Quantitative Image Analysis with Mathematical Morphology

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Abstract— **The goal of this research is to use mathematical morphology and the pattern spectrum to make a quantitative analysis on the wear of composite sliding bearing materials. Also it is possible to use the parameters of the pattern spectrum to make classifications of areas in an image. In this paper we describe the results of our initial experiments. After we have implemented an efficient algorithm, we will investigate which parameters can be extracted and are useful.**

Keywords— **mathematical morphology, pattern spectrum, quantitative analysis, sliding bearing materials, classification**

I. Introduction

COMPOSITE materials are useful as friction bearing materials. An important research topic is to study their friction and wear properties. A microscopic study of the fibers can help us understand what is happening physically, and allows us to choose the right materials to build bearing constructions. These microscopic images have to be analyzed, so image processing is needed for preprocessing and to do the analysis.

Mathematical Morphology is a way of treating images without altering the shape of the objects in the images. It also provides a basis for the theory of the pattern spectrum which gives a histogram of the distribution of the sizes of various objects comprising an image. The parameters distilled from this spectrum allow us to perform a quantitative analysis of the wear of the sliding bearing.

There is also a computational cost involved when processing an image. Our goal is to implement algorithms that are fast and flexible. Initially we concentrate on gray scale images.

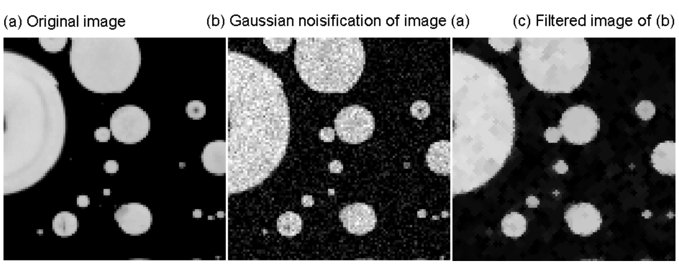

Fig. 1. Morphological filtering: opening by reconstruction, followed by a closing by reconstruction, followed by a P_k-filter. A cross-like structuring element is used.

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II. Techniques

Mathematical morphology ([1]) is based on set theory. The shapes of objects in a binary image are represented by object membership sets. This theory can be extended to gray scale images. Morphological operations can simplify image data, preserving the objects' essential shape characteristics, and can eliminate irrelevant objects. The main advantage of a morphological filter (fig. 1) is the ability to preserve the shape of large enough objects, unlike a Gaussian filter which blurs the image. Mathematical morphology is based on two basic operations: *dilation*, which fills holes and smoothens the contour lines, and *erosion*, which removes small objects and disconnects objects connected by a small bridge. Such operations are defined in terms of a *structuring element* (short: *strel*), a small window that scans the image and alters the pixels in function of its window content. The choice of the proper strel is important. A dilation of image A with strel B ($A \oplus B$) blows up the object, an erosion ($A \ominus B$) lets it shrink (see fig. 2).

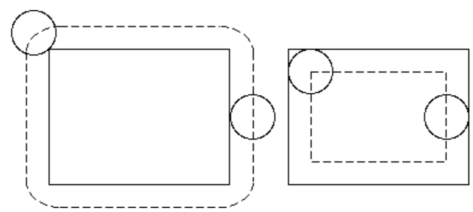

Fig. 2. Schematic example of the basic morphological operators. Solid line: original object; Dashed line: result object; Circle: structuring element. Left: *dilation*; Right: *erosion*.

Other operations, like the *opening* (an erosion followed by a dilation) and the *closing* (a dilation followed by an erosion), are derived from the basic operators. If we take a strel and perform an opening on an image, some elements will disappear. If we take a bigger strel, then more elements in the image will vanish. In this way we can create a *pattern spectrum* ([2], [3]), a plot of the size n of the strel ($nB = B \oplus B \oplus \ldots \oplus B$, n times) versus the number of eliminated pixels after opening the current image. The result image (the residue) is then used as image for the $(n+1)$-calculation. There is an analogy with the Fourier spectrum: the low frequencies in the Fourier spectrum relate to the global features of the image or the smooth objects, the high frequencies to the details or the fast gray scale variations. Similarly, big structuring elements in the pattern spectrum preserve the global features of the image or the large smooth objects, while small sized strels also preserve the details or the small rough objects.

Fig. 3 shows the pattern spectrum of the first image in

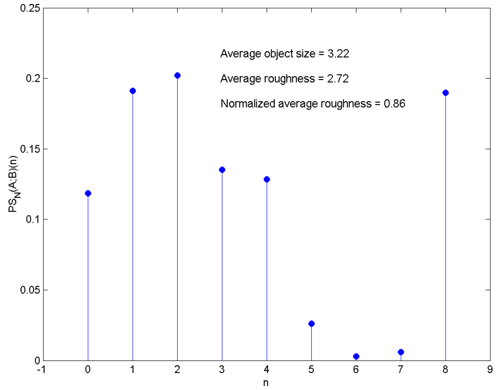

Fig. 3. The pattern spectrum (norm.) of image A (fig. 4 upper-left) with opening with structuring element B (a disk with radius 5).

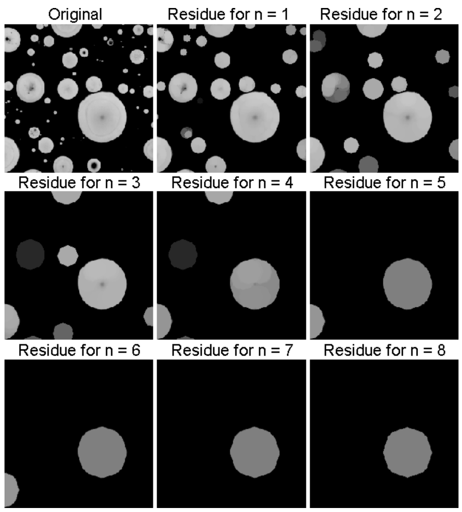

Fig. 4. The residues after opening the image with increasing structuring element (a disk starting with radius 5).

the series of fig. 4. In this figure you can see the residues after an opening operation (left to right, top to bottom). First the small objects are eliminated, finally the big ones.

From the pattern spectrum we can extract parameters such as the *mean object size* (area) or the *entropy*, a measure for the roughness of the object boundaries ([2], [4]). With these parameters we have statistical information about the content of the image, like mean object size, shape, direction, variation, ... Notice that using a different strel results in another pattern spectrum, and thus in other values for the parameters. Compare figures 3 and 5 to see how a different image and structuring element affect the pattern spectrum and its parameters.

The algorithm used for the generation of fig. 4 is a very time consuming one, because for every n value a new image is calculated, and because n needs to be incremented until no more changes occur. Moreover, with increasing n, the strel becomes bigger and bigger. That's why we need a more efficient algorithm to process big gray scale images with a complex content.

A few algorithms are available ([5], [6]) that are significantly faster. Only one or two scans of the image are

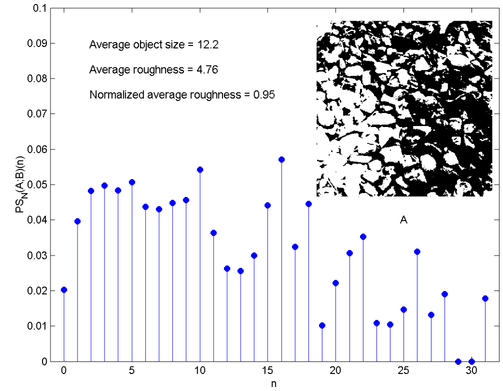

Fig. 5. The pattern spectrum (norm.) of image A (insert) with opening with structuring element B (a cross element).

needed. Some algorithms can only be used with linear strels or compositions of linear strels. Others only work with binary images. Which algorithm suits our needs best is currently under investigation. A fast, gray scale compatible and relatively easy to implement algorithm with freedom of choice of the structuring element, is the ideal one.

III. Applications and Future Work

The main reason for investigating the use and usefulness of the pattern spectrum is the quantitative analysis in material science. In collaboration with the department of Mechanical Construction and Production, microscopic images of the wear of composite sliding bearing materials will be examined.

Different applications of the pattern spectrum are possible. Different textures yield different pattern spectra, and thus different parameters, when an appropriate structuring element has been chosen. This way, we can analyze texture, segment regions with different parameters, and make a classification of the textures.

Apart from the possibility of using the pattern spectrum, the use of fractals is another option. In [7], fractal dimensions in relation to wear mechanisms are investigated.

References

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