UNIVERSITI PUTRA MALAYSIA

COMPUTER-ASSISTED DIAGNOSIS SYSTEM FOR ANGIOGENESIS DETECTION AND CLASSIFICATION IN COMPUTED TOMOGRAPHY LASER MAMMOGRAPHY

AFSANEH JALALIAN

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By

AFSANEH JALALIAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

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DEDICATION

This thesis dedicated to my beloved husband, Babak Karasfi, to my dear and lovely daughter Parmida, to my little sweet son Bardia, to my dear mother Tooba Soltanieh and my lovely father Hossein Jalalian, and compassionate sisters Elham and Ameneh jalalian that I owe them all of success in my life

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Philosophy

COMPUTER-ASSISTED DIAGNOSIS SYSTEM FOR ANGIOGENESIS DETECTION AND CLASSIFICATION IN COMPUTED TOMOGRAPHY LASER MAMMOGRAPHY

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Computed Tomography Laser Mammography (CTLM) is a full tomographic system to explore neo-angiogenesis in the breast by generating a volumetric image. Angiogenesis is a new forming of blood vessels which supply the tumour and seen in different shapes such as free standing, polypoid, ring shaped, dumb-bell shaped, diverticular, and spindle shaped. The manual detection of angiogenesis and differentiation of the shapes is a challenging procedure for physician and a CAD system is expected to help radiologists as a second reader.

In this research, a CAD on CTLM images is proposed to detect and classify the angiogenesis. The proposed CAD systems contain four main steps which are segmentation, objects dissociation, feature extraction, and classification. In segmentation stage, three automatic segmentation techniques are implemented to extract and reconstruct the volume of interests (VOIs) on CTLM images. The ground truth is extracted from window-level technique on the original CTLM images.

As the pre-processing before feature extraction step, the VOIs have been dissociated to sub-VOIs. The two region properties features include centroid and extrema which have been utilised to prepare the dissociation model of VOIs. According to the characteristics of abnormalities in CTLM image that critically depends on shape and intensity, various shape and texture properties are extracted in the feature extraction level. Three different compactness features are extracted from dissociated objects (sub-VOIs). The Harlick's features are extracted based on 3D Grey Level Co-occurrence (GLCM) matrix. Hence, different combination of shape features and Harlick's features have been used for the training procedure.

In the image classification, support vector machine (SVM) and multilayer perceptron neural network (MLPNN) have been used to classify the abnormality in CTLM images. CTLM data set in this work includes 180 patients which are diagnosed by two expert radiologists that considered 132 cases as benign and 48 cases as malignant. In order to overcome the imbalanced dataset, various techniques such as soft margin, kernel function transformation, and oversampling method have been applied to enhance the performance of the proposed classifiers.

The Jaccard and Dice coefficients in addition to the volumetric overlap error are employed to quantify the accuracy of segmentation methods. According to the outcomes, the 3D Fuzzy C-Means clustering presents reasonable results compared to other methods.

The K-fold cross-validation with k=10 is used in the training and test of the proposed classifier. The experimental results show that SVM with radial basis function (SVM-RBF) on oversampled data by Adaptive Synthetic Sampling (ADASYN) method achieved the highest performance in terms of accuracy, sensitivity, and specificity which are 98.6%, 97.78% and 99.43%, respectively.

The results of angiogenesis diagnosis by SVM-RBF on oversampled data by ADASYN completely matched with the reports of two expert radiologists in localisation and shapes of angiogenesis. The proposed CTLM-CAD recognise the diverticular shape, polypoid, spindle shaped and free standing shape of angiogenesis.

Abstrk tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Doktor Falsafah

SISTEM DIAGNOSIS BERBANTU KOMPUTER UNTUK PENGESANAN DAN KLASIFIKASI ANGIOGENESIS DALAM TOMOGRAFI LASER MAMMOGRAFI

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Computed Tomography Laser Mammography (CTLM) adalah sistem tomografik penuh untuk meneroka neo-angiogenesis pada payudara dengan menjana imej berisipadu. Angiogenesis adalah pembentukan saluran darah baru yang membekalkan tumor dan ia boleh dilihat dalam pelbagai bentuk seperti berdiri bebas, polypoid, cincin berbentuk, bisu-loceng berbentuk, diverticular, dan gelendong berbentuk. Pengesanan manual angiogenesis dan pembezaan bentuk adalah prosedur mencabar bagi pakar perubatan dan sistem diagnosis berbantu computer (CAD) dijangka untuk membantu ahli radiologi sebagai pembaca kedua.

Dalam kajian ini, CAD mengenai imej CTLM dicadangkan untuk mengesan dan mengklasifikasikan angiogenesis. Sistem CAD yang dicadangkan mengandungi empat langkah utama iaitu segmentasi, objek pemisahan, pengekstrakan ciri, dan klasifikasi. Dalam peringkat segmentasi, tiga teknik segmentasi automatik dilaksanakan untuk mengekstrak dan membina semula jumlah minat (VOI) pada imej CTLM. Kebenaran tanah diekstrak dari teknik tetingkap pada imej CTLM asal.

Sebagai pra-pemprosesan sebelum langkah pengekstrakan ciri, VOIs telah dipisahkan kepada sub-VOIs. Ciri-ciri hartanah dua wilayah termasuk centroid dan extrema yang telah digunakan untuk menyediakan model pemisahan VOI. Menurut ciri-ciri kelainan dalam imej CTLM yang secara kritikal bergantung pada bentuk dan keamatan, pelbagai bentuk dan sifat tekstur diekstrak dalam tahap pengekstrakan ciri. Tiga ciri padat yang berbeza diekstrak dari objek yang dipisahkan (sub-VOI). Ciri-ciri Harlick diekstrak berdasarkan matriks 3D Grey Level Co-occurrence (GLCM). Oleh itu, gabungan ciri-ciri bentuk yang berbeza dan ciri-ciri Harlick telah digunakan untuk prosedur latihan.

Dalam klasifikasi imej, mesin vektor sokongan (SVM) dan rangkaian neural perceptron multilayer (MLPNN) telah digunakan untuk mengklasifikasikan kelainan pada imej CTLM. Data CTLM yang ditetapkan dalam kerja ini termasuk 180 pesakit yang didiagnosis oleh dua ahli radiologi ahli yang menganggap 132 kes sebagai benigna dan 48 kes sebagai malignan. Untuk mengatasi dataset yang tidak seimbang, pelbagai teknik seperti margin lembut, transformasi fungsi kernel, dan kaedah oversampling telah digunakan untuk meningkatkan prestasi pengelas yang dicadangkan.

Pekali Jaccard dan Dice di samping ralat pertindihan isipadu digunakan untuk mengukur ketepatan kaedah segmentasi. Berdasarkan hasil, 3D Fuzzy C-Means kelompok menghasilkan keputusan yang memuaskan berbanding dengan kaedah lain. *K-fold* pengesahan silang dengan k = 10 digunakan dalam latihan dan ujian pengelas yang dicadangkan. Keputusan eksperimen menunjukkan bahawa SVM dengan fungsi asas jejarian (SVM-RBF) data terlebih sampel oleh kaedah sintetik persampelan bolehubah (ADASYN) mencapai prestasi tertinggi dari segi ketepatan, kepekaan, dan kekhususan yang 98.6%, 97.78% dan 99.43%, masing-masing.

Hasil diagnosis oleh SVM-RBF data terlebih sampel oleh ADASYN dipadankan sepenuhnya dengan laporan dua pakar radiologi dalam penempatan dan bentuk angiogenesis. Kaedah CTLM-CAD yang dicadangkan berjaya mengenalpasti angiogenesis bentuk diverticular, polypoid, gelendong berbentuk dan berdiri bebas.

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

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LIST OF ABBREVIATIONS

ABC	Array Box Constraint
ABUS	Automated Breast Ultrasound
ADASYN	Adaptive Synthetic Sampling
ANN	Artificial Neural Network
AUROC	Area under Receiver Operating Characteristic Curve
BDT	Boosted Decision Tree
BPNN	Back Propagation Neural Network
BUS	Breast Ultrasound
C	Compactness
CADe	Computer Aided Detection
CADx	Computer Aided Diagnosis
CADs	Computer Aided Detection /Diagnosis Systems
C-CONT	Compactness-Contrast
C-COR	Compactness-Correlation
C-ENR	Compactness-Energy
C-ENT	Compactness-Entropy
CDOM	Centroid-Based Object Dissociated Model
CE	Classification Entropy
C-GLCM 3D	Compactness-Grey Level Co-occurrence 3D
C-INT	Compactness-Inertia
C-IVAR	Compactness-Inverse Variance
C-HOMO	Compactness-Homogeneity
C-MPROB	Compactness-Max Probability

CNN	Combined Neural Network
CQ	Colour Quantization
C-SMEAN	Compactness-Sum mean
CTLM	Computed Tomography Laser Mammography
C-VAR	Compactness-Variance
DEOWNN	Differential Evaluation Optimized Wavelet Neural Network
DNA	Deoxyribonucleic Acid
DTF	Decision Tree Forest
EDOM	Extrema-Based Object Dissociated Model
FCM	Fuzzy C-means Clustering
FN	False Negative
FNAB	Fine Needle Aspiration Biopsy
FNB	Fine Needle Biopsy
FP	False Positive
FPR	False Positive Rate
FSVM	Fuzzy Support Vector Machine
FTB	Front to Back Projection
GABOR	GABOR Feature
GLCM	Grey Level Co-occurrence Matrix
GONN	Genetically Optimized Neural Network
GT	Ground Truth
IDSI	Imaging Diagnostic System
KNN	K-Nearest Neighbour
LDA	Linear Discriminant Analysis

LM	Levenberg-Marquardt
LPSVM	Linear Programming Support Vector Machine
LSVM	Lagrangian Support Vector Machine
LS-SVM	Least Squares Support Vector Machine
LTEM	Law Texture Energy Measure
MIP	Maximum Intensity Projection
MLP	Multilayer Perceptron
MLPNN	Multilayer Perceptron Neural Network
MRI	Magnetic Resonance Imaging
NBC	Nave Bayes Classifier
NIR	Near-Infrared
NPV	Negative Predictive Value
NSVM	Newton Lagrangian SVM
OSS	One Side Selection
PC	Partition Coefficient
PET	Positron Emission Tomography
PNN	Probabilistic Neural Network
PPV	Positive Predictive Value
PSOWNN	Particle Swarm Optimized Wavelet Neural Network
RBF	Radial Basis Function
RDM	Radial Distance Measure
RNN	Recurrent Neural Network
ROC	Receiver Operating Characteristic
S	Separation Index

SBC	Scalar Box Constraint
SC	Partition Index
SDT	Single Decision Tree
SGLD	Spatial Grey level Dependence
SMOTE	Synthetic Minority Oversampling Technique
SONN	Swarm Optimized Neural Network
SVM	Support Vector Machine
SVM-ABC	Support Vector Machine-Array Box Constraint
SVM-L-ABC	SVM-Linear-Array Box Constraint
SVM-L-ADASYN	SVM- Adaptive Synthetic Sampling
SVM-L-SBC	SVM-Linear-Scalar Box Constraint
SVM-RBF-ADASYN	SVM- Radial Basis Function - Adaptive Synthetic Sampling
SVM-RBF-SBC	SVM- Radial Basis Function -Scalar Box Constraint
SVM-SBC	Support Vector Machine-Scalar Box Constraint
SSVM	Smooth Support Vector Machine
St-SVM	Standard Support Vector Machine
TN	True Negative
TP	True Positive
TPR	True Positive Rate
US	Ultrasound
VOE	Volumetric Overlap Error
VOI	Volume of Interest
WNN	Wavelet Neural Network

CHAPTER 1

INTRODUCTION

1.1 Introduction

Breast cancer is the most prevalent cancer that affects women all over the world. Early detection and diagnosis of breast cancer play a significant role to reduce the mortality rate as well as to increase the prognosis of patients. Mammography is the golden standard for breast imaging. Breast screening with mammography involves passing radiation (x-ray) through the breast. Evidence indicates the growth of risk of breast cancer with exposure to multiple mammographies, especially in women with genetic predisposition due to impaired DNA (Deoxyribonucleic Acid) repair mechanisms (Helbich et al. 2012). The results show the sensitivity in women with fatty breast is roughly 88% but drastically decreased in women with dense breast which is 62% (Carney et al. 2003). On top of that, the risk of developing breast cancer in dense breasts is 4 to 6 times higher than in non-dense breasts (Boyd et al. 2007).

In recent years, several studies have been conducted to find alternative methods to adjunct mammography in order to enhance sensitivity and specificity. Ultrasound is a valuable tool that acts as an adjunct to mammograms due to its characteristics, namely availability, non-invasive, and costs-effective. Ultrasound has potential benefits to supplement mammographic screening of women with dense breast tissue. Magnetic resonance imaging (MRI) is another alternative that is suggested for screening women who have a high risk of developing breast cancer, or it can be used to investigate suspicious areas found by the mammogram to help measure the size mass.

Computed Tomography Laser Mammography (CTLM) is an optical imaging technique which is presented for breast screening presented by imaging diagnostic system company (IDSI)(IDSI 2016) , particularly in women under the age of 40 and who have dense breasts. CTLM is a non-invasive and cost-effective modality that uses Near-Infrared light propagation through the tissue to assess its optical properties. Different tissue components have unique scattering and absorption characteristics for each wavelength. In new forming tumours, the blood flow increases and the CTLM then looks for high haemoglobin concentration (angiogenesis) in the breast to detect neovascularisation, which may be hidden in mammography images, especially in dense breast (Flöry et al. 2010, Eid, Hegab, and Schindler 2006, Poellinger et al. 2008a). Malignant lesions will be detected based on their higher optical attenuation compared to the surrounding tissue, which is mainly related to the increase in light absorption by their higher haemoglobin content (Zhu et al. 2005).

Some issues have increased the miss diagnosis of radiologists in visual manner assessment such as technical reasons which are related to imaging quality and human error due to the structural complexity in appearance. Computer-Aided

Detection/Diagnosis (CAD) systems have been developed for automatic detection and classification of the suspicious area on different modality. CAD systems help the radiologist in the interpretation of medical images to detect and differentiate between benign and malignant lesions. CAD systems are used as a double reader for accuracy enhancement and final decision which is made by the physician. In recent years, several computerised diagnosis approaches have been developed on different modalities for breast cancer detection/diagnosis such as the mammography (Xi et al. 2016, Abbas, Fondo'n, and Celebi 2015), Ultrasound (US) (Abdelwahed, Eltoukhy, and Wahed 2015, Jinsamol, Shiji, and Thomas 2015, Rizzi and D'Aloia 2014), Magnetic Resonance Imaging (MRI) (Song et al. 2015, Meyer-Baese et al. 2015) and thermography (Calderon-Contreras et al. 2015) .

Some automated frameworks have been proposed for angiogenesis detection in chick embryo chorioallantoic membrane (Alacam et al. , Shi et al. 2014, Doukas et al. 2006) and fluorescence angiogram image (Zhao et al. 2015). The proposed methods conducted on 2D image and have considered the branch structure of vessels to detect angiogenesis areas. While CTLM image is a 3D imaging modality which angiogenesis detection rely on the characteristics of shape volumes and intensity of vascularity pattern. The existing angiogenesis detection framework unable to adopt for angiogenesis detection in CTLM image. Based on literature review, a similar study has not been conducted as a computer assisted system to detect and classify the angiogenesis area in CTLM images.

1.2 Problem Statement

CTLM is an optical imaging modality that uses Near-Infrared (NIR) laser light propagation to investigate the optical characteristics of the breast tissue, and is expected to play a significant role in breast cancer detection (Herranz and Ruibal 2012). During the CTLM screening, the NIR light in 808 nm penetrates through the breast. CTLM acts on the principle that different tissue components have different absorption and scattering coefficient (Poellinger et al. 2008a). In the screening procedure, both the absorption and scattering light by tissue are recorded. After the screening is completed, the images are reconstructed and displayed in three plane, namely Sagittal, Axial, and Coronal as well as a 3D view of the whole breast. CTLM is sensitive to high haemoglobin concentration that is associated with cancer growth. Malignant lesions are detected based on their higher optical attenuation compared to their surrounding tissues and visualised brighter in the vascular areas (Floery et al. 2005, Qi and Ye 2013).

The radiologist need a lot of practice to be familiar with regular appearance in CTLM image and ability to discriminating between normal blood vessels and angiogenesis. A variety of benign lesions also demonstrated increased vessels which may be considered as malignant lesion (Qi and Ye 2013). Analysis of CTLM image is based on the absorption pattern of haemoglobin in vessels. Bright areas indicate the aggressiveness of cancer while angiogenesis can appear in any shade of green. The detection of angiogenesis in CTLM images does not only rely on the brightness but also the various abnormality shapes and volumes (Qi and Ye 2013, Poellinger et al. 2008b). The radiologist needs to explore in a 2D plane to find any bright green areas that show distortion or deviation and investigates the irregular shape of angiogenesis in 3D view (Qi and Ye 2013).

The fact that diagnosis in CTLM images for a radiologist is time-consuming and complicated due to variety of angiogenesis shapes (Poellinger et al. 2008b). The essence of machine learning algorithms can be apply to find out the significant characteristics of angiogenesis which is a sign of tumour growth.

The purpose of this study is to design a computer assisted framework for angiogenesis detection and classification normal vessels and angiogenic areas in CTLM image. The proposed system would act to help radiologist in order to reduce miss diagnosis as well as to discriminate between normal vessels and angiogenesis within the breast.

1.3 Objectives of the Study

The overall hypothesis that motivate this work is that computer-assisted systems for breast cancer detection on different modalities can enhance the performance of radiologists to classify suspicious lesions. The aim of this work is to design an automated system for angiogenesis detection and classify the suspicious lesions into normal vascularity and angiogenesis. The presented CTLM-CAD system can improve the accuracy of expert and non-expert readers to discriminate angiogenesis. We propose the following specific objectives:

1) To achieve a reliable segmentation technique to extract the vascularity structure from the background of CTLM image.
2) To design a dissociated model for dividing the extracted vascularity volume into small objects in order to exploit the specific characteristics of normal vascularity and angiogenesis.
3) To extract and select the best combinations of 3D shape and 3D GLCM texture features from dissociated objects according to the characteristics of the normal appearance and angiogenesis in CTLM.
4) To obtain the best solution for imbalanced data phenomena on the training data set and compare the outcome of supervised classification techniques to discriminating the normal vascularity and angiogenesis.

1.4 Scope and Motivation of Research

In this study, the CTLM breast images of women have been acquired from clinical screening in Breast Wellness centre, Malaysia and two datasets from Medoc centre in Budapest, Hungary and TATA Hospital in Mumbai, India. The data collection in Malaysia has been conducted between April 2014 and September 2015. A total of 180 patients has been examined with CTLM and ultrasound for patients under the age of 40, while CTLM, ultrasound, and mammography were conducted for those above the age of 40. The patients have been examined for breast ultrasound and mammography in the Golden Horses Health Sanctuary (GHHS) Malaysia.

The contribution of this research is in two respects. From the medical viewpoint, this CAD system would be effective by significantly enhancing radiologists' overall performance to detect and diagnosis of angiogenesis through sensitivity and specificity. From the technical view point, the first contribution is to create a dissociation model and identify the best combination features to classify angiogenesis and normal vascularity. Solving the imbalance data phenomena and tuning of supervised classifiers for angiogenesis diagnosis is the other aspect of technical contributions. The results of our system are matched to the report of expert radiologists with a correlation of mammography and ultrasound images.

1.5 Organization of the Thesis

In Chapter 1, a brief review related to background of research, problem statement, objectives of research, and scope of research is presented. In Chapter 2, a general literature review related to the medical aspects of CTLM modality for breast cancer detection will be introduced. This section is then followed by the introduction on different modalities for breast cancer detection and review on CAD systems on these modalities. The cornerstones of the CAD system are investigated in the rest of this section. In Chapter 3, the details of the proposed methodology are explained. The 3D segmentation and reconstruction techniques are described in this section to extract volume of interests (VOIs) for further analysis. The overview of dissociation model to split VOIs and the extracted features are also described in details. The classification techniques and resolving methods in the imbalanced dataset are presented in this chapter. In the next section of this chapter, the experimental design and evaluation approaches to assess the proposed CAD system are presented. In Chapter 4, the experimental results and discussion to discover the most optimal 3D segmentation technique in CTLM images are presented. The impact of combination features in different proposed classification methods are investigated in his section. Finally, the performance of SVM and MLP classification methods are evaluated. The conclusion is provided together with the limitations of CTLM CAD system and future works are offered in Chapter 5.

REFERENCES

(IDSI), Imaging Diagnostic System. "An Innovative Breast Imaging System to Aid in the Detection of Breast Abnormalities." http://imds.com/about-computed-tomography-laser-mammography/benefits-of-ctlm.

Abbas, Qaisar, Irene Fondo'n, and Emre Celebi. "A Computerized System for Detection of Spiculated Margins Based on Mammography." *International Arab Journal of Information Technology (IAJIT)* 12, no. 6 (2015).

Abdel-Zaher, Ahmed M, and Ayman M Eldeib. "Breast Cancer Classification Using Deep Belief Networks." *Expert Systems with Applications* 46 (2016): 139-44.

Abdelwahed, Noura MA, Mohamed Meselhy Eltoukhy, and ME Wahed. "Computer Aided System for Breast Cancer Diagnosis in Ultrasound Images." (2015).

Abdi, Mohammad Javad, Seyed Mohammad Hosseini, and Mansoor Rezghi. "A Novel Weighted Support Vector Machine Based on Particle Swarm Optimization for Gene Selection and Tumor Classification." *Computational and Mathematical Methods in Medicine* 2012 (2012).

Abonyi, Janos, and Balazs Feil. *Cluster Analysis for Data Mining and System Identification*. Springer Science & Business Media, 2007.

Al-Amri, Salem Saleh, and Namdeo V Kalyankar. "Image Segmentation by Using Threshold Techniques." *arXiv preprint arXiv:1005.4020* (2010).

Al-Bayati, Moumena, and Ali El-Zaart. "Mammogram Images Thresholding for Breast Cancer Detection Using Different Thresholding Methods." (2013).

Al-Faris, Ali Qusay, Umi Kalthum Ngah, Nor Ashidi Mat Isa, and Ibrahim Lutfi Shuaib. "Breast Mri Tumour Segmentation Using Modified Automatic Seeded Region Growing Based on Particle Swarm Optimization Image Clustering." In *Soft Computing in Industrial Applications*, 49-60: Springer, 2014.

———. "Computer-Aided Segmentation System for Breast Mri Tumour Using Modified Automatic Seeded Region Growing (Bmri-Masrg)." *Journal of digital imaging* 27, no. 1 (2014): 133-44.

Alacam, Burak, Birsen Yazici, Britton Chance, and Shoko Nioka. "Characterization of Breast Tumors with Nir Methods Using Optical Indices." Paper presented at the Engineering in Medicine and Biology Society, 2007. EMBS 2007. 29th Annual International Conference of the IEEE, 2007.

Albregtsen, Fritz. "Statistical Texture Measures Computed from Gray Level Coocurrence Matrices." *Image processing laboratory, department of informatics, university of oslo* (2008): 1-14.

Almogahed, Bassam A, and Ioannis A Kakadiaris. "Empowering Imbalanced Data in Supervised Learning: A Semi-Supervised Learning Approach." In *Artificial Neural Networks and Machine Learning–Icann 2014*, 523-30: Springer, 2014.

Anand, Ashish, Ganesan Pugalenthi, Gary B Fogel, and PN Suganthan. "An Approach for Classification of Highly Imbalanced Data Using Weighting and Undersampling." *Amino acids* 39, no. 5 (2010): 1385-91.

Azar, Ahmad Taher, and Shereen M El-Metwally. "Decision Tree Classifiers for Automated Medical Diagnosis." *Neural Computing and Applications* 23, no. 7-8 (2013): 2387-403.

Azar, Ahmad Taher, and Shaimaa Ahmed El-Said. "Performance Analysis of Support Vector Machines Classifiers in Breast Cancer Mammography Recognition." *Neural Computing and Applications* 24, no. 5 (2014): 1163-77.

Azencott, Robert, Jia-Ping Wang, and Laurent Younes. "Texture Classification Using Windowed Fourier Filters." *Pattern Analysis and Machine Intelligence, IEEE Transactions on* 19, no. 2 (1997): 148-53.

Balleyguier, Corinne, Karen Kinkel, Jacques Fermanian, Sebastien Malan, Germaine Djen, Patrice Taourel, and Olivier Helenon. "Computer-Aided Detection (Cad) in Mammography: Does It Help the Junior or the Senior Radiologist?". *European journal of radiology* 54, no. 1 (2005): 90-96.

Bensaid, Amine M, Lawrence O Hall, James C Bezdek, Laurence P Clarke, Martin L Silbiger, John A Arrington, and Reed F Murtagh. "Validity-Guided (Re) Clustering with Applications to Image Segmentation." *Fuzzy Systems, IEEE Transactions on* 4, no. 2 (1996): 112-23.

Berg, Wendie A, Jeffrey D Blume, Jean B Cormack, Ellen B Mendelson, Daniel Lehrer, Marcela Böhm-Vélez, Etta D Pisano*, et al.* "Combined Screening with Ultrasound and Mammography Vs Mammography Alone in Women at Elevated Risk of Breast Cancer." *Jama* 299, no. 18 (2008): 2151-63.

Bezdek, James C. *Pattern Recognition with Fuzzy Objective Function Algorithms*. Springer Science & Business Media, 2013.

Bhardwaj, Arpit, and Aruna Tiwari. "Breast Cancer Diagnosis Using Genetically Optimized Neural Network Model." *Expert Systems with Applications* 42, no. 10 (2015): 4611-20.

Bílková, A, V Janík, and B Svoboda. "[Computed Tomography Laser Mammography]." *Casopis lekaru ceskych* 149, no. 2 (2009): 61-65.

Bird, Richard E, Terry W Wallace, and Bonnie C Yankaskas. "Analysis of Cancers Missed at Screening Mammography." *Radiology* 184, no. 3 (1992): 613-17.

Boquete, Luciano, Sergio Ortega, Juan Manuel Miguel-Jiménez, José Manuel Rodríguez-Ascariz, and Román Blanco. "Automated Detection of Breast Cancer in Thermal Infrared Images, Based on Independent Component Analysis." *Journal of medical systems* 36, no. 1 (2012): 103-11.

Boujelben, Atef, Ali Cherif Chaabani, Hedi Tmar, and Mohamed Abid. "Feature Extraction from Contours Shape for Tumor Analyzing in Mammographic Images." Paper presented at the Digital Image Computing: Techniques and Applications, 2009. DICTA'09., 2009.

Boyd, Norman F, Helen Guo, Lisa J Martin, Limei Sun, Jennifer Stone, Eve Fishell, Roberta A Jong*, et al.* "Mammographic Density and the Risk and Detection of Breast Cancer." *New England Journal of Medicine* 356, no. 3 (2007): 227-36.

Bradley, Andrew P. "The Use of the Area under the Roc Curve in the Evaluation of Machine Learning Algorithms." *Pattern recognition* 30, no. 7 (1997): 1145-59.

Bribiesca, Ernesto. "An Easy Measure of Compactness for 2d and 3d Shapes." *Pattern Recognition* 41, no. 2 (2008): 543-54.

Calderon-Contreras, Jorge D, Mario I Chacon-Murguia, Adrian J Villalobos-Montiel, and Leticia Ortega-Maynez. "A Fuzzy Computer Aided Diagnosis System Using Breast Thermography." Paper presented at the Biomedical Imaging (ISBI), 2015 IEEE 12th International Symposium on, 2015.

Cao, Ying, Xin Hao, Xiaoen Zhu, and Shunren Xia. "An Adaptive Region Growing Algorithm for Breast Masses in Mammograms." *Frontiers of Electrical and Electronic Engineering in China* 5, no. 2 (2010): 128-36.

Carney, Patricia A, Diana L Miglioretti, Bonnie C Yankaskas, Karla Kerlikowske, Robert Rosenberg, Carolyn M Rutter, Berta M Geller*, et al.* "Individual and Combined Effects of Age, Breast Density, and Hormone Replacement Therapy Use on the Accuracy of Screening Mammography." *Annals of internal medicine* 138, no. 3 (2003): 168-75.

Celebi, M Emre, and Gerald Schaefer. *Color Medical Image Analysis*. Vol. 6: Springer Science & Business Media, 2012.

Chabi, Marie-Laure, Isabelle Borget, Rosario Ardiles, Ghassen Aboud, Samia Boussouar, Vanessa Vilar, Clarisse Dromain, and Corinne Balleyguier. "Evaluation of the Accuracy of a Computer-Aided Diagnosis (Cad) System in Breast Ultrasound According to the Radiologist's Experience." *Academic radiology* 19, no. 3 (2012): 311-19.

Chang, Ruey-Feng, Wen-Jie Wu, Woo Kyung Moon, Yi-Hong Chou, and Dar-Ren Chen. "Support Vector Machines for Diagnosis of Breast Tumors on Us Images." *Academic radiology* 10, no. 2 (2003): 189-97.

Chaudhuri, Bidyut Baran, and Nirupam Sarkar. "Texture Segmentation Using Fractal Dimension." *Pattern Analysis and Machine Intelligence, IEEE Transactions on* 17, no. 1 (1995): 72-77.

Chawla, Nitesh V, Nathalie Japkowicz, and Aleksander Kotcz. "Editorial: Special Issue on Learning from Imbalanced Data Sets." *ACM Sigkdd Explorations Newsletter* 6, no. 1 (2004): 1-6.

Chawla, Nitesh V., Kevin W. Bowyer, Lawrence O. Hall, and W. Philip Kegelmeyer. "Smote: Synthetic Minority over-Sampling Technique." *Journal of artificial intelligence research* (2002): 321-57.

Chen, Chung-Ming, Yi-Hong Chou, Ko-Chung Han, Guo-Shian Hung, Chui-Mei Tiu, Hong-Jen Chiou, and See-Ying Chiou. "Breast Lesions on Sonograms: Computer-Aided Diagnosis with Nearly Setting-Independent Features and Artificial Neural Networks 1." *Radiology* 226, no. 2 (2003): 504-14.

Chen, Dar-Ren, Wen-Jia Kuo, Ruey-Feng Chang, Woo Kyung Moon, and Cheng Chun Lee. "Use of the Bootstrap Technique with Small Training Sets for Computer-Aided Diagnosis in Breast Ultrasound." *Ultrasound in medicine & biology* 28, no. 7 (2002): 897-902.

Cheng, Irene, Xinyao Sun, Noura Alsufyani, Zhihui Xiong, Paul Major, and Anup Basu. "Ground Truth Delineation for Medical Image Segmentation Based on Local Consistency and Distribution Map Analysis." Paper presented at the Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE, 2015.

Choi, Jong Myong. "A Selective Sampling Method for Imbalanced Data Learning on Support Vector Machines." (2010).

Choksuriwong, Juthamas Sittichoksataporn1 Dr Anant. "Comparison of Support Vector Machine's Kernel Function for Unsmoke Sheet Rubber Price Forecasting." (2012).

Christoyianni, Ioanna, A Koutras, E Dermatas, and G Kokkinakis. "Computer Aided Diagnosis of Breast Cancer in Digitized Mammograms." *Computerized Medical Imaging and Graphics* 26, no. 5 (2002): 309-19.

Chu, A, Chandra M Sehgal, and James F Greenleaf. "Use of Gray Value Distribution of Run Lengths for Texture Analysis." *Pattern Recognition Letters* 11, no. 6 (1990): 415-19.

Corsetti, Vittorio, Nehmat Houssami, Marco Ghirardi, Aurora Ferrari, Michela Speziani, Sergio Bellarosa, Giuseppe Remida*, et al.* "Evidence of the Effect of Adjunct Ultrasound Screening in Women with Mammography-Negative Dense Breasts: Interval Breast Cancers at 1year Follow-Up." *European journal of cancer* 47, no. 7 (2011): 1021-26.

Cortes, Corinna, and Vladimir Vapnik. "Support-Vector Networks." *Machine learning* 20, no. 3 (1995): 273-97.

Costantini, Melania, Paolo Belli, Roberta Lombardi, Gianluca Franceschini, Antonino Mulè, and Lorenzo Bonomo. "Characterization of Solid Breast Masses Use of the Sonographic Breast Imaging Reporting and Data System Lexicon." *Journal of ultrasound in medicine* 25, no. 5 (2006): 649-59.

De Carvalho, Francisco De AT, Yves Lechevallier, and Filipe M De Melo. "Partitioning Hard Clustering Algorithms Based on Multiple Dissimilarity Matrices." *Pattern Recognition* 45, no. 1 (2012): 447-64.

Dean, Judy C, and Christina C Ilvento. "Improved Cancer Detection Using Computer-Aided Detection with Diagnostic and Screening Mammography: Prospective Study of 104 Cancers." *American Journal of Roentgenology* 187, no. 1 (2006): 20-28.

Dheeba, J, and S Tamil Selvi. "An Improved Decision Support System for Detection of Lesions in Mammograms Using Differential Evolution Optimized Wavelet Neural Network." *Journal of medical systems* 36, no. 5 (2012): 3223-32.

———. "A Swarm Optimized Neural Network System for Classification of Microcalcification in Mammograms." *Journal of medical systems* 36, no. 5 (2012): 3051-61.

Dheeba, J, and N Albert Singh. "Computer Aided Intelligent Breast Cancer Detection: Second Opinion for Radiologists—a Prospective Study." In *Computational Intelligence Applications in Modeling and Control*, 397-430: Springer, 2015.

Dheeba, J, N Albert Singh, and S Tamil Selvi. "Computer-Aided Detection of Breast Cancer on Mammograms: A Swarm Intelligence Optimized Wavelet Neural Network Approach." *Journal of biomedical informatics* 49 (2014): 45-52.

Dice, Lee R. "Measures of the Amount of Ecologic Association between Species." *Ecology* 26, no. 3 (1945): 297-302.

Dinnes, J, S Moss, J Melia, R Blanks, F Song, and J Kleijnen. "Effectiveness and Cost-Effectiveness of Double Reading of Mammograms in Breast Cancer Screening: Findings of a Systematic Review." *The Breast* 10, no. 6 (2001): 455-63.

Doi, Kunio. "Computer-Aided Diagnosis in Medical Imaging: Achievements and Challenges." Paper presented at the World Congress on Medical Physics and Biomedical Engineering, September 7-12, 2009, Munich, Germany, 2009.

Doukas, Charalampos N, Ilias Maglogiannis, Aristotle Chatziioannou, and Andreas Papapetropoulos. "Automated Angiogenesis Quantification through Advanced Image Processing Techniques." Paper presented at the Engineering in Medicine and Biology Society, 2006. EMBS'06. 28th Annual International Conference of the IEEE, 2006.

Dromain, C, B Boyer, R Ferre, S Canale, S Delaloge, and C Balleyguier. "Computed-Aided Diagnosis (Cad) in the Detection of Breast Cancer." *European journal of radiology* 82, no. 3 (2013): 417-23.

Drukker, Karen, Maryellen L Giger, Karla Horsch, Matthew A Kupinski, Carl J Vyborny, and Ellen B Mendelson. "Computerized Lesion Detection on Breast Ultrasound." *Medical Physics* 29, no. 7 (2002): 1438-46.

Drukker, Karen, Karla J Horsch, Lorenzo L Pesce, and Maryellen L Giger. "Interreader Scoring Variability in an Observer Study Using Dual-Modality Imaging for Breast Cancer Detection in Women with Dense Breasts." *Academic radiology* 20, no. 7 (2013): 847-53.

Eid, MOHAMMED EMAD E, HASSAN MANSOUR H Hegab, and ADOLF E Schindler. "Role of Ctlm in Early Detection of Vascular Breast Lesions." *Egyp J Radiol Nucl Med* 37, no. 1 (2006): 633-43.

El Atlas, Nadia, Mohammed El Aroussi, and Mohammed Wahbi. "Computer-Aided Breast Cancer Detection Using Mammograms: A Review." Paper presented at the Complex Systems (WCCS), 2014 Second World Conference on, 2014.

Ertosun, Mehmet Gunhan, and Daniel L Rubin. "Probabilistic Visual Search for Masses within Mammography Images Using Deep Learning." Paper presented at the Bioinformatics and Biomedicine (BIBM), 2015 IEEE International Conference on, 2015.

Fawcett, Tom. "An Introduction to Roc Analysis." *Pattern recognition letters* 27, no. 8 (2006): 861-74.

———. "Roc Graphs: Notes and Practical Considerations for Researchers." (2004).

Filipczuk, Paweł, Thomas Fevens, Adam Krzyżak, and Andrzej Obuchowicz. "Glcm and Glrlm Based Texture Features for Computer-Aided Breast Cancer Diagnosis." *Journal of Medical Informatics and Technologies* 19 (2012): 109-15.

Floery, Daniel, Thomas H Helbich, Christopher C Riedl, Silvia Jaromi, Michael Weber, Sepp Leodolter, and Michael H Fuchsjaeger. "Characterization of Benign and Malignant Breast Lesions with Computed Tomography Laser Mammography (Ctlm): Initial Experience." *Investigative radiology* 40, no. 6 (2005): 328-35.

Flöry, Daniel, Michael W Fuchsjaeger, Christian F Weisman, and Thomas H Helbich. "Advances in Breast Imaging: A Dilemma or Progress?". *Minimally Invasive Breast Biopsies* (2010): 159-81.

Freer, Timothy W, and Michael J Ulissey. "Screening Mammography with Computer-Aided Detection: Prospective Study of 12,860 Patients in a Community Breast Center 1." *Radiology* 220, no. 3 (2001): 781-86.

Gabriel, Courtney A, and Susan M Domchek. "Breast Cancer in Young Women." *Breast Cancer Res* 12, no. 5 (2010): 212.

Ganganwar, Vaishali. "An Overview of Classification Algorithms for Imbalanced Datasets." *International Journal of Emerging Technology and Advanced Engineering* 2, no. 4 (2012): 42-47.

Gao, Xiaohong, Yu Qian, Rui Hui, Martin Loomes, Richard Comley, Balbir Barn, A Chapman, and J Rix. "Texture-Based 3d Image Retrieval for Medical Applications." *Proceedings of IADIS e-Health. Freiburg, Germany* (2010).

Gc, Sailesh, Chulwoo Pack, Sung Shin, and Hyung D Choi. "Breast Cancer Classification of Mammographic Masses Using Improved Shape Features." Paper presented at the Proceedings of the 2015 Conference on research in adaptive and convergent systems, 2015.

Gilbert, Fiona J, Susan M Astley, Maureen GC Gillan, Olorunsola F Agbaje, Matthew G Wallis, Jonathan James, Caroline RM Boggis, and Stephen W Duffy. "Single Reading with Computer-Aided Detection for Screening Mammography." *New England Journal of Medicine* 359, no. 16 (2008): 1675-84.

Gnonnou, Christo, and Nadia Smaoui. "Segmentation and 3d Reconstruction of Mri Images for Breast Cancer Detection." Paper presented at the Image Processing, Applications and Systems Conference (IPAS), 2014 First International, 2014.

Gómez, S Sanchez, M Torres Tabanera, A Vega Bolivar, M Sainz Miranda, A Baroja Mazo, M Ruiz Diaz, P Martinez Miravete*, et al.* "Impact of a Cad System in a Screen-Film Mammography Screening Program: A Prospective Study." *European journal of radiology* 80, no. 3 (2011): e317-e21.

Gómez, Walter, WCA Pereira, and Antonio Fernando C Infantosi. "Analysis of Co-Occurrence Texture Statistics as a Function of Gray-Level Quantization for Classifying Breast Ultrasound." *Medical Imaging, IEEE Transactions on* 31, no. 10 (2012): 1889-99.

Gonçalves, Vagner Mendonça, Márcio Eduardo Delamaro, and Fátima de Lourdes dos Santos Nunes. "A Systematic Review on the Evaluation and Characteristics of Computer-Aided Diagnosis Systems." *Revista Brasileira de Engenharia Biomédica* 30, no. 4 (2014): 355-83.

Grable, Richard J, Steven L Ponder, Nikolaos A Gkanatsios, William Dieckmann, Patrick F Olivier, Robert H Wake, and Yueping Zeng. "Optical Computed Tomography for Imaging the Breast: First Look." Paper presented at the Photonics Taiwan, 2000.

Gruszauskas, Nicholas P, Karen Drukker, and Maryellen L Giger. "Robustness Studies of Ultrasound Cadx in Breast Cancer Diagnosis." *Machine Learning in Computer-Aided Diagnosis: Medical Imaging Intelligence and Analysis: Medical Imaging Intelligence and Analysis* (2012): 1.

Guan, Sheng, Min Chen, Hsin-Yu Ha, Shu-Ching Chen, Mei-Ling Shyu, and Chengde Zhang. "Deep Learning with Mca-Based Instance Selection and Bootstrapping for Imbalanced Data Classification." Paper presented at the The First IEEE International Conference on Collaboration and Internet Computing (CIC), 2015.

Haaland, Fredrik. "Making Sense of the Human Genome Using Machine Learning." (2013).

Hanley, James A, and Barbara J McNeil. "The Meaning and Use of the Area under a Receiver Operating Characteristic (Roc) Curve." *Radiology* 143, no. 1 (1982): 29-36.

Hanusiak, RK, Luiz S Oliveira, E Justino, and Robert Sabourin. "Writer Verification Using Texture-Based Features." *International Journal on Document Analysis and Recognition (IJDAR)* 15, no. 3 (2012): 213-26.

Haralick, Robert M, Karthikeyan Shanmugam, and Its' Hak Dinstein. "Textural Features for Image Classification." *Systems, Man and Cybernetics, IEEE Transactions on*, no. 6 (1973): 610-21.

Haris, Kostas, Serafim N Efstratiadis, Nicos Maglaveras, and Aggelos K Katsaggelos. "Hybrid Image Segmentation Using Watersheds and Fast Region Merging." *Image Processing, IEEE Transactions on* 7, no. 12 (1998): 1684-99.

Hassanien, Aboul Ella, Hossam M Moftah, Ahmad Taher Azar, and Mahmoud Shoman. "Mri Breast Cancer Diagnosis Hybrid Approach Using Adaptive Ant-Based Segmentation and Multilayer Perceptron Neural Networks Classifier." *Applied Soft Computing* 14 (2014): 62-71.

He, Haibo, Yang Bai, Edwardo Garcia, and Shutao Li. "Adasyn: Adaptive Synthetic Sampling Approach for Imbalanced Learning." Paper presented at the Neural Networks, 2008. IJCNN 2008.(IEEE World Congress on Computational Intelligence). IEEE International Joint Conference on, 2008.

He, Haibo, and Edwardo Garcia. "Learning from Imbalanced Data." *Knowledge and Data Engineering, IEEE Transactions on* 21, no. 9 (2009): 1263-84.

Helbich, Thomas H, L Ponhold, H Bickel, and K Pinker. "Mammography Screening and Follow-up of Breast Cancer." *HAMDAN MEDICAL JOURNAL* 5, no. 1 (2012): 5–18.

Henschke, Claudia I, Dorothy I McCauley, David F Yankelevitz, David P Naidich, Georgeann McGuinness, Olli S Miettinen, Daniel M Libby*, et al.* "Early Lung Cancer Action Project: Overall Design and Findings from Baseline Screening." *The Lancet* 354, no. 9173 (1999): 99-105.

Herranz, Michel, and Alvaro Ruibal. "Optical Imaging in Breast Cancer Diagnosis: The Next Evolution." *Journal of oncology* 2012 (2012).

Heywang, Sylvia H, Anton Wolf, Elke Pruss, Thomas Hilbertz, W Eiermann, and W Permanetter. "Mr Imaging of the Breast with Gd-Dtpa: Use and Limitations." *Radiology* 171, no. 1 (1989): 95-103.

Hidalgo-Muñoz, Antonio R, Javier Ramírez, Juan M Górriz, and Pablo Padilla. "Regions of Interest Computed by Svm Wrapped Method for Alzheimer’s Disease Examination from Segmented Mri." *Frontiers in aging neuroscience* 6 (2014).

Horsch, Karla, Maryellen L Giger, Luz A Venta, and Carl J Vyborny. "Computerized Diagnosis of Breast Lesions on Ultrasound." *Medical Physics* 29, no. 2 (2002): 157-64.

Horsch, Karla, Maryellen L Giger, Carl J Vyborny, and Luz A Venta. "Performance of Computer-Aided Diagnosis in the Interpretation of Lesions on Breast Sonography." *Academic radiology* 11, no. 3 (2004): 272-80.

Hsu, Chih-Wei, Chih-Chung Chang, and Chih-Jen Lin. "A Practical Guide to Support Vector Classification." (2003).

Huang, Yan-Hao, Yeun-Chung Chang, Chiun-Sheng Huang, Tsung-Ju Wu, Jeon-Hor Chen, and Ruey-Feng Chang. "Computer-Aided Diagnosis of Mass-Like Lesion in Breast Mri: Differential Analysis of the 3-D Morphology between Benign and Malignant Tumors." *Computer methods and programs in biomedicine* 112, no. 3 (2013): 508-17.

Huang, Yu-Len, Dar-Ren Chen, and Ya-Kuang Liu. "Breast Cancer Diagnosis Using Image Retrieval for Different Ultrasonic Systems." Paper presented at the Image Processing, 2004. ICIP'04. 2004 International Conference on, 2004.

Huang, Yu-Len, Sheng-Hsiung Lin, and Dar-Ren Chen. "Computer-Aided Diagnosis Applied to 3-D Us of Solid Breast Nodules by Using Principal Component Analysis and Image Retrieval." Paper presented at the Engineering in Medicine and Biology Society, 2005. IEEE-EMBS 2005. 27th Annual International Conference of the, 2006.

IDSI. "Imaging Diagnostic Systems, Inc." http://www.imds.com/ctlm/.

Islam, Mohammed J, Majid Ahmadi, and Maher A Sid-Ahmed. "Computer-Aided Detection and Classification of Masses in Digitized Mammograms Using Artificial Neural Network." In *Advances in Swarm Intelligence*, 327-34: Springer, 2010.

Issac Niwas, S, P Palanisamy, Rajni Chibbar, and Wen-Jun Zhang. "An Expert Support System for Breast Cancer Diagnosis Using Color Wavelet Features." *Journal of medical systems* 36, no. 5 (2012): 3091-102.

Jaccard, Paul. "The Distribution of the Flora in the Alpine Zone." *New phytologist* 11, no. 2 (1912): 37-50.

Jain, Anil K. "Data Clustering: 50 Years Beyond K-Means." *Pattern recognition letters* 31, no. 8 (2010): 651-66.

Jalalian, Afsaneh, Syamsiah BT Mashohor, Hajjah Rozi Mahmud, M Iqbal B Saripan, Abdul Rahman B Ramli, and Babak Karasfi. "Computer-Aided Detection/Diagnosis of Breast Cancer in Mammography and Ultrasound: A Review." *Clinical imaging* 37, no. 3 (2013): 420-26.

James, David, Bradley D Clymer, and Petra Schmalbrock. "Texture Detection of Simulated Microcalcification Susceptibility Effects in Magnetic Resonance Imaging of Breasts." *Journal of Magnetic Resonance Imaging* 13, no. 6 (2001): 876-81.

Japkowicz, Nathalie, and Shaju Stephen. "The Class Imbalance Problem: A Systematic Study." *Intelligent data analysis* 6, no. 5 (2002): 429-49.

Jesneck, Jonathan L, Joseph Y Lo, and Jay A Baker. "Breast Mass Lesions: Computer-Aided Diagnosis Models with Mammographic and Sonographic Descriptors 1." *Radiology* 244, no. 2 (2007): 390-98.

Jinsamol, KK, TP Shiji, and Vinu Thomas. "Cad System for Breast Ultrasoundimages Using Multi-Scaleblob Detectionand Active Contoursegmentation Algorithm." (2015).

Kannan, SR, S Ramathilagam, R Devi, and A Sathya. "Robust Kernel Fcm in Segmentation of Breast Medical Images." *Expert Systems with Applications* 38, no. 4 (2011): 4382-89.

Karkanis, SA, GD Magoulas, D Iakovidis, DE Maroulis, and MO Schurr. "On the Importance of Feature Descriptors for the Characterisation of Texture." 2000.

Kerlikowske, Karla, Patricia A Carney, Berta Geller, Margaret T Mandelson, Stephen H Taplin, Kathy Malvin, Virginia Ernster, *et al.* "Performance of Screening Mammography among Women with and without a First-Degree Relative with Breast Cancer." *Annals of Internal Medicine* 133, no. 11 (2000): 855-63.

Khan, Mr Ajaj, and Ms Nikhat Ali Syed. "Image Processing Techniques for Automatic Detection of Tumor in Human Brain Using Svm." *Image Processing Techniques* 4, no. 4 (2015).

Kim, Jeoung Hyun, Joo Hee Cha, Namkug Kim, Yongjun Chang, Myung-Su Ko, Young-Wook Choi, and Hak Hee Kim. "Computer-Aided Detection System for Masses in Automated Whole Breast Ultrasonography: Development and Evaluation of the Effectiveness." *Ultrasonography* 33, no. 2 (2014): 105.

Kohlberger, Timo, Vivek Singh, Chris Alvino, Claus Bahlmann, and Leo Grady. "Evaluating Segmentation Error without Ground Truth." In *Medical Image Computing and Computer-Assisted Intervention–Miccai 2012*, 528-36: Springer, 2012.

Koza, John R, and James P Rice. "Genetic Generation of Both the Weights and Architecture for a Neural Network." Paper presented at the Neural Networks, 1991., IJCNN-91-Seattle International Joint Conference on, 1991.

Kozegar, Ehsan, Mohsen Soryani, Behrouz Minaei, and Inês Domingues. "Assessment of a Novel Mass Detection Algorithm in Mammograms." *Journal of cancer research and therapeutics* 9, no. 4 (2013): 592.

Krig, Scott. *Computer Vision Metrics: Survey, Taxonomy, and Analysis*. Apress, 2014.

Kubat, Miroslav, and Stan Matwin. "Addressing the Curse of Imbalanced Training Sets: One-Sided Selection." Paper presented at the Proceedings of the Fourteenth International Conference on Machine Learning, 1997.

Kuhl, Christiane K. "Current Status of Breast Mr Imaging Part 2. Clinical Applications 1." *Radiology* 244, no. 3 (2007): 672-91.

Kurani, Arati S, Dong-Hui Xu, Jacob Furst, and Daniela Stan Raicu. "Co-Occurrence Matrices for Volumetric Data." Paper presented at the 7th IASTED International Conference on Computer Graphics and Imaging, Kauai, USA, 2004.

Lee, Howard, and Yi-Ping Phoebe Chen. "Image Based Computer Aided Diagnosis System for Cancer Detection." *Expert Systems with Applications* 42, no. 12 (2015): 5356-65.

Lee, Lay Khoon, Siau Chuin Liew, and Weng Jie Thong. "A Review of Image Segmentation Methodologies in Medical Image." In *Advanced Computer and Communication Engineering Technology*, 1069-80: Springer, 2015.

Lefebvre, Françoise, Martine Meunier, Fabienne Thibault, Pascal Laugier, and Geneviève Berger. "Computerized Ultrasound B-Scan Characterization of Breast Nodules." *Ultrasound in medicine & biology* 26, no. 9 (2000): 1421-28.

Lehman, Constance D, Jeffrey D Blume, Wendy B DeMartini, Nola M Hylton, Benjamin Herman, and Mitchell D Schnall. "Accuracy and Interpretation Time of Computer-Aided Detection among Novice and Experienced Breast Mri Readers." *American Journal of Roentgenology* 200, no. 6 (2013): W683-W89.

Li, Yibao, Jaemin Shin, Yongho Choi, and Junseok Kim. "Three-Dimensional Volume Reconstruction from Slice Data Using Phase-Field Models." *Computer Vision and Image Understanding* (2015).

Liu, Guang-Hai, and Jing-Yu Yang. "Content-Based Image Retrieval Using Color Difference Histogram." *Pattern Recognition* 46, no. 1 (2013): 188-98.

Liu, Haixia. "Texture Feature Analysis of Breast Lesions in Automated 3d Breast Ultrasound." (2013).

Liu, HX, RS Zhang, Feng Luan, XJ Yao, MC Liu, ZD Hu, and Bo Tao Fan. "Diagnosing Breast Cancer Based on Support Vector Machines." *Journal of Chemical Information and Computer Sciences* 43, no. 3 (2003): 900-07.

Longo, Renata, Maura Tonutti, Luigi Rigon, Fulvia Arfelli, Diego Dreossi, Elisa Quai, Fabrizio Zanconati*, et al.* "Clinical Study in Phase-Contrast Mammography: Image-Quality Analysis." *Philosophical Transactions of the Royal Society of London A: Mathematical, Physical and Engineering Sciences* 372, no. 2010 (2014): 20130025.

Ma, Jian, Zhao Yang Dong, and Pei Zhang. "Using a Support Vector Machine (Svm) to Improve Generalization Ability of Load Model Parameters." Paper presented at the Power Systems Conference and Exposition, 2009. PSCE'09. IEEE/PES, 2009.

Maciejewski, Tomasz, and Jerzy Stefanowski. "Local Neighbourhood Extension of Smote for Mining Imbalanced Data." Paper presented at the Computational Intelligence and Data Mining (CIDM), 2011 IEEE Symposium on, 2011.

Mahmood, Faleh H, and Wafaa A Abbas. "Texture Features Analysis Using Gray Level Co-Occurrence Matrix for Abnormality Detection in Chest Ct Images." *Iraqi Journal of Science* 57, no. 1A (2016): 279-88.

Malich, Ansgar, Tarek Azhari, Thomas Böhm, Marlies Fleck, and WernerA Kaiser. "Reproducibility—an Important Factor Determining the Quality of Computer Aided Detection (Cad) Systems." *European journal of radiology* 36, no. 3 (2000): 170-74.

Marquardt, Donald W. "An Algorithm for Least-Squares Estimation of Nonlinear Parameters." *Journal of the society for Industrial and Applied Mathematics* 11, no. 2 (1963): 431-41.

Martinez, Jose Maria. "Mpeg-7 Overview (Version 10), Iso." IEC JTC1/SC29/WG11, 2004.

Marx, Christiane, Ansgar Malich, Mirjam Facius, Uta Grebenstein, Dieter Sauner, Stefan OR Pfleiderer, and Werner A Kaiser. "Are Unnecessary Follow-up Procedures Induced by Computer-Aided Diagnosis (Cad) in Mammography? Comparison of Mammographic Diagnosis with and without Use of Cad." *European Journal of Radiology* 51, no. 1 (2004): 66-72.

Maskarinec, Gertraud, Ian Pagano, Zhao Chen, Chisato Nagata, and Inger Torhild Gram. "Ethnic and Geographic Differences in Mammographic Density and Their Association with Breast Cancer Incidence." *Breast cancer research and treatment* 104, no. 1 (2007): 47-56.

Meeuwis, Carla, Stephanie M van de Ven, Gerard Stapper, Arancha M Fernandez Gallardo, Maurice AAJ van den Bosch, P Th M Willem, and Wouter B Veldhuis. "Computer-Aided Detection (Cad) for Breast Mri: Evaluation of Efficacy at 3.0 T." *European radiology* 20, no. 3 (2010): 522-28.

Meyer-Baese, Anke, Adrian Barbu, Marc Lobbes, Sebastian Hoffmann, Bernhard Burgeth, Andreas Kleefeld, and Uwe Meyer-Bäse. "Computer-Aided Diagnosis of Breast Mri with High Accuracy Optical Flow Estimation." Paper presented at the SPIE Sensing Technology+ Applications, 2015.

Meyer, David, and FH Technikum Wien. "Support Vector Machines." *The Interface to libsvm in package e1071* (2015).

Moftah, Hossam M, Ahmad Taher Azar, Eiman Tamah Al-Shammari, Neveen I Ghali, Aboul Ella Hassanien, and Mahmoud Shoman. "Adaptive K-Means Clustering Algorithm for Mr Breast Image Segmentation." *Neural Computing and Applications* 24, no. 7-8 (2014): 1917-28.

Moon, Woo Kyung, Yi-Wei Shen, Min Sun Bae, Chiun-Sheng Huang, Jeon-Hor Chen, and Ruey-Feng Chang. "Computer-Aided Tumor Detection Based on Multi-Scale Blob Detection Algorithm in Automated Breast Ultrasound Images." *Medical Imaging, IEEE Transactions on* 32, no. 7 (2013): 1191-200.

Moon, Woo Kyung, Yi-Wei Shen, Chiun-Sheng Huang, Li-Ren Chiang, and Ruey-Feng Chang. "Computer-Aided Diagnosis for the Classification of Breast Masses in Automated Whole Breast Ultrasound Images." *Ultrasound in medicine & biology* 37, no. 4 (2011): 539-48.

Moraru, Luminita, Simona Moldovanu, and Anjan Biswas. "Intensity-Based Classification and Related Methods in Brain Mr Images." In *Classification and Clustering in Biomedical Signal Processing*, 78-105: IGI Global, 2016.

Mostaço-Guidolin, Leila B, Alex C-T Ko, Fei Wang, Bo Xiang, Mark Hewko, Ganghong Tian, Arkady Major, Masashi Shiomi, and Michael G Sowa. "Collagen Morphology and Texture Analysis: From Statistics to Classification." *Scientific reports* 3 (2013).

Mousa, Rafayah, Qutaishat Munib, and Abdallah Moussa. "Breast Cancer Diagnosis System Based on Wavelet Analysis and Fuzzy-Neural." *Expert Systems with Applications* 28, no. 4 (2005): 713-23.

Narkhede, HP. "Review of Image Segmentation Techniques." *Int. J. Sci. Mod. Eng* 1, no. 5461 (2013): 28.

Nelson, Heidi D, Kari Tyne, Arpana Naik, Christina Bougatsos, Benjamin K Chan, and Linda Humphrey. "Screening for Breast Cancer: An Update for the Us Preventive Services Task Force." *Annals of internal medicine* 151, no. 10 (2009): 727-37.

Nie, K. "Development of Breast Mri Computer-Aided Diagnosis System." University of California, Irvine, 2009.

Nothacker, Monika, Volker Duda, Markus Hahn, Mathias Warm, Friedrich Degenhardt, Helmut Madjar, Susanne Weinbrenner, and Ute-Susann Albert. "Early Detection of Breast Cancer: Benefits and Risks of Supplemental Breast Ultrasound in Asymptomatic Women with Mammographically Dense Breast Tissue. A Systematic Review." *BMC cancer* 9, no. 1 (2009): 335.

Nukala, Bhargava Teja, Naohiro Shibuya, Amanda Rodriguez, Jerry Tsay, Jerry Lopez, Tam Nguyen, Steven Zupancic, and Donald Yu-Chun Lie. "An Efficient and Robust Fall Detection System Using Wireless Gait Analysis Sensor with Artificial Neural Network (Ann) and Support Vector Machine (Svm) Algorithms." *Open Journal of Applied Biosensor* 3, no. 04 (2015): 29.

Nunes, Fátima LS, Homero Schiabel, and Claudio E Goes. "Contrast Enhancement in Dense Breast Images to Aid Clustered Microcalcifications Detection." *Journal of digital imaging* 20, no. 1 (2007): 53-66.

Ohuchi, Noriaki, Akihiko Suzuki, Tomotaka Sobue, Masaaki Kawai, Seiichiro Yamamoto, Ying-Fang Zheng, Yoko Narikawa Shiono*, et al.* "Sensitivity and Specificity of Mammography and Adjunctive Ultrasonography to Screen for Breast Cancer in the Japan Strategic Anti-Cancer Randomized Trial (J-Start): A Randomised Controlled Trial." *The Lancet* (2015).

Oliver, Arnau, Jordi Freixenet, Joan Marti, Elsa Perez, Josep Pont, Erika RE Denton, and Reyer Zwiggelaar. "A Review of Automatic Mass Detection and Segmentation in Mammographic Images." *Medical Image Analysis* 14, no. 2 (2010): 87-110.

Orchard, Michael T, and Charles A Bouman. "Color Quantization of Images." *Signal Processing, IEEE Transactions on* 39, no. 12 (1991): 2677-90.

Pal, Nikhil R, and Sankar K Pal. "A Review on Image Segmentation Techniques." *Pattern Recognition* 26, no. 9 (1993): 1277-94.

Pant, Raghav, Theodore B Trafalis, and Kash Barker. "Support Vector Machine Classification of Uncertain and Imbalanced Data Using Robust Optimization." Paper presented at the Proceedings of the 15th WSEAS international conference on computers, 2011.

Poellinger, Alexander, Jan C Martin, Steven L Ponder, Torsten Freund, Bernd Hamm, Ulrich Bick, and Felix Diekmann. "Near-Infrared Laser Computed Tomography of the Breast." *Academic radiology* 15, no. 12 (2008): 1545.

Poellinger, Alexander. "Near-Infrared Laser Computed Tomography of the Breast: First Clinical Experience." *Academic radiology* 15, no. 12 (2008): 1545-53.

Preim, Uta, Sylvia Glaßer, Bernhard Preim, Frank Fischbach, and Jens Ricke. "Computer-Aided Diagnosis in Breast Dce-Mri—Quantification of the Heterogeneity of Breast Lesions." *European Journal of Radiology* 81, no. 7 (2012): 1532-38.

Qi, Jin, and Zhaoxiang Ye. "Ctlm as an Adjunct to Mammography in the Diagnosis of Patients with Dense Breast." *Clinical imaging* 37, no. 2 (2013): 289-94.

Rahman, M Mostafizur, and DN Davis. "Addressing the Class Imbalance Problem in Medical Datasets." *International Journal of Machine Learning and Computing* 3, no. 2 (2013): 224-28.

Rangayyan, Rangaraj M, Naga R Mudigonda, and JE Leo Desautels. "Boundary Modelling and Shape Analysis Methods for Classification of Mammographic Masses." *Medical and Biological Engineering and Computing* 38, no. 5 (2000): 487-96.

Rastgarpour, M, and J Shanbehzadeh. "Application of Ai Techniques in Medical Image Segmentation and Novel Categorization of Available Methods And." Paper presented at the Tools, Proceedings of the International MultiConference of Engineers and Computer Scientists 2011 Vol I, IMECS 2011, March 16-18, 2011, Hong Kong, 2011.

Rizzi, Maria, and Matteo D'Aloia. "Computer Aided System for Breast Cancer Diagnosis." *Biomedical Engineering: Applications, Basis and Communications* 26, no. 03 (2014): 1450033.

Rizzi, Maria, Matteo D’Aloia, and Beniamino Castagnolo. "Review: Health Care Cad Systems for Breast Microcalcification Cluster Detection." *Journal of Medical and Biological Engineering* 32, no. 3 (2012): 147-56.

Rohler, David P, Sastry LA Kasibhatla, and Steven Ross. "Method for Reconstructing the Image of an Object Scanned with a Laser Imaging Apparatus." Google Patents, 2000.

Rouhi, Rahimeh, Mehdi Jafari, Shohreh Kasaei, and Peiman Keshavarzian. "Benign and Malignant Breast Tumors Classification Based on Region Growing and Cnn Segmentation." *Expert Systems with Applications* 42, no. 3 (2015): 990-1002.

Rundo, Leonardo, Carmelo Militello, Salvatore Vitabile, Carlo Casarino, Giorgio Russo, Massimo Midiri, and Maria Carla Gilardi. "Combining Split-and-Merge and Multi-Seed Region Growing Algorithms for Uterine Fibroid Segmentation in Mrgfus Treatments." *Medical & biological engineering & computing* (2015): 1-14.

Saha, Monjoy, Sanjit Agarwal, Indu Arun, Rosina Ahmed, Sanjoy Chatterjee, Pabitra Mitra, and Chandan Chakraborty. "Histogram Based Thresholding for Automated Nucleus Segmentation Using Breast Imprint Cytology." In *Advancements of Medical Electronics*, 49-57: Springer, 2015.

Sahiner, Berkman, Heang-Ping Chan, Marilyn A Roubidoux, Lubomir M Hadjiiski, Mark A Helvie, Chintana Paramagul, Janet Bailey, Alexis V Nees, and Caroline Blane. "Malignant and Benign Breast Masses on 3d Us Volumetric Images: Effect of Computer-Aided Diagnosis on Radiologist Accuracy 1." *Radiology* 242, no. 3 (2007): 716-24.

Sathya, A, S Senthil, and Anudevi Samuel. "Segmentation of Breast Mri Using Effective Fuzzy C-Means Method Based on Support Vector Machine." Paper presented at the Information and Communication Technologies (WICT), 2012 World Congress on, 2012.

Scheel, John R, Janie M Lee, Brian L Sprague, Christoph I Lee, and Constance D Lehman. "Screening Ultrasound as an Adjunct to Mammography in Women with Mammographically Dense Breasts." *American journal of obstetrics and gynecology* 212, no. 1 (2015): 9-17.

Seiffert, Chris, Taghi M Khoshgoftaar, Jason Van Hulse, and Amri Napolitano. "Rusboost: A Hybrid Approach to Alleviating Class Imbalance." *Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on* 40, no. 1 (2010): 185-97.

Shen, Liang, Rangaraj M Rangayyan, and JE Leo Desautels. "Application of Shape Analysis to Mammographic Calcifications." *Medical Imaging, IEEE Transactions on* 13, no. 2 (1994): 263-74.

Shi, Peng, Jinsheng Hong, Yue Huang, Zhenhuan Zhang, Mei Zhang, and Lurong Zhang. "Automated Computational Framework of Blood Vessel Quantification in Chick Chorioallantoic Membrane Angiogenesis." *Journal of biomedical optics* 19, no. 10 (2014): 106005-05.

Shi, Xiangjun, HD Cheng, Liming Hu, Wen Ju, and Jiawei Tian. "Detection and Classification of Masses in Breast Ultrasound Images." *Digital Signal Processing* 20, no. 3 (2010): 824-36.

Shiraishi, Junji, Qiang Li, Daniel Appelbaum, and Kunio Doi. "Computer-Aided Diagnosis and Artificial Intelligence in Clinical Imaging." Paper presented at the Seminars in nuclear medicine, 2011.

Sone, Shusuke, Shodayu Takashima, Feng Li, Zhigang Yang, Takayuki Honda, Yuichiro Maruyama, Minoru Hasegawa*, et al.* "Mass Screening for Lung Cancer with Mobile Spiral Computed Tomography Scanner." *The Lancet* 351, no. 9111 (1998): 1242-45.

Sonego, Paolo, András Kocsor, and Sándor Pongor. "Roc Analysis: Applications to the Classification of Biological Sequences and 3d Structures." *Briefings in bioinformatics* 9, no. 3 (2008): 198-209.

Song, Sung Eun, Bo Kyoung Seo, Kyu Ran Cho, Ok Hee Woo, Gil Soo Son, Chulhan Kim, Sung Bum Cho, and Soon-Sun Kwon. "Computer-Aided Detection (Cad) System for Breast Mri in Assessment of Local Tumor Extent, Nodal Status, and Multifocality of Invasive Breast Cancers: Preliminary Study." *Cancer Imaging* 15, no. 1 (2015): 1.

Star, Willem M. "Diffusion Theory of Light Transport." *Optical-thermal response of laser-irradiated tissue* (2011): 145-201.

Sun, Yanmin, Mohamed S Kamel, Andrew KC Wong, and Yang Wang. "Cost-Sensitive Boosting for Classification of Imbalanced Data." *Pattern Recognition* 40, no. 12 (2007): 3358-78.

Sun, Yanmin, Andrew KC Wong, and Mohamed S Kamel. "Classification of Imbalanced Data: A Review." *International Journal of Pattern Recognition and Artificial Intelligence* 23, no. 04 (2009): 687-719.

Sundararaj, G Kharmega, and V Balamurugan. "An Expert System Based on Texture Features and Decision Tree Classifier for Diagnosis of Tumor in Brain Mr Images." Paper presented at the Contemporary Computing and Informatics (IC3I), 2014 International Conference on, 2014.

Svensson, WE. "A Review of the Current Status of Breast Ultrasound." *European Journal of Ultrasound* 6, no. 2 (1997): 77-101.

Tan, Tao, Jan-Jurre Mordang, Jan van Zelst, André Grivegnée, Albert Gubern-Mérida, Jaime Melendez, Ritse M Mann*, et al.* "Computer-Aided Detection of Breast Cancers Using Haar-Like Features in Automated 3d Breast Ultrasound." *Medical physics* 42, no. 4 (2015): 1498-504.

Tan, Tao, Bram Platel, Henkjan Huisman, Clara Sánchez, Roel Mus, and Nico Karssemeijer. "Computer-Aided Lesion Diagnosis in Automated 3-D Breast Ultrasound Using Coronal Spiculation." *Medical Imaging, IEEE Transactions on* 31, no. 5 (2012): 1034-42.

Tan, Tao, Bram Platel, Roel Mus, Laszlo Tabar, Ritse M Mann, and Nico Karssemeijer. "Computer-Aided Detection of Cancer in Automated 3-D Breast Ultrasound." *Medical Imaging, IEEE Transactions on* 32, no. 9 (2013): 1698-706.

Tiedeu, Alain, Christian Daul, Aude Kentsop, Pierre Graebling, and Didier Wolf. "Texture-Based Analysis of Clustered Microcalcifications Detected on Mammograms." *Digital Signal Processing* 22, no. 1 (2012): 124-32.

Tsai, Fuan, Chun-Kai Chang, Jian-Yeo Rau, Tang-Huang Lin, and Gin-Ron Liu. "3d Computation of Gray Level Co-Occurrence in Hyperspectral Image Cubes." Paper presented at the Energy Minimization Methods in Computer Vision and Pattern Recognition, 2007.

Übeyli, Elif Derya. "Implementing Automated Diagnostic Systems for Breast Cancer Detection." *Expert Systems with Applications* 33, no. 4 (2007): 1054-62.

Vacic, Vladimir. "Summary of the Training Functions in Matlab's Nn Toolbox." *Computer Science Department at the University of California* (2005).

van de Ven, SMWY, SG Elias, MAAJ van den Bosch, P Luijten, and WP Th M Mali. "Optical Imaging of the Breast." *Cancer Imaging* 8, no. 1 (2008): 206.

Verma, AK, and Sachin Maheshwar. "Comparative Study of Intelligent Prediction Models for Pressure Wave Velocity." *Journal of Geosciences and Geomatics* 2, no. 3 (2014): 130-38.

Wang, Benjamin X, and Nathalie Japkowicz. "Boosting Support Vector Machines for Imbalanced Data Sets." *Knowledge and Information Systems* 25, no. 1 (2010): 1-20.

Wang, Lilian C, Wendy B DeMartini, Savannah C Partridge, Sue Peacock, and Constance D Lehman. "Mri-Detected Suspicious Breast Lesions: Predictive Values of Kinetic Features Measured by Computer-Aided Evaluation." *American Journal of Roentgenology* 193, no. 3 (2009): 826-31.

Warner, Elizabeth E, and James L Mulshine. "Lung Cancer Screening with Spiral Ct: Toward a Working Strategy." *Oncology (Williston Park, NY)* 18, no. 5 (2004): 564-75, discussion 78, 83-4, 87.

Warren, RML, and W Duffy. "Comparison of Single Reading with Double Reading of Mammograms, and Change in Effectiveness with Experience." *The British journal of radiology* 68, no. 813 (1995): 958-62.

Williams, Teresa C, Wendy B DeMartini, Savannah C Partridge, Sue Peacock, and Constance D Lehman. "Breast Mr Imaging: Computer-Aided Evaluation Program for Discriminating Benign from Malignant Lesions 1." *Radiology* 244, no. 1 (2007): 94-103.

Xi, Dongdong, Ming Fan, Lihua Li, Juan Zhuang, Yanna Shan, Gang Dai, and Bin Zheng. "Mass Classification in Mammography with Multi-Agent Based Fusion of Human and Machine Intelligence." Paper presented at the SPIE Medical Imaging, 2016.

Xie, Xuanli Lisa, and Gerardo Beni. "A Validity Measure for Fuzzy Clustering." *IEEE Transactions on Pattern Analysis & Machine Intelligence*, no. 8 (1991): 841-47.

Xu, Dong, and Hua Li. "Geometric Moment Invariants." *Pattern recognition* 41, no. 1 (2008): 240-49.

Yang, Mingqiang, Kidiyo Kpalma, and Joseph Ronsin. "A Survey of Shape Feature Extraction Techniques." *Pattern Recognition* (2008): 43-90.

Yang, Xiaofeng, Srini Tridandapani, Jonathan J Beitler, S Yu David, Emi J Yoshida, Walter J Curran, and Tian Liu. "Ultrasound Glcm Texture Analysis of Radiation-Induced Parotid-Gland Injury in Head-and-Neck Cancer Radiotherapy: An in Vivo Study of Late Toxicity." *Medical physics* 39, no. 9 (2012): 5732-39.

Yong, Ho Wei, Abdullah Bade, and Rajesh Kumar Muniandy. "3d Reconstruction of Breast Cancer from Mammograms Using Volume Rendering Techniques." *Jurnal Teknologi* 75, no. 2 (2015).

Yoshida, Hiroyuki, Yoshitaka Masutani, Peter Maceneaney, David T Rubin, and Abraham H Dachman. "Computerized Detection of Colonic Polyps at Ct Colonography on the Basis of Volumetric Features: Pilot Study 1." *Radiology* 222, no. 2 (2002): 327-36.

Yu-qian, Zhao, Gui Wei-hua, Chen Zhen-cheng, Tang Jing-tian, and Li Ling-yun. "Medical Images Edge Detection Based on Mathematical Morphology." Paper presented at the Engineering in Medicine and Biology Society, 2005. IEEE-EMBS 2005. 27th Annual International Conference of the, 2006.

Zanaty, EA. "Determining the Number of Clusters for Kernelized Fuzzy C-Means Algorithms for Automatic Medical Image Segmentation." *Egyptian Informatics Journal* 13, no. 1 (2012): 39-58.

Zhang, Yu-Jin. "An Overview of Image and Video Segmentation in the Last 40 Years." *Advances in Image and Video Segmentation* (2006): 1-15.

Zhang, Yu, Noriko Tomuro, Jacob Furst, and Daniela Stan Raicu. "Building an Ensemble System for Diagnosing Masses in Mammograms." *International journal of computer assisted radiology and surgery* 7, no. 2 (2012): 323-29.

Zhao, Yitian, Ian JC MacCormick, David G Parry, Nicholas AV Beare, Simon P Harding, and Yalin Zheng. "Automated Detection of Vessel Abnormalities on Fluorescein Angiogram in Malarial Retinopathy." *Scientific reports* 5 (2015).

Zhu, Quing, Edward B Cronin, Allen A Currier, Hugh S Vine, Minming Huang, NanGuang Chen, and Chen Xu. "Benign Versus Malignant Breast Masses: Optical Differentiation with Us-Guided Optical Imaging Reconstruction 1." *Radiology* 237, no. 1 (2005): 57-66.

Žunić, Joviša, Kaoru Hirota, and Carlos Martinez-Ortiz. "Compactness Measure for 3d Shapes." Paper presented at the Informatics, Electronics & Vision (ICIEV), 2012 International Conference on, 2012.

Žunić, Joviša, Kaoru Hirota, and Paul L Rosin. "A Hu Moment Invariant as a Shape Circularity Measure." *Pattern Recognition* 43, no. 1 (2010): 47-57.