

AN ALGORITHM OF DIGITAL IMAGE PROCESSING APPLIED TO QUANTIFICATION OF GRAINS WITH DISCONTINUOUS BOUNDARIES

L.C.M. Pinto¹, V. Vasconcelos¹, W.L. Vasconcelos², J.C. Bressiani³

¹ CDTN, Caixa Postal 941, CEP 30161-970, Belo Horizonte, MG, Brazil

² UFMG, R. Espírito Santo 35, CEP 30160-030, Belo Horizonte, MG, Brazil

³ IPEN, Travessa R, Campus USP, CEP 05508-900, São Paulo, SP, Brazil

Introduction

A meaningful grain size measurement using computerized image analyzers requires that the grains be completely outlined by continuous black boundaries. An human operator would have no problem distinguishing visually the grains when making intercept measurement, but incomplete boundaries can cause problems for automatic image analyzers. To solve these difficulties usually sophisticated processing softwares based on artificial intelligence are employed [1]. This paper presents an alternative algorithm, called XPERT, to be used in quantification of grains with discontinuous boundaries by the intercept method. The algorithm, based on some hypothesis about the grain anisotropy and digital image processing techniques [2], was implemented in the Quantikov image analyzer [3] and applied to typical ceramographic images.

The XPERT algorithm

The computer algorithm (Figure 1) which automatically estimates the mean intercept of each grain was developed on the basis of assumptions about the grain shape. The ellipse is a geometric entity that can be used to model the grain anisotropy, depending on the relation of its half-axes. The proposed algorithm assumes that the grain boundary has nearly an elliptical shape. Let n be the chosen number of intercepts crossing the center of each grain. According to these assumptions, adjacent intercepts, s_i and s_{i+1} , should not deviate among them more than a maximum possible value, χ , obtained for a given ellipse as $\chi = \max[R_i]$, where i ranges from 1 to n . The \max is a mathematical operator numerically implemented and R_i is given by Equation, (1) where a and b are the half-axes of the ellipse.

$$R_i = \frac{s_{i+1}}{s_i} = \sqrt{\frac{b^2 \cos^2 \left[\frac{(i-1)\pi}{n} \right] + a^2 \sin^2 \left[\frac{(i-1)\pi}{n} \right]}{b^2 \cos^2 \left(\frac{i\pi}{n} \right) + a^2 \sin^2 \left(\frac{i\pi}{n} \right)}} \quad (1)$$

Based on estimations of χ , the XPERT algorithm selects the *right* intercepts, i.e., the intercepts that do not traverse the grain boundary. The estimated wrong intercepts should correspond to incomplete boundaries and are not taken into account on grain size estimations.

```

Begin of the Xpert Algorithm.
Set  $n$ , the number of intercepts in each grain.
For each grain do:
Begin.
Estimate  $a$  and  $b$  {graphically }.
Calculate  $\chi$  {equation (1) }.
Store all intercepts in a vector  $all(n)$ .
Set  $i = 1, j = 1$  and  $right(1) = all(1)$ .
While  $i < n$  do:
Begin.
{select right intercepts}.
While  $all(i+1) \leq \chi \cdot all(i)$  do:
Begin. Set  $i = i+1, j = j+1$  and  $right(j) = all(i)$ . End.
{eliminate wrong intercepts}.
While  $all(i+1) > \chi \cdot right(i)$  do:
Begin. Set  $i = i+1$ . End.
End.
{estimate  $\bar{\lambda}$ , the mean intercept of the grain}.
set  $\bar{\lambda} = \frac{1}{j} \sum_{k=1}^j right(k)$ .
End.
End of Algorithm.

```

Figure 1 - XPERT algorithm.

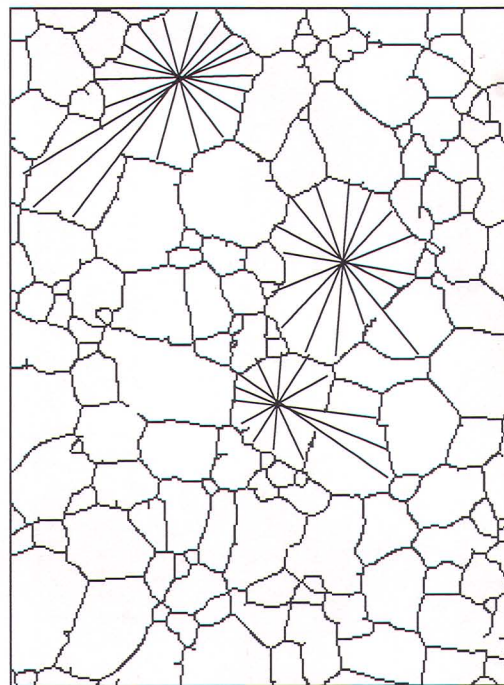


Figure 2 - Application example.

Implementation of the algorithm and example of application

The algorithm was implemented in the C language in the Quantikov image analyzer [3] under Windows95™ environment. The application of the algorithm to a typical ceramographic image with discontinuous grains is illustrated on Figure 2. The mean intercept of each grain, obtained by this algorithm, present maximal errors that ranges from 10% to 30%, when compared to the values estimated by area calculations using manually reconstructed images. Some changes are being implemented in order to use the algorithm to grain boundary reconstruction.

Conclusion

The proposed algorithm is an useful alternative for size estimation of grains with discontinuous boundaries and it is now available on Quantikov image analyser.

Acknowledgments

The authors thank FINEP/PADCT for financial support for this research.

References

- [1] FRIEL, J.J., GREENHUT, V. and OLIVER, J. Computer-aided imaging in ceramics. American Ceramic Society Bulletin, 73(3):73-8, 1994.
- [2] JOHNSON, N.L. Advanced Graphics in C. Programming and Techniques. Osborne McGraw-Hill, 1994.
- [3] PINTO, L.C.M. Quantikov - Um analisador microestrutural para o ambiente Windows™. Ph.D. Thesis, USP, IPEN, São Paulo, Brasil, 1996.