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The application of the automatic search for visually similar geological layers in a borehole in introscopic camera recordings

Mariusz Młynarczuk [a,*], Magdalena Habrat [a], Norbert Skoczylas [b]

[a] AGH University of Science and Technology, Department of Geoinformatics and Applied Computer Science, Poland
[b] Strata Mechanics Research Institute of the Polish Academy of Sciences, Poland

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ABSTRACT

The paper discusses the opportunities for obtaining valuable knowledge on the basis of video recordings from introscopic cameras, used to investigate mining boreholes. It also presents an original approach to the task of building a system, which would facilitate the process of searching for visually similar geological structures, and which would constitute an alternative to time-consuming manual profiling. The analysis of measurements performed with an introscopic camera is based on a feature space defined by the Authors, and uses the methods of mathematical morphology for processing video sequences, as well as data analysis for the decision-making process. As a result of the research, it was established that the methods of image processing and data analysis are an effective tool when it comes to automate the decision-making process with regards to the determination of the visual similarity of geological layers which make up a given, investigated area of a borehole. The methods in question yield a high percentage of correct decisions.

1. Introduction

The technological progress in the area of mining and geotechnical works calls for thorough identification of rocks and rock massifs. This is done by drilling exploratory boreholes with the purpose of improving safety in the area of mining exploitation, e.g. by identifying the types of rocks making up the investigated rock mass, as well as by localizing structural discontinuities within the borehole (cracks, voids, caverns, areas characterized by lower rock cohesion, etc.). The knowledge of geological structure, obtained in this way, is essential when it comes to expert evaluations whose purpose is to identify the threats that may occur in a given area [1–3]. The dynamic development of computerization contributed to the flourishing research into the automatization of measurements in boreholes by means of various methods of acquisition and analysis of digital images. The fact that image acquisition devices such as digicams are these days increasingly more accessible paves the way for their common and fully justified usage also in the mining industry [4,5]. An example of the application of such a device in mining is investigating the structure of a rock mass involving profiling an exploratory borehole by means of an introscopic camera. An irrefutable advantage of this method is the fact that such a measurement is simple and easy to perform. The growing popularity of image acquisition devices results also in a considerable increase in the amount of information included in video recordings, provided by various industries, e.g. the mining industry. In practice, such data is obtained in the course of a lengthy penetration of an exploratory borehole, which frequently lasts for hours on end. The complete analysis of this data (recreating the geological structure of the borehole, detecting discontinuities, etc.) is often performed manually, by human beings. Such a

* Corresponding author.
E-mail address: mlynar@agh.edu.pl (M. Młynarczuk).

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situation necessitates the automatization of the process of extracting knowledge from this type of visual data [6,7]. The Authors investigate the possibility of an automatic analysis of video recordings of an exploratory borehole penetration by presenting a set of certain feasible steps, which are based on both the methods of digital image processing and analysis, and the methods of data analysis, such as clustering or unsupervised classification. The problem being solved involves an attempt to classify the visual data according to a pattern specified by the user. The pattern has a form of a digital image in this case, it is a selected screen from a video recording. The goal is to find visually similar rock images in the investigated material. The idea proposed by the Authors is a system, which facilitates the decision-making process during an attempt to recreate the geological structure of a borehole. At the same time, the Authors are aware that full automatization of such a process (e.g. the recording of the penetration of a borehole with a camera in real light) is a difficult task, characterized by knowledge deficiency, and often requires an additional interference of the user. This is due to the diversity, blur, and distortion of the pattern. Proposed solution is based on a combination of digital image processing, data analysis and non-parametric classification methods, which and are a well-known, dynamically developing discipline, so its basic issues were omitted here, while referencing referring to the existing publications.

2. The method of the automatic description of the layers in a borehole by means of video sequence analysis

The Authors intended to develop a method that would help a mining geologist when it comes to the process of identifying rocks making up a rock mass and detecting all types of rock mass discontinuity, performed solely on the basis of the evaluation of video recordings provided by research instruments prepared for this particular purpose (an introscopic probe). The advantage of the discussed instrument, in comparison with other measurement methods and tools, is the fact that this instrument equipped with a video camera enables visual detection of the types of rock layers occurring in the investigated area, as well as detection of any discontinuities. So far, under mining conditions, making the use of such equipment has involved recording the image from the inside of the borehole, and then viewing (unautomatically) these recordings by an examiner, usually in order to track down some potentially dangerous areas. The Authors would like to help researchers in this respect, and thus suggest the application of a computer system facilitating the decision-making process, based solely on visual differences in the image recorded by the camera.

A fully automatic analysis of rock videos is a difficult process due to the lack of regularity in the macro scale, visual description of the research material. A relatively high effectiveness in the process of the automatic recognition of rocks is revealed by the methods of machine learning with a precisely selected and prepared learning sequence, which is a fair representation of the analyzed population. Despite of the fact that the Authors of research [8–10] achieve high efficiency in that respect (often reaching 98%), such an approach seems impossible to be adopted whenever there is a need to explore a video sequence that have not been described in any way. In such cases, it becomes impossible to isolate a representative learning sequence, as no detailed information about it is available. Thus, the Authors propose using non-model methods that combine data exploration to obtain knowledge about analyzed rock borehole. The search is based exclusively on an image request, to which the system respond with a set of images presenting visually similar rocks (also called QBIC system – Query By Image Content [11]). The proposed construction of the system (Fig. 1) is based on the application of image analysis and artificial intelligence concepts. The very process of inference, in turn, makes use of the methods of data classification and grouping. The Authors have already undertaken the topic of searching of visually similar microscopic geological images [12]. We have provided a detailed description of proposed algorithm along with the discussion of its parameters. For define set of texture parameters, we compared the effectiveness of data reduction methods. Efficiency of popular cluster analysis methods in the area of defining an image similarity as a distance function in predefined feature space were also compared. Based on the conclusions, the proposed algorithm was here adopted for macroscopic data of mining origin. This data, as far as a diverse appearance is concerned requires defining the new parameters of an algorithm.

2.1. The description of the analyzed video material

The research material are digital recordings from an introscopic camera. The test head is equipped with a CCD camera and a specially designed optical system. The device comes with a macro mode. The camera is placed inside a pipe-shaped casing, so that it can be moved in a borehole where diameter is 65 mm. The device makes it possible to register video sequences in the resolution HDTV 720p (1280×720), with the speed of 60 frames per second. The inside of the investigated borehole was lit up with a set of LED diodes, powered by a lithium-ionium battery. The video material registered by the camera was recorded on a SD memory card with the capacity of 8 GB, using the H.264/MPEG-4 AVC standard. Such parameters made it possible to register the material, which was approximately 1 h long.

The measurement discussed in the present paper was performed in an outgassing borehole in the Zofiwka hard coal mine located in the Upper Silesian Coal Basin (Poland). In order to ensure the control over the movement of the probe, special wedges made of solid beech wood were installed inside the borehole (Fig. 2). Each wedge was equipped with a steel bar of the diameter of 10 mm. The bars served the purpose of stabilizing the wedge inside the drilling rod while it was moving towards the bottom of the borehole. The length of the borehole was 80.5 m, and its diameter was 65 mm. The tests were performed after the drillings ended, and lasted for several hours [13,14]. The result was a video material registered in the visible spectrum. Selected (one after another) frames from