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APPLICATION OF DATABASE TECHNOLOGY TO ANALYSIS OF ROCK STRUCTURE IMAGES

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Abstract: The aim of this paper is to present a possibility to use information technology in the form of databases for processing and analyzing large image sets based on methods of image analysis and mathematical morphology. Up to now the use of databases in the image analysis process has been reduced to storing large amounts of data in the form of images. However, all transformations and analyses of such sets are made on user's computers. This requires a large data set (images) to be sent by network each time, and also it may possess the problems resulting from managing such large amounts of analyzed photographs on a computer. The proposed approach completely eliminates these problems by moving all transformations of image analysis to a database platform. For this purpose a set of routines realizing transformations of the image analysis and mathematical morphology was developed. The proposed approach allows the unification of the image processing and analysis area and advanced statistical analyses of obtained parameters describing geometrical sizes of objects on photographs. The proposed methodology was illustrated by practical realization of two measurement types for a simple structure of copper concentrate and more complicated, from the point of view of image analysis, structures such as dolomites from Redziny and Laskowa Gora and sandstones from Tumlin and Wisniowka.

Keywords: *image processing, mathematical morphology, quantitative analysis of rocks, databases, user defined functions*

Introduction

The idea and application of stereological analysis in mining and geology has been developing in Poland since 1960s. The initial, mainly theoretical ideas, dealt with the determination of estimators of total curvature for diameters of the objects under examination (Bodziony, 1965), determination of numerical and geometric characteristics of rock structures on an example of stereological analysis of selected rock structures. Examples of such studies are the analyses of sandstone from the Rudna mine (Bodziony et al., 1979) and Lower Silesian coals from the Thorez mine

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(Kraj and Ratajczak, 1989), measurements of spatial orientation of granite discontinuities (Kraj and Kruszyński, 1981), stereological analysis of traces of intercrystalline and transcrystalline cracks observed on thin sections of various rock types (Bodziony et al, 1993). The beginnings of studies on automation of rock structure measurements by using methods of image analysis go back to the 1990s (Młynarczuk, 1999). The full automation of measurements is an unusually task due to high degree of complication and wide variety of rock structures (Mlynarczuk, 2008). However, the use of image analysis algorithms allows the studies to be quick. An important feature of such methods should be its universality and usability not only to individual photographs but also to large series of images.

In recent years, the development of network services changed the way of data gathering and accessing. They became no longer connected with a computer or data carrier but became the open-access resources stored on network servers as databases. These changes apply also to data in the form of digital images. Such tendency induces a change in approach to the way of analysis and interpretation of data contained in digital images. It seems that the image analysis systems being currently available on the market do not keep a pace with changes mentioned above, and still offer a possibility of the image analysis on a local computer only, while reducing the database support to importing a desired image from a database, performing appropriate operations on a local computer, and (possibly) writing the obtained result to the database. However, it seems that the feature of the automatic image analysis systems relies on integrating them with the database systems and developing such technologies that enable the image processing and analysis to be moved directly into the systems compatible with network servers. The approach consisting in leasing of the virtual disc and computational space for customers who want not only a store but also process large-sized data sets in a distributed and mobile way becomes more and more popular among commercial providers. The question of leasing of a dynamic number of computer resources is known in the literature under the name of cloud computing. In this paper, the results of efforts targeted at creation of a system enabling analysis of digital data in a homogenous database environment are presented. The proposed system allows database technologies and statistic software to be used to do complex analysis based on microscopic rock images. It was shown that such approach enables the determination not only simple parameters but also those requiring advanced and complicated algorithms of mathematical morphology to be programmed.

Experimental studies

The idea of data processing and analysis by using database technologies

Image processing is a well-known dynamically developing discipline. In this paper its basic issues will be omitted, because of available publications of other authors (Gonzalez and Wintz, 1987; Serra, 1982; Tadeusiewicz and Korohoda, 1997).

In computer image analysis the purpose of transformations is most often to gain a properly segmented binary image. To obtain such image a series of transformations of the input image is carried out. As a result a contrast imaging is obtained where objects are clearly distinguishable from the background. This result is a starting point of measurements of stereological analysis for all parameters under examination. A series of transformations of the input image are made, to get this image. These transformations are in most cases defined and programmed in the computer image analysis systems, and the role of the observer is to determine the correct sequence and the correct parameters with which these transformations are called. This approach is widespread to process and analyse the image. Despite its apparent simplicity, it requires a thorough knowledge of the field of image processing and analysis and also high programming skills. The analysis of some of the images is very difficult to implement and sometimes even impossible. In recent years, many works have been reported by stating effective methods of computer image analysis to describe the geometrical structures of rocks (Petruk, 1989; Serra and Mlynarczuk, 2000, Mlynarczuk, 2006; Obara, 2007). Many of the publications on this subject deal with typical problems of mineral processing (Petruk, 1988a; Petruk, 1988b; Petruk et al, 1991 Tasdemir, 2008; Tasdemir et al., 2011) including Mineral Liberation Analysis (MLA) or QEMSCAN® (Miller et al., 1982; Pirrie et al., 2004; Goodalll et al., 2005; Fandrich et al., 2007). The authors of this paper are aware that the proposed method in comparison to MLA can be considered as less effective, but their intention was not to present a substitute for commonly used image analysis softwares, but to present an alternative, easily extensible methodology for image exploration of very large data sets. Literature on this subject is limited to description of the image processing only on the local computers and using images in the computer local memory or imported from databases. The authors of this paper believe that the future of image analysis involves the calculation of the total transfer of database servers. However, the desktop computers (in the form of desktops, laptops, tablets, smartphones etc.) will be used only to manage the calculations and to review the obtained results.

The idea of data processing and analysis by using database technologies

The database in the context of this paper is understood as a data set in the form of digital images gathered according to the rules of a specialized computer program referred to as database management system (DBMS). The database management systems is necessary for any course in the database systems or file organization (Ullman, 1985; Batini et al., 1992; Ramakrishnan and Gehrke, 2000). The detailed description of the structure and performance issues of the proposed system is available in literature (Ladniak et al., 2013a; Ladniak et al., 2013b). As mentioned above, the database environments were used so far mainly as containers of large amounts of data – e.g. images. By moving the problem of image processing and analysis directly to the database servers, that are fully compatible with network servers it will be possible to increase mobility, widen the range of application, make workspace accessible for other users without intervention in a complicated catalogue structure. The realization of such approaches enable also considerable reduction in the number of necessary programs used for the full analysis of two-dimensional (2D) data.

The use of the mechanism of the user defined functions in the database environment gives the user complete freedom in creating his/her own image processing operations and algorithms, including advanced ones. These algorithms were created by the authors for the purpose of this study. The absolute freedom in designing a database schema should be here emphasized. The stored images can be taken out by DMBS for user's request, processed and the results can be placed into a result table. Any number of operations can be involved each time in processing. This may be either a single operation that builds a complex algorithm or a set of cyclic image processing operations. Any number of input images can be processed. In addition, it is possible to write images being partial solutions in the database. The mechanisms used allows easy reference also to these images what is of the importance to the creation process and verification of proper operation of new image processing algorithms. Information flow and schematic context of analysis for the presented example is given in Fig. 1.

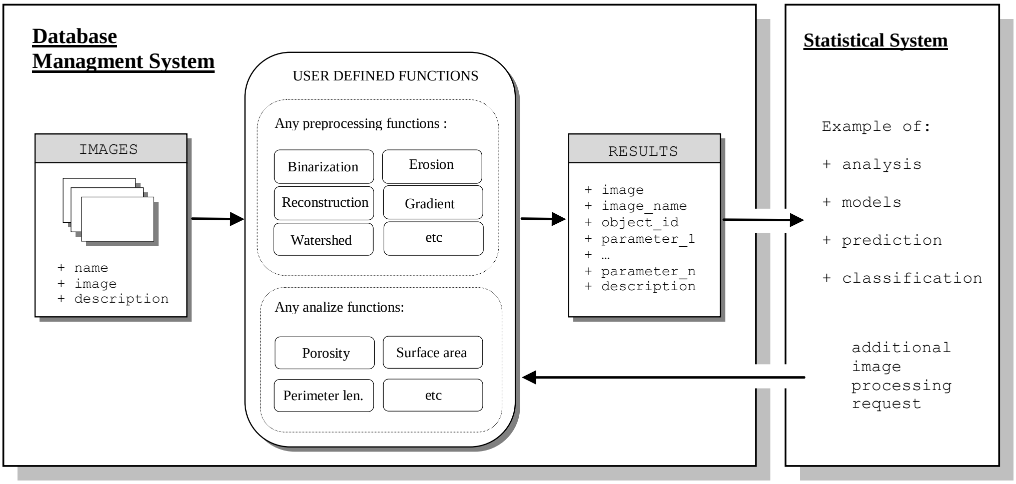
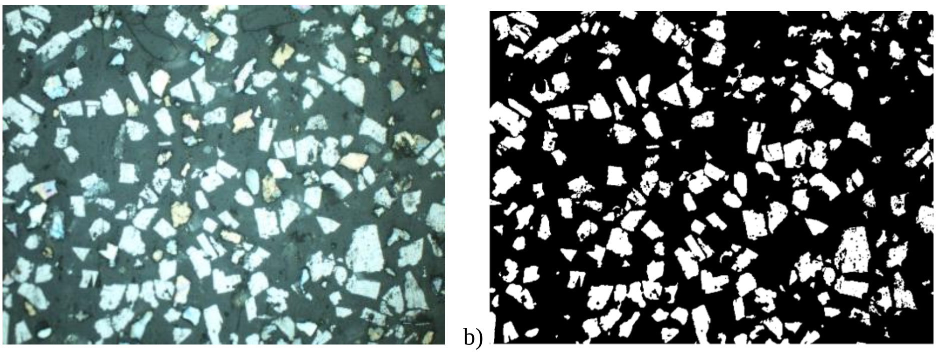


Fig. 1. Proposed schematic process information using database technology and statistical tools

The application of the proposed solution enables construction of knowledge base of very large number of parameters. This can be used in the next step in the statistical data analysis. There are many tools for the whole process of converting data into usable knowledge. In a study described here a Waikato environment for knowledge analysis (Weka) was used. This is an open source software under the general public license (Chuchro and Piorkowski, 2010). The possibility of direct communication with a database system and graphic presentation of data were utilized in this software. Thanks to provided communication with a database user's request for image processing is sent directly by doing the queries of a structured query language (SQL). In practice, it indicates a capability to run image analysis routines directly from a statistical tool (for instance Statistica software), when the user sees a potential need for an additional analysis.

Realization of simple morphological transformations to retrieve information on grain size in copper concentrate

The described measuring methodology was implemented in detection of well contrasted grains in copper concentrate. The material was taken from the ore enrichment process in dense liquids. The grains obtained in this process were drowned in a glue and photographed by using an optical microscope at magnification 200x (Fig. 2a). In total 150 photographs of this preparation were taken for purposes of this study. For object detection purposes the information on the pixel grey levels for individual RGB colour components was used. The top-hat operation enabling the image background equalization was carried out. In the picture in Fig. 2a there are also pyrite particles (in yellow colors). They were excluded from the calculations. The individual color channels were then binearized. To remove measuring noise the morphological filtering, opening by reconstruction was performed. These operations allow to obtain the correctly segmented binary images (Fig. 2b).



a) b)

Fig. 2. Sample image of copper concentrate (a) and the result of its binarization (b)

In total 47,267 copper grains were selected in the analysed photographs. The following parameters set were used to describe them.

- Surface area was calculated by summing all pixels within the object and multiplying by the calibration factor (this value depends on the magnification of optical microscope and for copper concentrate photographs is 0.82*)*.
- Average object chord length was calculated using the average length of the intersection between the segmented image and the regular set of horizontal/vertical lines.
- To determine approximate length of object perimeters the eroded object was subtracted from the original one.

- Volume diameter (equivalent) *d*, that is the diameter of a sphere having the same volume as the grain under consideration (Drzymala, 2009) was calculated by using the mathematical formula (for 2D images):

$$d = 2\sqrt{\frac{S}{\pi}}$$

where *S* is the surface area of a grain, $\pi = 3.14$.

The results are given in Table 1 and the histograms for chosen parameters are shown in Fig. 3. In fact, it is possible to measure a much larger set of object parameters.

Table 1. Values of basic statistics of copper concentrate parameters

	Surface area μm^2	Chord length µm	Perimeter length µm	Equivalent spherical diameter µm
Mean	482	11.14	130	20.74
Std-Dev	579	7.01	112	13.58

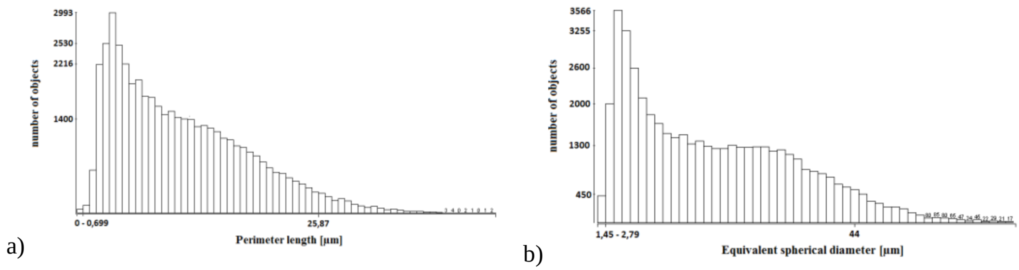


Fig. 3. Histograms of perimeter length (a) and equivalent spherical diameter (b) for copper concentrate – graphical visualization in Weka

Algorithm for grain segmentation in thin sections

At the next stage of this study it was decided to check measuring capabilities of the proposed database system on the significantly more complex structures. There following rocks were selected: dolomite from Redziny (hereinafter referred to as DZR), quartzite from Wisniowka (KZW), dolomite from Laskowa Gora (DZLG) and sandstone from Tumlin (PZT). For each of the rocks the photographs of 150 randomly distributed measuring fields were taken under optical microscope equipped with a specialized CCD camera (Mlynarczuk, 2008) at magnification 100x (see Fig. 4).

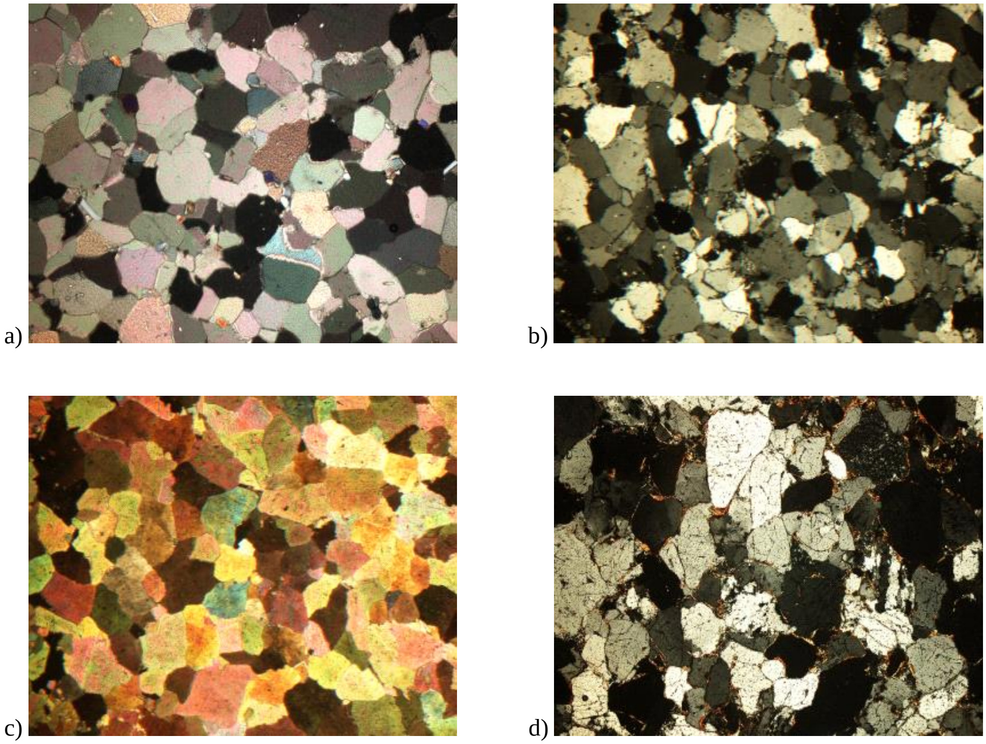


Fig. 4. Sample images of dolomite from Redziny (a), quartzite from Wisniowka (b), dolomite from Laskowa Gora (c) and sandstone from Tumlin (d)

To analyse grain sizes in rocks under examination, the advanced algorithm described by Mlynarczuk (2008) was employed (Fig. 5). A method of grain size segmentation based on the watershed transformations was proposed in this algorithm. The main idea is to find such input image transformation to obtain two output images: masks (marked MASK in Fig. 5) and marker image (denoted MARKER in Fig. 5). The mask is created as the maximum gradients of the individual RGB channels of an input image under investigation. The marker image (much more difficult to obtain) is determined on the basis of opening by dynamics of grey levels followed by binearization and opening by reconstruction. The dynamics parameters are the variables in this algorithm and are different for each of rocks under examination. The detailed algorithm used in application of the described procedure is presented schematically in Fig. 5. It should be noted that for the PZT additional photographs taken with a polarizer were analyzed and they were used as a basis for getting information on binder location in the examined images. An example of the result of segmentation for the selected DZR photograph is presented in Fig. 6. Such images were then used for further measurements describing the size of individual minerals forming rock.

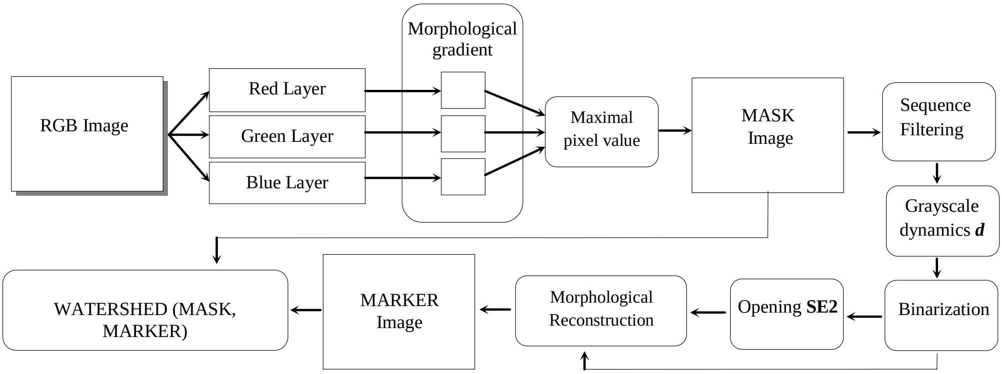


Fig. 5. Diagram of algorithm for grain segmentation

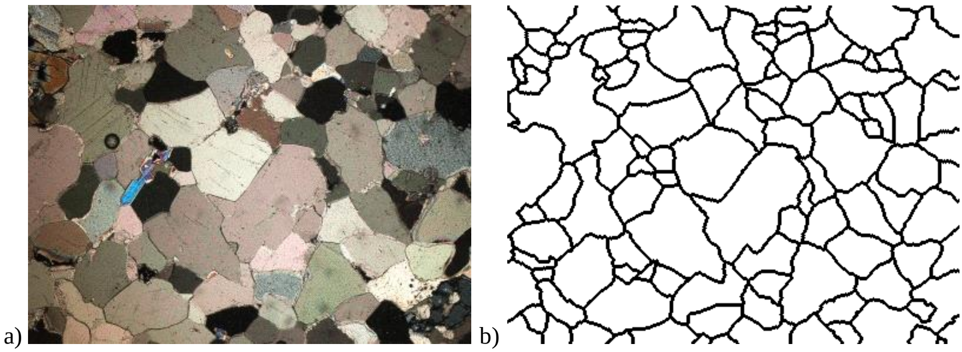


Fig. 6. Image of DZR (a) and the result of its segmentation (b)

Analysis results

The measurements of dynamic parameters of grey levels and size were made for each grain identified with the described algorithm. A set of 600 photographs was used. As a result, a very large knowledge set related to basic graining geometry of rocks under examination is obtained. The following amounts of grains were selected: 14,800 dolomite grains from DZR, 8,795 dolomite grains from DZLG, 18,539 quartzite grains from KZW and 12,588 quartzite grains from PZT. All measurements were made automatically by using the database technologies (Table 2). The user was required only to parameterize a request for type and range of computations to be done. The histograms of individual equivalent spherical parameters and values of basic statistics are shown in Fig. 7.

Table 2. Values of basic statistics of DZR, DZLG, KZW, PZT parameters

	Rock	Surface area µm^2	Chord length µm	Perimeter length µm	Equivalent spherical diameter µm
Mean	DZR	40044	126.92	896.36	193.52
	DZLG	67582	178.44	1170.85	265.37
	KZW	31647	123.62	848.06	187.23
	PZT	47470	130.60	934.73	198.71
Std-Dev	DZR	69402	72.53	686.20	116.53
	DZLG	61474	87.67	670.33	125.01
	KZW	30217	46.86	849.06	72.39
	PZT	99538	84.23	922.99	144.77

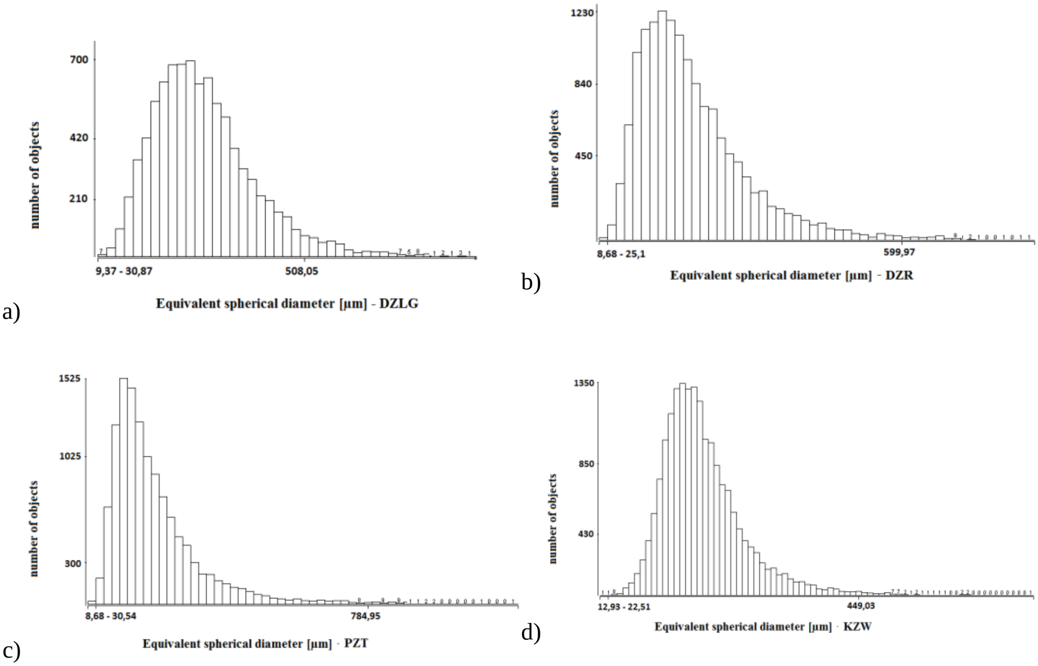


Fig 7. Histograms of individual equivalent spherical diameter for (a) DZLG, (b) DZR, (c) PZT and (d) KZW, graphical visualization in Weka

Conclusions

In this paper, the possibilities of extending database systems using the methods of image analysis and mathematical morphology were presented. Therefore, the authors of this paper proposed a system that offers storage and analysis of raster images on the database side, while providing possibility for easy exploration of such data by using a common statistical software. The Authors' intention was not to present a substitute for the commonly used image analysis software, but to present an alternative methodology for exploration of very large data sets, and perhaps in the future, construction of fully automatic systems capable to learn and recognize the examined rock structures. The idea of the presented system allows the application of database technologies and statistical software not only for simple strictly defined transformations, but also for highly complicated authorial algorithms retrieving information contained in the microscopic images of rocks. The presented studies demonstrated suitability of the proposed methodology.

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