial photography data is always related to inability of the data collection with the required density of points per square meter with feasible economic costs. This fact leads to inaccuracies or generalizations of digital elevation models. Therefore, the digital terrain model does not provide detailed information that is expected for detailed mapping of micro-relief forms (e.g. for the location of buildings). The studied area is situated in the territory of the University Forest Holding Company in Zvolen. We focused on natural micro-relief forms as well as on anthropogenic form - one-way road to the medieval settlement. The studied area is covered by the broad-leave forest. Our results are based on combination of several procedures and methods. We elaborated digital elevation models by contactless mapping methods. Data of models were compared with data from the fieldwork which were obtained by GNSS and precise electronic tachymeter. Terrestrial scanners or method of terrestrial photogrammetry is used for refinement of data about micro-relief forms in the large scale mapping. In our research we obtained the point clouds by procedures of terrestrial photogrammetry and crucial data were from large-scale aerial laser scanning (Riegl LMS Q680i) with assumed average density of 5 points per m² under the crown canopy of trees and aerial digital photogrammetry - ADP (camera Ultracam Xp) with a geometric resolution of 10 cm. Also we used the resources of terrestrial photogrammetry (Canon EOS 5D MarkII with a 35 mm lens). Measurement of missing data about details of relief forms consume a lot of time while it is done with classical geodetic devices and instruments, and this process requires appreciable experiences in the fieldwork with tachometric methods. Based on a comparison of individual methods, we suggest the most appropriate way of elaboration of precise models with sufficient accuracy and reliability. We combined precious digital models of relief which are based on aerial photography or scanning with interpretations of the terrestrial photogrammetry. Our interpretation of interesting data sources about the relief forms could be implemented into various scientific disciplines (archaeology, landscape ecology, forestry), or in many economic sectors. We achieved significant rationalization in the processing of precise spatial data which were collected and interpreted in a relatively short time. The effectiveness of the workflow rises from a combination of the above mentioned methods.

Keywords: detailed digital terrain models, terrestrial photogrammetry, aerial photogrammetry, airborne laser scanning, mapping of forest environment

DETERMINATION OF DISTRIBUTION OF SURFACE WATER VELOCITY IN THE RIVER USING SEQUENTIAL IMAGES

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ABSTRACT

The primary aim of this study is to determine the velocity distribution on water surface of the river from a digital camera recorded image sequences.

The study of an object such as river, which has irregular shape and liquid state, requires the use of signalized points, that can be clearly identified on all video frames. Location of each point in every frame was measured and then transformed into coordinate system associated with the river. For this purpose, a projective transformation of a plane was used. Then, it was possible to calculate the displacement vectors between the successive positions of points in the sequence. Speed on the water surface was determined by dividing the value of displacement and the time interval between frames. Based on the discrete speed values, the interpolation was carried out and the velocity distribution maps were created.

Velocity distribution maps were generated for the speed values calculated between the positions of points, as well as their components, according to the course of the river and perpendicular to the course of the river. When registering measuring material, three types of points were used in order to investigate the effect of their size and weight on the results.

Received distributions were reviewed for compliance with the theoretical assumptions in the field of hydrology. Their utility to determine the shape of the river bottom, or finding obstacles under the surface of the water, was also analyzed. In the end, it was considered which technologies are the best to determine the velocity distribution on water surface and for what kind rivers doing this kind of research is reasonable.

Keywords: sequential images, close-range photogrammetry, river, velocity distribution

DIGITAL AEROTRIANGULATION WITH VERTICAL DATUM SCALE MODIFICATION RESPECTS NATIONAL HORIZONTAL COORDINATE SYSTEM

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ABSTRACT

The Geometric quality of a photogrammetric product is given mainly by the accuracy of the determination of the sensor orientation. There are several ways how to determine the exterior orientation parameters of aerial frame cameras. In the past, the most frequent option was the aerotriangulation with the bundle block adjustment based on tie and ground control points. At the beginning of the 21st century there was a mass commencement exercitation of the on-the-board GNSS and IMU devices and a few new possibilities have emerged. However, the simplest solution comprises direct georeferencing from GNSS/IMU data but many experiments have confirmed that superior results are given by integrated sensor orientation. It means digital aerotriangulation with the GNSS/IMU orientations as the observations. Observations of several ground control points are proposed to eliminate systematic errors and to assure absolute accuracy of the whole block.

The GNSS positioning refers to the 3D rectangular earth-centred coordinates in the WGS84 coordinate system. However, the results of the block aerotriangulation are, due to the cartographical demands, mostly required in the national vertical and horizontal reference system. Therefore, GNSS/IMU data has to be transformed to the desirable coordinate systems before the integration to adjustment. Nevertheless, computations in the national coordinate system cause a few problems because the geometric model of block adjustment operate within cartesian coordinate system with the identical scale of each axis. As all the modern national horizontal coordinate systems are conforming with some scale error, the condition of the identical scale is not accomplished. Furthermore, if the gravity-related vertical datum is used, not even the condition of orthogonality is fulfilled. While non-orthogonality has practically no impact, different scale of positioning coordinate system seriously affects altitudes of image projection centers and causes biases in the block adjustment. There are two ways how to avoid this effect. The first one is based on the camera focal length modification and the second one on changing the vertical coordinate system scale. Unfortunately, none of these exact methods are commonly not been used in practice.

The article looks at modification of altitudes of aerial photograph projection centers before integrated sensor orientation. Numerous outcomes affirming the theory are performed.

Keywords Integrated sensor orientation, Aerotriangulation, Direct georeferencing, Datum problem, Scale error

ENHANCEMENT OF THE VERTICAL ACCURACY OF LIDAR DATA WITH THE USE OF AUTOMATIC IMAGE MATCHING

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ABSTRACT

The aim of this research was to verify whether it is possible to use the results of aerial image matching to increase the vertical accuracy of LIDAR data. The experiment consisted in generating a point cloud through automatic image matching, which then was compared with the LIDAR data. Image matching was carried out with the use of Image Station Automatic Elevation software which offers a feature-based matching algorithm. The main element of the study was to determine the optimal parameters of image matching. It was found that the most important parameters to control this process are the size of correlation window and the correlation coefficient threshold. After setting the optimal correlation parameters (correlation window 9 x 9 pixels, correlation coefficient threshold 99%), the image matching was carried out for the whole study area. The filtering of points lying above the ground from the point cloud obtained through image matching was conducted using the LIDAR data. The resulting data served as the basis for the determination of the difference in elevation between LIDAR and photogrammetric survey. The mean elevation discrepancy was determined in relation to the image matching results for each of the LIDAR strips individually. The elevation correction was then introduced to each of the LIDAR strips. The evaluation of the effectiveness of elevation correction of LIDAR data was conducted with regard to GNSS RTK field surveys. Statistical parameters showed that the DTM generated from the corrected LIDAR data is closer to the field surveys. It can be concluded that the image matching can provide very precise elevation data, which may be used for the correction of the LIDAR data.

Keywords: LIDAR, Matching, Correlation, Correction, DEM/DTM

FIELD COMPARISON OF PULSE-BASED AND PHASE-BASED LASER SCANNERS FOR CIVIL ENGINEERING APPLICATIONS

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ABSTRACT

Laser scanning is more and more being applied in different fields of applications, including civil engineering. However, when considering pulse-based and phase-based laser scanners, there are important differences that have an influence on the choice of the most suited type of laser scanner, depending on the project's specifications and the accuracy requirements. Aspects that can be assessed are the horizontal and vertical angle error, range error, noise on the distance measurement, spot size, achievable point resolution etc. Moreover, the reflectance properties of the object's material also have an important influence on the accuracy of the resulting point cloud. When including a more economical factor, the field of view, the scanning speed and maximal range play a significant role.

Notwithstanding the need for a comparison between different types of measurement instruments before starting a project, the manufacturer's specifications are not sufficient to thoroughly decide which type of laser scanner is the most suited for a specific project. The manufacturer's specifications are determined in laboratory conditions and mostly a systematic and standardized definition of the accuracy, e.g. in accordance with an internationally accepted protocol, is not present. Several uniform methodologies to assess the accuracy of different types of laser scanners already exist, but most of these methodologies are based on laboratory measurements, providing no answer to the question how the measurement instrument will perform in actual field conditions.

The research described in this paper handles a comparison between pulse-based and phase-based laser scanners for civil engineering applications, based on field measurements. For the comparison, measurements with a Leica HDS6100 (phase-based) laser scanner, a Leica C10 (pulse-based) and a Leica ScanStation 2 (pulse-based) laser scanner are used. Not only the accuracy, but also the edge effects and the achievable resolution are assessed. Furthermore, the influence of different types of commonly used construction materials on the accuracy is compared.

Based on the measurements of several flat reference targets, the results indicate no significant difference in 3D accuracy between the tested pulse-based and phase-based laser scanners. When using spherical targets, significant differences can be observed. The phase-based laser scanner results in a finer achievable resolution at short distances (e.g. tested on 6 m), where the pulse-based laser scanner delivers better results at longer distances (e.g. tested on 22 m). The tested edge effects show no significant differences between both types of laser scanners. Furthermore, the measurements indicate that the pulse-based laser scanner results in lower noise levels for the different tested construction materials.

FLYING LABORATORY OF IMAGING SYSTEMS (FLIS) AT CZECHGLOBE

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ABSTRACT

Ecosystems, their services, structures and functions are affected by complex environmental processes, which are both natural and human-induced and globally changing. For example, changing temperatures are relocating the ecological zones and consequently forcing plant species to adapt to new climatic regimes or to migrate into more suitable environments. Furthermore, frequent acute stress events (disturbances) and long-term chronic environmental loads (pollution) are alternating the plant eco-physiological functions, resulting in changes of primary production and carbon fluxes. In order to understand how ecosystems behave in globally changing environment, it is essential to monitor the current status of ecosystems and their structural and functional changes in time and space.

Global Change Research Centre – CzechGlobe is building a new scientific infrastructure, which allows monitoring of ecosystem changes. One of its main components is a platform for remote sensing observations – FLIS (Flying Laboratory of Imaging Systems). FLIS consists from an airborne carrier equipped by passive as well as active remote sensing systems. The core instrument of FLIS is a hyperspectral imaging system provided by Itres Ltd. The hyperspectral system consists of three spectroradiometers, covering the reflective spectral range from 380 to 2450 nm as well as the thermal range from 8 to 10 μm . In the near future, FLIS will be equipped by a full-waveform airborne laser scanner (in cooperation with AdMaS project). Installation of hyperspectral and laser scanners onboard the same airborne platform allows synchronous data acquisition under same geometric conditions.

A new data processing chain for hyperspectral images was developed. Processing chain includes radiometric and geometric corrections as well as quality layers which were developed within the FP7 project EUFAR - join research action HYQUAPRO. The processing chain was recently expanded by adding several methods of atmospheric corrections, which were established and developed in a way allowing to process data effectively and to meet specific requirements of hyperspectral flight campaigns and end-users.

Keywords: imaging spectroscopy, airborne hyperspectral remote sensing, processing chain, atmospheric corrections, quality layers

IDENTIFICATION OF HISTORIC ROADS IN THE FOREST LANDSCAPE BY MODERN CONTACTLESS METHODS OF LARGE-SCALE MAPPING

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ABSTRACT

The studied locality is situated close to the Deserted Castle, near the Zvolen city, in the central part of Slovakia. Locality called Drahy attracted us by various anthropogenic relief forms that are primarily related to significant medieval settlements. The object of our research is a system of hollow ways on the northern and eastern foothills of the mountain massif of the castle hill. The system of hollow ways belongs to the historic roads that are located in the forest landscape around the Deserted Castle. We mapped by GNSS about 50 km of historic roads in the field. Near the area covered with hollow ways is a defensive rampart with a ditch (7th-8th century AD). Problematic factor in the field measurement and evaluation of anthropogenic relief parameters is the position of the studied area in the forest landscape. The locality is covered with broad-leaved trees with high stand density and stands have compact canopy of tree crowns. Forest stands prevented researchers to have an overview in a broader perspective on the investigated territory in the fieldwork in comparison with non-forested areas. Materials of air digital photogrammetry (ADP) and remote sensing (RS) provide a comprehensive overview on landforms. The system of hollow ways in the forest landscape was identified by modern air contactless methods of large-scale mapping - airborne laser scanning (ALS) (Riegl LMS Q680i). Data were collected under the canopy of tree crowns at a density point clouds 5 points per m² and by air digital photogrammetry (Ultracam Xp) with a geometric resolution 10 cm. Then we determined the morphometric data of hollow ways and elaborated their longitudinal and transverse profiles. These results were confronted with the reference data obtained from the fieldwork. Results of the presented contactless methods were compared in terms of their application in the winter and summer vegetation aspects. On the example of representative profiles we compared the accuracy of contactless methods and we reconsidered possibility of measuring and evaluation of their quantitative parameters. Based on the results of mapping historical linear objects in the forest landscape, we expect a wider usability of modern air contactless methods (ALS and ADP) in archaeological research. These modern methods are suitable for data processing in larger territorial units. Previously, such a research was difficult in terms of the fieldwork done by terrestrial measurements, although it was carried out by modern geodetic methods and instruments (electronic tachymeter or GNSS).

Keywords: mapping of the forest landscape, historical landforms, morphometric data, air digital photogrammetry, airborne laser scanning.

**IMPROVEMENT OF THE DIGITAL TERRAIN MODEL OF THE CZECH
REPUBLIC OF THE 4TH GENERATION FOR THE AERIAL PHOTOGRAPHS
ORTHORECTIFICATION**

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ABSTRACT

Since 2009 airborne laser scanning of the entire area of the Czech Republic has been carried out. One of principal products gained from acquired data is the 4th Generation Digital Terrain Model of the Czech Republic (DMR 4G). It is primarily created for production of the Orthophoto of the Czech Republic. Prior to orthorectification of digital aerial photographs the replenishment of some technical objects which are not a part of terrain surface (bridges, dams, etc.) into the model is necessary. Adverse image deformation of their representation in the orthophoto can be minimized using those complementary data.

For the ortogonalization purposes at the built-up areas with a large number of high objects the true ortophoto is commonly used. Unfortunately, the true ortophoto production is very expensive, because it requires large side and forward overlaps of the aerial photographs and preparation of the digital surface model instead of digital terrain model. As the above mentioned project is countrywide, due to the economical reasons it is impossible to realize a true ortophoto as its output. As an alternative, ortogonalization by hybrid digital elevation model improved by some elements from current available geographic databases can be used. The article deals with the possible technological variants and data sources for digital terrain model replenishment and assesses application of each approach in practise.

Keywords: airborne laser scanning, digital elevation model, orthorectification, surface modeling, true orthophoto

INFLUENCE OF ILLUMINATION AND WHITE REFERENCE MATERIAL FOR HYPERSPECTRAL IMAGING OF CULTURAL HERITAGE OBJECTS

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ABSTRACT

Hyperspectral imaging (also called imaging spectroscopy) is a relatively new method that has been used multidisciplinarily in last years. This process has been speeded up by technological developments and opens new topics of analyses and research. Spectroscopy has been used as a powerful quantitative tool in laboratories for many years now, and a lot of investigative methods have been developed. These methods can now be transferred into the cultural heritage field and may lead to new findings in this branch of study. This scientific discipline studies light as a function of wavelength, where light can be emitted, deflected and scattered by a specific material. Unlike multispectral imaging, which is commonly known from satellite imagery when investigating the Earth's surface and provides a small amount of wide, non-continuous bands, hyperspectral imaging shifts the imagery a level up. Tens or hundreds continuous narrow bands are detected which allow one to see all the spectral information in the explored spectral range. This enables spectral reflectance extraction on a pixel level and when compared to laboratory measurements, material type and characteristics can be determined. A hyperspectral sensor (Hyperspec VNIR A-series by Headwall Photonics) is available at the Czech Technical University in Prague, Faculty of Civil Engineering, Department of Geomatics will be used for this analysis.

Illumination plays a key role in spectral characteristics extraction because reflectance (the amount of reflected light) is measured. It is required that the quantity of reflected light should be just enough to reach (but not exceed) the saturation level of the hyperspectral instrument. If the amount of light detected by the instrument is too low, significant noise will appear in the data. This noise cannot be mathematically corrected because it affects dark parts of the investigated object more than the light ones. One can dispose of the noise via careful and fine illumination. Several sets of illuminations will be tested. Another important issue is the white reference material. White and black reference imagery is used for calibration in order to extract the actual response of analysed object. This paper deals with white reference materials used for the calibration of the hyperspectral sensor. It is an image of white material with a maximum reflectance. In this study, several white reference materials (classic office paper, technical white reference material and SpectralonTM) will be analysed and the noise level will be shown. A cultural heritage object (painting) will be used for this test. The illumination influence will be closely observed due to the possibility of harming the painting. Old paintings are very susceptible to temperature, thus higher temperatures (>35°C) can make the bee wax (present in the painting) melt. This paper will provide useful information regarding the hyperspectral set-up for the future investigation of cultural heritage objects.

Keywords: hyperspectral imaging, cultural heritage, illumination, white reference material, woodcut graphics

LASER SCANNING FOR GEOMETRY ANALYSIS OF THE RIBBED VAULTS FROM LUXEMBOURG TIME

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ABSTRACT

The main objective of this project was drawing of the technical documentation for the ribbed vaults of an auditorium (called “Lednice”) in the Old King Palace of Prague Castle and for the ribbed vaults in the Old Town Bridge Tower of the Charles Bridge. Both gothic ribbed vaults were built in 14th century in the Luxembourg era by the building mortar of the Petr Parler master builder. Both spaces were constructed on an irregular quadrangle ground plan, but it was evident that the used circular arcs have the same radius for the space from the provisional architecture exploration. The documentation based on the data measured by the 3D laser scanning technology was carried out for verification of this theory. We created 3D models of the spaces. We created specially the 3D models of the ribbed vaults and their feet, which have very interesting ending where individual arcs are ended in the different places. Ground plans and cross sections of the spaces were drawn after 3D modelling. The created outputs serve for examination of the ribs geometry, their construction technology and for needs of knowledge extension for more gentle and more accurate reconstruction of the gothic ribbed vaults of this era.

Keywords: laser scanning, ribbed vaults, drawing, Luxembourg

LYTRO CAMERA TECHNOLOGY AND ITS USABILITY FOR CLOSE-RANGE PHOTOGRAMMETRY

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ABSTRACT

Beginning in the nineties, new technology for the documentation of archaeological and historical objects has been preferred in research. Very rapid development of the new technologies based on computer processing or computer-aided techniques with rapid digital camera development such as laser scanning meant a great change in general. The modern approach in spatial documentation deals with image-based modeling. There is a problem with the focusing of whole spatial objects. Non-sharp parts cannot be successfully processed to a precise point cloud or 3D model. So far, it has been necessary to capture spatial or significantly curved objects in small increments. Recently, there has been an evolving commercial market of plenoptic camera technology. Such a well-known product is the Lytro camera, a low-cost plenoptic camera. The main ability of this technology is to capture traces of light rays inside the camera. Due to this property of plenoptic cameras, we are able to produce images with extended depths of field. Photogrammetry has faced the image focus problem in the whole area since the beginning. The ability of creating images with an extended depth of field is suitable property for close range photogrammetry, where objects could be imaged in a very short distance. Low image resolution and the ability of producing images with an extended depth of field makes this technology usable for small object documentation. This paper will introduce the testing of this technology for the Czech Technical University in Prague for the documentation of small bronze archaeological findings. Images with an extended depth of field have been used as a base for the creation of 3D documentation of these archaeological findings.

Keywords: Lytro camera, plenoptic camera, light field, close-range photogrammetry, 3D documentation.

MOBILE MAPPING AND THE USE OF BACKSCATTER DATA FOR THE MODELLING OF INTERTIDAL ZONES OF BEACHES

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ABSTRACT

Mobile mapping with laser scanning is frequently limited to the sole geometric reconstruction of objects or surfaces. In the special case of the construction of Digital Elevation Models (DEMs) of intertidal zone of beaches, this task is known to be very challenging. In the context of the interdisciplinary research project named 'SeArch', which aims at documenting and managing archaeological patrimony in the North Sea, a field campaign was organized in the summer of 2013. During this campaign, an amphibious vehicle (ARGO) was equipped with a Terrestrial Laser Scanner (TLS) in profiler mode, an Inertial Measurement Unit (IMU), a Real-Time Kinematic Global Navigation Satellite System (RTK GNSS) and a PC hydrographic data acquisition software and huge storage capacity. Based on previous research, this configuration appeared to have the best performance under the environmental conditions at the Belgian North Sea coast. Especially for the intertidal zones of beaches, the use of this mobile platform resulted in very promising results from a geometrical point of view. A summary of the results of the campaign is presented in this paper.

Although the focus of this campaign was on the construction of DEMs with a high resolution and a high accuracy, the used Leica HDS 6200 phase-based laser scanner also returned a backscatter value for each measured point. A provisional analysis of these values suggested a relation between the physical properties of the reflecting surface and the registered backscatter values. However, earlier studies have also demonstrated the influence of the incidence angle and measured distance on this backscatter value. As will be discussed in this paper, a correction function can be defined that takes these parameters into account as weights for corrected backscatter data. In combination with the commonly used point cloud, the corrected values allow the calculation of false-color composites of the measured surface and the detection and description of features.

Keywords: mobile mapping, backscatter analysis, beach measurements, archaeology

**MONITORING AND EVALUATION OF PRESTRESSED CONCRETE
ELEMENT USING PHOTOGRAMMETRIC METHODS**

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ABSTRACT

The prestressed thin-walled concrete elements enable the bridge a relatively large span. These structures are advantageous in economic and environmental way due to their thickness and lower consumption of materials. The bending moments can be effectively influenced by using the pre-stress. However, shear forces can cause unexpected shear cracks and deflection of the structure. A set of experiments were done to monitor the shear cracks. During the experiment the discrete points were monitored. To determine a large number of points, the photogrammetric methods combined with polar method using the total station were chosen.

Keywords: concrete, shear crack, photogrammetry

MULTIPLE HOMOGENEOUS COORDINATE TRANSFORMATIONS USED IN PHOTOGRAMMETRY & REMOTE SENSING

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ABSTRACT

This paper describes multiple homogeneous coordinate transformations necessary for interior and exterior (relative and absolute) orientation in analytical and digital photogrammetry & remote sensing. In this paper, I intend to analyze the 3D operations like rotations, translations and scaling which are performed using matrices and lineal algebra in homogeneous coordinates. Each operation is performed by multiplying the 3D vertices by a specific transformation matrix. Using 4x4 transformation matrices allows us to combine rotations, translations, scales and shears into a single matrix. Because a 3D object or scene is composed of a collection of 3D models, which have four different coordinates systems or spaces (Space-global, Space-object, Space-view and Space-screen), the homogeneous transformations presented are referring to the transition from one system to another. The algorithms of the transformations presented are examples of affine transformations which are fast to compute and very useful throughout computer graphics. In the same time, this paper reviews basic philosophy concerning homogenous transformations very useful in the relationship between photogrammetry and computer vision applications.

Keywords: Mathematics, Photogrammetry, Remote Sensing, 2D/3D/4D Modeling

OBJECT MONITORING IN URBAN LANDSLIDE AREAS USING TERRESTRIAL LASER SCANNING

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ABSTRACT

Cresnjevec landslide is a reactivated landslide with an unknown precise location, time and cause of initial landslide movement. In the first documents concerning the slopes instability, construction works as well as vegetation removal, were determined to be the causes of landslide activity. Also, future landslide activity was predicted. Landslide remedial works encompassing regulation of the stream in the valley bottom, and construction of drainage wells in the valley, took place in 2004. Despite the remedial works, the landslide remains active and is threatening the houses which are still inhabited. A clear borderline of the landslide can be observed on a digital terrain model created from aerial laser scanning data. Still, due to accuracy limitations of aerial laser scanning, changes in topography cannot be detected to an adequate degree. Data obtained through terrestrial laser scanning (TLS) on the other hand, having millimeter accuracy, is capable of providing satisfactory insight into landslide activity. Thus, object monitoring in the zone of the landslide activity, as well as its vicinity, using TLS was chosen to obtain relevant data. Results of analysis conducted on the gathered data are shown in this paper. The results clearly show this methodologies application capabilities for urban areas facing similar problems.

Keywords: reactivated landslide, slope instability, laser scanning, digital terrain model, urban areas

PRESERVATION AND REVITALIZATION OF ERDÖDY CASTLE IN JASTREBARSKO, CROATIA

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ABSTRACT

One of Erdödy family estates, a Castle located in the town of Jastrebarsko in Croatia, has immeasurable historical value for Croatia as well as the residents of Jastrebarsko. Unfortunately, the Castle is currently in an extremely ruinous state due to absence of maintenance for a significant amount of time. This was the result of both the changes in proprietary structure as well as the insufficient funding capabilities of the local government. Thus, a cross border project was applied for EU financing by the local government for the purpose of Castle revitalization. A prerequisite to any such project is as always documentation of the current state. The complexity of the object in question and its current state proved to be a significant challenge for conducting adequate survey. The castle is a four winged structure with a courtyard in the centre adorned with arcades and baroque pillars. Out of four of its cone like towers, two remain while the other two are on the foundation level. Beside defensive the Castle had a residential purpose as well. It is surrounded by a moat and continuing on is a beautiful park spreading on 9.47 hectares. It also contains a brook named Reka and a pond named Park. Across from the palace, there is an old granary with a beautiful green patio in front of it.

Due to afore mentioned complexity of the task, laser scanning was the method of choice for conducting surveys. The resulting 124 scans and over 3 billion points speak volumes about the magnitude of the undertaken task. Both the exterior and interior of the object had to be surveyed with sufficient accuracy to ensure the quality of subsequent analysis for other professions involved. The castle has four floors with the first being the basement and the fourth encompassing two rooms of the remaining towers. Those were actually completely inaccessible as no staircase leading to them exists anymore and are too high up to reach using normal ladders for instance. The complete process of survey, and all the challenges encountered on the project will be further elaborated in the paper.

To complement laser scanning conventional surveying techniques were also applied. GPS survey provided the basis while total station survey was implemented for point cloud georeferencing as well as for control surveys facilitating quality analysis. Quality control and quality analysis are integral and indispensable aspects of any survey work but they weigh even heavier in laser scanning projects of this complexity and magnitude.

Keywords: Laser scanning, Cultural heritage, Erdödy Castle, Quality control, Quality analysis

PROGRAMMABLE SYSTEM FOR PUMPING UNITS CONTROL IN PETROLEUM EXTRACTION

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ABSTRACT

This paper presents a programmable system design methodology used for controlling and supervising the motors of pumping units in petroleum extraction operations. The system is based on using Programmable Logic Controllers (PLCs), fixed and mobile data networks, TCP/IP protocols and GPRS services.

Keywords: petroleum extraction, pumping units, control system, programmable logic controller.

RECONSTRUCTION OF HISTORICAL LANDSCAPE FROM AERIAL PHOTOGRAPHS FOR RIVER DEVELOPMENT ASSESSMENT

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ABSTRACT

This article describes use of archive aerial photographs for reconstruction of historical landscape for river development assessment. Photogrammetric methods are a well applicable tool for reconstruction of land-use change and digital surface model development. The software ERDAS 2013 enables fast and high-quality processing of sets of many archive aerial photographs without the need of data from the calibration protocol. Historical photographs from years 1938–1994 and actual orthophotomap from year 2010 were used for studying of the Ploucnice River channel change in the village Borecek close to the town Minon (Ceska Lipa district).

Historical digital surface model reconstructed from the historical orthophotomaps with 60% overlaps were used for 3D visualisation of historical landscape. The digital terrain model from a laser scanning dataset was used for the accurate digital elevation model creation. The comparison of time series images shows three-dimensional land-use changes.

The channel of Ploucnice River in all time horizons was digitized and then analysed by software ArcGIS Desktop 10.2. The study of river channel migration and lateral shifts of the channel in last 70 years were identified by use of spatial analysis, distance analysis and statistic assessments.

Keywords: archive photographs, landscape reconstruction, orthophoto, digital surface model, river development

REDUCE NOISE OF LASER SCANNING DATA

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ABSTRACT

The data obtained by 3D scanners with required higher accuracy and density contain disturbing noise, this noise makes the data processing, mainly by means of triangulated irregular networks using automated procedures, more complicated. The paper presents a new methods of noise reduction based on natural redundancy of continuous objects and surfaces where, however, some deformation of the object shape occurs. The second method is based on wavelet transform.

The first method involves a gradual choice of a selected number of the nearest points for each point of a scan, a selected surface is fitted with them and by the elongation or shortening of a beam with a given horizontal direction and the zenith angle onto the intersection with the surface a new (smoothed) position of the points is obtained. As the surface for fitting are used plane, polynomials of 2nd, 3rd and 4th degree. For the better calculation stability Chebyshev bivariate orthogonal polynomials are used. These surfaces are complemented by method using the mean. The solution of surface fitting may apply the least squares method, but also a robust method – the minimisation of the sum of absolute values of corrections (L1 norm). The second method used characteristics of wavelet transform.

Keywords: Laser scanning, noise reduction, surface fitting, points

**RESEARCH METHODS AGROLANDSCAPES OF THE MOUNTAIN RIVER
BASINS BASED ON SATELLITE IMAGES (AN EXAMPLE THE BASIN OF
RIVER KEGEN)**

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ABSTRACT

In a changing climate and natural manifesting of weather consequence in a mountain slope effluents washout processes of soil and soil cover leads to decreasing productivity of cultures, pollution and degradation of rivers. Therefore agricultural landscapes of the mountain river basins are consider based on adaptive landscape system of agriculture (ALSA) and investigation their changing dynamics. Research of mountain river basin lands used for an agriculture and pastures, observation through satellite images is one of the main purpose of nowadays. For this purpose were chosen Landsat satellite images from different years, comparing these satellite images as a result of the agricultural landscapes dynamic analysis for rational land use, biodiversity investigates and widely used to identify the consequence of natural appearance on the agricultural crops.

Keywords: Remote sensing, adaptive-landscape system of agriculture, satellite images, NDVI.

RPAS AS A TOOL FOR THE MONITORING OF A NATURAL RESERVE

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ABSTRACT

For the monitoring of ecologically valuable areas, terrestrial measurements and a precise actual thematic map are needed. For the creation of this, several methods can be used. In less accessible or inactive areas, remote sensing or aerial methods are suitable. For remote measurement, they are satellite data, aerial data or Remotely Piloted Aircraft Systems (RPAS) data respectively. The satellite data has sub meter geometric resolution (50cm per pixel), aerial data in decimeters; both data types are often too expensive or designed for larger areas. RPAS have a geometrical resolution of about a cm and can be used for small areas in one flight only, but from an economical point of view, it is low cost and environmentally friendly. This contribution deals with the use of unmanned aerial vehicles in cartographic tasks. The eBee drone system that is introduced in this paper is used for mapping specific tasks. The problems of planning, data acquisition and processing are illustrated by the creation of orthophoto and NDVI. The theoretical preparation of data acquisition deals with mission planning and operation. “Božídarské rašeliniště” moorland is a national nature reserve in the district of Karlovy Vary, the largest area in the Ore Mountains. It is located west of the city of Boží Dar at an altitude of 940 to 1,115 meters. Peat extraction took place here until the Second World War. The protection of this natural area was declared in 1965 over an area of about 1000 hectares. The laboratory of photogrammetry at the Czech Technical University in Prague (CTU) monitored this area to obtain comprehensive databases for ecologists, biologists and municipalities (touristic access and activity planning) as a case project.

Keywords: RPAS, UAV, UAS, natural reserve, monitoring

SPATIAL DOCUMENTATION AND VISUALISATION OF HISTORICAL ARTIFACTS

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ABSTRACT

The documentation of historical objects and artifacts is still a very popular topic of many scientific articles. This proposed paper deals with the documentation and visualization of several small archaeological artifacts or findings. Two methods of documentation are used and compared for this purpose. One of them is spatial documentation with the short-range 3D triangulation scanner Konica – Minolta VI9. Using this technology, a precise 3D model of the artifact is obtained. On the other hand, the drawback of this method is the missing texture which is important for quality visualizations.

Another approach deals with image-based modeling. This technology is based on a sequence of images of the object. In our laboratory we use the Agisoft PhotoScan or Photomodeler Scanner software. The final product of the processing is a high quality textured 3D model. This method can be considered as a non-expensive way of documenting large amounts historical objects or findings with quality results suitable for future visualization. But there are problems with very small and slender artifacts (small image overlapping area).

One part of this article is focused on ways of visualization. The model can be exported to the 3D PDF format. Another way is using 3D viewers like Cortona and BS Contact. Nowadays, 3D printing has become very popular. We are able to produce a real print of the artifact.

Keywords: historical artifacts, image-based modeling, laser scanning, 3D print

**STUDIES ON THE USE OF TERRESTRIAL LASER SCANNING IN THE
MAINTENANCE OF BUILDINGS BELONGING TO
THE CULTURAL HERITAGE**

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ABSTRACT

Within the frames of the use of terrestrial laser scanning we find numerous examples of registration of building facilities, including also historical and valuable in their culture. In the case presented in this paper, at the root of the problem there is a preservation of the historic blacksmith's forge located in Gdansk Orunia. The facility dating from the early nineteenth century was intended to repair involving the complete demolition and rebuilt in the historical form but with the use of new materials. Only selected elements were to be retained, creating a kind of architectural artefacts and handicrafts.

Implementation of the laser scanning was carried out in a conventional manner, though in difficult field conditions. The obtained data have become good material to carry out analyses concerning construction and surveying. The paper presents results of studies on using laser scanning and possible problems which can appear during measurements and data processing. It also indicated solutions for proliferation of the data and models based on point clouds.

Keywords: archiving of cultural heritage, arcaded house, terrestrial laser scanning, database, point cloud

**TESTING MOBILE PHONE APPLICATIONS FOR PHOTOGRAMMETRICAL
3D RECONSTRUCTION OF OBJECTS BY USING IMAGE
CORRELATION METHOD**

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ABSTRACT

Mobile phones have become a part of everyday's life in the 21st century, this piece of hardware can be found in almost every pocket all around the world. The evolution of mobile phone applications is a key issue to many IT specialists and developers. These applications are cheap and available for everyone with a smartphone and an internet access. Nowadays, mobile phone applications have also been developed for 3D reconstruction of objects. It is very simple, one can make fine 3D model of desired object (for example building) with just a few clicks on the phone. Thanks to improvements in computer technology, automatic reconstruction of urban 3D models is an important part of photogrammetrical research in last decades. 3D modelling and visualizations are widely used for urban drafts and their creation has become a developers standard.

In this paper, we focus on testing an optical performance of today's mobile phones for the purpose of the 3D reconstruction of the objects by using image correlation methods. Two objects were captured by a mobile phone and the images were processed with a photogrammetrical application for image correlation, resulting in a virtual 3D model. The 3D model of one of the objects was then compared to "ground truth", given by a laser scanning technique with a high accuracy scanner.

Keywords: Image-based modelling, auto-correlation, mobile phone application, 3D model creation

THE APPLICATION OF CLOSE-RANGE PHOTOGRAMMETRY FOR A DOCUMENTATION OF METALLURGICAL ART-HISTORICAL OBJECTS

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ABSTRACT

Historical monuments, whether in the form of immovable objects or movable antiquities, are part of our lives, they represent our history and should be also maintained for future generations. That can be done as an appropriate care about them or as a documentation of their current state. Nowadays, in the world full of information and digital technologies, there is a wide range of possibilities to document these historical monuments and to convert them into a digital form, in which they can be preserved “intact” for a very long time. Laser scanning and digital photogrammetry can be included among the two most frequently used technology, but photogrammetry is more suitable in terms of financial costs. The objective of this paper is to present the use of this method for the documentation of one of the most costly exhibit of the Slovak Technical Museum in Košice, the bronze door from 1580 decorated with motives and reliefs from Dionys celebrations, and to highlight advantages, disadvantages and limitations of this method.

Keywords: Photogrammetric scanning, Structure from Motion, Cultural Heritage.

THE METHOD OF ANALYSIS OF DAMAGE REINFORCED CONCRETE BEAMS USING TERRESTRIAL LASER SCANNING

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ABSTRACT

The authors present an analysis of the possibility to assess deformations and mode of failure of R-C beams using terrestrial laser scanning. As part of experiments carried out at the Regional Laboratory of Construction (at Gdansk University of Technology), reinforced concrete beams were subjected to destruction by bending and by shear. The process of press impact on the reinforced concrete beam was recorded using terrestrial laser scanner. Development of scanning effects was performed using Leica Cyclone software and MeshLab. In order to verify results, the independent recording of beam deflection with use of extensometer and the recording with non-meter synchronous digital cameras were carried out, photos from these cameras were subjected to photogrammetric processing. However, the principal subject of this paper is to show the usefulness of laser scanning for the analysis of reinforced concrete beams damages and authors of this paper focused on this subject.

In the description of the experiment there are six stages of measurement mentioned for the reinforced concrete beam: from the zero condition (no force), through intermediate conditions up to the stage of destruction. Scanning was performed from one stable measurement station to avoid in processing the effect of correlation errors (matching and linking) of ScanWorld.

Analysis of the materials from laser scanning allowed to assess the geometry of element subjected to destruction with an accuracy not worse than 1 mm. For this purpose, the method of spheres translation was developed and in its characteristic groups of points from scanning the spheres were described. Spheres centers grew to be geometrical element to be assessed on scans in subsequent measurement epochs. Additionally, through the use of automated analysis of intensity map of laser light reflection, it was indicated the possibility of rapid identification of the beam, in which there may occur microcracks and changes in the structure. The usefulness of the evaluation mechanism can be appreciated in the mass studies or inspective examinations of constructional components.

As a result of the authors' research and in the course of measurements analysis it was possible to establish the concise procedure to specify the mode of the reinforced concrete destruction and it was defined the minimum size of cracks that may be recorded in the cloud of points from laser scanning.

Keywords: laser scanning, deformation measurement, reinforced concrete, beam, cracks, mode of failure

TWO-STAGE SUBPIXEL IMPERVIOUS SURFACE COVERAGE ESTIMATION: COMPARING C 5.0/CUBIST AND RANDOM FOREST

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ABSTRACT

The paper presents accuracy comparison of subpixel classification based on medium resolution satellite images (Landsat 5TM), performed using two machine learning algorithms (C5.0/Cubist and Random Forest) built on decision and regression trees method. The research was conducted for the immediate catchment of the Dobczyce Reservoir (which is the main source of water supply for the city of Cracow, Poland) along with an adjacent area of towns (Myślenice and Dobczyce). The land use in the catchment is dominated by agriculture with numerous villages of dispersed development. The southern part of the study area is covered mainly by forests. The aim of the study was to obtain image of percentage impervious surface coverage, valid for the period of 2009-2010. Imperviousness index map generation was a two-stage procedure based on two algorithms. The first step was hard classification, performed using decision trees method, which divided the study area into two categories: i) completely permeable (imperviousness index less than 1%) and ii) fully or partially impervious areas. In a second stage, for pixels classified as impervious, the percentage of impervious surface coverage in pixel area was estimated using regression trees approach. Accuracy of the final imperviousness index map was checked based on validation data set, which was not used for learning and testing of classifiers. The root mean square error (RMS) of determination of the percentage of the impervious surfaces within a single pixel was $\pm 12.8\%$ for C5.0/Cubist method and $\pm 13.9\%$ in case of Random Forest method. Further results analysis shown, that in intensively urbanized areas small imperviousness index value differences occurred. Larger differences of up to a few percent were found in agriculture and forests areas, with more accurate results obtained using C5.0/Cubist method.

Keywords: subpixel classification, impervious surfaces, decision and regression trees, Landsat TM

**UAS AERIAL DIGITAL PHOTOGRAMMETRY FOR LANDSCAPE
MODELING AND REHABILITATION DESIGN OF THE “SAN FRANCESCO”
ABANDONED MINE (SARDINIA-ITALY)**

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ABSTRACT

In the Ottana–Orani mining district (Central Sardinia - Italy) several talc-chlorite bodies, hosted in Palaeozoic metamorphic rocks and granites, have long been exploited. Most of these operations are underground excavations but mining activity have deeply modified natural landforms with a lot of landfills and trenches in the “San Francesco” area where a rehabilitation project should be considered as an overall project of landscape restoration. In this research field the aerial digital photogrammetry is an important tool for the realization of detailed 3D digital surface model (DSM) required for any realistic visualization during the development of a restoration planning. In this work we report the results of a proximal photogrammetric survey using an unmanned aerial system (UAS) and based on the acquisition of non-metric high resolution digital images, to generate detailed 3D models. This method is especially designed for sites with a complex topography and high morphological steepness and as vertical walls, deep excavation holes, slopes and allows to create digital terrain models (DTM) at different consistent resolution where different survey altitude is required. The survey was based on geo-referenced GPS grid and the aerial images dataset was processed with different photogrammetric software to obtain a geo-referenced orthomosaic, DSM, DTM and 3D models. Finally we have carried out a realistic 3D digital reconstruction and rendering, that constitute a powerful and sophisticated method to manage landscape design into restoration projects.

Keywords: abandoned mine, UAS proximal sensing, photogrammetry, DSM, landscape restoration

**URBAN HEAT ISLAND DETECTION BY INTEGRATING SATELLITE
IMAGE DATA AND GIS TECHNIQUES. CASE STUDY: CLUJ-NAPOCA
CITY, ROMANIA**

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ABSTRACT

Continuously increasing urbanization of big cities worldwide is nowadays an important issue in urban development studies. One of the most significant consequences is the intensification of urban heat islands over the big cities. This study aims to detect the different surfaces temperature in Cluj-Napoca city, Romania, by using satellite data images and GIS specific methods. The paper is based on satellite images of Landsat 5 and Landsat 7 missions and provided by USGS (United States Geological Survey) database. The images that passed the cloud cover controlled are taken in the summer months (June, July, and August). To evaluate the surface temperatures, we combined the satellite data images processing with GIS techniques. They have been integrated in a surface temperature estimation model where the spectral radiance is converted into temperature values. Then the surfaces with temperature higher than 30°C have been identified and their total area has been calculated. Erdas Imagine 2013 și ArcMap 9.3 software have been used in processing the raster images. For a detailed investigation, temperature on two profiles over the city area was analyzed. The main findings of the paper are: there are important temperatures difference for various type of surfaces; the green areas and water bodies have the coldest surface temperature, which is usually 8 - 10 °C lower compared to the hottest surfaces specific to built civil and industrial areas.

Keywords: urban heat island detection, Satellite images, Cluj-Napoca, Romania

USEFULNESS OF THE FRACTAL DIMENSION IN THE CONTEXT OF HYPERSPECTRAL DATA DESCRIPTION

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ABSTRACT

The number of hyperspectral sensors and data grows systematically and dynamically. Hyperspectral data delivers huge number of precise information but character of data requires specific methods of processing. One of these methods can be the use of the fractal description. In literature there are only a few attempts to analyze hyperspectral images using fractal parameters. Most of them concern on measuring fractal dimension of spectral signatures corresponding to the single pixels. The second group focuses on describing every hyperspectral image channel by fractal parameter.

In this research we verify the fractal dimension usability for hyperspectral channels description. In order to calculate the fractal dimension we use the Differential Box-Counting method which is accurate and computationally efficient. We analyze the variability of fractal dimension calculated for hyperspectral image channels for two types of data – the radiance and the reflectance. The data we use has been acquired by AVIRIS sensor; designed and developed in Jet Propulsion Laboratory. Analyzed data include 224 channel images of solar reflected spectrum from 400nm to 2500nm and present homogenous land cover classes (water, mountains, agriculture and urban areas), as well as heterogeneous samples.

Conducted analysis show advantages and limitations of the fractal parameter as a channel content descriptor. In particular, we observe that different land cover classes may be categorized basing on fractal dimension values of channels from specific parts of electromagnetic spectrum where values fluctuations are observed. Only water sample presents stable behavior of fractal dimension. For individual land cover class we observe differences between fractal dimension of radiance and reflectance data mainly for visible part of electromagnetic spectrum. Moreover, in cases of radiance data, irregularities of fractal parameter values indicate noisy channels.

Summarizing, fractal dimension values seem to be useful as the channel quality measure and information capacity measure. Moreover, it could be used for noisy channels discrimination, usability estimation, different land cover classes categorization or atmospheric correction quality estimation.

Keywords: fractal dimension, hyperspectral, AVIRIS, image descriptor

USING PANORAMIC PICTURE FOR MEASURING PURPOSES

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ABSTRACT

This paper deals with a role of panoramic picture in object 3D documentation. Four panoramic interior images were used for 3D documentation and ground control points were surveyed for proportion determination. Ground control points served as a base for pictures screening centre definition. Panoramic pictures are perceived as a set of surveyed directions and zenith angles. If the projection of panoramic picture is known one receives a set of ground control points' surveyed directions and zenith angles. It is necessary to find angles between panoramic images and appropriate geodetic and coordinate system. The knowledge of these angles enables one to determine the location of projection centre in a coordinate system. Iteration was used as a method of angle calculation. The X and Y axes inclination in coordinate system was determined together with the orientation shift of the panoramic picture set (turning around Z axis). The location of panoramic picture projection centre in coordinate system is determined by Mean Squared Error equalization. Two methods were used for detailed survey point coordinates calculation – determination of detailed survey points from height base and the Mean Squared Error equalization. The first method was used in areas with sharp intersect angle on detailed survey point, iteration methods has been used in this calculation. For Mean Squared Error is necessary to determine the approximate coordinates of detailed survey point using forward intersection. The Mean Squared Error equalization was performed using iteration methods. An experiment has been carried out - lengths between points of real objects were measured and these were compared to calculated lengths derived from panoramic picture. Wide-angle lens and telephoto lens were tested and their effect on the measured lengths accuracy was analyzed (is the deformation of panoramic picture bigger when acquired by telephoto lens?).

Keywords: panoramic picture, GigaPan Epic Pro, Mean Squared Error

USING RADAR DATA IN ARCHEOLOGICAL SITES

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ABSTRACT

Using a radar data widens the possibilities of archeological prospection extremely. The resolution of the available sensors was quite limited that the detection of huge upstanding monuments or culture landscape was possible. Data of the remote sensing have different purposes of use. Radar data make it possible to monitor the Earth's surface in any weather. Radar is an active system that generates its own radiation in the microwave part of the electromagnetic spectrum. The radar systems work in the wavelength range distances 0.8 - 100 cm. This interval is divided into sub-bands, called the Ka, Ku, K, X, C, L, P. This paper shows two radar sensors. Sensor PALSAR with fine resolution of up to 7m, which is part of satellite ALOS and sensor SAR, which is part of the German satellites TanDEM-X with resolution of 6 m. In Peru there are many of archeological sites. Some of them are buried under a layer of sand or soil. The layer is usually tens of centimeters thick. For these purposes, we need sensor that can penetrate the soil and provide information about buried archeological sites as well. The archeological site Chankillo is a gut example. About Chankillo was written many articles. Chankillo is located near the small town of Casma in an area that is very rich in interesting historical objects (Sechin). Chankillo is a famous complex with thirteen towers that were used as a solar observatory (Ghezzi and Rugless, 2007 and Pavelka at all, 2013). Chankillo also has residential and gathering areas that we can see on Google Earth (GE). On GE we can also see that near Chankillo are a few rectangular constructions. About these construction sites there is not information. Therefor it is good to use radar data for information about this place. If radar sensors can penetrate the sand and detect the buried objects, it will be good strategic information for archaeologists. A second archeological site is the very famous Nazca desert plain in Peru, where there are well known structures called geoglyphs. The geoglyphs were studied by German mathematician named Maria Reiche (Reiche 1996). But the place near Nasca city called Palpa de Nasca is not only geoglyphs (Pavelka at all, 2013). A lot of other very interesting cultural and archaeological sites can be found in the Nasca area. At CTU, we started a new project that is focused on archaeo-astronomical orientations of important objects in Peru as a part of long term "Nazca" project. In this paper we use the radar data to identify historical object in the Nasca area.

Keywords: radar data, PALSAR, TanDEM-X, archeological site, Chankillo, Nasca, Peru

**UTILISATION OF LASER SCANNING FOR INVENTORY OF AN
ARCHITECTURAL OBJECT USING THE EXAMPLE OF RUINS OF THE
KRAKOW BISHOPS' CASTLE IN IŁŻA, POLAND**

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ABSTRACT

The terrestrial laser scanning with the close-range photogrammetry is now one of the most effective and most accurate, non-invasive methods of historic monuments inventory, especially during in-field archaeological and architectural works. In addition to the possibility of object's geometry registration, together with imaging documentation, the laser beam intensity of reflectance has recently become more important. It has been widely applied (as a complementary parameter) directly in the analytical works and monumental objects' surface detection, as well as, indirectly, during the diagnosis of the historical substance. The objective of this paper is to discuss selected issues related to performed field works concerning the ruins of the castle in Iłża, in Poland, which include acquisition and integration of data, as well as analysis and interpretation of the mentioned intensity of the reflectance parameter. The final result is the practical utilization of data for evaluation of behaviour of selected parts of a described object. Works are performed with the use of non-destructive methods of documenting and recognition of cultural resources, developed by the Stefan Wyszyński University in Warsaw within the research project "Utilisation of laser scanning and remote sensing for protection, investigations and inventory of the cultural heritage. Development of non-destructive, digital methods of documenting and recognition of resources of the architectural and archaeological heritage", within the programme of the Minister for Science and Higher Education, called "The National Programme for Development of Humanities". [6].

Keywords: TLS, photogrammetry, archaeology, stratigraphy, beam intensity of reflectance

**VEGETATION CHANGE DETECTION IN LANDSAT TM TIME SERIES
USING SINGULAR SPECTRUM ANALYSIS AND REGULAR FOREST
INVENTORY DATA**

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ABSTRACT

The lack of the fine temporal coverage of multispectral satellite data, the insufficient historical field data and impacts of unique conditions during satellite image acquisition are significant challenges for land cover change detection and characterization. The aim of this study is to evaluate the potential of Singular Spectrum Analysis (SSA) for detecting trends in vegetation change with small number of temporal data points available. Efficiency of SSA was tested for vegetation change trend classification in three groups: stands with no changes, stands with changes associated with forest growing and stands with abrupt changes. SSA trends were robust to variations of employed image features (NDVI, Tasseled cap Greenness and subpixel vegetation fractions) not related with actual land cover and characteristics of the SSA trends improved classification of forest stands (overall accuracy (OA) 94.67 %) comparing with the use of the same descriptors for unprocessed time vectors (OA 85 %). Date of the changes was estimated using unprocessed time vectors and for the 70% of the 100 test stands change data was estimated correctly as closest year of actual changes according to RFI.

Keywords: singular spectrum analysis, vegetation change detection, Landsat TM

VISUALIZATION OF TRACKS USING DIGITAL TERRAIN MODEL AND IMAGE PROCESSING METHODS

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ABSTRACT

This article describes visualization and image processing methods that can be applied on digital terrain models (DTM) to highlight objects hidden in the landscape. This can help archaeologists understand the landscape evolution including the differentiation between natural processes and human interventions. Different visualization methods were applied on a system of parallel tracks hidden in a forest and its surroundings – part of old route called “Devil’s Furrow” near the town of Sázava. The data from the airborne laser scanning acquired by the Czech Office for Surveying, Mapping and Cadastre was used. The average density of the point cloud was approximately 1 point/m². The goal of the project was to visualize the utmost smallest terrain discontinuities, e.g. tracks and erosion furrows, which some were not wholly preserved. Generally we were interested in objects that are clearly not visible in DTMs displayed in the form of shaded relief. Some of the typical visualization methods were tested (shaded relief, aspect and slope image). To get better results we applied image-processing methods that were successfully used on aerial photographs in the past. This article summarizes the results of testing on a selected area.

Keywords: archaeology, ALS, DTM, slope image, image filtering