A NEW TECHNIQUE OF THE ENHANCEMENT OF SCANNED COLOUR DOCUMENTS

B. Smolka K. Wojciechowski

Silesian Technical University
Department of Computer Science
Akademicka 16
44-101 Gliwice, Poland

bsmolka@ia.polsl.gliwice.pl

K.N. Plataniotis A.N. Venetsanopoulos

Department of Electrical
and Computer Engineering
University of Toronto
Toronto, ON, M5S 3G4, Canada

kostas@dsp.toronto.edu

1. INTRODUCTION

Colour image processing has been the subject of extensive research during the last years. With the expanding use of colour in multimedia applications the interest in the preprocessing of color images has been growing rapidly. As a result, a large number of techniques of colour image enhancement has been proposed [1-5]. These techniques seek to reduce the image noise, while preserving important image details, such as edges and texture. Especially the edge information is of high importance to human reception and therefore its preservation and possibly enhancement is a very desired feature of the performance of the enhancement techniques.

Most of the existing techniques of multichannel filtering are based on multivariate ordering, which is a powerfull tool in color image processing and analysis. The best known examples are the Vector Median Filter [3], α-trimmed and arithmetic mean filter and vector directional filter [1, 2, 4].

In this paper a new approach to the colour image enhancement is presented. The new filtering technique is based on a self-avoiding random walk and it enables the suppression of noise and contrast enhancement of document images. This combination is quite novel since the commonly used algorithms are mostly not able to perform both of the tasks simultaneously, as the new procedure does.

2. SELF-AVOIDING RANDOM WALK ALGORITHM

Self-avoiding random walk (*SAW*) is a special walk along an *m*-dimensional lattice, such that adjacent pairs of edges in the sequence share a common vertex of the lattice, but no vertex is visited more than once and in this way the trajectory never intersects itself. In other words *SAW* is a path on a lattice that does not pass through the same point twice. On the two-dimensional lattice (m=2) SAW is a finite sequence of distinct 3-dimensional lattice vectors (colour image) (x_0,y_0), (x_1,y_1), (x_2,y_2), ..., (x_n,y_n), which are in neighbourhood relation and $(x_i, y_i) \neq (x_j,y_j)$ for all $i \neq j$ [6, 7].

Let us introduce a virtual walking particle, which performs a SAW on a two-dimensional image lattice with eight-neighbourhood system and let the transition probabilities between points (x_0, y_0) and (x_n, y_n) at n steps be described by [8, 9]

$$P\left[(x_0,y_0) \rightarrow (x_n,y_n)\right] = \frac{\exp\left\{-\beta\left[\| F(x_0,y_0) - F(x_1,y_1) \| + \cdots + \| F(x_{n-1},y_{n-1}) - F(x_n,y_n) \|\right]\right\}}{\sum\limits_{\{(x_0,y_0)\rightarrow(x_n,y_n)\}} \exp\left\{-\beta \sum\limits_{\kappa=1}^{n} \| F(x_{\kappa-1},y_{\kappa-1}) - F(x_\kappa,y_\kappa) \|\right\}}$$

where (x_0, y_0), (x_n, y_n) are starting and ending points, $\{(x_{0,}y_0) \to (x_{n,}y_n)\}$ is a set of all trajectories leading from (x_0, y_0) to (x_n, y_n), $F(x_{i,}y_j)$ is the vector assigned to colour image point (x_i, y_j) and $\|F(x_{0,}y_0) - F(x_{i,}y_i)\|$ is the distance in L_1 metric.

Let us now define a smoothing operator J based on the self-avoiding walk model $J(x_{0,}y_0) = \sum_{\{(x_{0,}y_0) \to (x_{n,}y_n)\}} P[n, (x_{0,}y_0) \to (x_{n,}y_n)] \cdot F(x_{n,}y_n)$, where the sum is taken over all pixels (x_n, y_n), which are connected by a trajectory of the walking particle starting at the point (x_0, y_0) and ending at (x_n, y_n). In this way the operator J is defined as

$$J(x_0, y_0) = \frac{\exp\{-\beta[\| F(x_0, y_0) - F(x_1, y_1) \| + \cdots + \| F(x_{n-1}, y_{n-1}) - F(x_n, y_n) \|]\}}{\sum_{\{(x_0, y_0) \to (x_n, y_n)\}} \exp\left\{-\beta \sum_{\kappa=1}^{n} \| F(x_{\kappa-1}, y_{\kappa-1}) - F(x_\kappa, y_\kappa) \|\right\}} F(x_n, y_n)$$

If $\beta = 0$ then this operator defines the moving average and for $\beta \to \infty$ this operator assigns at (x_0, y_0) the value of $F(x_n, y_n)$ for which $(x_n, y_n) = \arg\min\left\{\sum_{\kappa=1}^{n} \|F(x_{\kappa-1}, y_{\kappa-1}) - F(x_\kappa, y_\kappa)\|\right\}$.

3. PERORMANCE OF THE NEW ALGORITHM

The new operator has the ability of noise filtering and image sharpening while preserving image edges. Figures below present the effects of noise reduction performed on a test scanned document provided by the Silesian Library, Katowice, Poland after 3 iterations, at high β value. As can be seen the noise component is reduced and the edges are preserved and even much sharper as before the filtration. Another advantage of this filtration technique is that only about half of the amount of data is needed to store the image using losless compression techniques. This effect is due to the segmentation of letters and background of the scanned test image and it can be used for the efficient presentation of documents in various multimedia applications.

4. REFERENCES

[1] Pitas I., Venetsanopoulos A.N. , Nonlinear Digital Filters : Principles and Applications, Kluwer Academic Publishers, Bostan, MA, 1990

[2] Plataniotis K.N., Venetsanopoulos A.N.: Color Image Processing and Applications, Springer Verlag, ISBN 3-590-66953-1, May 2000

[3] Astola J., Haavisto P., Neuovo Y., Vector median filters, Proceedings of the IEEE, 78, 678-689, 1990

[4] Trahanias P.E., Venetsanopoulos A.N., Vector directional filters. A new class of multichannel image processing filters, IEEE Trans. on Image Processing, 2, 528-534, 1993

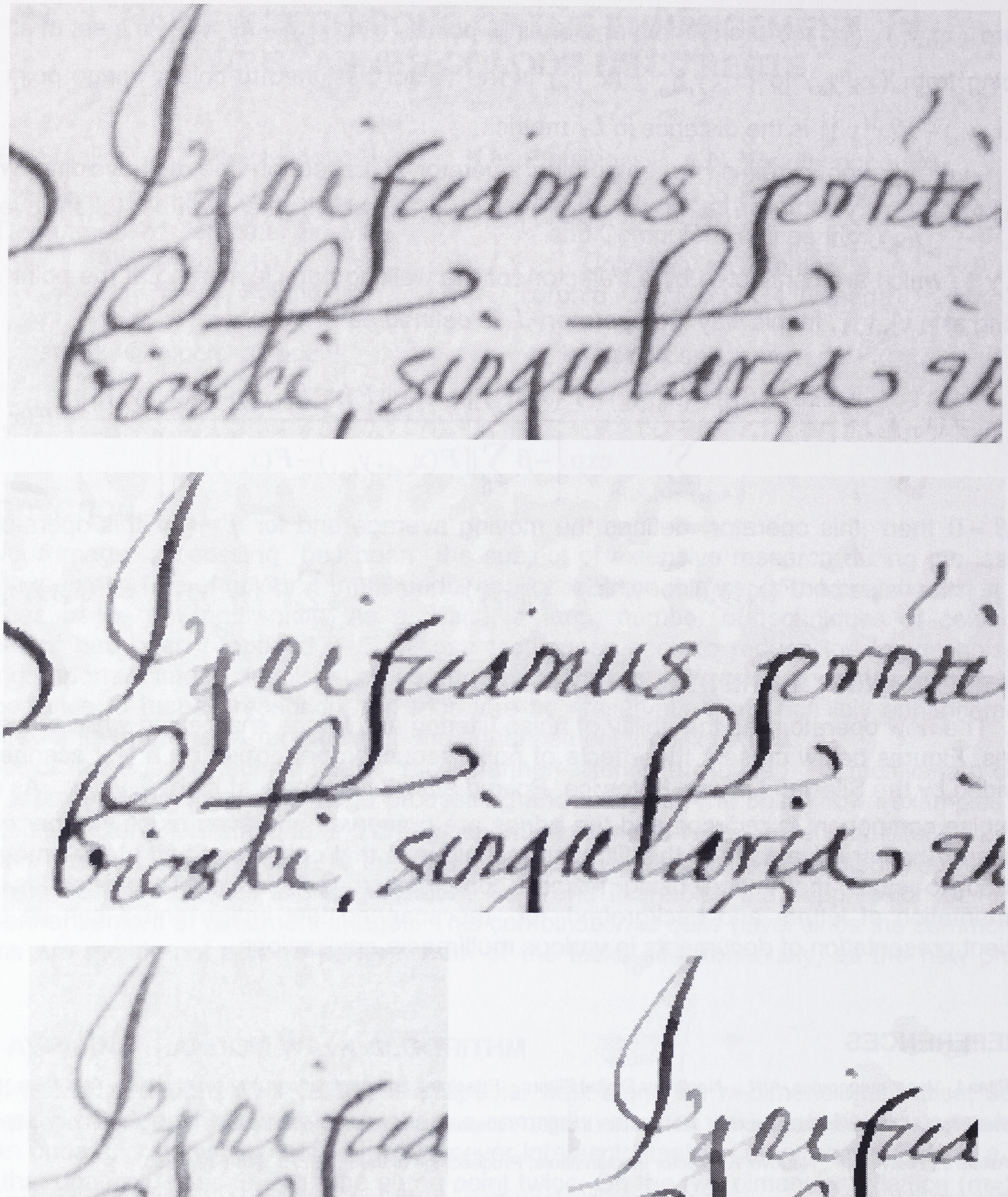
[5] Karakos D.G., Trahanias P.E., Generalized multichannel image filtering structures, IEEE Trans. on Image Processing, 6, 1038-1045, 1997

[6] Lawler G.F., Intersections of random walks (Probability and its Applications), Birkhauser Boston, 1996.

[7] Madras N., Slade G., The Self-Avoiding Walk (Probability and its Applications), Birkhauser Boston, 1996.

[8] Smolka B., Wojciechowski K., Edge Preserving Probabilistic Smoothing Algorithm, Lecture Notes in Computer Science, 1689, 41–48, 1999.

[9] Smolka B., Wojciechowski K., Contrast Enhancement of Gray Scale Images Based on the Random Walk, Lecture Notes in Computer Science, 1689, 411–418, 1999.



Examples of the performance of the new algorithm of scanned colour documents (depicted in gray scale). Fragment of a king's letter (top) and below the result of filtration for *n*=2, at the bottom the result for *n*=4 .