International Journal of Advanced Computer and Mathematical Sciences
ISSN 2230-9624. Vol 3, Issue 1, 2012, pp 186-193
http://bipublication.com

A PERFORMANCE CHARACTERIZATION OF ADVANCED DATA SMOOTHING TECHNIQUES USED FOR SMOOTHING IMAGES IN OPTIC FLOW COMPUTATIONS

B. N. Shobha, S. R. Shankapal, Govind R. Kadambi
M.S.Ramaiah School of Advanced Studies, Bangalore-560058

[Received-10/12/2011, Accepted-03/03/2012]

ABSTRACT
Optical flow is the distribution of apparent velocities of movement of brightness patterns in an image. Optical flow can arise from relative motion of objects and the viewer which can give important information about the spatial arrangement of the objects viewed. Discontinuities in the optical flow can help in segmenting images into regions that correspond to different objects. The accuracy of the optic flow obtained depends on the noise content in the input image frames. Smoothing or filtering is a to remove the noises in the input image sequence thus making the obtained optic flow much more suitable for applications like image segmentation. In this paper the comparisons are presented to evaluate the results from different smoothing filters which are used as preprocessing in order to obtain good optic flow vectors. The filters presented are Gaussian filter, Kuwahara filter, Savitzky-Golay filter and hybrid median filter. The methods are outlined and then evaluated on the extent to which edge information is preserved and unwanted noise is suppressed.

Keywords: Optical flow computation, Image smoothing filters, Savitzky-Golay, Kuwahara, hybrid median filter.

1. INTRODUCTION

The noisy images presented in optic flow computations have led researchers to investigate methods of smoothing image noise while maintaining important information like edges. There are many types of smoothing which have being extensively studied in literature. Nonlinear filters, the most common being the median filter, modifies the value of the pixel by some nonlinear function of the pixel value and its spatial neighbours. Nonlinear filters like Kuwahara maintain edges but the filtering results in a loss of resolution by suppressing fine details [1]. Image processing includes techniques that are used to correct defects in images and to enhance the visibility of features interest. Smoothing algorithms are classified into two categories: linear and nonlinear smoothing. Traditional linear filters are mean, average and Gaussian which attempt to remove noise by replacing each pixel by an average or weighted average of its spatial neighbours [2]. While this reduces the amount of noise present in the image, it also has the disadvantage of removing or blurring the edges. A major shortcoming of linear smoothing is that important features, e.g. boundary between different regions, are blurred after smoothing. Nonlinear smoothing has been developed to overcome the shortcoming, which tends to preserve important features along with noise removal during smoothing. Adaptive smoothing is a class of typical nonlinear smoothing techniques that have been studied for many years [5] [7] [8]. The general idea underlying adaptive smoothing is to adapt pixel intensities to the local attributes of an image on the basis of discontinuity measures. Filters like averaging, Gaussian and Savitzky-Golay are examples of Multiplicative filters, which tend to introduce many more intermediate gray pixels as they blur the image, but rank based techniques use actual values appearing in the image. These rank based filters are generally computationally involved since each 2- dimensional neighborhood needs to be ordered [9] [10].

This paper compares different filters used for pre-smoothing the images to obtain better optic flow vectors. The basic Gaussian filter is a convolution with a Gaussian mask with variance one, Kuwahara filter, the linear Savitzky-Golay filter is a convolution of the image with the least-squares fitting of a polynomial and rank based hybrid median filter.

2. Image smoothing methods

In order to understand an image, a multi-stage processing is necessary in human visual system. The early stage of a vision system plays an important role in visual information processing, which critically determines the interpretation of an image. On the other hand, real images are complex since there are large numbers of diversified objects in the physical world and the imaging process is inevitably corrupted by noise from various sources. In computer vision, smoothness is a generic assumption that many types of images have approximately piecewise constant gray levels, which characterizes the coherence and homogeneity of an object. Therefore, smoothing is viewed as a general tool in the low-level of machine vision. A comparison paper is presented to evaluate the results from different smoothing filters. The methods are outlined and then evaluated on the extent to which edge information is preserved and unwanted noise is suppressed.

2.1. Gaussian Smoothing

The Gaussian smoothing operator is a 2-D convolution operator that is used to blur images and remove detail and noise. It uses a kernel that represents the shape of a Gaussian (`bell-shaped') hump. The degree of smoothing is determined by the standard deviation of the Gaussian.

2.2. Kuwahara filter

Edges play an important role in our perception of images as well as in the analysis of images. So, it is important to smooth images without disturbing the sharpness and, the position of edges Although Kuwahara filter can be implemented for a variety of different window shapes, the algorithm is described for a square window of size J=K=4L+1where L is an integer. The window is partitioned into four regions. In each of the four regions $(i = 1, 2, 3, 4)$, the mean brightness, m_i and the variance i, is measured. The output value of the center pixel in the window is the mean value of that region that has the smallest variance [3].

2.3. Savitzky-Golay filter

The Savitzky-Golay smoothing filters smoothes data and computes the numerical derivatives [4].

The smoothed points are found by replacing each data point with the value of its fitted polynomial. The process of Savitzky-Golay is to find the coefficients of the polynomial which are linear with respect to the data values. Therefore the problem is reduced to finding the coefficients for fictitious data and applying this linear filter over the complete data. The size of the smoothing window is given as $N X N$ where N is odd and the order of the polynomial to fit is k, where N > k + 1.

$$\mathrm{d(i)} \approx \mathrm{f}(\mathrm{x}_i, \mathrm{y}_i) = a_{00} + a_{10}x_i + a_{01}y_i + a_{20}x_i^2 + a_{11}x_iy_i + a_{02}y_i^2 + a_{30}x_i^3 + a_{21}x_i^2y_i + a_{12}x_iy_i^2 + a_{03}y_i^3 \quad \text{----(1)}$$

We then want to fit a polynomial of type in Equation 1 to the data. Solving the least squares we can find the polynomial coefficients. We start with the general equation, $A.a = f$, where a is the vector of polynomial coefficients $a = (a_{00}a_{01}a_{10}.......a_{ok})^T$. We can then compute the coefficient matrix as follows, $(A^T.A).a = (A^T.f)$, which in least squares can be written as $a = (A^T.A)^{-1}.(A^T.f)$. Due to the linear-squares fitting being linear to the values of the data, the coefficients can be computed independent of data. The general coefficient matrix becomes $C = (A^T A)^{-1} A^T.C$ can then be reassembled back into a traditional looking filter of size NXN. In order to smooth the image the first coefficient is used, higher order coefficients are used to calculate derivatives. The advantage of the Savitzky-Golay filter has the ability to preserve higher moments in the data and thus reduce smoothing on peak heights. In more homogeneous areas the smoothing approaches an average filter.

2.4 Hybrid Median filter

Hybrid median filter preserves edges better than a square kernel median filter because it is a three-step ranking operation: data from different spatial directions are ranked separately. Three median values are calculated: MR is the median of horizontal and vertical R pixels, and MD is the median of diagonal D pixels. The filtered value is the median of the two median values and the central pixel $C : median([MR, MD, C])$. As an example, for $n = 5$:

$$\begin{bmatrix} D & * & R & * & D \\ * & D & R & D & * \\ R & R & DCR & R & R \\ * & D & R & D & * \\ D & * & R & * & D \end{bmatrix}$$

3. Experimentation

Various filters are applied to the taxi sequence image. The results of each filter are assessed by their ability to smooth homogeneous areas while preserving the areas with higher moments. Smoothing of homogeneous areas is measured using the standard deviation while the preservation of edges is measured using the strength and spread of the edge in the filtered images. Standard deviation is measured over a small edge portion of the input image [1].

The filters are tested on a set of various input images, figures 1 to 5 highlights one set of input images of standard taxi sequence. Parameters of the filters were chosen to give the optimal results on visual inspection.

Figure 1: Input taxi sequence images

Figure 2: Taxi Sequence images filtered using Gaussian Smoothing

Figure 3: Taxi Sequence images filtered using Kuwahara filter

Figure 4: Taxi Sequence images filtered using Savitzky-Golay Filter

Figure 5: Taxi Sequence images filtered using Hybrid Median filter

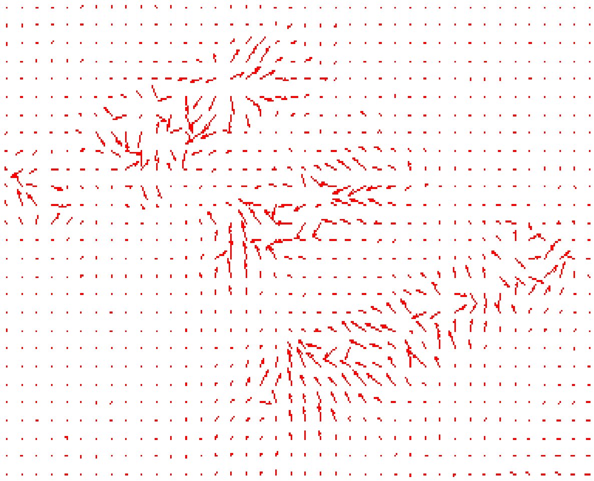


Figure 6: Optic flow vectors for original images

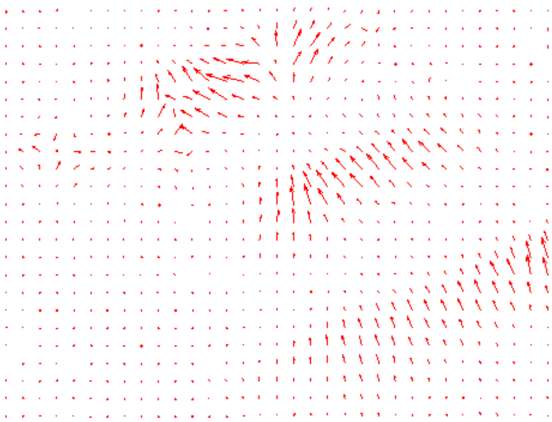


Figure 7: Optic flow vectors for Gaussian filtered images

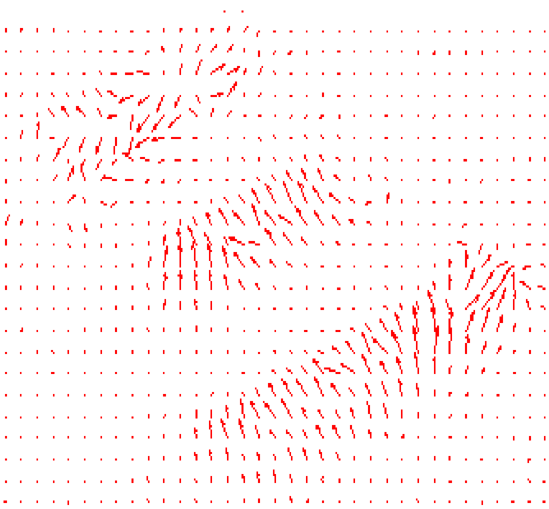


Figure 8: Optic flow vectors for Kuwahara filtered images

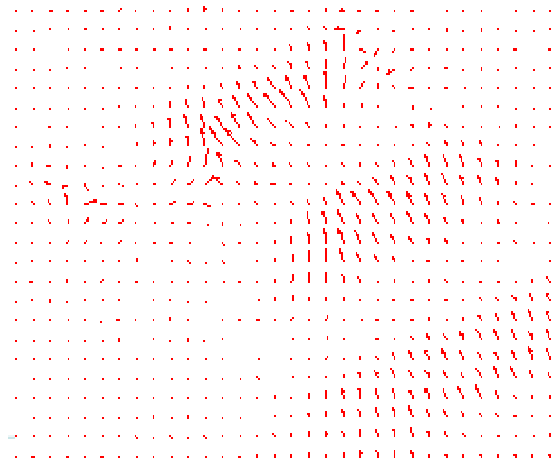


Figure 9: Optic flow vectors for Savitzky-Golay Filtered images

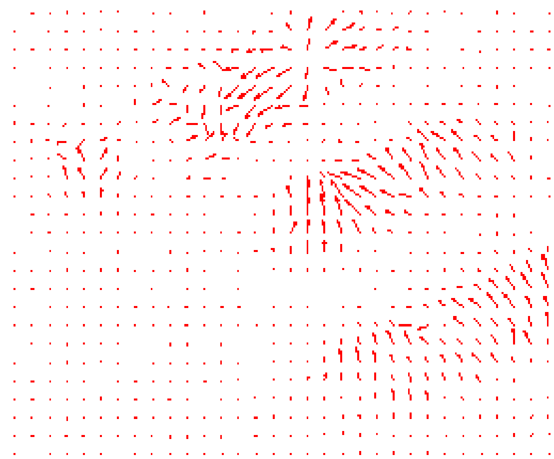


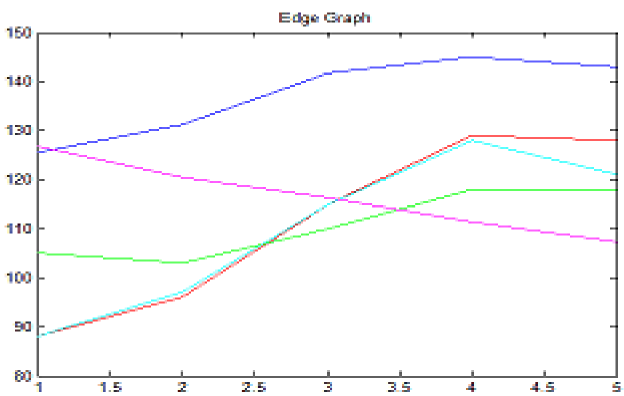
Figure 10: Optic flow vectors for Hybrid Median filtered images

Time taken to compute different smoothing techniques in MATLAB for one image is as shown in table 1.

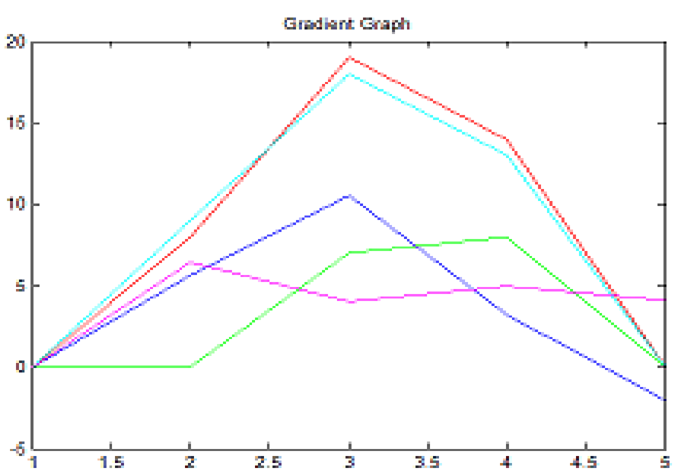
Filters → Time in secs	Gaussian	Kuwahara	Savitzky -Golay	Hybrid Median
taxi image	0.2	57.43	3.38	1.44
Ultrasound image	0.13	57.08	3.4	1.34

Table 1. Time taken by the different smoothing techniques

Figure 11: A portion of the image is taken for Edge & Gradient Analysis



Graph 1: Pixel intensities for various filtered images



Graph 2: Gradients for various filtered images

	Taxi Image			
	Color in graph	SD	Edge Height	Edge Width
Original	Red	8.43	19	4
Gaussian	Green	4.12	08	3
Kuwahara	Magenta	2.3	6.4	4
Savitzy-Golay	Blue	4.91	10.6	3.6
Hybrid Median	Cyan	7.97	18	4

Table 2. Edge height and widths for the different smoothing techniques

4. Results and Evaluation

The taxi sequence which is considered as the input sequence is shown in figure 1. The input images filtered with Gaussian filter, Kuwahara filter, Savitzky-Golay filter and Hybrid Median filters are shown in figure 2, figure 3, figure 4 and figure 5 respectively. Figure 6 shows the optic flow vectors obtained using Horn and Schunck method [11] for the input images. Figure 7 to figure 10 shows the optical vectors calculated for the input images filtered or smoothed using Gaussian filter, Kuwahara filter, Savitzky-Golay filter and Hybrid Median filter respectively. Visual inspection shows that the flow vectors are smoother in the case of Gaussian filtered images and Savitzky-Golay filtered images, the actual edges are preserved in the Kuwahara filtered images and Hybrid Median filter.

Graph 1 shows pixel intensities for various filtered images while Graph 2 shows gradients for various filtered images.

The time taken for execution of smoothing techniques for the taxi image sequence and ultrasound image sequence [6] in MATLAB is shown in Table 1, while Table 2 gives Edge height and widths for the different smoothing techniques. Hybrid Median preserves the edge most as depicted in Table 2 and graph 2 while Kuwahara filter has least preservation of the edges.

5. Conclusion

Motion research has typically focused on only accuracy or only speed. We have reviewed many different approaches to achieving higher speed. Different filters were evaluated using two criteria, texture smoothing and edge preservation. The filters were Gaussian, Kuwahara, Savitzky-Golay, Edge Preserving and Hybrid Median. The Kuwahara performs the worst of all the filters. We hope that this initial study can generate more interesting discussions and shed some light on the use of motion algorithms in real world tasks.

6. References

1. Michael Lynch, Kevin Robinson, Ovidiu Ghita and Paul F. Whelan, A performance characterization in advanced data smoothing techniques, Proceedings of the Irish Machine Vision & Image Processing Conference 2004.
2. M. Petrou and P. Bosdogianni. Image Processing: The Fundamentals. Wiley Publishing, Inc., first edition, 1999.
3. http://www.ph.tn.tudelft.nl/DIPlib/docs/FIP.pdf
4. A. Savitzky and M.J.E Golay Smoothing and differentiation of data by simplified least squares procedures. Analytical Chemistry, 36(8):1627–1639, 1964.
5. K. Chen, A Feature Preserving Adaptive Smoothing Method for Early Vision, Technical report, National Laboratory of Machine Perception and The Center for Information Science, Peking University, Beijing, China, 1999
6. http://www.biomecardio.com/matlab/hmf.html
7. S. Geman and D. Geman, Stochastic relaxation, Gibbs distributions, and the Bayesian restoration of images, *IEEE Trans. Pattern Analysis Mach. Intell.* **6**, 721-741 (1984).
8. P. Saint-Marc, J. S. Chen, and G. Medioni, Adaptive smoothing: A general tool for early vision, *IEEE Trans. Pattern Analysis Mach. Intell.* **13**, 514-529 (1991).
9. M. Petrou and P. Bosdogianni. *Image Processing: The Fundamentals*. Wiley Publishing, Inc., 1st edition, 1999.
10. Cliff Reiter, With J: Image Processing 1: Smoothing Filters, Mathematics Department Lafayette College, Easton PA 18042, USA
11. B. K. P Horn and B. G Schunck, “Determining Optical Flow”, *Artificial Intelligence*, Vol. 17, 1981, pp 185-203.

B.N.Shobha, is a Asst. Professor, M.S.Ramaiah School of Advanced Studies, Bangalore. She received B.E. degree in Electronics and Communications and M,E degree in Electronics from Bangalore University. She is persuing her Ph.D degree from Coventry University, U.K. She has been associated with various Academic activities in UG and PG courses. Her areas of interest are in Image processing, Image Fusion and Operating Systems.

Govind R Kadambi, is a Professor and Dean, PEMP,

M.S.Ramaiah School of Advanced Studies, Bangalore. He received B.E. degree in Electronics and Communications from the University of Mysore, India and the M.S. and Ph.D. degrees from the Indian Institute of Technology (IITM), Madras. He has been associated with various R&D Labs in India and abroad. His current research interests are mainly focused on Antennas, Digital

Beamforming, and Signal Processing for Wireless Communication and Image Processing Applications.

Dr. S.R.Shankapal, B.E., M.Tech., Ph.D is professor and President of M.S.Ramaiah School of Advanced Studies. He has more than 28 years of experience in academic, research and consultancy. He has been awarded research grants of more than Rs. 50 million from Indian government departments, industries and EU in the last 8 years. He has published 66 research papers, contributed in 11 books in his areas, supervised around 60 undergraduate projects, 45 PG Theses, 5 Ph.D scholars and is the Principal Investigator for more than 15 projects. He also has 3 patents to his credit. He has offered technical consultancy to solve more than 100 industrial problems. His areas of interest include IC Engines, Gas Turbines, control systems, Vehicle Dynamics, Image processing, Computer Vision and CFD & FE Methods. He is responsible for the establishment of M.S. Ramaiah School of Advanced Studies in collaboration with Coventry University of UK in the year 1999 and is the director since. He was awarded merit Scholarship throughout his student career, won ISTE student project awards and Team Tech award for Professional Excellence and MAV-07 award, and he is a member of SAE, CI, ISTE and widely travelled to UK, Germany, Bulgaria, US, Nigeria, China, Malaysia, Singapore and Dubai.