Hybrid Parallel Image Processing Algorithm for Binary Images with Image Thinning Technique

A. Sathesh[1], Edriss Eisa Babikir Adam[2]

[1]Department of Electronics and Communication Engineering, Eritrea Institute of Technology, Eritrea.

[2]Assistant Professor, Department of EEE, Mainefhi College of Engineering and Technology, Mainefhi, Eritrea.

E-mail: [1]Sathesh4you@gmail.com, [2]bonzoga20@gmail.com

Abstract

Image thinning is the most essential pre-processing technique that plays major role in image processing applications such as image analysis and pattern recognition. It is a process that reduces a thick binary image into thin skeleton. In the present paper we have used hybrid parallel thinning algorithm to obtain the skeleton of the binary image. The result skeleton contains one pixel width which preserves the topological properties and retains the connectivity.

Keywords: Image thinning, parallel thinning algorithm, image processing, skeleton, binary image, connectivity.

1. Introduction

Thinning is a process which maintains the connectivity of original pattern and transforms digital pattern from one form to another with reduced thickness [1]. Skeleton in image processing is achieved through image thinning by removing the selected foreground pixels from binary images. To construct a good image shape thinning is applied on various images and it is achieved by reducing the width of the pattern to single pixel skeletons [2]. When it is applied on the binary image we get a thin like drawing named as thinned image. The

parallel thinning algorithm improves the speed and quality of the thinned image [3]. The previous methodologies were tried to improvise the performance of the Thinning algorithm but they could not achieve the desired goal, in the proposed method we have used hybrid parallel algorithm on binary image [4]. It comprises of three stages namely pre-processing stage, peeling stage and post processing stage. The initial pre-processing stage is used for determined and preparation of the contour. The second peeling stage is used for testing and removal of undesirable pixels. The final post-processing stage is used for producing final one-pixel width skeleton. The final stage works even when the previous two stages fail to produce the required number of pixels [5]. Pre-processing and Post-processing stages follows sequential approach and the Peeling stage follow the parallel approach. By using hybrid parallel approach we can achieve better results.
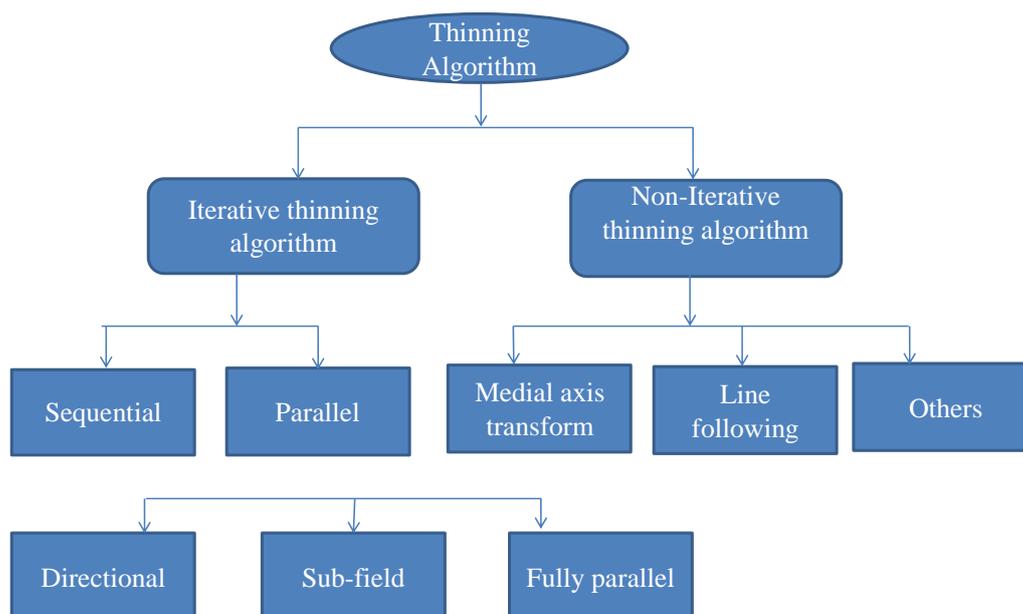
Figure 1. Classification of Thinning Algorithm

2. Related Work

The thinning algorithm plays a vital role in computer vision and image processing. The thinning process is carried out as iterations. The thinning algorithm has two main divisions. It

is a combinational algorithm to obtain skeleton [6]. Two pass parallel thinning algorithm is applied on the binary image to achieve one pixel width skeleton and it preserves the connectivity and removes noise [7]. A hybrid thinning algorithm based on directional approach is applied on binary image to achieve thinning on images. Here the ZS algorithm is combined with the subfield method to obtain the skeleton [8]. Real time image processing issue are solved by using different image processing frameworks. The VHGW algorithm is implemented on the GPU framework to achieve better results. Comparative study of GPU and CUDA is done on images [9]. An algorithm based frame work is designed to rectify the problems arrived on binary images. Query pixel and labelling has major impact on image processing [10]. By detecting the thin edge of a noise image we can develop a new method. It mainly concentrates on the edges and preserves it for further needs [11]. Binary images are mostly used for image analysis because of its morphological characteristics. One of the best methodologies is parallel thinning method that can be applied to the binary image for better results. Many techniques come under parallel thinning algorithm such as GPU, CUDA, Hadoop and MATLAB are discussed with their advantages and disadvantages [12]. Iterative thinning algorithm improvises the result and reduces the low accuracy problem. It eliminates unwanted pixels at each stage and carries the useful pixels for next iteration [13]. The thinning algorithm can be applied on real time with handwritten texts. It is quite difficult to achieve in real time by using template matching technique we can achieve it easily [14-16]. The process of skeletonization is to obtain one pixel width skeletons from a binary image. Fussy logic can also applicable to obtain skeletons. This is quite complex process [17].

3. Proposed Work

A binary image has pixels of only two colours namely black and white. Their pixel value is either 0 or 1. It is stored in one bit so it is termed as 1 bit it is also coined as bi-level or two levels. The value 0 is for black and value 1 or 255 is for white [18]. Often we use binary image because we can accurately determine the size, shape, positioning and orientation of the object with the help of sufficient data present in the binary image. It is helpful to analyse an

object in 2 dimensions and it also used to determine the defects on the object easily [19-21]. Here we take the binary image as input, in this process the black pixel is assigned with any one of the following three pixels namely pattern pixel, contour pixel or skeleton pixel. The value of black pattern pixel is 1 and it is represented as a blank black cell [22]. The black contour pixel has the value 2 and represented as a black cell along with the flag C. finally the black skeleton pixel has the value 3 and represented as a black cell with a flag S. By the same time the white pixels are quoted with a value 0 and represented by a white cell. Row-by-row scanning is done from top left corner to the bottom right corner of the image [23]. Scanning scopes the pixel of the image for one time and symbolized by P. like so we get eight pixels with (x, y) positions.

Table1. Pixel arrangement

P(x-1, y-1)	P(x, y-1)	P(x+1, y-1)
P(x-1, y)	P(x, y)	P(x+1, y)
P(x+1, y+1)	P(x, y+1)	P(x+1, y+1)

The pixels are represented mathematically as (x-1, y-1), (x, y-1), (x+1, y-1), (x+1, y), (x+1, y+1), (x, y+1), (x-1, y+1) and (x-1, y). The scoped pixels fall under the angels 0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°. The neighbouring eight pixels are indicated as P_1, P_2, P_3, P_4, P_5, P_6, P_7, P_8. The proposed hybrid parallel method aims to utilize all the pros of both sequential and parallel methods and omits their drawbacks [24-25]. The proposed work initially detects the contour pixel and enriches the noisy edges in sequential pre-processing stage. Then the undesirable pixels of the contour are detached by using parallel peeling stage and finally after the completion of above stages the skeleton is primed to reach a seamless skeleton in one pixel width.
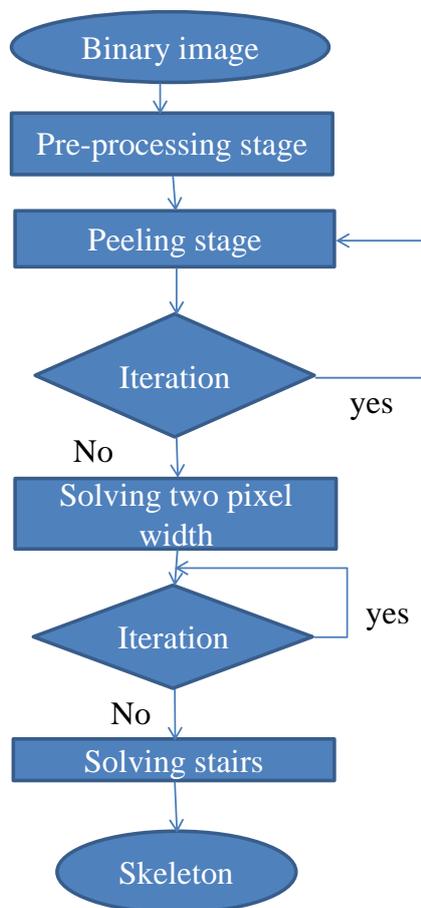
Figure 2. Flow chart of thinning algorithm

3.1   Pre-Processing

The stage 1 is Pre-processing stage. In this stage the contour pixels are determined by removing or keeping the tested contour pixels. It is an iterative process. Contour pixel is spotted by considering the pattern pixel associated with any one of the angles 0°, 90°, 180°, 270°.

The outer contour layer is obtained only if it comes under these degrees, so that the outer layer of the pattern pixel will become contour pixel. This makes removing and testing process easy. The scoped pixel gets value 2 if it satisfies the conditions scoped pixel equals 1 and even neighbouring pixels equals 0

If P=1

{

If $\{P_2 \times P_4 \times P_6 \times P_8 = 0\}$ then P=2

Else if {otherwise} then P=1

}

Removing the noisy pixel at edges is a complex task in thinning. The unwanted noisy pixels at the edges are prominent and they are wrongly scoped as contour pixel and finally it arises tailing problems. So it is very much important to remove the noisy pixels at edges. To fix this problem the conditions are applied on the scoped pixel and if it obeys the below conditions they are considered as noisy pixels and they are removed. The other pixel which comes under 0°, 90°, 180°, 270° are considered as new contour pixels. The removed pixels will be assigned with the value 0 and the new contour pixel will get the value 2. The Algorithm is as follow

Preparation of Noisy edge

If P=2

{

If $\{P_4+ P_5+P_6+P_7+P_8 =0$ & $P_1+P_3 \neq 0$ & $P_2 \neq 0\}$ then P =0, $P_2 =2$

Else if $\{P_1+P_2+P_6+P_7+P_8=0$ & $P_3+P_5 \neq 0$ & $P_4 \neq 0$ }then P=0, $P_4=2$

Else if $\{P_1+P_2+P_3+P_4+P_8=0$ & $P_5+P_7 \neq 0$ & $P_6 \neq 0\}$then P=0, $P_6=2$

Else if $\{P_2+P_3+P_4+P_6=0$ & $P_1+P_7= 0$ & $P_8 \neq 0\}$ then P=0, $P_8=2$

}

3.2 Peeling Process

The second stage is the Peeling stage. It is used for testing and removal of undesirable pixels and it follows parallel process. It is done once the pre-processing stage is completed. The testing is carried out by applying a set of rules on the contour pixels and checks whether it has to be removed or not.

3.2.1 Preserving One Pixel Width Strokes

Here we have to consider the Stroke with one pixel width. In some cases these thickness will appear one pixel width at the beginning or at any stage of thinning process. It may look like unwanted pixels by actually these are main strokes of skeletons that will be in-between two back ground pixels. We should not remove it when it detected as unwanted pixel. It should be preserved as final result of skeleton and coined with the value 3 and this must not be carried in next iteration. The algorithm is as follows

One pixel strokes preservation

If P=2

{

If $\{P_2+P_6=0\}$ then P=3

Else if $\{P_4+P_8=0\}$ then P=3

Else if $\{P_1 \neq 0 \ \& \ P_2+P_8=0\}$ then P=3

Else if $\{P_3 \neq 0 \ \& \ P_2+P_4=0\}$ then P=3

Else if $\{P_5 \neq 0 \ \& \ P_4+P_6=0\}$ then P=3

Else if $\{P_7 \neq 0 \ \& \ P_6+P_8=0\}$ then P=3

}

3.2.2   Corner Pixel Removal

The other pixel which doesn't satisfy the previous condition may be unwanted contour pixels. These must be taken into account and tested. Almost all the pixels will stay in between foreground and pattern pixel. We have to check for the unwanted contour pixel among them by using the following algorithm. If these conditions are satisfied those pixels will be removed.

Corner pixel removal

If P=2

{

If $\{P_1+ P_2+ P_8 =0$ & $P_4 = 2$ & $P_6 = 2$ & $P_5=1\}$ then P =0

Else if $\{P_2+P_3+P_4=0$ & $P_6=2$ & $P_8=2$ & $P_7=1\}$ then P=0

Else if $\{P_4+P_5+P_6=0$ & $P_2=2$ & $P_8=2$ & $P_1=1\}$ then P=0

Else if $\{P_6+P_7+P_8=0$ & $P_2=2$ & $P_4=2$ & $P_3=1\}$ then P=0

Else if $\{(P_2 =1$ & $P_6=0) || (P_6 =1$ & $P_2=0)\}$ then P=0

Else if $\{(P_8 =1$ & $P_4=0) || (P_4 =1$ & $P_8=0)\}$ then P=0

}

Once the process is done the contour pixels will be detected and those will be removed based on the condition. The resultant contour pixel and the skeleton pixels will be obtained after the testing. The removed pixels will be coined with the value 0, the remaining contour pixels will get the value 2 and carried out for the next iteration of pre-processing and peeling and finally the skeleton pixels will get the value 3 and this will be considered as end resultant value and this will not be taken for next iterations. This process is repeated until we get nil contour pixels for removal.

3.3 Post-Processing

The final stage is the Post-processing stage. Here the resultant skeleton with one width pixel is obtained. Almost we will achieve the skeleton with one width pixel in above stage but still we also get skeletons with two width pixel, the accurate one has only one width pixel skeleton so we apply conditions to the pixels in sequential order. Here the values are assigned for each pixel. Value 0 is assigned for background, value 2 is assigned for pattern pixel with two pixel width skeleton and value 3 is assigned for one pixel width skeleton.

3.3.1 Solution For Two Pixel Width

The crucial part in thinning process is solving two pixel width skeletons. These are from the even strokes thickness. One among this two pixel width skeleton is the resultant pixel we need to achieve our skeletons topology. This has any one of the angle 0°, 90°, 180° or 270°. We use the following algorithm to fix the problem. When the pattern pixel with value 1 connected diagonally (45°, 135°, 225°, 315°) with other pixels it will be removed. This should not affect the connectivity of testing and also the opposite pixel considered as background pixel with value 0. This iteration repeats until we achieve our expected result. Now we get our skeleton with one pixel width with both horizontal and vertical strokes.

If P=1

{

If $\{P_1+P_2+P_8=0 \ \& \ P_5=1\}$ then P=0

Else if $\{P_2+P_3+P_4=0 \ \& \ P_7=1\}$ then P=0

Else if $\{P_4+P_5+P_6=0 \ \& \ P_1=1\}$ then P=0

Else if $\{P_6+P_7+P_8=0 \ \& \ P_3=1\}$ then P=0

}

3.3.2   Solution For Stairs

The other problem is formation of stairs. This is formed when the pattern pixel with value 1 is connected between two pixel width values 1 or 3 which are diagonally connected in 45º, 135º, 225º, 315º. To remove this problem one time scanning is applied on to the two pixel width skeleton. Finally we get accurate diagonal skeleton with one pixel width.

If P=1

{

If $\{P_2 \times P_8 \neq 0$ & $P_1=0\}$ then P=0

Else if $\{P_2 \times P_4 \neq 0$ & $P_3=0\}$ then P=0

Else if $\{P_4 \times P_6 \neq 0$ & $P_5=0\}$ then P=0

Else if $\{P_6 \times P_8 \neq 0$ & $P_7=0\}$ then P=0

}

4.   Result and Discussion

The proposed work is experimented with existing thinning process to show the better results. It has been compared with Abu-ain, K3M, Zhang and Huang methods. We have taken visual and statistical experiments on these methods to achieve better results. The above mentioned methods have similar iterative process as our proposed work. The visual experiment gives a clear view of the best result.
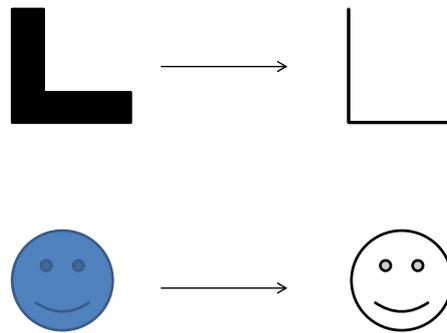
Figure3. Binary image to skeleton

Though the visual experiment gives better understandable view of the outputs we need statistical experiments to get more accurate values in the form of numbers. Thinning rate, noise sensitivity, NOS and Heads are the four parameters to determine the statistical performance of the proposed work.

Table 2. statistical performance analysis table

	TR	Result	NS	Result	HN	Result
Proposed	99.72	2547	98.12	1735	96.53	0
Abu-ain	99.68	2113	92.09	1886	91.96	0
Huang	98.88	2579	91.50	1717	83.58	1
Zhang	95.62	2681	93.25	1912	90.34	0
K3M	87.64	2612	94.92	1749	92.88	0
Standard	-	2535	-	1744	-	0
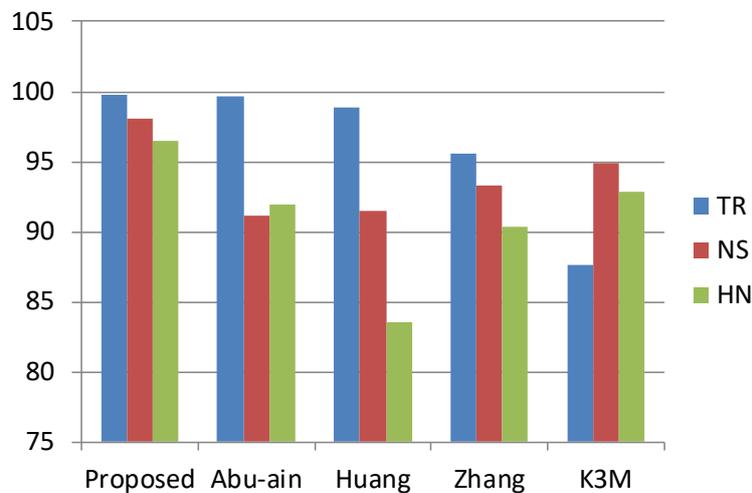
Figure 4. Graphical representation of statistical performance

5. Conclusion

The aim of this paper is to achieve parallel thinning process on the binary image. We have performed thinning process with three stage namely pre-processing, peeling and post processing. The foreground pixel of the binary image is removed by a morphological operation called hybrid parallel algorithm. The end result is compared with Abu-ain, K3M, Zhang and Huang methods and it is proven visually and statistically that the hybrid parallel processing gives betters result. It is easy to design, it does not affect the topological shape and connectivity of the image and the one pixel width are also preserved under every aspects.

References

[1] Bilal Bataineh, "An Iterative Thinning Algorithm for Binary Images Based on Sequential and Parallel Approaches", Pattern recognition and image analysis vol.28 no.1 (2018).

[2] Sungheetha, Akey, and Rajesh Sharma. "3D Image Processing using Machine Learning based Input Processing for Man-Machine Interaction." Journal of Innovative Image Processing (JIIP) 3, no. 01 (2021): 1-6.

[3]   Ponmaniraj, S., Tapas Kumar, and Amit Kumar Goel. "Intrusion Detection: Spider Content Analysis to Identify Image-Based Bogus URL Navigation." In Intelligent Data Communication Technologies and Internet of Things: Proceedings of ICICI 2020, pp. 603-617. Springer Singapore, 2021.

[4]   Gaurav Kumar, Pradeep Kumar, "Parallel Thinning Algorithm for Binary Images", research gate 255707568 (2012).

[5]   Palani, U., Mrs D. Vasanthi, and Ms S. Rabiya Begam. "Enhancement of Medical Image Fusion Using Image Processing." Journal of Innovative Image Processing (JIIP) 2, no. 04 (2020): 165-174.

[6]   Jacob, Joel Eliza, and S. Saritha. "Video Enhancement and Low-Resolution Facial Image Reconstruction for Crime Investigation." In Intelligent Data Communication Technologies and Internet of Things: Proceedings of ICICI 2020, pp. 773-788. Springer Singapore, 2021.

[7]   Ranganathan, G. "A Study to Find Facts Behind Preprocessing on Deep Learning Algorithms." Journal of Innovative Image Processing (JIIP) 3, no. 01 (2021): 66-74.

[8]   Lynda, et al., "A New Thinning Algorithm for Binary Images", International conference on control, engineering and information technology (2015).

[9]   Sahila, K. M., and Bibu Thomas. "Secure Digital Image Watermarking by Using SVD and AES." In Intelligent Data Communication Technologies and Internet of Things: Proceedings of ICICI 2020, pp. 805-818. Springer Singapore, 2021.

[10]   Adam, Edriss Eisa Babikir. "Survey on Medical Imaging of Electrical Impedance Tomography (EIT) by Variable Current Pattern Methods." Journal of ISMAC 3, no. 02 (2021): 82-95.

[11]   Sanjay, et al., "Study of Parallel Image Processing with the Implementation of vHGW algorithm using CUDA on NVIDIA's GPU framework", proceeding on world congress on engineering vol. 1 WCE (2017).

[12] Manoharan, J. Samuel. "A Novel User Layer Cloud Security Model based on Chaotic Arnold Transformation using Fingerprint Biometric Traits." Journal of Innovative Image Processing (JIIP) 3, no. 01 (2021): 36-51.

[13] Reddy, Satthi, Praharsha Nishanth, Dattatreya Dash, and N. Rakesh. "Image Classification Using Machine Learning Techniques for Traffic Signal." In Intelligent Data Communication Technologies and Internet of Things: Proceedings of ICICI 2020, pp. 233-244. Springer Singapore, 2021.

[14] T. Asano, et al., "A new Algorithm Framework for Basic Problems on Binary Images", Discrete Applied mathematics 10.1016 (2016).

[15] Tesfamikael, Hadish Habte, Adam Fray, Israel Mengsteab, Adonay Semere, and Zebib Amanuel. "Simulation of Eye Tracking Control based Electric Wheelchair Construction by Image Segmentation Algorithm." Journal of Innovative Image Processing (JIIP) 3, no. 01 (2021): 21-35.

[16] T. Ahmad et al., "Detection of Continuous and Thin Edges of Noisy Images by New Kernel approach", IEEE 9th annual information technology, electronics and mobile communication conference pp. 716-724 (2018).

[17] Khattar, Anuradha, and S. M. K. Quadri. "Deep Domain Adaptation Approach for Classification of Disaster Images." In Intelligent Data Communication Technologies and Internet of Things: Proceedings of ICICI 2020, pp. 245-259. Springer Singapore, 2021.

[18] Dhaya, R. "Analysis of Adaptive Image Retrieval by Transition Kalman Filter Approach based on Intensity Parameter." Journal of Innovative Image Processing (JIIP) 3, no. 01 (2021): 7-20.

[19] Sanjay et al., "Parallel image Processing Techniques, Benefits and Limitations", research journal of applied science, engineering and technology 12.2324 (2016).

[20] Dutta, Sayantan, and Ayan Banerjee. "Highly Precise Modified Blue Whale Method Framed by Blending Bat and Local Search Algorithm for the Optimality of Image Fusion Algorithm." Journal of Soft Computing Paradigm (JSCP) 2, no. 04 (2020): 195-208.

[21] G.V. Padole et al., "New Iterative Algorithm for Thinning Binary Images", 3rd International conference on emerging trends in engineering and technology (2010).

[22] Chen, Joy Iong Zong, and Lu-Tsou Yeh. "Analysis of the Impact of Mechanical Deformation on Strawberries Harvested from the Farm." Journal of ISMAC September 2020, no. 3 (2020): 166-172

[23] Liangbin et al., "A Fast thinning Algorithm of square Hmong Character handwriting using template Matching Mechanism", 8th International conference on digital home (2020).

[24] Dhaya, R. "Flawless Identification of Fusarium Oxysporum in Tomato Plant Leaves by Machine Learning Algorithm." Journal of Innovative Image Processing (JIIP) 2, no. 04 (2020): 194-201.

[25] Punam K. Saha et al., "Fuzzy Object Skeletonization: Theory, Algorithm and Application", IEEE Transactions on Visualization and computer graphics vol.24 issue 8 (2018).

Author's biography

A. Sathesh completed his master's degree in the year 2006 and has published several papers in national and international journals. His areas of interest include wavelets and multi-resolution transforms for image denoising. Currently, he is occupying an academic position in Eritrea after having worked in a reputed University in South India for the past 5 years. He is pursuing his research work in the area of complex wavelets for image approximations with a deep learning approach.

Edriss Eisa Babikir Adam received his B.S. degree in electrical engineering from Blue Nile University, Damazein, Sudan, in 2004 and his MSc. degree in Electronics and Information Engineering from Sudan University of Science and Technology, Sudan, in 2008. Currently, he is working in Mainefhi College of Engineering and Technology, Eritrea. He has published several papers in national and international journals. His current research interests are in the

areas of cooperative wireless communications, and sensor MIMO systems. He received CHINA SCHOLARSHIP COUNCIL CSC 2010 collaboration with the Sudan government.