A survey on Microcalcification identification and classification using CAD System

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Abstract : Micro-calcifications (µCas) are early indications of a malignant lesion: µCa detection and analysis of their spatial arrangement ensures basic diagnostic information. As µCa clustering suggests a tumor, the description of µCa distribution plays a major role in the design of a computational tool to help mammographic diagnosis. Micro-calcifications look like light tiny spots in a complex background and resemble a highly structured random field.

IndexTerms **- Mammography,Calcification,CAD,SVM,GSP,DDSM,SCLGM.**

I. SURVEY ON MICRO-CALCIFICATION DETECTION

Oliver et al. (2012) introduced a boosting based approach to automatically detect micro-calcifications in mammographic images. The proposed approach was developed on the basis of implementing local features which are obtained from a filter bank to acquire an explanation regarding various micro-calcifications morphology. First, a training stage was performed in the proposed approach to study and choose the very significant features, automatically, which are consecutively employed in a boosting classifier for achieving detection. 112 mammograms were obtained from a popular digitized MIAS database and 280 mammograms were obtained from a full-field digital database and used for the authentication of the proposed approach. In terms of ROC analysis, the results acquired was Az= 0.88 and Az= 0.90 respectively and FROC analysis was also performed. The demonstration shows the practicability of the proposed approach to detect micro-calcifications in both digitized and digital mammograms.

Torrent et al. (2010) proposed a supervised technique to detect micro-calcifications in an automatic way. The proposed system was based on extracting local features to characterize the morphology of the micro-calcifications by the implementation of a bank of filters. Subsequently, a pixel-based boosting classifier was trained using this set of features and consequently, the salient feature was selected automatically at every round. Hence, to test a novel mammogram, the salient features were only computed and as a part of micro-calcification or truly normal tissues, the classification for all pixels in the mammogram is utilized. The proposed method was authenticated by the experimental results obtained. A digitized database was used for the process of learning and a diverse one for testing to illustrate the robustness of the proposed technique which gave adequate solutions.

Arai et al. (2012) proposed an automated approach for the detection of clustered MC by implementing two important techniques, for detection of clustered MC-multi-branches standard deviation analysis and for detection of particular MC-surrounding region dependence approach. 70.8% classification rate was resulted from the proposed method and 79% sensitivity and 87% specificity was accomplished. The results obtained were very promising and in few areas it facilitated further development.

A wide range of CAD systems; Computer-Aided Detection (CADe) and Computer-Aided Diagnosis (CADi) have been suggested to decrease the radiologist's workload. Boujelben et al. (2011) focused on CADe tool to assist radiologists in cancer detection. A three-step procedure namely detection, analysis and classification are followed by the proposed CADe. The challenges faced in automatic detection of Region of Interest (ROI) based on Level Set scheme depending on edge and region criteria are addressed in this study. Efficient visual information obtained from the radiologist is provided by the proposed method, subsequent to which the differentiation of various ACR (American College of Radiology) classification is performed adopting the features extraction by textures characteristics and the vector classification by implementing Multilayer Perception (MLP) and k-Nearest Neighbors (k-NN). In the experiments, Digital Database for Screening Mammography (DDSM) is implemented and the results obtained were present between 60% and 70% in accuracy and to assist radiologists, the results should be ameliorated.

Zhang & Agyepong (2010) using the Gaussian Markov Random Fields (GMRF) representation introduced a novel micro-calcification clusters detection approach. Three major stages are included in the designing and estimation of the algorithm. The first stage comprises of the application of a training dataset for the purpose of training and obtaining the GMRF texture features of all image block and subsequently acquires the cluster centre and bias. The second stage of the proposed algorithm is the GMRFs usage to attain texture feature using a provided image block. The last stage was to decide whether the micro-calcification cluster is present or not by observing the distance among the provided image block GMRFs features and the cluster center. The results attained from the experiments illustrate the out performance of the proposed approach in the detection of micro calcification clusters.

II. MASS CLASSIFICATION

An early indicator of breast cancer is "masses". A mammogram is divided into regions of interest which comprises both normal tissues and masses which cause false positives. Hence, the classification of ROIs into normal tissues and masses is the only way to decrease the problem of false positives. And, the masses detected are to be distinguished into malignant and benign. Hussain et al. (2012) in order to address the issues in mass classification, evaluated the six varied Gabor feature extraction method's performance.

The Gabor filter was used in these methods to obtain multi scale and multi orientation texture features so that the structural properties of masses and normal dense tissues in mammograms were represented. The ROIs obtained from MIAS database was calculated by the feature extraction methods. To classify the produced unbalanced datasets in an effective way, a Successive Enhancement Learning based weighted Support Vector Machine is implemented. In terms of area under ROC curve (Az = 1.0) was the Gabor features extorted by implementing the first order statistics of the Gabor responses and Linear Discriminant Analysis (LDA). Thus, the features extracted implementing LDA Window based Statistics of Magnitude Gabor Responses (LDA_WSMGR) feature extraction approach illustrates the best performance to address two problems in classification.

Khuzi et al. (2009) investigated on normal breast images and images of breast containing masses (obtained from Mammographic Image Analysis Society (MIAS) digital mammogram database) which were employed as the basic input to the proposed system. The grouping of masses in MIAS database were as circumscribed, ill-defined or speculated. The location of the masses centers and the masses radius are the additional information present. Using gray level co-occurrence matrices (GLCM), the textural features of ROIs are extracted which was created in four varied directions for all ROI. The important texture information used to classify masses and non-masses tissues were resulted by using GLCM at 0º, 45º, 90º and 135º including 8X8 as the block size. The GLCM properties were investigated i.e., energy, homogeneity and contrast leading to Az= 0.84 in receiver operating characteristics (ROC) curve area for the Otsu's approach, in thresholding approach Az=0.82 and for K-mean clustering Az= 0.7. There was no complex algorithm in the proposed method. Analysis based on decision tree with five criterions was the basis for detection. It requires less time for computation due to the simplicity of the proposed method and hence, for automated real-time breast cancer detection system, it was the appropriate one.

III. Detection Based On Feature Extraction

Hajare & Dixit (2012) focused on identification of relevant, representative and important, discriminate image features for breast cancer analysis. Mammogram image features representing normal tissues or benign/malign tumors are extracted through Gabor wavelets. These features with large dimensions (1024x1024) are applied to Principal Component Analysis (PCA) to reduce data dimensionality and converted into 140x140 pixel size images. Finally, extracted features are classified by proximal support vector machines and features with orientations of 0, $\pi/4$, $3\pi/4$ and $\pi/2$ and with Gabor filters orientations combine with low and high frequency filters are compared for Recognition rate. The Gabor filter obtained rate with low frequency and total orientation is the highest at 84.37%, when compared to others.

Talha et al. (2012) proposed an approach which has an integration of various techniques. Initially, to improve the quality of the image, the improvement on breast mammogram was performed using Contrast Limited Adaptive Histogram Equalization (CLAHE). Next, for features extraction, local window based discrete cosine transform was employed. And for the purpose of features reduction and selection, principle component analysis was employed. For the classification into benign and malignant, a classifier was employed. The results obtained from the experiments performed on MIAS dataset were adequate and remarkably good.

Panda et al. (2009) proposed the development of an image processing algorithm to identify mass and micro-calcifications lesions in order to facilitate diagnosis of breast cancer at premature stage. For feature extraction of the mass and micro-calcifications lesions, the proposed method applies a new scheme. There are three steps involved in the proposed scheme. They are: (a) specification of regions of interest (ROI), (b) transformation of two dimensional wavelet and (c) extraction of features on the basis of OTSU thresholding, the region of interest to recognize mass and micro-calcifications lesions. A wavelet-based transformation technique was implemented for the preprocessing of ROIs and the elimination of mass and micro-calcifications lesions was achieved by applying a thresholding method. The database containing many images extracted from mini-MIAS (Mammogram Image Analysis Society, UK) was used to analyze the proposed approach. As the proposed algorithm's implementation was performed employing MATLAB codes, programming makes its ability to perform on a basic personal computer containing collected digital mammogram as data which requires efficient evaluation.

Geetha & Thanushkodi (2008) proposed a Genetic Algorithm (GA) hybrid integrated with Particle Swarm Optimization (PSO) in order to identify the breast border and position of the nipple automatically to detect the dubious sections in the digital mammogram on the basis of asymmetries among the right and left breast image. To segment the dubious section, the right and left images are subtracted analogously which was the general aim of asymmetry scheme. There are two steps involved in the proposed model. Initially, the advancement of mammogram images was performed by implementing median filter, wherein the image was normalized and removal of pectoral muscle region was done and for both right and left images obtained from the binary image, the border of the mammogram was detected. To improve the detected border, PSO was employed. To reveal the concern that the border detected was accurate or not was performed by evaluating and estimating the Figure of merit. Implementing ACS, the identification of the nipple position was done. Using the already present techniques, the performance of the proposed model was compared. Next, the mammogram image's references (the border points and nipple position) were arranged and subtracted to obtain the dubious sections. Sixty abnormal digitized mammograms obtained from MIAS database were used for testing the proposed algorithm. The performance was measured by the true positive detection rate and the number of false positive detection rates at different thresholds of the asymmetry images

IV. Computer Aided Mammography

Mohanty et al. (2011) performed a study based on the research which examined digital mammograms by using the state-of- art computer aided detection systems and estimated the associated methods in image pre-processing, feature extraction and digital mammogram classification. Additionally, the future directions for research for the subsequent generation CAD for mammograms

were discovered. It provided more knowledge concerning masses and micro-calcifications using computer-aided detection methods. However for architectural misrepresentation and asymmetry in mammograms, challenges are still occurring in the detection methods.

Grim et al. (2009) proposed a novel method for diagnostic estimation of screening mammograms on the basis of local statistical texture models with the idea of enhancing the determination of dubious sections. An appropriately selected search window, a multivariate probability density of gray levels was the form of the local evaluation tool. Initially, in the data extracted by means of scanning the mammogram along with the search window evaluation of density function in the form of Gaussian mixture was performed. Next, in every position, the estimated mixture's evaluation was performed and the corresponding log-likelihood value was displayed in the window center like a gray level. Compared to the structural descriptions of the original mammogram, the resulting log-likelihood image was very alike and correlated each other with the illustrations and the main focus was on the dubious places. In parallel comparison, the log-likelihood image utilization might support malignant lesions determination in screening mammograms as untypical areas were of extreme difference.

Frigas et al. (2009) tested and verified a micro-calcification classification algorithm to know whether it was accurate or not to detect micro-calcifications in a particular area in a mammogram. The testing of the proposed algorithm was performed in three regions for each mammogram (two random ones and one -biopsy proven abnormal) revealed from doctors collaborative work in a dataset containing 50 mammograms obtained when the clinical trial of the system was performed in Athens Hippocratio's Hospital Breast Unit. For the purpose of evaluating the final risk and to designate micro-calcification in any one of the five assigned risk groups, all the micro-calcifications were examined using 7 characteristics and a value for all of them was designated. A color-based classification was used to color every micro-calcification present in a particular risk group for quicker recognition of the doctor distinguishing it from the other risk groups. In the 50 mammograms associated with biopsy test results, 150 regions had been tested. 12.55 was the average number of micro-calcifications per cm2 identified in random areas and it was 21.17 in the biopsy proven abnormal areas. For the random areas tested, the average number of high risk micro-calcifications per cm2 was 1.32 and it was 6.96 for the biopsy proven abnormal areas. The results were obtained and they illustrated that the micro calcifications of suspicious' areas clusters were classified accurately due to the considerable increase in number of high risk micro-calcifications in abnormal regions compared to the random ones.

Papadopoulos et al. (2005) suggested an automated method for the characterization of micro-calcification clusters in digitized mammograms. This is implemented in three stages:(a) cluster detection stage for identification of micro-calcifications clusters, (b) feature extraction stage for comparing each clusters important features and (c) classification stage. In the classification stage, a rule-based system, a neural network and a SVM were implemented and evaluated using receiver operating characteristic analysis. The original feature set was enhanced by adding four rule-based features. In Nijmegen dataset, SVM performance was Az = 0.79 and 0.77 for the original and enhanced feature sets respectively, while in MIAS datasets corresponding characterization scores were Az = 0.81and 0.80. Using neural network classification, Nijmegen dataset corresponding performance was Az = 0.70 and 0.76 and that of the MIAS dataset, Az = 0.73 and 0.78 respectively.

V. Genetic Algorithms in Mammograms

Ferrero et al. (2010) proposed a feature selection algorithm obtained from a large quantity of features on the basis of a statistical distance scheme combined with a genetic algorithm (GA). The optimality criterion, statistical distance was enhanced in combination with genetic algorithms to choose a suitable subset of features which increases the ability of the proposed algorithm to achieve feature selection in a large collection of initial features. In addition, a criterion was given for choosing a suitable number of features required to be implemented. Using Generalized Softmax Perceptrons (GSP) which were trained employing a Strict Sense Bayesian cost function for the purpose of direct probability evaluation which are used as micro-calcification classifiers, were implemented to perform the experiments. The intricacy of the network was revealed using a Posterior Probability Model Selection (PPMS) algorithm. The results obtained illustrated that the Area Under Curve (AUC) of the Receiver Operating Curve (ROC) and classification rate possessed by the proposed algorithm was superior as it converged into a subset of features.

A new feature extraction method to build a CAD model for cancer discrimination, benign and healthy parenchyma was introduced by Elfarra & Abuhaiba (2012). Both human and computational features were used for feature extraction, as obtained by Digital Database for Screening Mammography (DDSM). A new feature extraction method called Square Centroid Lines Gray Level Distribution Method (SCLGM) was proposed. The results were from a data set of 410 images of various types from DDSM. The proposed method selected 31 features from 145 extracted features. 18 selected features were from the proposed feature extraction method (SCLGM) which used both Receiver Operating Characteristics (ROC) and confusing matrix to measure performance. In the training stage, the proposed method attained an overall classification accuracy of 96.3%, with 92.9% sensitivity and 94.3% specificity. In testing stage, the proposed method achieved an overall classification accuracy of 89%, with 88.6% sensitivity and 83.3% specificity.

Umamaheswari & Radhamani (2011) proposed a hybrid approach for DICOM image classification consisting of feature extraction and classification. The classification includes Multi Linear Discriminant Analysis (MLDA) and Support Vector Machine (SVM). Classification is based on parameter extracted by Gray Level Co-occurrence Matrix (GLCM) and histogram texture feature extraction. Feature is chosen in the course of the use of fuzzy rough set and Genetic Algorithm (GA). The proposed approach showed the capability for high approximation and much faster convergence.

VI. IMAGE PROCESSING ALGORITHMS IN DIGITAL MAMMOGRAPHY

Singh et al. (2011) used texture based segmentation and genetic algorithm to detect and diagnose the patterns of micro calcifications in digital mammograms by presenting a system based on fuzzy-C Means clustering and feature extraction approaches. By analyzing several number of feature extraction approaches, three features combination (i.e.) standard deviation, entropy and number of pixels was found to be the superior one to differentiate between the benign micro calcification pattern and the malignant one. Using contrast enhancement and by investigating its respective histograms, it can be concluded that the proposed approach will be an accurate aid to the radiologist for early diagnosis of breast cancer. The results attained revealed that correct result was produced by the genetic algorithm explained in this study for the breast cancer data classification and a very satisfactory and intelligible classification rule was recognized.

Dubey et al. (2011) performed a comparative performance in breast tumor segmentation by evaluating two varied semi-automated techniques (i.e.) modified gradient magnitude region growing technique (MGMRGT) and watershed technique. The efficiency of the segmentation techniques are authenticated using a collection of 6 mammogram images. The results show that MGMRGT segmentation outperformed compared to watershed method. Thus, the current application was adapted to perform a detailed breast investigation which has less time consumption and supports the radiologists.

Tzikopoulos et al. (2010) implemented Relevance-Feedback methods and introduced an experimental "morphological analysis" system for retrieval in mammograms. First-order statistics of the Normalized Radial Distance which was obtained from the annotated mass boundary were implemented as the features. An extensive dataset containing 2274 masses of the DDSM database which included 7 distinct classes were used for the evaluation of the proposed system. The experiments validated that the introduction of retrieval process advanced the results obtained up to 90% of precision rate and efficiently enhances retrieval in complicated classification task. Hence, as a tool the Relevance-Feedback was successfully complemented to the existing Computer Aided Diagnosis system.

VII. WAVELET AND FUZZY BASED MAMMOGRAPHY IMAGE PROCESSING

Garge et al. (2011) addressed the image processing in mammogram with the implementation of balanced multi-wavelets. For various problems such as enhancing the energy compaction ratio, the preservation of smoothness in images, the balancing property is verified to be central. The pre and post filtering steps necessitated in the systems based on unbalanced multi-wavelets are avoided by means of balanced multi-wavelets. For early diagnosis of breast cancer, efforts are made by several researchers including technologists and mathematicians. In the area of computer aided diagnostics of cancer, till now the application of the wavelet and multi-wavelet theory was applied effectively. But, the high potential of balanced multi-wavelets in the image processing of mammograms was highlighted in the analytic assumptions. The reports provided are regarding mammogram image processing implementing balanced multi-wavelets employed with MATLAB.

Quintanilla-Dominguez et al. (2010) based on the synergy of the image processing, artificial intelligence and pattern recognition, introduced an efficient substitutive strategy for detection of micro-calcification clusters in digital mammograms. For image enhancement, mathematical morphology, an image processing method was employed. In order to cluster the data on the basis of feature's vectors, a k-means algorithm was applied and additionally an artificial neural network-based classifier was used and using an ROC curve the classification performance was estimated. The results illustrated from the experiments showed that 99.72% was the correct classification percentage providing 100% sensitivity (true positive) and 99.67% specificity (false positive) by the implementation of the proposed classifier. The estimation of classification performance was Az = 0.9875 for the best classifier.

Wei et al. (2009) for the diagnosis of breast cancer, proposed a micro-calcification classification method which was supported with content-based mammogram retrieval. A machine learning technique was developed in recent times in which next to skilled observers, the modeling of the similarity measure among two lesion mammograms was done. The examination is mainly emphasized on the retrieval of similar cases which were used as references to enhance a numerical classifier's performance. The justification provided was that to advance the classification accuracy, the local proximity information was incorporated into a classifier in an adaptive manner which provides "second opinion" to radiologists in an efficient way. A mammogram database containing 200 mammogram images extracted from Department of Radiology at the University of Chicago was used for performing experiments and the results showed that the classification performance was improved from 0.78 to 0.82 in terms of the region under the ROC curve by using the proposed retrieval-driven method including an adaptive support vector machine (SVM).

VIII. CONCLUSION

Breast cancer is one of the genuine explanations behind death among women. Digital mammography screening undertakings can enable early area and break down of the Breast cancer which reduces the mortality and constructs the chances of complete recovery. Screening programs convey a remarkable measure of mammographic pictures which must be deciphered by radiologists. In light of the broad assortment of chest varieties from the standard's features a couple of irregularities may be missed or misconstrued. PC upheld area and conclusion counts have been made to empower radiologists to give a correct investigation and to decrease the amount of false positives. There are a more algorithms are created for distinguishing proof of masses and calcifications. Encourage it is contemplated that headways in each count required to improve the general execution of PC bolstered area and diagnosis algorithms.

REFERENCES

[1] Oliver, A, Torrent, A, Lladó, X, Tortajada, M, Tortajada, L, Sentís, M & Zwiggelaar, R 2012, 'Automatic microcalcification and cluster detection for digital and digitised mammograms', Knowledge-Based Systems, vol. 28, pp. 68-75.

[2] Torrent, A, Oliver, A, Lladó, X, Marti, R & Freixenet, J 2010, 'A supervised micro-calcification detection approach in digitised mammograms', IEEE seventeenth International Conference on Image Processing (ICIP), pp. 4345-4348.

[3] Arai, K, Abdullah, IN & Okumura, H 2012, 'Automated Detection Method for Clustered Microcalcification in Mammogram Image Based on Statistical Textural Features', International Journal of Advanced Research in Artificial Intelligence, vol. 1, no. 3, pp. 22-26.

[4] Boujelben, A, Tmar, H, Mnif, J & Abid, M 2011, 'Automatic application level set approach in detection calcifications in mammographic image', International Journal of Computer Science & Information Technology, vol. 3, no. 4, pp.1-14.

[5] Zhang, P & Agyepong, K 2010, 'Wavelet-based fractal feature extraction for microcalcification detection in mammograms', IEEE Proceedings of the SoutheastCon 2010, pp. 147-150.

[6] Hussain, M, Khan, S, Muhammad, G & Bebis, G 2012, 'A Comparison of Different Gabor features for Mass Classification in Mammography', IEEE Eighth International Conference on Signal Image Technology and Internet Based Systems (SITIS), pp. 142-148.

[7] Khuzi, MA, Besar, R, Wan-Zaki, W & Ahmad, N 2009, 'Identification of masses in digital mammogram using gray level co-occurrence matrices', Biomedical imaging and intervention journal, vol. 5, no. 3, pp.1-13.

[8] Hajare, PS, & Dixit, VV 2012, 'Breast Tissue Classification Using Gabor Filter, PCA and Support Vector Machine', International Journal of advancement in electronics and computer engineering (IJAECE), vol. 1, no. 4, pp.116-119.

[9] Talha, M, Sulong, GB, Alarifi, A, Noor, S & Uddin M 2012, 'Breast Mammograms Classification using Reduced Features by Bayesian Classifier', Archives Des Sciences, vol. 65, no. 8, pp. 539-556.

[10] Panda, RN, Panigrahi, BK & Patro, MR 2009, 'Feature extraction for classification of microcalcifications and mass lesions in mammograms', International Journal of Computer Science and Network Security, vol. 9, no. 5, pp. 255-265.

[11] Geetha, K & Thanushkodi, K 2008, 'New particle swarm optimization for feature selection and classification of microcalcifications in mammograms', IEEE International Conference on Signal Processing, Communications and Networking, ICSCN'08, pp. 458-463.

[12] Mohanty, AK, Beberta, S & Lenka, SK 2011, 'Classifying Benign and Malignant Mass using GLCM and GLRLM based Texture Features from Mammogram', International Journal of Engineering Research and Applications, vol. 1, no. 3, pp. 687-693.

[13] Grim, J, Somol, P, Haindl, M & Danes, J 2009, 'Computer-aided evaluation of screening mammograms based on local texture models', IEEE Transactions on Image Processing, vol. 18, no. 4, pp. 765-773.

[14] Frigas, A, Spyrou, G, Ligomenides, P, Diomidous, M & Mantas, J 2009, 'Investigating the Classification Robustness of a Computer Aided Diagnosis System Using Mammographic Images', Acta Informatica Medica, vol. 17, no. 2, pp. 64-66.

[15] Papadopoulos, A, Fotiadis, DI & Likas, A 2005, 'Characterization of clustered microcalcifications in digitized mammograms using neural networks and support vector machines', Artificial Intelligence in Medicine, vol. 34, no. 2, pp. 141-150.

[16] Ferrero, A, Salicone, S, Mencattini, A, Rabottino, G & Salmeri, M 2010, 'Uncertainty evaluation in a fuzzy classifier for microcalcifications in digital mammography', IEEE International conference on Instrumentation and Measurement Technology Conference (I2MTC), pp. 1250-1255.

[17] Elfarra, BK & Abuhaiba, IS 2012, 'Mammogram Computer Aided Diagnosis', International Journal of Signal Processing, Image Processing and Pattern, vol. 5, no.4, pp. 1-30.

[18] Umamaheswari, J & Radhamani, G 2011, 'A Hybrid Approach for Classification of DICOM Image', World of Computer Science and Information Technology Journal (WCSIT), vol. 1, no. 8, pp. 364-369.

[19] Singh, S, & Al-Mansoori, R. 2000, 'Identification of regions of interest in digital mammograms', Journal of Intelligent Systems, vol. 10, no. 2, pp. 183-217.

[20] Dubey, RB, Hanmandlu, M & Vasikarla, S 2011, 'Evaluation of Three Methods for MRI Brain Tumor Segmentation', IEEE Eighth International Conference on Information Technology and New Generations (ITNG 2011), pp. 494-499.

[21] Tzikopoulos, SD, Georgiou, HV, Mavroforakis, ME & Theodoridis, S. 2010, 'Shape-based tumor retrieval in mammograms using relevance-feedback techniques', Artificial Neural Networks–ICANN 2010, pp. 251-260.

[22] Garge, DM & Bapat, VN 2011, 'Balanced Multiwavelet Based Mammogram Image Processing', International journal of latest trends in network and communication, vol. 1 no. 1 pp 1-5.

[23] Quintanilla-Dominguez, J, Cortina-Januchs, MG, Ojeda-magaña, B, Jevtic, A, Vega-Corona, A & Andina, D 2010, 'Microcalcification detection applying artificial neural networks and mathematical morphology in digital mammograms', IEEE World Automation Congress (WAC), 2010, pp. 1-6.

[24] Wei, L, Yang, Y & Nishikawa, RM 2009, 'Microcalcification classification assisted by content-based image retrieval for breast cancer diagnosis', Pattern recognition, vol. 42, no. 6, pp. 1126-1132.