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

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## 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, $\chi$, 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.

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

Based on estimations of $\chi$, 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 χ {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) ≤ χ . all(i) do:
    Begin. Set i = i+1, j = j+1 and right(j) = all(i). End.
  {eliminate wrong intercepts}.
  While all(i+1) > χ . right(i) do:
    Begin. Set i = i+1. End.
  End.
{estimate λ̄, the mean intercept of the grain}.
set λ̄ = (1/j) Σ_{k=1}^{j} right(k).
End.
End of Algorithm.
```

Figure 1 - XPERT algorithm.

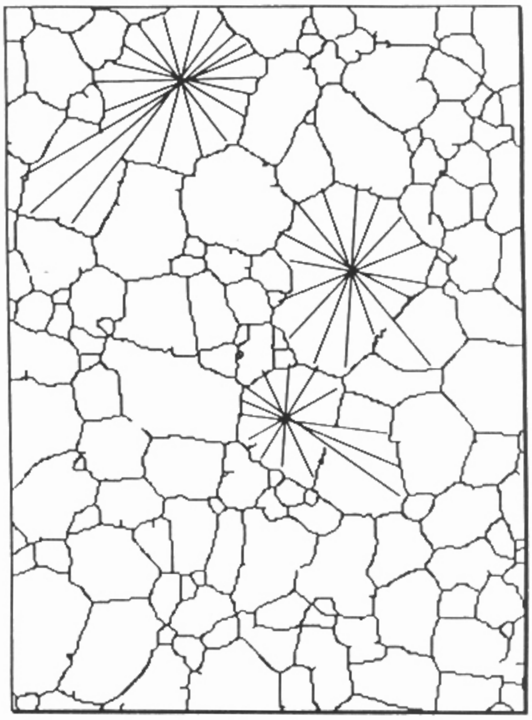

Figure 2 - Application example.

**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.

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