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A Short Review of Methods for Face Detection and Multifractal Analysis

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Abstract

The purpose of this paper is to present short reviews the face detection techniques and to study the effect of Multifractal analysis in detecting facial features. In reviewing the existing techniques, we have compared the performance of Nilsson et al's algorithm, Haar Training implemented within Open Source Computer Vision Library (OpenCV) and Keinzle's algorithm in face detection. Then, we have produced some experimental results suggesting that the Multifractal approach would help to extract key facial features of a human face. We conclude the paper with some discussions on how the work can be taken further.

1. Introduction

It is well know that traditional means of user authentication such as the use of ID cards and passwords are not reliable enough. Furthermore, many biometric techniques available for security are not most convenient and are not natural enough for the user. For example, in the case iris scan technology the subject is required to comply and pose for the iris scanner.

Face recognition, on the other hand, can offers non-intrusive and perhaps the most natural way of authentication [1]. This is due to the fact that it is intuitive and is usually non-invasive. Many applications have adapted face recognition. Examples include biometric passports and driving licences, authentications for secure banking and financial transactions and video surveillance. For instance, recently, Cotsaces et al [2] proposed face-based digital signature in video retrieval.

This paper is presented in six sections. Section 2 presents the background of face detection, followed by, in Section 3, a detailed review of face detection techniques and comparison of three face detection techniques. Section 4 will discuss a methodology of Multifractal Analysis which we adopted on face images. The results of this study are presented in Section 5. Then we conclude this paper in Section 6.

2. Background

The motivation for this work arises from a research project funded by UK Engineering Physical Sciences Research Council under the theme of the facial analysis for real-time profiling project. The aim of the project is to provide a real-time dynamic passive profiling technique which will assist as a decision aid to Border Control Agencies, which has the potential to improve hit rates. The project is intended to combine and build on several research areas, which include multi-modality face and eye-movement tracking, eye-movement related to intent, dynamic thermal/visible face information related to intent, statistical shape and appearance modelling and face modelling and recognition. In this paper, we will concentrate in visual face detection which we hope will form the basis for a real-time algorithm for tracking and both the face and the associated facial features.

The goal of face recognition is to find a similarity measure invariant to illumination changes, head pose, and facial expressions so that images of faces can be successfully matched in spite of these variations [3]. Hence, these issues have become the challenges in face detection. The face detection algorithms aim to detect present of people in complex background, diversity of variations in the face class such as racial characteristics, facial expressions, hair-style, make-up, glasses, beard, illumination and head pose [3]. The performance of visual face recognition may degrade under poor illumination conditions or for subjects of various skin colours [1]. Some constraints in visual face detection have opened the research for thermal infra-red images in facial analysis [4, 5].

3. A Review

Face recognition being an important problem much research in this has been undertaken. Consequently, there are a great number of face detection and face recognition algorithms available. The theories to develop the application can be categorised as:

a) **Feature-based geometrical constraints** [6] (invariance to scale and rotation)
The algorithms based on feature-based geometrical constraints detects feature points using spatial filters, groups them into face candidates using geometric and gray level constraints and applying probabilistic framework reinforce probabilities and evaluate the likelihood of the candidate as a face [6].

b) Multi-resolution segmentation
In multi-resolution segmentation, face candidates are found by merging regions until their shapes approximate ellipses. Then, these candidates are validated using facial features [3], which encode human knowledge of what constitutes a typical face [7]. Note that the skin colour segmentation has been successfully used in complex background [8, 9].

c) Multi-scale searches with classifiers of fixed size. Here face detection can be viewed as a two class problem: face and non-face [1]. Hence, in multi-scale searches with classifiers of fixed size, classifiers are trained from examples using several learning techniques. This is useful especially when no colour information and the faces are too small to use facial features implemented [3]. Early approaches involved intensity to formulate face candidates, e.g. edge-based facial features [10], maximum likelihood classifiers, support vector machine classifiers [11], and neural network [12].

This paper discusses and compares three algorithms in the following subsections.

3.1 Local SMQT Features and Split up Snow Classifier

This algorithm is developed by Nilsson et al [13]. Two main issues in face detection are the illumination and the speed of detection. Nilsson et al [11] combine the local Successive Mean Quantization Transform (SMQT) [14] and a split up Sparse Network of Winnows (SNoW) [15] to handle these issues. The SMQT uses an approach that performs an automatic structural breakdown of information and this information is employed on local areas in an image to extract illumination insensitive features [14]. The SNoW is a sparse network of linear units over a feature space [15]. SNoW has the capability of creating look-up tables for classification. To speed up the classification process, full SNoW classifier can be split up in sub classifiers to create a cascade of classifiers [11].

Combination of the features from SMQT and a split SNoW classifier is used for frontal view face detection. The algorithm was evaluated on MIT+CMU and BioID databases [11]. They have concluded that the algorithm yields the best published results in BioID database, but produced comparable result to state-of-art face detectors in MIT+CMU database. For further reading, please refer to [13] and the software is available in Matlab Central.

3.2 Haar training in Open Source Computer Vision Library (OpenCV)

OpenCV [16] is a cross-platform computer vision library and originally developed by Intel. Besides, it is open source software. Researchers interested in OpenCV could refer to [17] for further information. The OpenCV library provides useful functions for face detection. Particularly, we are interested in the functions utilised to train classifiers for face detection systems – Haar Training [17].

Haar-like features used by Papageorgiou et al [18] and Viola et al [19] proposed a very fast computation scheme, and further improved by Lienhart et al [20]. Haar-like features are computed similar to the coefficients in Haar Wavelet transforms [15]. They encode the existence of oriented contrasts between regions in the image [19]. In this case, encode the contrasts exhibited by a human face and their special relationships. As in the preliminary stage of this project, we have implemented Haar frontal view face detection algorithm from OpenCV on different source of images. The result of the implementation is shown in Figure 1 and Figure 2.

3.3 fdlibmex – fast and simple face detection

Kienzle [21] has developed a mex library for detecting frontal faces in images. The author claims that it is an efficient and easy-to-use. Unfortunately there are no further explanations or references from the author as this is a piece of unpublished work. We found it is quite an effective tool and it is worth to investigate into its performance. The software is available at [21].

3.4 Comparison of the algorithms

We have compared the performance of the algorithms on different resources of images and databases. Nilsson et al algorithm [13] and Kienzle's algorithm [21] are available from Matlab Central, while the Haar Training [16] is implemented in OpenCV. First we compare the performance on webcam containing a face image [13], image from Kienzle [21], and the popular Lena image. Then we have extended the experiment to face databases: AT&T Laboratories database (formerly 'The ORL Database of Faces') [22], University of Stirling database [23], University of Aberdeen database [16] and University of Nottingham database [16].

Figure 1 and 2 visually illustrate the performance of three algorithms, namely, Nilsson et al algorithm [13], Haar Training face detection algorithm [13] and Kienzle [21] algorithm on different source of images. It is important to point out that we have utilised the Haar training algorithm for the frontal face detection algorithm directly from OpenCV without modification.

Figure 1 (a) is an image captured from webcam [13] and we have observed that Haar Training had false positive detection on the image. Figure 1 (b) is an image from Kienzle's work [21], showing multiple faces on the image. The popular Lena image is also tested, in figure 1(c), Kienzle algorithm failed to detect the face area of Lena.

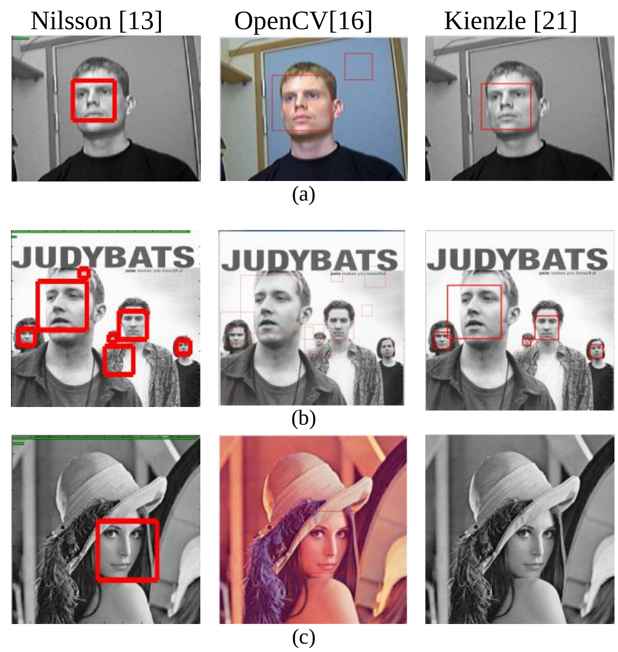

Figure 1. Performance comparison between Nilsson et al algorithm [13], Haar Training face detection algorithm [17] and Kienzle algorithm [21] on different source of images: (a) webcam containing a face from Nilsson [13], (b) image from Kienzle [21], (c) popular Lena image.

Figure 2(a) is the AT&T Laboratories database [22], which contains a set of face images taken between April 1992 and April 1994 in the lab. Haar Training face detection algorithm failed to detect the face with glasses. All of the algorithms performed well for University of Stirling database [23] (as shown in Figure 2(b)), University of Aberdeen database [23] (as shown in Figure 2(c)), and University of Nottingham database [23] (as shown in Figure 2(d)).

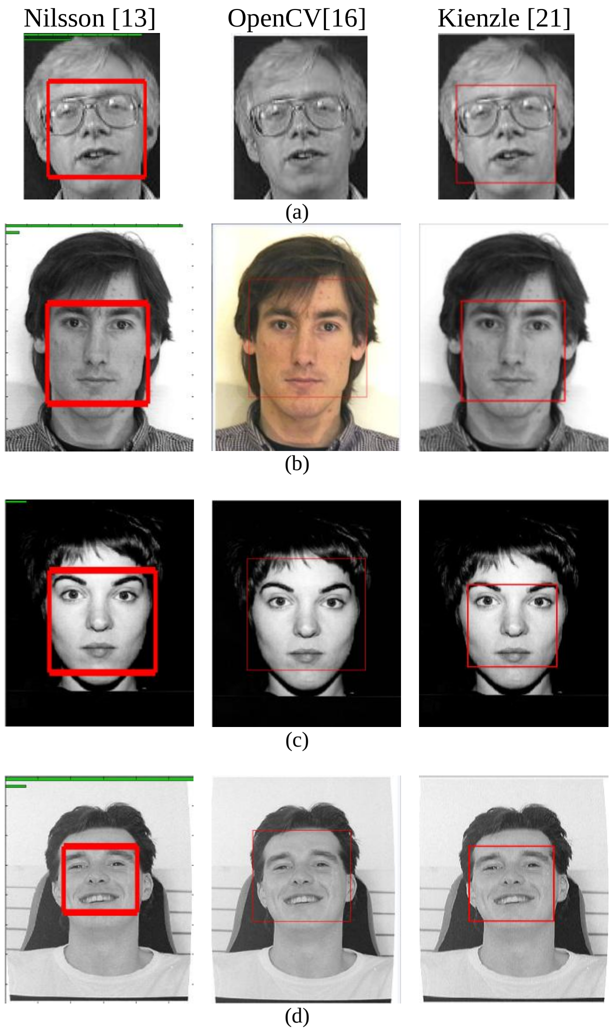

Figure 2. Performance comparison between Nilsson et al algorithm [13], Haar Training face detection algorithm [17], and Kienzle algorithm [21] on different source of database: (a) AT&T [22] database, (b) University of Stirling database [23], (c) University of Aberdeen database [23], (d) University of Nottingham database [23].

From the above experiments, we found that Nilsson et al algorithm [13] perform the best. We have adapted Nilsson et al algorithm [13] in our next study. The following section will discuss the methodology of the study on the effect of Multifractal Analysis on face images.

4. Multifractal Analysis

Multifractal Analysis has been widely used in medical image analysis [24], satellite image analysis [25], soil analysis [26] etc. The capability of Multifractal processing to separate the cancer lesion from non-cancer lesion [24] provided an indication on its potential on face recognition in images.

In fractal geometry, fractal dimension refers to a statistical quantity that gives an indication of how completely a fractal appears to fill space, as one zooms down to finer and finer scales [27]. Multifractal Analysis refers to the analysis of an image using multiple fractals.

The generalized formulation for Multifractal Dimension (*D*) of order *q* can be represented as [25]:

$$D_q = \begin{cases} \dfrac{1}{q-1} \lim\limits_{\varepsilon \to 0} \dfrac{\log(x_q(\varepsilon))}{\log(\varepsilon)} & \textit{for } q \in R \textit{ and } q \neq 1 \\[2ex] \lim\limits_{\varepsilon \to 0} \dfrac{\sum_i \mu_i \log \mu_i}{\log(\varepsilon)} & \textit{for } q = 1 \end{cases}$$

where ε is the linear size of the cells. Note that in our case, we use 3×3 pixel mask, hence, $\varepsilon = 3$, *q* is the order for cell size ε. Note also that when $q<0$, D_q is sensitive to the parts where the measure is very dense. On the other hand, if $q>0$, information on the sparse region can be obtained. In theory, *q* is in the range $-\infty$ to ∞, and D_q can have an infinite number of values.

The partition function x_q is defined as, $x_q(\varepsilon) = \sum_{i=1}^{N(\varepsilon)} \mu_i^q(\varepsilon)$, where *N(ε)* is the total number of cells of size ε, $\mu_i^q(\varepsilon)$ is the measure that is defined on a given set. In this case, the measures are defined as the probability of the grey scale level in the images, where all the grey levels fall in the range of 0 - 1.

We have implemented Multifractal Processing on human faces in this paper. For further reading in Multifractal Analysis, please refer to Yap et al's publication [24].

4.1 Methodology

In this section we discuss details of the experiment conducted in our study in Multifractal Analysis. The flow of the experiment is presented in Figure 3.

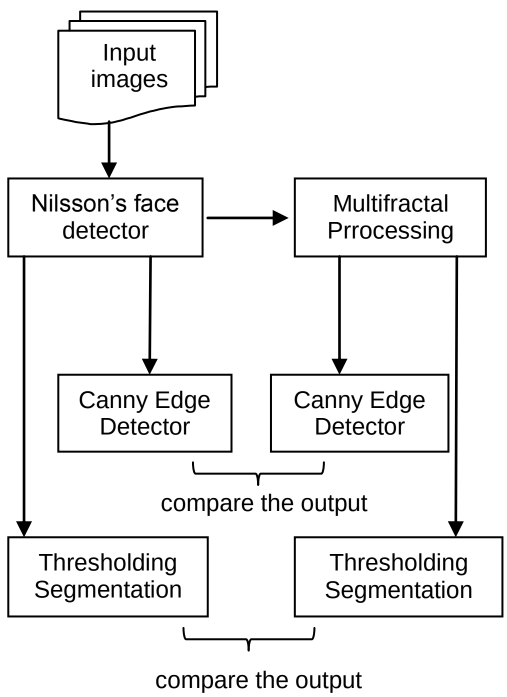

Figure 3. Illustration of the flow of the experiment to study the effect of Multifractal Analysis on face images.

The input image is first pre-processed by Nilsson et al algorithm [13] which is then followed by Multifractal Processing. The faces detected by Nilsson et al algorithm and the output from Multifractal Processing are processed by Canny Edge Detector and Thresholding Segmentation. We then compare and discuss on the output from the edge detector and segmentation result. The information within the block diagram is elaborated in detail in the following subsections.

4.2 Database

The University of Stirling database [23] is used in this experiment to study the effect of Multifractal Analysis to face detection. 650 images with frontal views of human faces are selected. There are two images for each of the subjects. The images are taken in different illumination. For example, Figure 2(a) and Figure 2(b) shows the images of a subject under different lighting condition.

4.3 Software

Our working environment is Visual Studio 2008 on Windows Vista, with OpenCV version 1.1pre1 installed. Besides, we have tested the existing algorithms (Nilsson et al algorithm and Kienzle algorithm) by using Matlab [28]. A further study is conducted by implementing Nilsson et al algorithm, followed by Multifractal Processing coding from [24], re-written in Matlab. Finally, Canny Edge Detector and Thresholding Segmentation from Matlab's library are implemented.

4.4 Canny Edge Detector

Generally, edge detection is implemented in the areas of feature detection and feature extraction. The popular edge detector, Canny edge detector was developed by John F. Canny in 1986 [29]. The Canny algorithm contains a number of adjustable parameters, whereby those parameters can affect the computation time and effectiveness of algorithm. We have implemented the Canny edge detector from Matlab library [28], a mature library to choose from.

4.5 Thresholding Segmentation

In general, segmentation is a process used to divide an image into its constituent parts. Thresholding segmentation [30] is the most basic, simplest, and fastest algorithm in segmentation. A thresholding procedure attempts to determine an intensity value, named the threshold, which separates the pixels into desirable classes [31]. A parameter θ, named the brightness threshold is chosen and applied to the image as follow:

$$\begin{aligned}&\textit{if}\ a[m,n] \geq \theta\\&\quad \textit{then}\ a[m,n] := 1\,(\textit{object})\\&\textit{else}\ a[m,n] := 0\,(\textit{background})\end{aligned}$$

Within the present research context, we are applying an automatic thresholding segmentation from Matlab library [28].

5. Results and Analysis

Figure 4 illustrates the results from our experiment. Figure 4(a) and Figure 4(b) is a pair of images under different illumination. Figure 4(c) is the face area detected from Figure 4(a) by Nilsson et al algorithm [13], while Figure 4(e) is the face area detected from Figure 4(b).

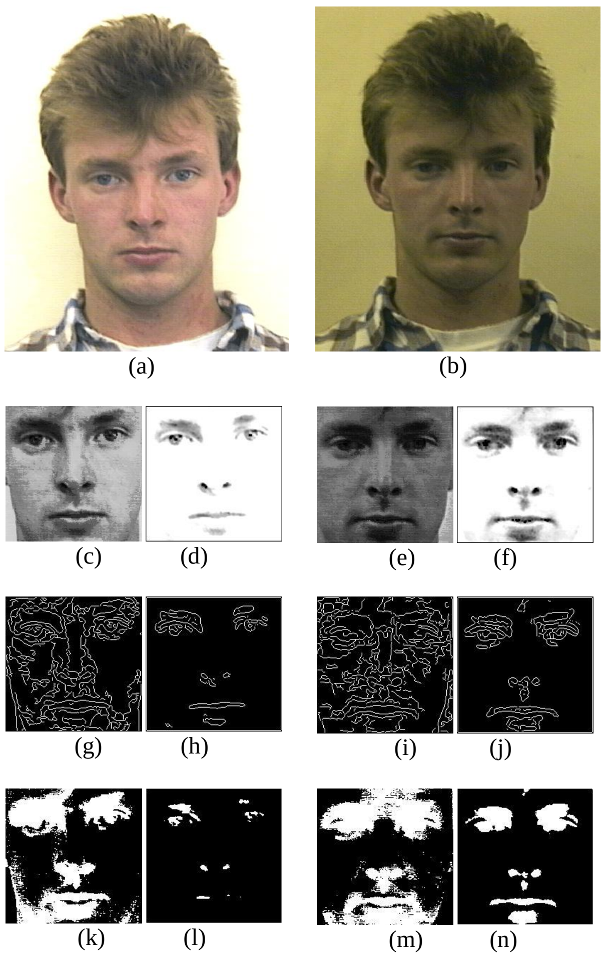

Figure 4. (a) and (b) are the pictures of a subject under different illumination. (c) shows the face area detected from (a) by implementing Nilsson et al algorithm [11]. (e) shows the face area detected from (b) by implementing Nilsson et al algorithm [13]. (d) presents the result of multifractal processing on (c). (f) presents the result of multifractal processing on (e). (g),(h),(i),(j) are the results of canny edge detection on (c),(d),(e),(f) respectively. (k),(l),(m),(m) are the results of thresholding segmentation on (c),(d),(e),(f) respectively.

By processing the images with Multifractal Processing on Figure 4(c) and 4(e), we observed that the key features of the faces are well separable from the skin, as illustrated in Figure 4(d) and 4(f). However, it is noteworthy that this has caused some loss of information in the images with high illumination.

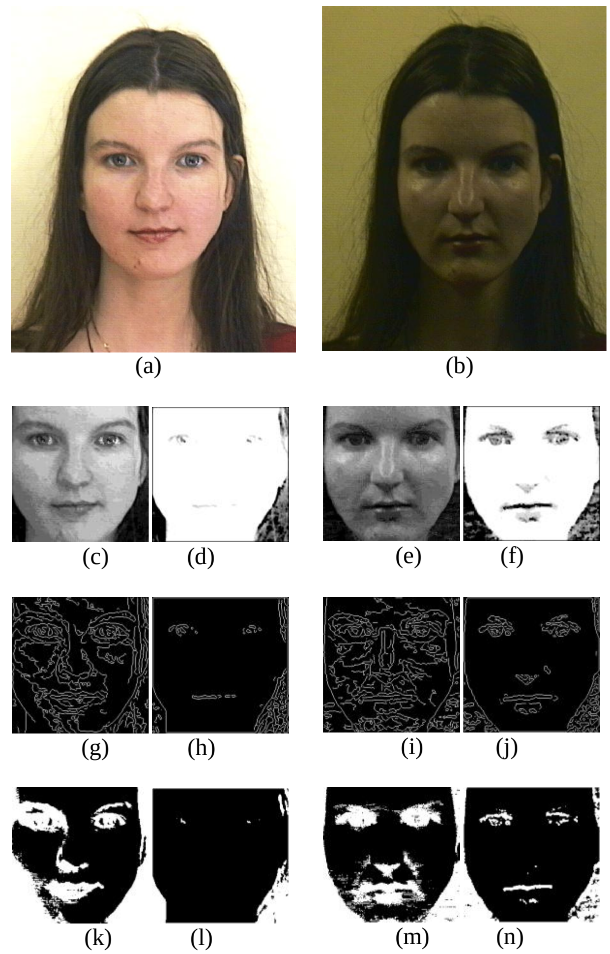

Figure 5. (a) and (b) are the images of a subject under different illumination. (c) shows the face area detected from (a) by implementing Nilsson et al algorithm [13]. (e) shows the face area detected from (b) by implementing Nilsson et al algorithm [11]. (d) presents the result of multifractal processing on (c). (f) presents the result of multifractal processing on (e). (g),(h),(i),(j) are the results of canny edge detection on (c),(d),(e),(f) respectively. (k),(l),(m),(m) are the results of thresholding segmentation on (c),(d),(e),(f) respectively.

Further, by implementing Canny edge detector, Figure 4(g) and 4(i), i.e. the face area without multifractal processing has shown oversegmentation. Figure 4(h) and 4(j), i.e. with Multifractal processing have produced a sharp features map on the faces. Comparing with the output from thresholding segmentation, the result of segmentation without Multifractal Processing, i.e. Figure 4(k) and Figure 4(m) have produced segments with more noise. While Figure 4(l) and figure 4(n) have produced some good reference points for the location of the key features of the faces. Figure 5 illustrates another set of result on different subject.

Overall, the Multifractal Processing can produce useful facial key feature points, especially in the images with low illumination. These key features might be an important input to thermal images as it is been very difficult to detect the reference points of face features on thermal images.

6. Conclusion

In this paper we have compared the performance of three algorithms on different source of images. We have found that Nilsson et al face detection algorithm out-performed. Further we have implemented a multifractal processing on human faces. From the experiment, we visually show that multifractal processing has the ability to filter out the non key features on face area and it might be useful in images taken under low illumination.

Future research will concentrate in experimenting multifractal processing in still images and video face recognition systems. This can be then extended to detect specific facial features which are dynamic. Detection of such features are important in order to develop systems which can undertake facial analysis in order to understand the psychological states [32] of a person.

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References

[1] S. G. Kong, J. Heo, B. R. Abidi *et al.*, “Recent advances in visual and infrared face recognition - a review,” *Computer Vision and Image Understanding, Elsevier Inc.*, vol. 37, pp. 103-135, 2005.

[2] C. Cotsaces, N. Nikolaidis, and I. Pitas, “Face-based digital signatures for video retrieval,” *IEEE transactions on Circuits and Systems for Video Technology*, vol. 18, no. 4, pp. 549-553, 2008.

[3] A. J. Colmenarez, Z. Xiong, and T. S. Huang, *Facial Analysis from Continuous Video with Applications to Human-Computer Interaction*: Kluwer Academic Publishers, 2004.

[4] I. Pavlidis, and J. Levine, "Thermal facial screening for deception detection," *Proceedings of the Second Joint EMBS/BMES Conference*, Houston, TX, USA, 2002.

[5] I. Pavlidis, and J. Levine, “Thermal image analysis for polygraph testing,” *IEEE Engineering in Medicine and Biology Magazine*, vol. 21, no. 6, pp. 56-64, 2002.

[6] K. Yow, and R. Cipolla, “Feature-based human face detection,” *Image and Vision Computing*, vol. 15, no. 9, pp. 713-735, 1997.

[7] M. H. K. Yang, D.J.; Ahuja, N., “Detecting Faces in Images: A Survey,” *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 24, no. 1, pp. 34-58, 2002.

[8] R. A.-M. Hsu, M.; Jain, A.K., “Face detection in Color Images,” *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 24, no. 5, pp. 696-706, 2002.

[9] M. A. Storring, H.J.; Granum,E., "Skin Colour detection under changing lighting conditions." pp. 1-9.

[10] Y. S. L. Gao, K.H., “Face Recognition using Line Edge Map,” *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 24, no. 6, pp. 764-779, 2002.

[11] G. L. Guo, S.Z.; Chan,K., "Face recognition by support vector machine." pp. 196-201.

[12] R. B. Feraud, O.J.; Viallet,J.E.; Collobert, M., “A fast and accurate face detector based on neural networks,” *IEEE Transactions on Pattern Analysis and Machine Intelligence*, vol. 23, no. 1, pp. 42-53, 2001.

[13] M. Nilsson, J. Nordberg, and I. Claesson, “Face Detection Using Local SMQT Features and Split Up Snow Classifier,” in IEEE Conference on Acoustics, Speech and Signal Processing, ICASSP, 2007, pp. II589-II592.

[14] M. D. Nilsson, M.; Claesson,I., “The successive mean quantization transform,” *IEEE International Conference on Acoustics, Speech, and Signal Processing*, vol. 4, pp. iv/429-iv/432, 2005.

[15] D. Y. Roth, M.; Ahuja,N., “A snow-based face detector,” *In Advances in Neural Information Processing Systems 12 (NIPS 12)*, pp. 855-861, 2000.

[16] Wikipedia. "OpenCV," 23/04109, 2009; http://en.wikipedia.org/wiki/OpenCV.

[17] G. K. Bradski, A., *Learning OpenCV: Computer Vision with the OpenCV Library*, First Edition ed., CA 95472, US.: O'Reilly Media, Inc., 2008.

[18] C. O. Papageorgiou, M.;Poggio, T., “A general framework for object detection,” in International Conference on Computer Vision, 1998.

[19] P. J. Viola, M.J., “Rapid Object Detection using a Boosted Cascade of Simple features,” in CVPR, 2001.

[20] R. M. Lienhart, J., "An Extended Set of Haar-like Features for Rapid Object Detection." pp. 900-903.

[21] W. Kienzle, "fdlibmex - fast and simple face detection," 2008.

[22] F. H. Samaria, A., "Parameterisation of a Stochastic Model for Human Face Identification."

[23] P. Hancock. "Welcome to the Psychological Image Collection at Stirling (PICS)," 03/04/09, 2009; http://pics.psych.stir.ac.uk/.

[24] M. H. E. Yap, E.A.; Bez, B.E., “A Novel Algorithm for Initial Lesion Detection in Ultrasound Breast Images,” *Journal of Applied Clinical Medical Physics*, vol. 9, no. 4, pp. 181-199, 2008.

[25] G. Du, and T. S. Yeo, "A Multifractal Approach for Auto-segmentation of SAR Images."

[26] H. David, *Multifractals - Theory and Application*: Chapman & Hall/CRC, 2001.

[27] B. B. Mandlebrot, *The Fractal Geometry of Nature*: W.H. Freeman and Company, 1982.

[28] Matlab. "The MathWorks - Accelerating the pace of engineering and science," 24/04/09, 2009; http://www.mathworks.com/.

[29] Wikipedia. "Canny edge detector," 24/04/09, 2009; http://en.wikipedia.org/wiki/Canny_edge_detector.

[30] P. K. Sahoo, S. Soltani, A. K. C. Wong *et al.*, “A Survey of Thresholding Techniques,” *Computer Vision, Graphics and Image Processing*, vol. 41, pp. 233-260, 1988.

[31] R. C. Gonzalez, R. E. Woods, and S. L. Eddins, *Digital Image Processing using Matlab*: Pearson Prentice Hall, 2004.

[32] I. Pavlidis, J. Dowdall, N. Sun *et al.*, “Interacting with human physiology,” *Computer Vision and Image Understanding, Elsevier Inc.*, vol. 108, no. 2007, pp. 150-170, 2007.