AUTOMATION OF DATA ANALYSIS METHODS FOR METALLOGRAPHIC RESEARCH OF MATERIALS

Poturaev Petr Sergeevich
Post-graduate
Perm State National Research University
Kozlov Danil Anatolievich
Candidate of Chemical Sciences, Associate Professor
Perm State National Research University
Medvedeva Natalia Alexandrovna
Student
Perm State National Research University

Abstract. This article is devoted to the development of methods for optimizing the processing of experimental data of metallographic analysis. An algorithm for the initialization of objects in the image based on image segmentation has been developed, which can be used in the analysis when calculating the parameters of objects of the microstructure of alloys and metals. The efficiency of this method was tested by analyzing the microstructure of a magnesium-based alloy. The accuracy of the method makes it possible to determine defects and foreign phases in the microstructure of materials.
Keywords: software, data processing, metallographic analysis, information technology, python.

At a given moment, digital technologies, if not in all areas of human activity, then at least in the vast majority of them. The market of IT-technologies in various industries over the past 5-10 years has a general increasing trend (Fig. 1), and therefore the demand for software is steadily growing. Here one cannot fail to note the increasing popularity of instrumental software, that is, software products (SP) that perform, as the main task, the processing and analysis of large amounts of data [1].

In the field of materials science, more and more complex areas of materials research are being discovered every year, and therefore the load on the human factor only increases. Thus, the method of metallographic analysis, aimed at studying the macrostructure of metals and alloys, takes significant time resources at the stage of processing the obtained experimental data. In order to optimize and accelerate the process of studying the microstructure, there is a need to create highly efficient automated software tools for image analysis.

This article is devoted to the development of the main algorithms for a potentially realizable software product, the main task of which will be to automate the processing of data obtained during metallographic analysis. Today there are several software products, the main functionality of which is aimed at processing metallographic analysis data (Fig. 2). The overwhelming majority of such SP have modest expert assessments for one or several quality parameters, such as the quality of the user manual, functionality and ergonomics [5].

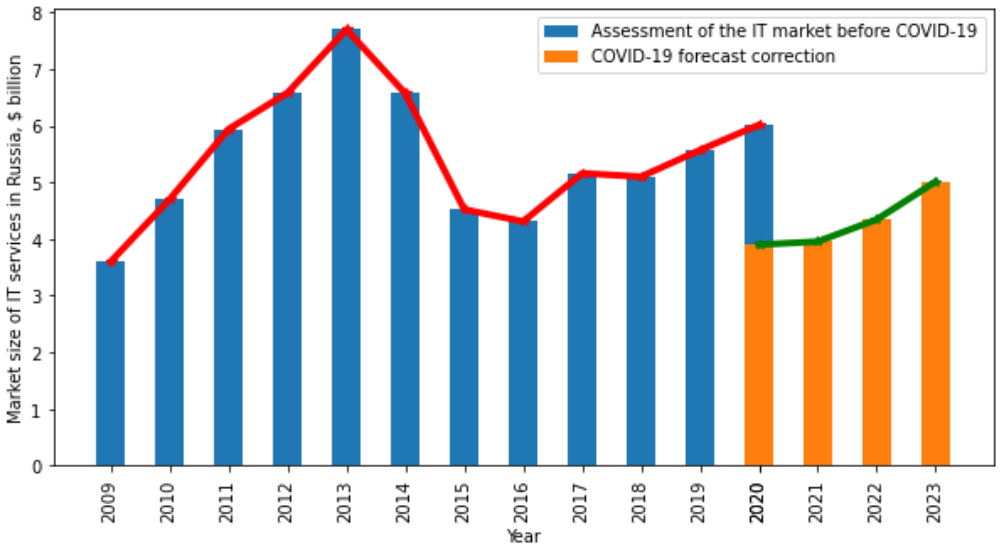


Fig. 1 Assessment and forecast of the growth of the IT services market in Russia for the period from 2009 to 2023

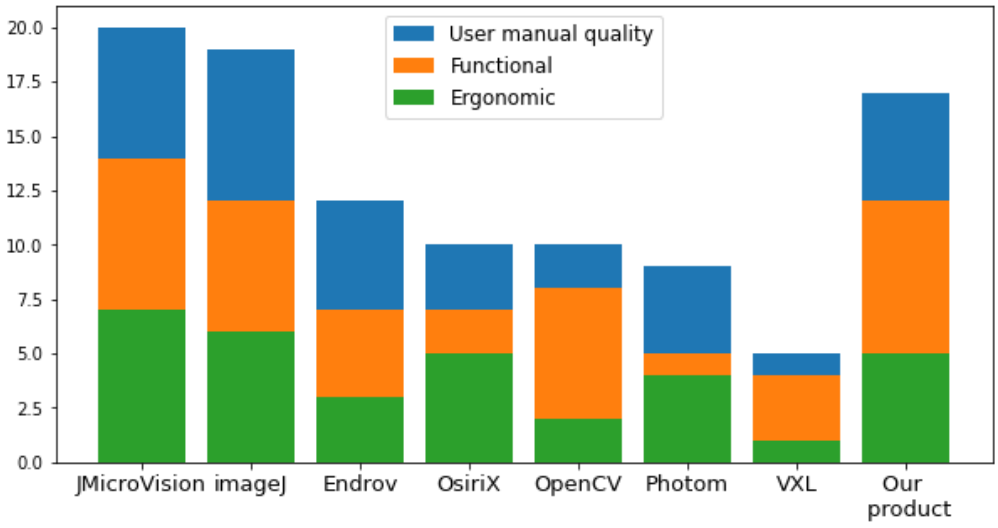


Fig.2 Ranking free software for image analysis using the method of expert estimates [5]

A tool for analyzing not only images, but video series, which has an open source code called OpenCV, has high functionality, for the absolute lack of a graphical user interface.

Therefore, our analysis algorithms were based on the main methods of this functional package with the addition of user interface elements.

The algorithms are mainly implemented using the python programming language, as well as C ++ and Java. The purpose of the described algorithms is to process images obtained using a metallographic microscope, in our case it is an «OLYMPUS BX51M» optical microscope. The principle of operation of the algorithms is shown in the diagram (Fig. 3).

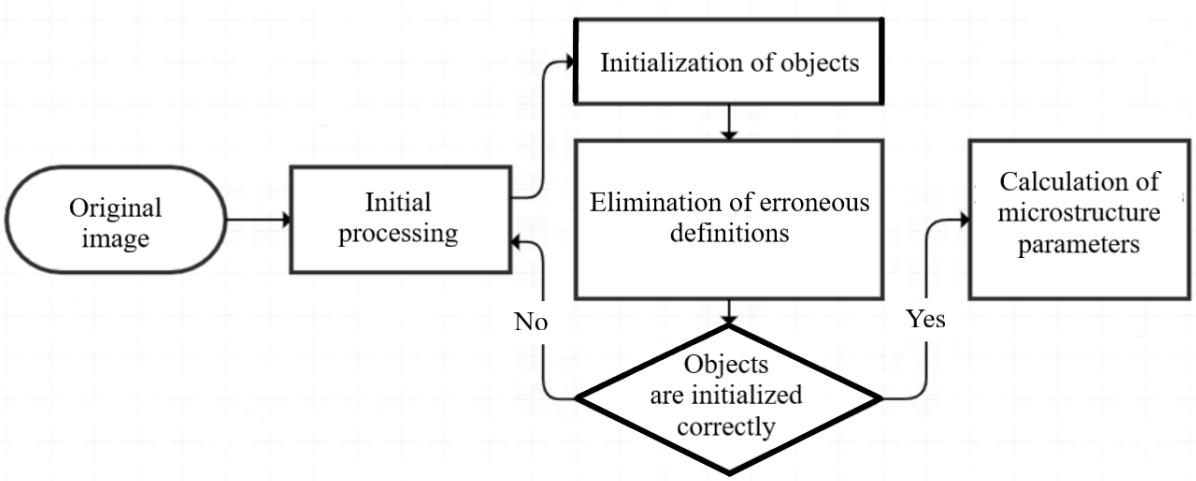


Fig. 3 The scheme of the image analysis algorithm

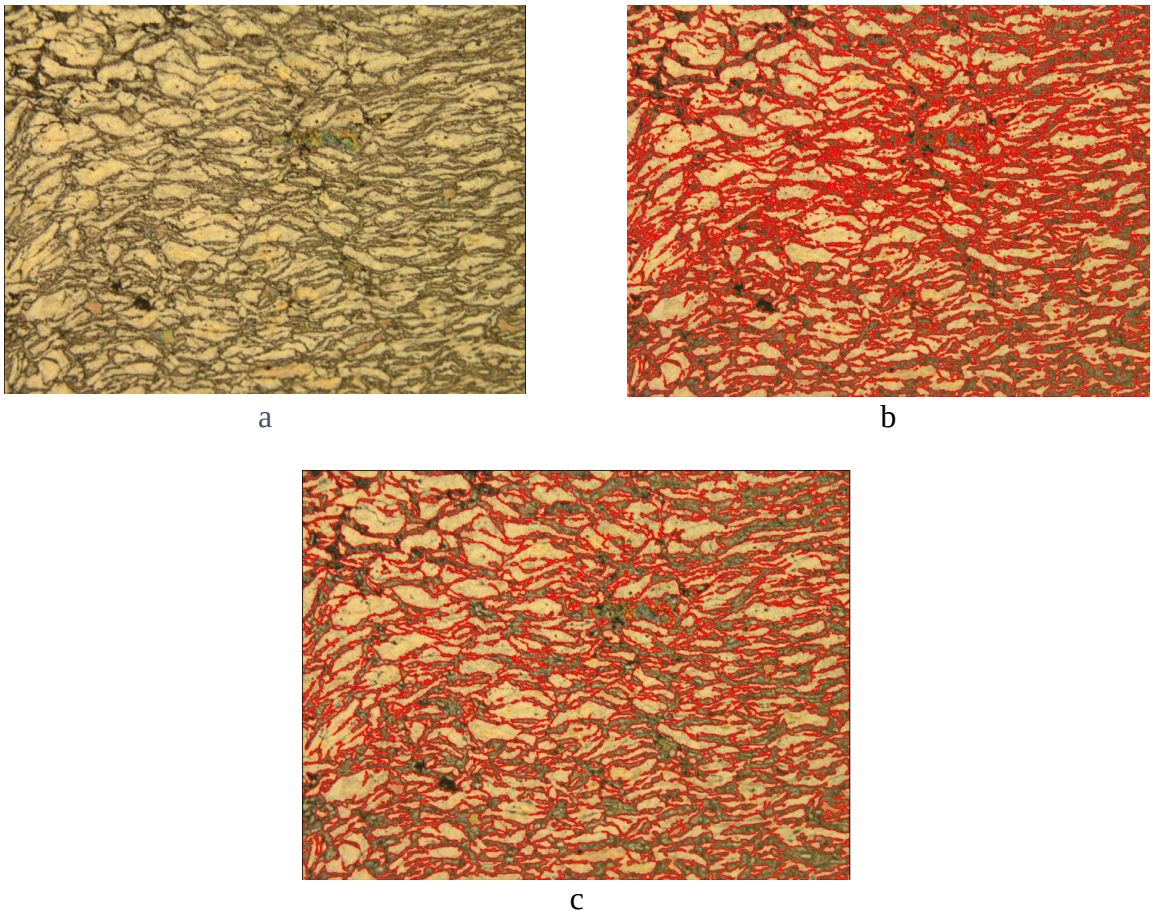
At the stage of initial processing, the image is divided into separate color channels [2, 3]. These channels are used to automatically determine the threshold value of the color characteristics of the boundaries of the desired objects. Based on this, the image will be converted to a black and white variation of the original image [4].

The initialization of the contours is carried out according to the approximation algorithm [4], while for all extracted contours their complete hierarchy is preserved. Despite all the transformations, when defining the contours of objects, there will still be false definitions or noise. Their elimination is carried out due to various variations in the threshold values of the intensity of the chromaticity of the pixels of the original image. At the same time, about 95% of all erroneous definitions are eliminated, which indicates the high accuracy of the implemented analysis algorithms.

The algorithm described and implemented by us is quite correctly able to determine such objects of the microstructure of metals and alloys as grains, defects, as well as objects of third-party phases of the material, for example, inclusions of carbon in steels of various grades [5, 6].

In the images (Fig. 4) it is not difficult to see the result of this algorithm when analyzing a micrograph of an alloy based on magnesium.

The result of the work can be fully considered relevant to reality, and the data obtained can be used in further calculations. Thus, the data obtained can be visualized in the form of a diagram of the distribution of the number of grains depending on their area (Fig. 5a). Diagrams of this type allow us to judge the dimensional characteristics of the microstructure of metallic materials, which is important in the overall assessment of the suitability of the material in a particular industry.

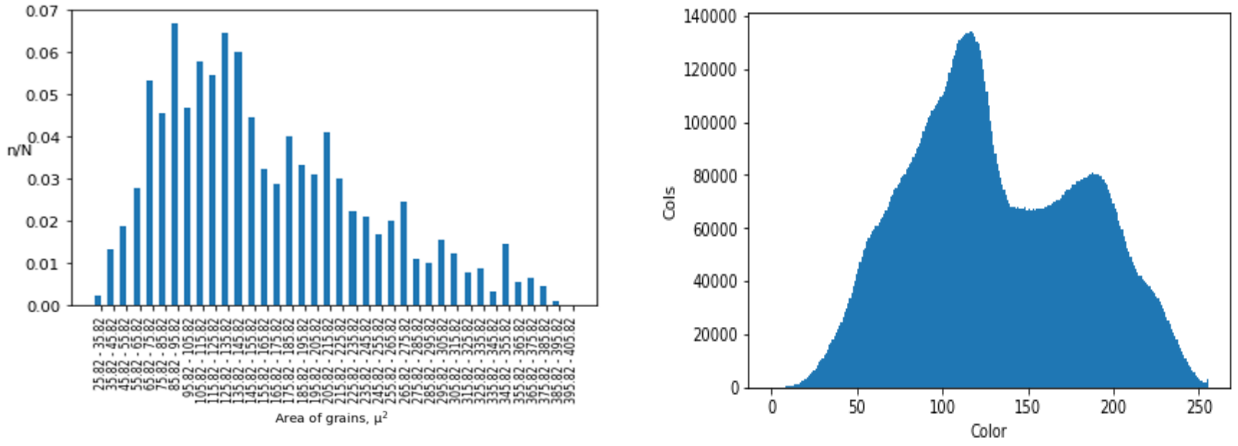


a b c

Fig. 4 Visualization of the algorithm for analyzing a micrograph of the surface of a magnesium alloy: a - the original image, b - initializing an object, c - noise elimination

As mentioned earlier, an algorithm for evaluating the phase characteristics according to the color parameters of the image of their surfaces is also implemented. A similar analysis method is based on the construction of a histogram (Fig. 5b) of the distribution of the number of pixels from the values of color values RGB (red-bue-green).

Based on such a representation of the microstructure image data, it becomes possible to approximately estimate the phase composition of the material, which has its advantages, for example, in the metallographic analysis of steels of various grades, as well as the automation of the determination of the steel grade itself.



a b

Fig. 5 Visualization of the results of microstructure analysis:

a - diagram of the distribution over the area of grains,

b - diagram of the distribution of the number of pixels from the value of the color intensity

Another important and promising method of analyzing microstructural functions is the algorithm for constructing and analyzing a 3D surface model (Fig.6). This approach will make it possible to optimize to a greater extent the analysis of the results of the microstructure necessary to assess the performance characteristics of materials.

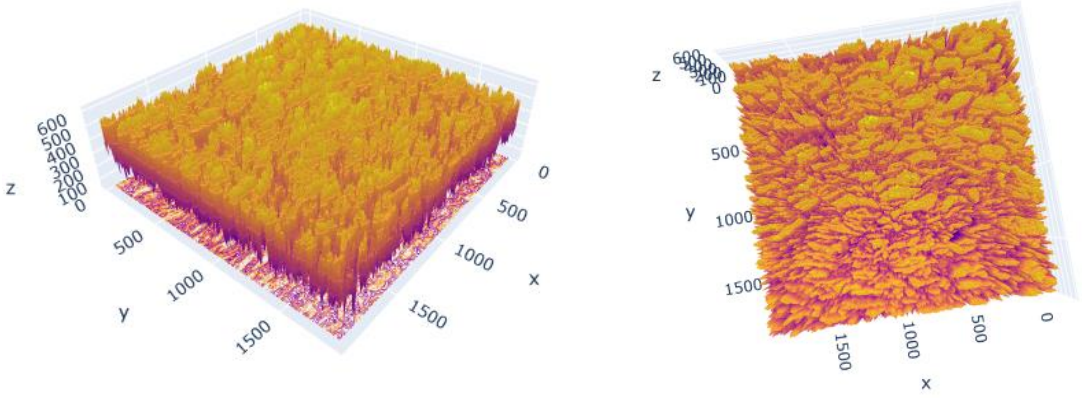


Fig. 6 Visual representation of a 3D-model of the surface of a material with a pronounced granular structure

Conclusion

The implemented image analysis algorithms significantly reduce the time spent on processing the data obtained as a result of metallographic analysis. In the future, such an approach contributes to the complete leveling of the human factor in attempts to determine the composition of the material and the parameters of its microstructure. Obtaining quantitative characteristics of the microstructure, such as, for example, the average dimension of the crystals of the material, or grains, the phase composition of the material, etc., will reveal the fields of application of metallic materials in various fields of industry.

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The authors declare no conflicts of interest.

References

1. Kim V.A., Bashkov O.V., Popkova A.A., Shpileva A.A., Zolotareva S.V., Belova I.V., Yemets N.E., Fundamentals of quantitative and computer metallography: study. Allowance, 2013, 133 p.
2. W. McKinney, Python for Data Analysis. Sebastopol: O'Reilly, 2017. 540 p.
3. Open Source Computer Vision Library. https://docs.opencv.org/master/index.html
4. Gafarov MF, Pavlova KP, Gafarova EA, Review of software products for metallographic analysis. Modern science: topical problems of theory and practice. Series "Natural and Technical Sciences". 2018. No. 11. pp. 69-73.
5. J. M. Li, Li L¨u, M. O. Lai and B. Ralph. Image–Based Fractal Description of Microstructures. Published by Kluwer Academic Publishers, 2003, pp. 1–273.
6. Rusanovsky, Matan & Beeri, Ofer & Ifergane, Sigalit & Oren, Gal. (2021). An End-to-End Computer Vision Methodology for Quantitative Metallography.