Features Extraction from High Frequency Domain for Retina Digital Images Classification

Salim Lahmiri
University of Quebec at Montreal/Department of Computer Science, Montreal, Canada
Email: lahmiri.salim@courrier.uqam.ca

***Abstract*— The purpose of this paper is to extract features from retina digital images based on a further analysis of high frequency components (HH) obtained with the discrete wavelet transform (DWT). In particular, the DWT is applied to the retina photograph to obtain its high-high (HH) image subband. Then, a further decomposition by DWT is applied to the HH image subband of the previous step to obtain HH*. Finally, statistical features are computed from HH*. The support vector machines (SVM) are employed to classify normal versus abnormal images using leave-one-out cross-validation method (LOOM). The simulation results show strong evidence of the effectiveness of features extracted from HH* than features extracted from HH. Thus, they are in accordance with our previous work where our approach was applied to mammograms. In summary, our methodology based on a further analysis of high frequency images using DWT helps extracting suitable features for automatic classification of normal and abnormal retina digital images.**

***Index Terms*— retina digital image, discrete wavelet transform, high frequency subband, features extraction, support vector machines, classification**

I. Introduction

Medical image analysis plays an important role in eye disease identification in the field of ophthalmology. Indeed, the automatic analysis of medical images has received a large scientific attention with the purpose of providing computational and intelligent tools to assist quantification of pathologies in the texture of digitized medical images. In order to extract features from retina digital images, different techniques have been employed; including co-occurrence matrices [1][2], Gabor filter banks [3][4], Fourrier transform [4][5], and morphological measures [5]. However, the discreet wavelet transform (DWT) is the most commonly adopted approach to process retina digital images for features extraction [6]-[10]. The DWT [11][12] is a multi-resolution analysis of a signal that has the advantage of great ability to identify and extract signal details at several resolutions. For instance, the two dimensional DWT hierarchically decomposes a digital image into a series of successively lower resolution images and their associated detail images: the approximation subband (LL), the horizontal detail subband (LH), the vertical detail subband (HL), and the diagonal detail subband (HH). The LL, LH, HL, and HH subband are respectively low frequencies for both directions, low frequencies for the horizontal direction and high frequencies for the vertical direction, high frequencies for the horizontal direction and low frequencies for the vertical direction, and high frequencies for both directions. Then, the obtained approximation images (LL) are decomposed again to obtain second-level detail and approximation images.

In the previous studies [6][7][9][10], retina features were extracted from LL, LH, HL, and HH subband, whilst only high frequency subbands were considered for features extraction in [8] and low frequency subband (LL) was excluded because ;according to the authors; the information at lower frequencies is not adapted to detect microaneurysms (MA) in retina. The role of high frequency; namely HH subband; features at characterizing changes in the biological tissue was also stated in [13]-[16].

The purpose of this paper is to perform an analysis of high frequency components of the HH subbands to extract valuable features from retina digital images. In particular, the DWT is applied to retina photograph and its high-high (HH) image is obtained. Then, a second DWT is applied to the HH image obtained in the previous step. The purpose of applying a second DWT uniquely to HH image is to accurately capture high frequency information from high frequency image. This approach has already proven its effectiveness in the problem of mammograms analysis and classification [16]. In this paper, the suggested approach in [16] will be applied to detect normal versus abnormal retina digital images.

The remaining of the paper is organized as follows: Section 2 presents the methodology. The results are presented in Section 3. Finally, we conclude in Section 4.

II. Methodology

As shown in Fig. 1, our methodology consists of applying second level decomposition DWT to retina digital image to obtain HH2 subband image, and applying a second DWT to the latter to obtain HH2* from which statistical features are extracted. Then, classification is performed and our system performance is evaluated. The following subsections describe each step.

doi:10.4304/jait.4.4.194-198

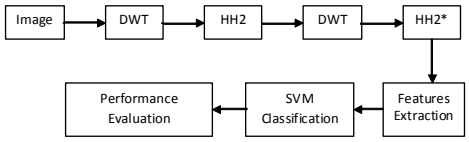

Figure 1. Flowchart of the proposed DWT-DWT approach.

A. Wavelet Transform

The continuous wavelet transform of a one dimension signal $x(n)$, square-integrable function, is defined as follows:

$$W_{\psi}(a,b) = \int_{-\infty}^{+\infty} x(n)\psi_{a,b}(n)\,dn \tag{1}$$

where,

$$\psi_{a,b}(n) = \frac{1}{\sqrt{a}}\psi\left(\frac{n-a}{b}\right) \tag{2}$$

The wavelet $\psi(t)$ is a real-valued mother wavelet, and a and b are respectively the dilation factor and the translation parameter.

For a given image, the discrete wavelet transform is applied following a process of subband decomposition that can be performed using low -$G(n)$- and high -$H(n)$- pass wavelet filters respectively (see Fig. 2) given by:

$$x_{low}(n) = \sum_{k=-\infty}^{+\infty} x[k]\,G[2n-k] \tag{3}$$

$$x_{high}(n) = \sum_{k=-\infty}^{+\infty} x[k]\,H[2n-k] \tag{4}$$

The two-dimensional (2-D) DWT is performed by consecutively applying a one dimension (1D) wavelet transform on rows and columns of the two dimension (2D) data. The 2-D WT, which is a separable filter bank in row and column directions, decomposes an image into four sub-images namely the LH, HL, and HH subband. In other words, a series of successively lower resolution images and their associated detail images are obtained: LL, LH, HL, and HH as shown in Fig. 2 where ↓2 denotes the downsampling operation by a factor of 2 [17][18].

The LL subband can be regarded as the approximation component or the background of the image, while the LH (horizontal high frequencies), HL (vertical high frequencies), HH (high frequencies in both directions) subband can be regarded as the detailed components of the image. Then, the obtained approximation images (LL) are decomposed again to obtain second-level detail and approximation images.

In this paper, we rely on high frequency components to extract features from retina digital images as they are adequate to characterize biological tissue images [8][13]-[16]. Thus, the DWT is applied to the image to obtain its HH subband as shown in Fig. 2. Then, a second DWT is applied to the latter to obtain HH* as presented in Fig. 1 from which the statistical features will be computed. In this study, the mother wavelet used is the Daubechies wavelet of order 4 (DB4) at two-level decomposition shown in Fig.4. For comparison purpose, Fig. 5 exhibits the standard Daubechies wavelet of order two (DB2). Note that; in contrary to DB2; the DB4 is near symmetric and smooth. This makes it suitable in biomedical image and signal processing. Indeed, various types of wavelets which can be used such as the Haar wavelet, Mexican Hat, Morlet wavelet, and Daubechies wavelet. However, the Mexican Hat and the Morlet wavelet are expensive to calculate; and the Haar wavelet is discontinuous; thus it is not suitable to approximate continuous signals. Besides, the popular Daubechies wavelet is a compactly supported orthonormal wavelet which is widely used in biomedical image processing [6]-[10][15][16].

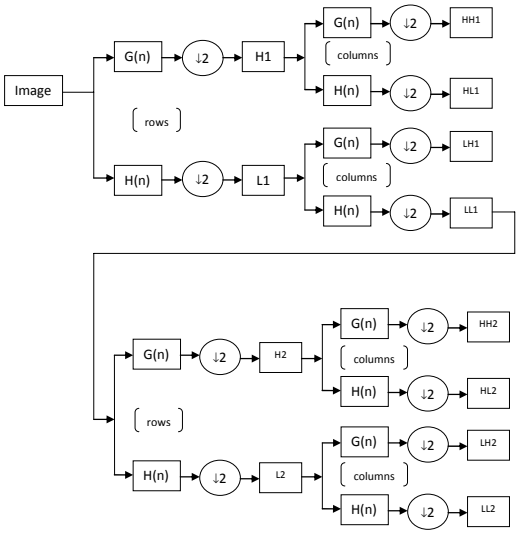

Figure 2. Two-level DWT decomposition.

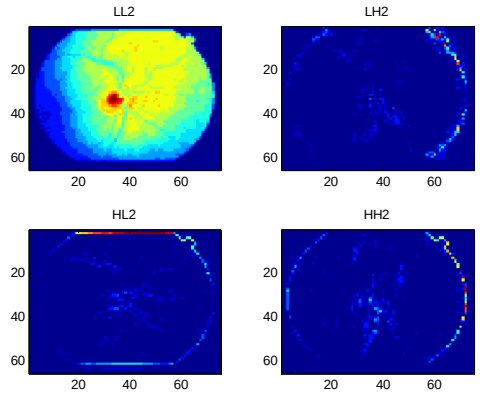

Figure 3. Decomposition of initial high frequency components by DWT.

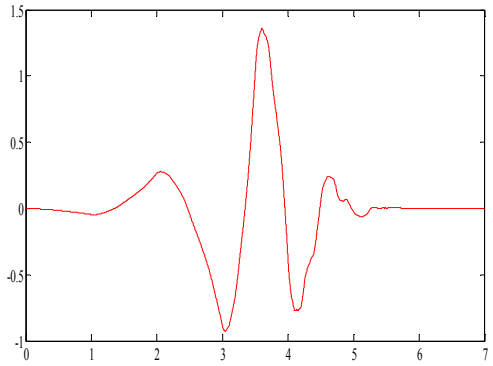

Figure 4. The Daubechies wavelet of order four.

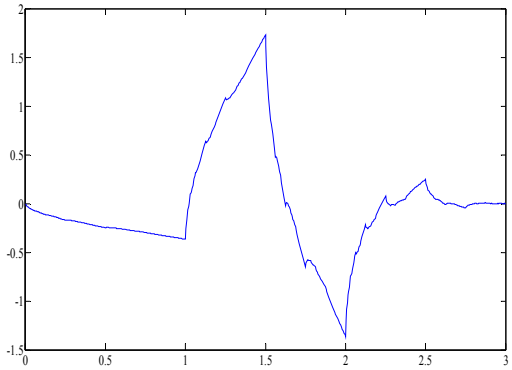

Figure 5. The Daubechies wavelet of order two.

B. Features Extraction

As shown in Fig.1, in order to extract better features from HH subband, a three-step process is followed. First, the DWT is applied to retina photograph and its high-high (HH) image is obtained. Second, a second DWT is applied to the HH image of the previous step to obtain HH* (see Fig.3). Finally, four statistical features are extracted from the high frequency subband HH*; including skewness, smoothness, uniformity, and entropy. They are defined as follows [19]:

$$Skewness = \sum_{i=0}^{L-1} (z_i - m)^3 p(z_i) \tag{5}$$

$$Smoothness = 1 - \frac{1}{1+\delta^2} \tag{6}$$

$$Uniformity = \sum_{i=0}^{L-1} p^2(z_i) \tag{7}$$

$$Entropy = -\sum_{i=0}^{L-1} p(z_i)\log(p(z_i)) \tag{8}$$

where z is a random variable indicating intensity, p is the probability density of the ith pixel in the histogram, L is the total number of intensity levels, and δ is the variance of pixels.

D. Support Vector Machines

In order to classify normal versus pathological retina images, support vector machines [20] are employed as the main classifier because of their scalability and ability to avoid local minima, and also because of their high classification performance shown in biomedical image recognition [10][15][16]. The discriminant function of the non-linear SVM for a binary classification problem is given by:

$$g(x) = sign\left(\sum_{i=1}^{S} \alpha_i y_i K(x_i, x) + b\right) \tag{9}$$

where x_i is the training data that belong to either {+1,-1}, S is the training data size, α_i are Lagrange multipliers subject to $0 < \alpha_i < c$, b is a bias weight, $K(\cdot)$ is the kernel function and c is a parameter that influences the tolerance to misclassifications. In this study, a polynomial kernel is used for the SVM since it is a global kernel, thus allowing data points that are far away from each other to have an influence on the kernel values as well. The polynomial kernel is given by:

$$K(x, x_i) = ((x_i \cdot x) + 1)^d \tag{10}$$

where the kernel parameter d is the degree of the polynomial to be used. For simplicity, it is set to 2 in this study.

Finally, the performance of the non-linear SVM is evaluated by computing the correct classification rate given by:

$$classification\ rate = \frac{classified\ samples}{total\ number\ of\ samples} \tag{11}$$

III. DATA AND RESULTS

A set of 93 color retina images from STARE database [21] were employed to test our DWT-DWT processing approach. The dataset includes 23 normal images, 20 images with drusens, 24 with microaneurysms (MA), and 26 with exudates. Selected examples of the dataset are shown in Fig. 5. A normal image in double color format and its mesh representation are shown in Fig.6. The mesh of each DWT subband (LL, LH, HL, HH) is presented in Fig.7. Note that a mesh draws a surface representation of the image where each color is proportional to surface height. The SVM were trained and test based on their ability to classify normal retina image and abnormal one. In other words, it is a one against one classification problem. The performance of the SVM was measured using the correct classification rate which is defined as the ratio of correctly classified samples over total classified samples as defined in Equation (11). In order, to enhance the generalization capability of the proposed approach, the leave-one-out method (LOOM) is adopted.

The description of the LOOM follows. First, the data is partitioned into *k* equally (or nearly equally) sized folds, where *k* is equals the number of instances in the data. Second, *k* iterations of training and validation are performed such that in each iteration nearly all the data are used for training except for a single observation for which the model is tested. This type of cross-validation method is suitable when the number of available observations is small. Following the LOOM, both the average and standard deviation of the correct classification rate are computed to assess the effectiveness of our DWT-DWT approach.

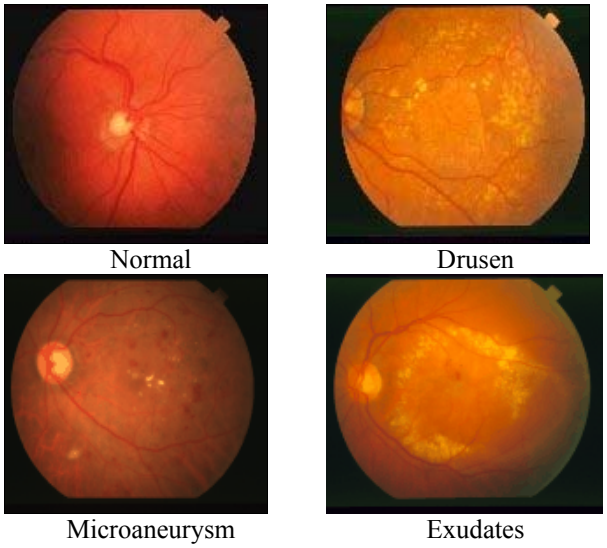

Figure 6. Examples of retina digital images.

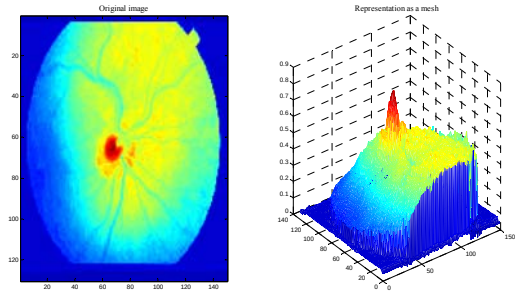

Figure 7. Normal image (left) and its mesh representation (right).

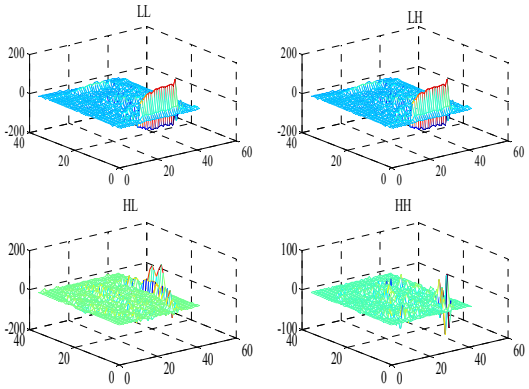

Figure 8. Mesh representations of subbands.

The simulation results show evidence of the effectiveness of our DWT-DWT methodology. For instance, in the case of normal versus microaneurysms classification problem, the obtained correct detection (classification) rate is 0.7086±0.0950 with HH (DWT) based features, and is 0.8030±0.1187 HH* (DWT-DWT approach). In the problem of classification of normal versus images with exudates, the obtained correct detection rate is 0.7807±0.1370 with HH based features, and is 0.8880±0.0673 following the DWT-DWT approach. Finally, the obtained accuracy in the detection of drusen is 0.3416±0.1033 using HH based features, and it is 0.6972±0.1127 using HH* features. In other words, following the suggested DWT-DWT approach the classification rate improves by 9.44%, 10.73%, and 35.56% basis point for microaneurysms, exudates, and drusen respectively.

In sum, the application of the DWT to high frequency images allows improving the accuracy rate; particularly for drusen detection. Indeed, drusen, microaneurysm, and exudates yield to a proliferation of fibrous tissue which causes deterioration in the structure of the cell components in the biological tissue. This deterioration is well represented by high frequency variations in the wavelet domain. In contrary, low frequency variations in the wavelet domain only represent smooth parts of the analyzed image which are not affected by pathologies. Finally, the proposed approach is suitable for features extraction from both retina digital images and mammograms [16].

TABLE I
SIMULATION RESULTS

	Microaneurysms	Microaneurysms	Exudates	Exudates	Drusen	Drusen
	HH (DWT)	HH* (DWT to DWT)	HH (DWT)	HH* (DWT to DWT)	HH (DWT)	HH* (DWT to DWT)
Average	0.7086	**0.8030**	0.7807	**0.8880**	0.3416	**0.6972**
Std.dev	0.0950	0.1187	0.1370	0.0673	0.1033	0.1127

VII. CONCLUSION

A new methodology for features extraction from retina digital images in the frequency domain is presented. In particular, the discrete wavelet transform (DWT) is applied to retina image to obtain its high-high (HH) subband. Then, a second decomposition by DWT is applied to the HH subband obtained in the previous step to obtain HH*. Finally, statistical features are computed from HH* and support vector machines were employed to classify normal versus abnormal retina digital images. The simulation results from leave-one-out cross-validation technique show the effectiveness of our DWT-DWT methodology in comparison with features extracted from HH subband alone. This finding suggests that multiresolution analysis of retina high frequency components help characterizing its biological tissue. This result is similar to our previous work where we applied the presented DWT-DWT methodology to mammograms. For future work, the suggested methodology will be applied to cerebral images. Also, the accuracy of features extracted from horizontal and vertical high frequency subbands will be examined. Finally, different decomposition levels will be investigated.

REFERENCES

[1] M. Baroni, S. Diciotti, A. Evangelisti, P. Fortunato, and A. La Torre, "Texture classification of retinal layers in optical coherence tomography," Proceedings of the Mediterranean Conference on Medical and Biological Engineering and Computing, Ljubljana, Slovania, June 26-30, 2007.

[2] N. Lee, A.F. Laine, and T.R. Smith, "Learning non-homogenous textures and the unlearning problem with application to drusen detection in retinal images," Proceedings of The 5th IEEE International Symposium on Biomedical Imaging, Paris, France, May 4-17, 2008.

[3] J. Meier, R. Bock, L.G. Nyúl, and G. Michelson, "Eye Fundus image processing system for automated glaucoma classification," Proceedings of The 52nd Internationales Wissenschaftliches Kolloquium Technische Universität Ilmenau, Ilmenau, Germany, September 10-13, 2007.

[4] A.M.A.-R. Franzco, T. Molteno, and A.C.B.M. Franzco, "Fourier analysis of digital retinal images in estimation of cataract severity," Clinical and Experimental Ophthalmology, vol. 36, pp.637-645, 2008.

[5] J. Nayak, R.U. Acharya, P.S Bhat, N. Shetty, and T.-C. Lim, "Automated diagnosis of glaucoma using digital fundus images," Journal of Medical Systems, vol. 33, pp. 337-346, 2009.

[6] M. Lamard, G. Quellec, P. M. Josselin, G. Cazuguel, B. Cochener, and C. Roux, "Detection of lesions in retina photographs based on the wavelet transform," World Congress on Medical Physics and Biomedical Engineering, vol. 14, pp.2435-2438, 2007.

[7] A. Khademi, and S. Krishnan, "Shift-invariant discrete wavelet transform analysis for retinal image classification," Medical and Biological Engineering and Computing, vol. 45, pp.1211-1222, 2007.

[8] G. Quellec, M. Lamard, P.M. Josselin, G. Cazuguel, B. Cochener, and C. Roux, "Optimal wavelet transform for the detection of microaneurysms in retina photographs," IEEE Transactions on Medical Imaging, vol. 27, pp. 1230-1241, 2008.

[9] F.D. Yagmur, B. Karlik, and A. Okatan, "Automatic recognition of retinopathy diseases by using wavelet based neural network," Proceedings of The IEEE International Conference on The Applications of Digital Information and Web Technologies, Ostrava, Czech Republic, August 4-6, 2008.

[10] L. Xu, and S. Luo, "Support vector machine based method for identifying hard exudates in retinal images," Proceedings of The IEEE Youth Conference on Information, Computing and Telecommunication, Beijing, China, September 20-21, 2009.

[11] I. Daubechies, "Orthonormal bases of compactly supported wavelets," Communications on Pure and Applied Mathematics, vol. 41, pp.909-996, 1988.

[12] S. Mallat, *A Wavelet Tour of Signal Processing*, Academic Press, 1999.

[13] M.H.J. Sepehr, R-R. Gholamali, and H. Behnam, "A novel method for breast cancer prognosis using wavelet packet based neural network," Proceedings of The IEEE Engineering in Medicine and Biology 27th Annual Conference, Shanghais, September 1-4, 2005.

[14] I. Buciu, and A. Gacsadi, "Gabor wavelet based features for medical image analysis and classification," Proceedings of The IEEE 2nd International Symposium on Applied Sciences in Biomedical and Communication Technologies, Bratislava, Slovak Republic, November 24-27, 2009.

[15] S. Lahmiri, and M. Boukadoum, "Hybrid discrete wavelet transform and Gabor filter banks Processing for features extraction from biomedical images," Journal of Medical Engineering, vol. 2013, Article ID 104684, 13 pages, 2013. doi:10.1155/2013/104684.

[16] S. Lahmiri, "A wavelet-wavelet based processing approach for mammograms," Journal of Advances in Information Technology, vol. 3, pp. 162-167, 2012.

[17] S.K. Meher, and S.K. Pal, "Rough-wavelet granular space and classification of multispectral remote sensing image," Applied Soft Computing, vol.11, pp.5662–5673, 2011.

[18] B.U. Shankar, S.K. Meher, and A. Ghosh, " Wavelet-fuzzy hybridization: Feature-extraction and land-cover classification of remote sensing images," Applied Soft Computing, vol.11, pp.2999-3011, 2011.

[19] R.C. Gonzalez, R.E. Woods, *Digital Image Processing*, Third Edition, Prentice Hall 2008.

[20] V.N. Vapnik, *The Nature of Statistical Learning Theory*, Springer-Verlag, 1995.

[21] http://www.ces.clemson.edu/~ahoover/stare/

Call for Papers and Special Issues

Aims and Scope

JAIT is intended to reflect new directions of research and report latest advances. It is a platform for rapid dissemination of high quality research / application / work-in-progress articles on IT solutions for managing challenges and problems within the highlighted scope. JAIT encourages a multidisciplinary approach towards solving problems by harnessing the power of IT in the following areas:

- **Healthcare and Biomedicine** - advances in healthcare and biomedicine e.g. for fighting impending dangerous diseases - using IT to model transmission patterns and effective management of patients' records; expert systems to help diagnosis, etc.
- **Environmental Management** - climate change management, environmental impacts of events such as rapid urbanization and mass migration, air and water pollution (e.g. flow patterns of water or airborne pollutants), deforestation (e.g. processing and management of satellite imagery), depletion of natural resources, exploration of resources (e.g. using geographic information system analysis).
- **Popularization of Ubiquitous Computing** - foraging for computing / communication resources on the move (e.g. vehicular technology), smart / 'aware' environments, security and privacy in these contexts; human-centric computing; possible legal and social implications.
- **Commercial, Industrial and Governmental Applications** - how to use knowledge discovery to help improve productivity, resource management, day-to-day operations, decision support, deployment of human expertise, etc. Best practices in e-commerce, e-commerce, e-government, IT in construction/large project management, IT in agriculture (to improve crop yields and supply chain management), IT in business administration and enterprise computing, etc. with potential for cross-fertilization.
- **Social and Demographic Changes** - provide IT solutions that can help policy makers plan and manage issues such as rapid urbanization, mass internal migration (from rural to urban environments), graying populations, etc.
- **IT in Education and Entertainment** - complete end-to-end IT solutions for students of different abilities to learn better; best practices in e-learning; personalized tutoring systems. IT solutions for storage, indexing, retrieval and distribution of multimedia data for the film and music industry; virtual / augmented reality for entertainment purposes; restoration and management of old film/music archives.
- **Law and Order** - using IT to coordinate different law enforcement agencies' efforts so as to give them an edge over criminals and terrorists; effective and secure sharing of intelligence across national and international agencies; using IT to combat corrupt practices and commercial crimes such as frauds, rogue/unauthorized trading activities and accounting irregularities; traffic flow management and crowd control.

The main focus of the journal is on technical aspects (e.g. data mining, parallel computing, artificial intelligence, image processing (e.g. satellite imagery), video sequence analysis (e.g. surveillance video), predictive models, etc.), although a small element of social implications/issues could be allowed to put the technical aspects into perspective. In particular, we encourage a multidisciplinary / convergent approach based on the following broadly based branches of computer science for the application areas highlighted above:

Special Issue Guidelines

Special issues feature specifically aimed and targeted topics of interest contributed by authors responding to a particular Call for Papers or by invitation, edited by guest editor(s). We encourage you to submit proposals for creating special issues in areas that are of interest to the Journal. Preference will be given to proposals that cover some unique aspect of the technology and ones that include subjects that are timely and useful to the readers of the Journal. A Special Issue is typically made of 10 to 15 papers, with each paper 8 to 12 pages of length.

The following information should be included as part of the proposal:

- Proposed title for the Special Issue
- Description of the topic area to be focused upon and justification
- Review process for the selection and rejection of papers.
- Name, contact, position, affiliation, and biography of the Guest Editor(s)
- List of potential reviewers
- Potential authors to the issue
- Tentative time-table for the call for papers and reviews

If a proposal is accepted, the guest editor will be responsible for:

- Preparing the "Call for Papers" to be included on the Journal's Web site.
- Distribution of the Call for Papers broadly to various mailing lists and sites.
- Getting submissions, arranging review process, making decisions, and carrying out all correspondence with the authors. Authors should be informed the Instructions for Authors.
- Providing us the completed and approved final versions of the papers formatted in the Journal's style, together with all authors' contact information.
- Writing a one- or two-page introductory editorial to be published in the Special Issue.

Special Issue for a Conference/Workshop

A special issue for a Conference/Workshop is usually released in association with the committee members of the Conference/Workshop like general chairs and/or program chairs who are appointed as the Guest Editors of the Special Issue. Special Issue for a Conference/Workshop is typically made of 10 to 15 papers, with each paper 8 to 12 pages of length.

Guest Editors are involved in the following steps in guest-editing a Special Issue based on a Conference/Workshop:

- Selecting a Title for the Special Issue, e.g. "Special Issue: Selected Best Papers of XYZ Conference".
- Sending us a formal "Letter of Intent" for the Special Issue.
- Creating a "Call for Papers" for the Special Issue, posting it on the conference web site, and publicizing it to the conference attendees. Information about the Journal and Academy Publisher can be included in the Call for Papers.
- Establishing criteria for paper selection/rejections. The papers can be nominated based on multiple criteria, e.g. rank in review process plus the evaluation from the Session Chairs and the feedback from the Conference attendees.
- Selecting and inviting submissions, arranging review process, making decisions, and carrying out all correspondence with the authors. Authors should be informed the Author Instructions. Usually, the Proceedings manuscripts should be expanded and enhanced.
- Providing us the completed and approved final versions of the papers formatted in the Journal's style, together with all authors' contact information.
- Writing a one- or two-page introductory editorial to be published in the Special Issue.

More information is available on the web site at http://www.academypublisher.com/jait/.