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EDGE DETECTION AND FILTERING APPROACH DEDICATED TO MICROSTRUCTURE IMAGES ANALYSIS

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Abstract

The processing of microstructure images dedicated to detection of the borders between material grains is still a difficult task. It is basically caused by a superimposed noise in form of visible scratches and micro inclusions. Thus, the analysis of the microstructure photographs is performed manually in most cases, which is time consuming for numerous set of images. To avoid this problem the approach of automated images processing has been proposed. This approach consists of two parts i.e. edge detection, designed and implemented using Canny Detector method (Ritter & Wilson, 1996) and data filtering, based on Particle Dynamics method (Rauch & Kusiak, 2005a). The results obtained from this approach is in form of new microstructure image with smoothed grain areas and precisely detected grain borders. Such effect allows to optimize further analysis of material structure including e.g. Watershed (Haris et al., 1998) edge fulfilment or statistical calculations of average grain size. The paper presents basic assumptions of proposed approach and details of both algorithms. The results of the analysis of microstructure images using edge detection and filtering algorithms are presented.

Key words: images analysis, material microstructure, grain analysis, data filtering

1. INTRODUCTION

The automated analysis of images plays important role in a wide range of applications. One of such fields of interest is processing of microstructure images used to determine material grains borders, which is required to perform statistical calculations or prepare material model for Finite Element Method (FEM) simulations. However, in all these applications the preprocessing stage, which includes edge detection in material structure, has to be completed.

The microstructure images, in most cases, consist of a set of various shapes with different sizes, what affects a final efficiency and reliability of the results obtained after images preprocessing. Moreover, most of the images possess superimposed noise in form of dark spots originating from various chemical elements (micro inclusions) or scratches inside analyzed material. Most of currently applied algorithms dedicated to edge detection or image segmentation e.g. Canny Detector or Shen-Castan (Nixon & Aguado, 2002) do not cope with these problems, giving the unsatisfactory results. Usually, this problem is solved by application of filtering algorithms, which try to remove additional noise from images. The most widely used algorithms are based on convolution approach including filters of median, Sobel, Robets, etc. (Tadeusiewicz & Korohoda, 1997). However, the main drawback of these techniques is performance of locally focused calculations. Due to this fact, each pixel of the input image is denoised in the same way, resulting in unwanted phenomenon of fuzzy areas of edges. Thus, the tests performed with application of traditional smoothing algorithms do not success as well. On the other hand the application of other filtering methods like e.g. neural networks (Haritopoulus et al., 2002) or wavelet analysis (Rauch et al., 2004) requires user's manual interaction.

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The paper presents the solution of the problem mentioned above, in form of the filtering system. This system is based on the combination of two different approaches, namely the modified Canny Detector algorithm used to edge detection and the Particle Dynamics filtering (PD) method dedicated to automated denoising of images (figure 1).

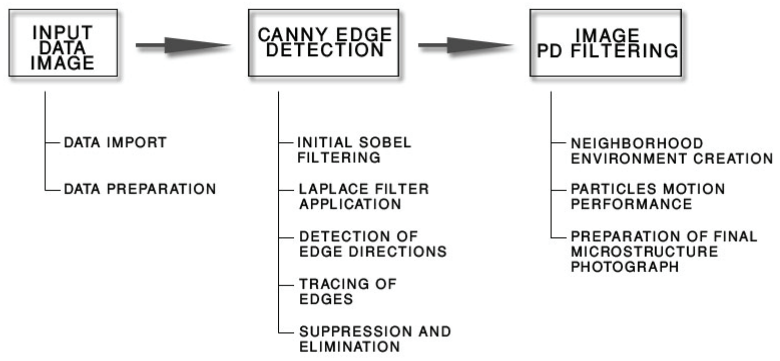

Fig. 1. The diagram of PD filtering system, based on edge detection and filtering algorithms.

2. PD FILTERING SYSTEM

The implementation of PD filtering system consists of the modules characterized by the following functionalities: data preparation, edge detection, neighbourhood establishment and filtering based on PD technique (Rauch & Kusiak, 2005b).

The first of these modules is responsible for an import of a data from image file and a processing of its structure to obtain the form, which can be analysed by subsequent algorithms. There are no constraints related to the extension of input files, resolution of the images or their colour palette. The system is independent of the mentioned features due to the application of special module, which converts all of the images into a greyscale mode. Afterwards, the process of data normalization is applied by using the following equation:

$$x_{norm} = \frac{x - min}{max - min} \qquad (1)$$

where x is the initial value, x_{norm} is a normalized value and min, max are minimum and maximum values in each dimension of the data. Image data is treated as the three dimensional data (figure 2a), where two of the dimensions define position of the pixel and the third dimension describes the pixel's value in the greyscale. Thus, the normalization process is performed for each of these three dimensions and the final values of the data are in the range $\langle 0,1 \rangle$. After the filtering process the data is renormalized to its initial ranges in each dimension.

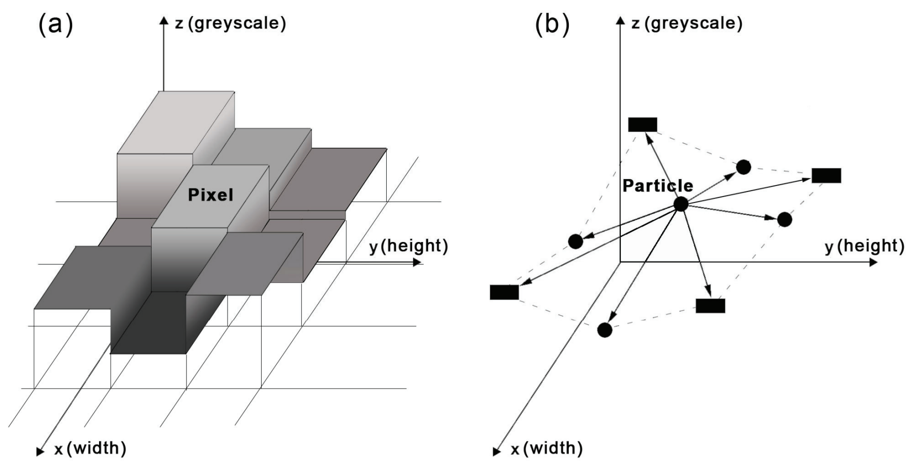

Fig. 2. Original pixels' values in greyscale (a), representation of particular pixels as a set of neighbouring particles (b).

The objective of the first step of calculations is to process the image to obtain edges as the results of the following procedures: convolution filtering, edge tracing and suppression, elimination of small groups of pixels. Then, the second phase of processing is applied, which aims to remove additional noise from microstructure images. This technique is performed in automated manner by the minimization of configuration parameters, which have to be setup before data processing. Such solution allows the reduction of the time of data analysis, eliminating many manual activities. The results obtained from proposed approach are presented in comparison to other conventional methods.

The next step after the normalization process is determination of border points and edge detection. This step allows a separation of the segments inside an analysed image, which are related to the particular material grains. Moreover, it is required by the subsequent PD filtering algorithm. This task is very important especially in case of filtering of microstructure photographs and it is crucial for the reliability of further calculations. Otherwise, the side effect presented in figure 3 appears – the edges are smoothed too much, making the image inconvenient to analyse.

The edge detection approach is based on the other popular technique, namely Canny Detector. This method has some drawbacks related to processing of noisy data. Hence, it was modified for the purpose of the analysis of microstructure images. The modified Canny Detector consists of the following steps:

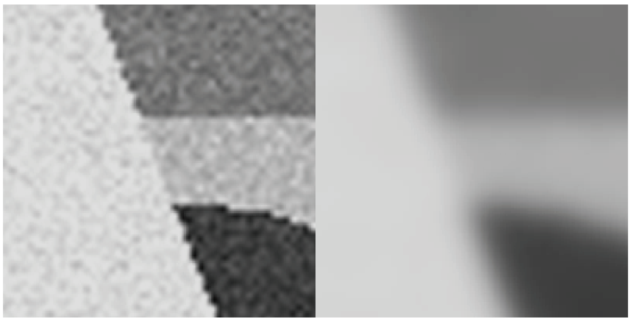

Fig. 3. Noisy data (left). Data denoised without proper edge detection (right).

– initial image filtering (figure 5) – Sobel convolution filtering for smoothing purposes. One iteration of Sobel filtering is applied to smooth particular pixels or small groups of pixels, which are distorted and can be misinterpreted as a border between grains. The performance of one iteration of this technique does not influence the shape of visible borders. Thus, it does not impede further analysis of the image and can be easily implemented and applied,
– edge detection and enhancement by using undirected Laplace convolution filter (figure 6) – this algorithm enhance the borders between different areas of the image by calculation colour gradients of neighbouring pixel. The main disadvantage of this technique is visible effect of twin borders, which is obtained through the convolution of two matrices, giving the left and right borders. The suppression of twin-border effect is performed in the subsequent step of proposed approach,
– detection of edges directions (figure 7) – this step is based on previously detected borders. Four main directions are taken into consideration i.e. horizontal, vertical and two diagonals and marked by four different grey colours. This assumption can be stated due to the regular deployment of pixels inside an image,
– tracing of edges (figure 8) – detected edges and their directions are used in the process of edge tracing. This is the most important step of calculations, giving efficient detection of edges, which are poorly visible. Two thresholds are used in this process, namely higher (T_H) and lower (T_L). T_H is used to determine initial edges characterized by the brightest pixels. Then T_L is applied to detect darker pixels, which are placed near by already detected borders. Therefore, the reliability of such solution is higher than in case of traditional approaches,
– elimination of small groups of pixels (figure 9) – the last step of calculations is focused on the thinning of thick borders and deletion of small groups of pixels. The thinned borders detected between grains are in most cases long and narrow, while the remaining distortions are still visible in form of compact groups of pixels. The size of such groups do not usually exceed several pixels.

The resultant structure of the data after the edge processing step is in form of array composed of 0 values (non-border pixels) and 1 values (border pixels). This structure is used to determine the particles' neighbourhood environment, which is crucial in the PD filtering method. The PD filtering algorithm is based on the idea of mapping of the image structure onto the set of particles (figure 2b). Due to the performed edge detection, an image is divided into different areas, which are mapped onto the separate subsets of connected particles. This step allows complete determination of neighbourhood environment for all particles. Afterwards, the filtering calculations are performed.

3. RESULTS OF MICROSTRUCTURE IMAGES ANALYSIS

The main goal of the calculations was focused on the reliable determination of material grains' borders to filter their internal areas by removing distortions originated from micro inclusions or scratches. The proposed approach, constructed of edge detection algorithm and PD filtering method, was tested using the set of several microstructure photographs.

The first phase of calculations presents the results obtained by using edge detection algorithm based on modified Canny Detector technique. Each step of image processing is presented in figures 4-9.

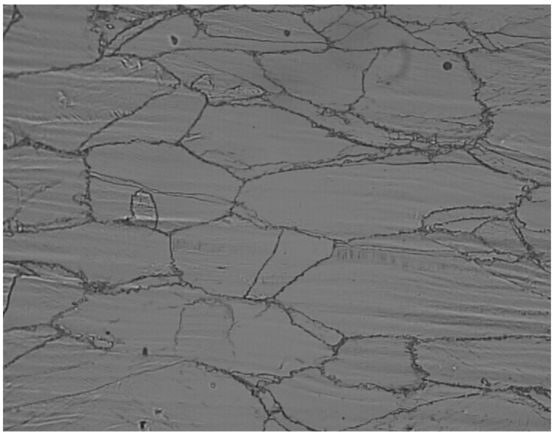

***Fig. 4.** The input image of material microstructure.*

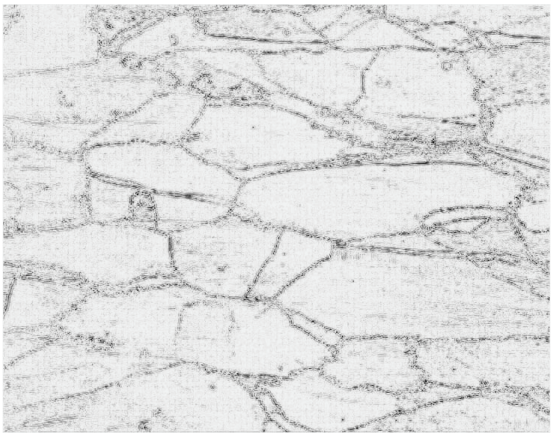

***Fig. 5.** First step focused on initial Sobel filtering for smoothing purposes.*

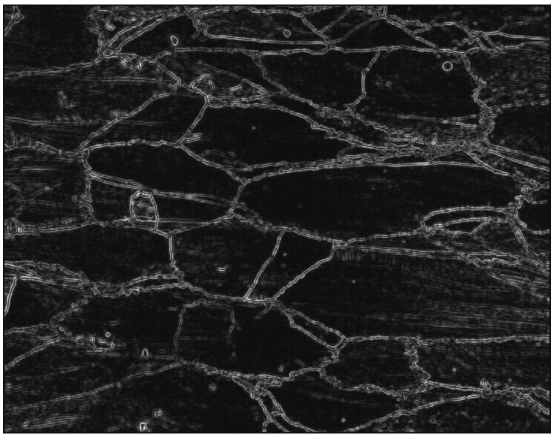

***Fig. 6.** Edge detection and edge enhancement from Laplace filter application.*

After successful determination of material grains' borders, the PD filtering approach is applied. The result obtained from this method is presented as 3D plot in figure 11 and in form of greyscale image in figure 15. It is clearly seen that the presented approach offers satisfactory results in comparison to original input image (figure 10).

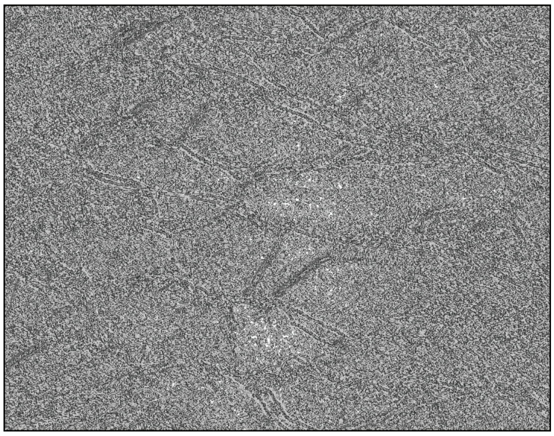

***Fig. 7.** Detection of edges directions using enhanced edges obtained in the previous step.*

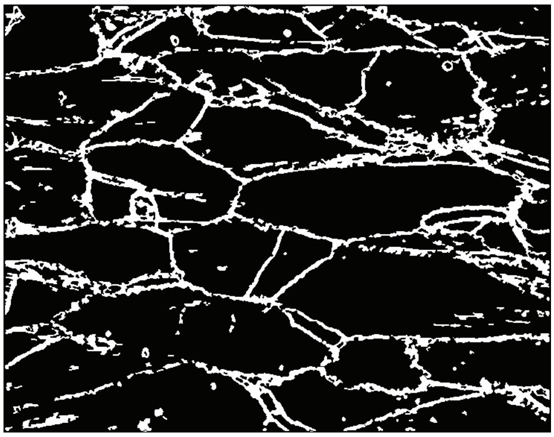

***Fig. 8.** Tracing of edges using edge directions.*

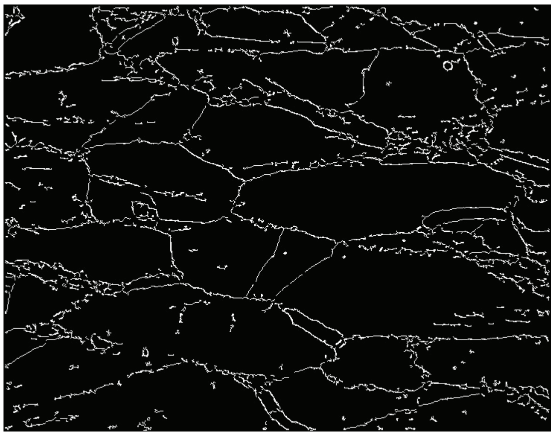

***Fig. 9.** Suppression of twin-border effect and elimination of small groups of pixels with compact shapes.*

Additionally, the results obtained from the edge detection and filtering methods were compared to the others offered by various conventional filtering techniques i.e. Gaussian, despeckle algorithm (developed by Photoshop vendor) and median. The results of this comparison are presented in figures 12-15.

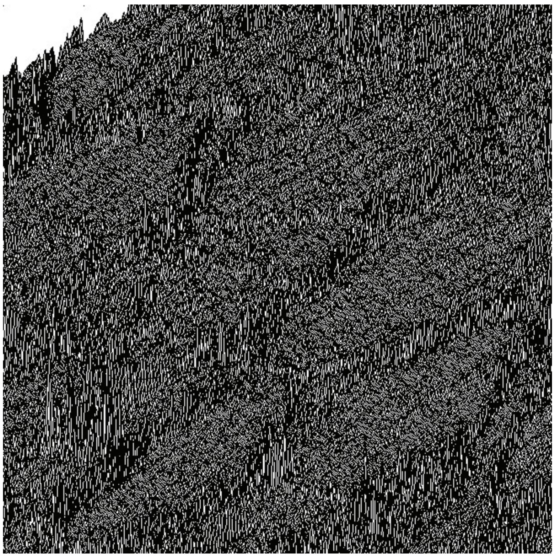

***Fig. 10.** Distorted surface of microstructure image before filtering.*

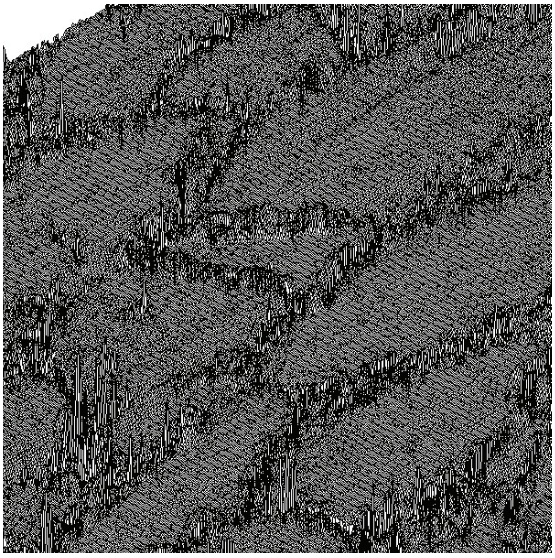

***Fig. 11.** Surface of microstructure image with suppressed noise and preserved edges after filtering.*

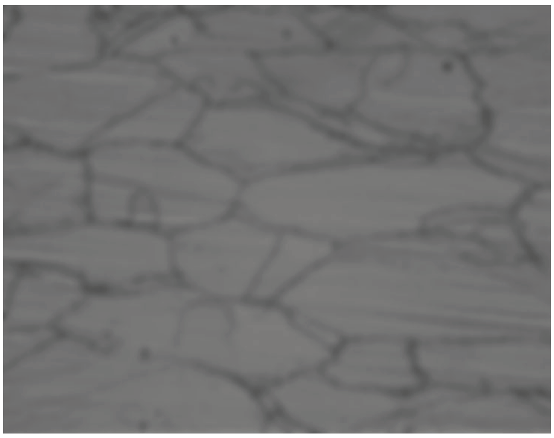

***Fig. 12.** The results of filtering obtained by using Gauss kernel.*

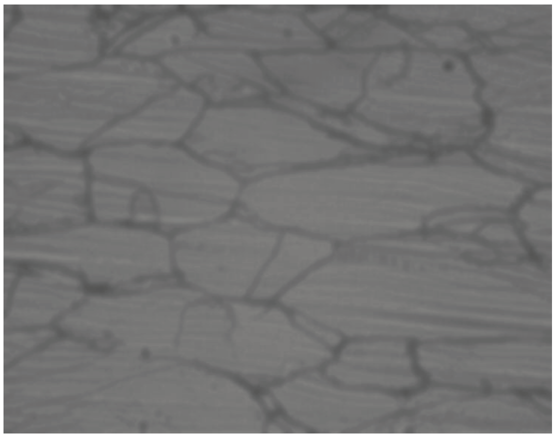

***Fig. 13.** The results of filtering obtained by using despeckle algorithm developed by PhotoshopCS.*

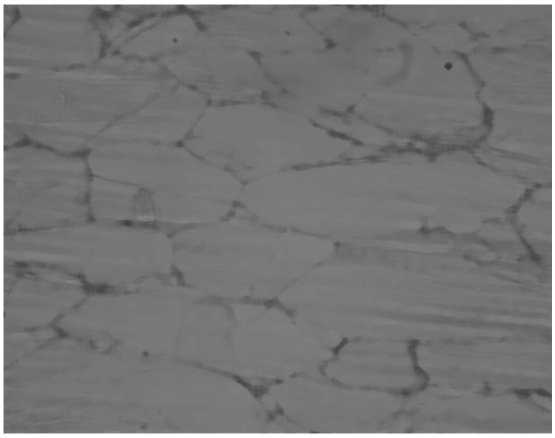

***Fig. 14.** The results of filtering obtained by using median filter.*

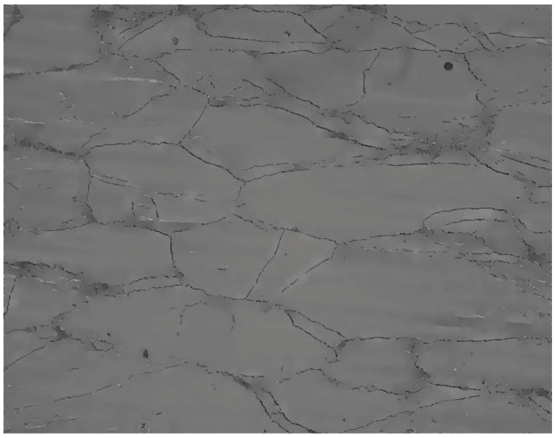

***Fig. 15.** The results of filtering obtained by using PD algorithm.*

The borders of material grains returned by conventional methods are fuzzy and hard to analyse automatically. Moreover, the distortions are still visible inside the grain areas. However, in case of results offered by PD filtering, thin edges are detected and the internal parts of grain areas are denoised.

4. CONCLUDING REMARKS

The paper presents the idea and implementation of the filtering system, consisted of two connected modules i.e. edge detection technique based on modified Canny Detector algorithm and PD filtering method. The proposed approach is applied automatically in the process of microstructure photographs analysis and many manual activities, which are required in conventional approaches, are eliminated.

The results obtained from presented system are satisfactory and better than the results offered by conventional filtering algorithms. The borders of material grains are thin and the internal part of grains' areas are denoised and smoothed. Thus, the processed images can be transferred to further analysis, which uses the algorithms of edges fulfilment. The proposed filtering system will be developed by adding one of such algorithms. Afterwards, it will be used in natural element methods as microstructure generator to create reliable input data in systems dedicated to simulations of metallurgical processes.

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PRZETWARZANIE OBRAZÓW MIKROSTRUKTUR W CELU DETEKCJI GRANIC MIĘDZY ZIARNAMI

Streszczenie

Przetwarzanie obrazów mikrostruktur w celu detekcji granic między ziarnami jest wciąż trudnym zadaniem. Spowodowane jest to przede wszystkim występującym na zdjęciach szumem w postaci zarysowań lub mikro wtrąceń. Dlatego też w większości przypadków analiza zdjęć nadal wykonywana jest ręcznie, co dla dużego zbioru obrazów jest bardzo czasochłonne. Aby uniknąć tego problemu, zaproponowano podejście automatycznego przetwarzania obrazów składającego się z dwóch części tj. wykrywanie krawędzi, zaprojektowane i zaimplementowane na podstawie algorytmu Canny Detector (Ritter & Wilson, 1996) oraz filtrowania danych w oparciu o metodę cząstek dynamicznych (Rauch & Kusiak, 2005a). W wyniku zastosowania tego podejścia powstaje nowy obraz mikrostruktury z wygładzonymi obszarami ziaren oraz precyzyjnie zdefiniowanymi granicami. Osiągnięty efekt umożliwia optymalizację procesu dalszej analizy struktury materiału np.: przy użyciu algorytmu uzupełniania granic Watershed (Haris et al., 1998) czy też obliczeń statystycznych średniego rozmiaru ziaren. Artykuł przedstawia podstawowe założenia proponowanego podejścia oraz szczegóły implementacji obydwu algorytmów składowych. Wyniki przeprowadzonej analizy obrazów mikrostruktur zostały również przedstawione w niniejszym artykule.

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