PHD PRIME
YOUR RESEARCH PARTNER
phdprimehelp@gmail.com
+91-97 91 62 64 69

Ph.D. Research Proposal

Doctoral Program in "Department Name"

Visual and Semantic Analytics Approach for Content based Medical Image Retrieval using Machine Learning and Similarity Matching

PHD PRIME
YOUR RESEARCH PARTNER

by

<Name of the Candidate>

<Reg. No of the Candidate>

<Supervisor Name>

<Date of Submission (DD MM 20YY>

I. INTRODUCTION / BACKGROUND

Medical imaging plays a vital role in current digital technology, which becomes the fundamental need in today's modern medicine. Its usage is highly increased in diverse of medical applications such as monitoring patient's body, disease diagnosis, treatment planning, and evaluating response for treatment [[1]. Content based Medical Image Retrieval (CBMIR) is recently emerging and used in many real-time medical image applications. Over the past few decades CBMIR has started research for radiologists and doctors [2].

Various types of image information is given in the database and it is acquired by several image capturing devices and machines such as Magnetic Resonance Imaging (MRI), Magnetic Resonance Spectroscopy (MRS), Positron Emission Tomography (PET), Computed Tomography Scanners (CT), Single Photon Emission Computer Topography Scanners (SPECT), Ultrasound Probes (US), Electrical Impedance Tomography (EIT) [3]. However, medical images are retrieved using low level and high level feature contents. Low level features represent visual contents and high level features represent semantic contents. Existing solutions are based on visual contents such as color, shape, texture, and other information. In order to effectively retrieve the medical images based on the image content, a specialized CBIR system is proposed [4]. Among several features, texture feature is essential for CBMIR and today it is widely supported in several medical applications (disease diagnosis) [4], [6].

For CBMIR, similarity between features is focused. Individual and local feature information helps to improve precision rate (PR) and retrieval rate (RR). Then, mean and standard deviation are focused to predict the exact values of PR and RR. However, texture feature information only does not sufficient to retrieve accurate results [5]. By new feature descriptors, LWP (Local Wavelet Pattern) [12], and CS-LBP [8], Domain Index [10], ELP [3], the number of CBMIR systems have been proposed. Furthermore, dictionary learning [11], and deep convolutional neural network [7] is proposed for CBMIR. Several distance functions are used for similarity computation between the query image and the large collection of image

database [9]. Such distance functions are follows: (1). Euclidean distance, (2). Manhattan distance, (3). Cosine similarity, (4). Canberra distance, (5). Minkowski distance and (6). Chi-square distance.

1.1 Research Outline & Scope

The main aim and scope in this research study is to retrieve the medical images according to user query image. In this research, two contents such as visual and semantic features based feature extraction and similarity matching is performed.

1.2 Research Objectives

The main research objective of this work is to develop a fast and accurate content-based medical image retrieval and recognition, which find the top-k medical images that are visually and semantically similar to the query image (target image). Other sub-objectives of this work can be follows:

- To extract visually similar features for enhancing the retrieval rate in CBMIR
- To use fast similarity function to reduce the retrieval time and improve the CBMIR system performance
- To extract and identify the relevant features for improving the accuracy in classification and retrieval performance of medical images.
- To develop the system must satisfies the user requirements and constraints

II. RESEARCH GAPS

2.1 Common Problem Statement

- *How to find and extract the optimum set of features from both small and large scale dataset?*

  By default, medical imaging dataset is very small in size where we cannot get the essential information of the specific image by extracting the most discriminative features set. With this limitation, the performance of the system is very limited and really poor to provide the accurate results.

- *How to fuse the several features extracted from the different datasets?*

  Fusion is a method to directly fuse the similar feature vectors into the single group, and it determines the proportional parameter that defines the different feature vectors.

2.2 Problem Definition

Medical sign detection is one of the important tasks currently in lung nodules (benign/malignant) classification. The major contributions of this paper are four-fold [1]: (1). In first step, deep learning algorithm is proposed for semantic features extraction, which efficiently represent the medical sign information, (2). In second step, high-dimensional image features are translated into compact binary codes using supervised hashing and principal component analysis (PCA), (3). In third step, similar images of lung nodules are retrieved using Adaptive Weighted Similarity Technique and finally (4) in fourth step, recognize nodules by retrieved results. The proposed approach is confirmed for two publicly available databases: LIDC-IDRI and LISS.

Problems

- KNN is the nearest neighbor algorithm proposed for nodule sign detection by computation of Euclidean Distance (ED). The ED metric does not suitable for finding similar image for nodule sign detection
- Image scaling (resize) is implemented using linear interpolation method, which is simple interpolation method usually suitable for small scale images. It does not smoothed edges of image. Query images are currently noise (salt and pepper), which degrade the retrieval performance. Semantic features are extracted using CNN is not efficient and effective

Proposed Solutions

- Semantic features are extracted using ROI based GRU is proposed, which accurately extract semantic features. Image resizing for 48×48 pixels is implemented using Cubic Interpolation method, which interpolation aids to keep smooth edges and also increase contract level

In [2] authors have proposed a new efficient CBMIR system based on convolutional neural networks (CNN) and hash coding. A Siamese network is presented in which contrastive loss function and weight sharing is employed. For feature extraction, CNN is used in each network branch and then applied Hashing technique and thus it reduces feature vector dimensionality. CNN based method is faster than conventional hashing methods and ancient deep learning methods.

Problems

- Hashing is a technique to find the similar images, which increases speed of hash code search, but binary hash codes are storage efficient in nature
- CNN is awesome to provide better performance in CBMIR, but it cause to serious issues such as Max Pooling Layers and Translation Invariance. In CNN, max pooling layer drops very significant information and it does not encode spatial relations between feature vectors and hence CNN is not exactly invariant for huge input data transformations.

Proposed Solutions

- Hybrid Wavelet Transform is applied over decomposed images, which reduces complexity in feature extraction.
- With the use of spatial transformer networks, we get the optimum set of features and minimize retrieval time

In [3], local neighborhood wavelet feature descriptor is proposed for CBMIR. Authors addressed high retrieval time due to high-length of feature vectors since huge numbers of features require too much amount of time for prediction, matching and retrieval. Triple half-band filter bank (THFB) is utilized to improve wavelet filters performance, which consists of three kernels. First level of decomposition (four sub-bands) of images is implemented using THFB. Then local neighborhood wavelet feature descriptor is applied on decomposed images.

Problems

- Local Neighborhood Wavelet Feature Descriptor is applied over four sub-bands which tend to still increase high feature vector length i.e. 1024 (1 sub-band is equal to 256 feature vectors and four sub-bands is equal to 1024). Despite of sign and magnitude computation for each feature vector, feature vector length will increases and feature extraction time and retrieval time is high

Proposed Solutions

- Hybrid Wavelet Transform is applied over decomposed images, which reduces complexity in feature extraction. With the use of this, we get the optimum set of features and minimize retrieval time

An integration of Tamura texture features and wavelet transform is applied [4] for medical image retrieval using Hausdorff distance. This Hausdorff distance metric defines the overall feature set similarity values. The main objective of this retrieval system is to retrieve top-k similar (accurate) images. Experiments conducted for two medical image databases: lung CT database and MRI database.

Problems

- Image preprocessing step is required since similarity measure Hausdorff does not reduce noise and abnormal points of medical images
- Importance of wavelet transform is not defined

Proposed Solutions

- Two preprocessing step is included in this work to improve the quality of image
- Hybrid wavelet decomposition and ROI based GRU is applied for visual and semantic features extraction

A new CBMIR is presented by fusion of context-sensitive similarity [5]. At the first step visual and semantic features are extracted and the similarities between the query image and image database are fused according to the pairwise similarities. Then weighted graph is constructed in which node refers to image and edges represent the pairwise similarity in the

given dataset. The pairwise similarity measure produce accurate CBMIR results for user and also it obtained high efficiency in computation.

Problems

- Medical image retrieval efficiency is less since searching for retrieval of top-k results require large amount of time. Clustering or classification of nodule is required to improve the efficiency of retrieval system

Proposed Solutions

- After visual and semantic features extraction, we cluster similar features into single group using GA-EM, which improve the retrieval efficiency in terms of average recognition rate and running time. Clustering using GA-EM also require O (1) for retrieval, but training we do not require much time. Thus our overall CBMIR system produces high performance in terms of precision and recall.

III. RESEARCH CONTRIBUTIONS

This work develops a CBMIR and Recognition system based on the visual and sematic analytics of contents of the given query image. Both are refers to the following.

1. Visual features (Color, Shape and Texture)
2. Semantic features (Contextual Meaning)

Steps followed to develop accurate and fast CBMIR is described in Section III. There are two phases involving in this work that is Testing and Training Phase. In offline phase, images in database are trained and then implemented preprocessing steps where we perform image scaling using cubic interpolation method, reduce noise (salt and pepper) using *adaptive median filtering*. Noise in image is reduced in *Zig Zag way*. Then we implement Histogram Equalization to reduce the redundant pixels on each image. This process not only increase contrast level and also it increase the speed of computation. After preprocessing, feature extraction process is initiated in which multiple features are extracted using *Hybrid Wavelet Transform (Hilbert Transform and Radon Transform).* These are combined to extract the wavelet features. Semantic features are

extracted using ROI based GRU. Table.1. shows the list of features. Then we implement feature clustering using Genetic Algorithm based Expectation Maximization (GA-EM) where redundant features are removed and only optimum set of features are grouped. This GA chooses best by running the global search operation.

List of features are follows,

Texture

- Correlation
- Contrast
- Homogeneity
- Sum of square variance
- Spectral, Spatial
- Entropy

Shape

- Area
- Irregularity
- Roundness
- Perimeter
- Circularity

Color

- Intensity
- Mean
- Standard Variance
- Kurtosis
- Skewness
- Median

Geometric

- Eccentricity
- Compactness
- Roughness
- Local Area Integral Invariant
- Radial Distance Signatures

Semantic

- Sphericity
- Malignancy
- Margin
- Texture
- Subtlety
- Spiculation
- Radiographic Solidity
- Calcification

PHD PRIME
YOUR RESEARCH PARTNER

In testing phase, user will give the query image. Before processing in the CBMIR, relevance feedback is invoked for user. Clustered image database environment has provide high results. For the query image our proposed system implements the process of preprocessing, feature extraction, feature selection and then similarity is computed using five distance metrics, manhattan distance, euclidean distance, canberra distance, chi-square distance, and d_1 distance. Indexing is performed to retrieve most similar top-k results. We find the most similar image from the retrieved results for nodule signs detection.

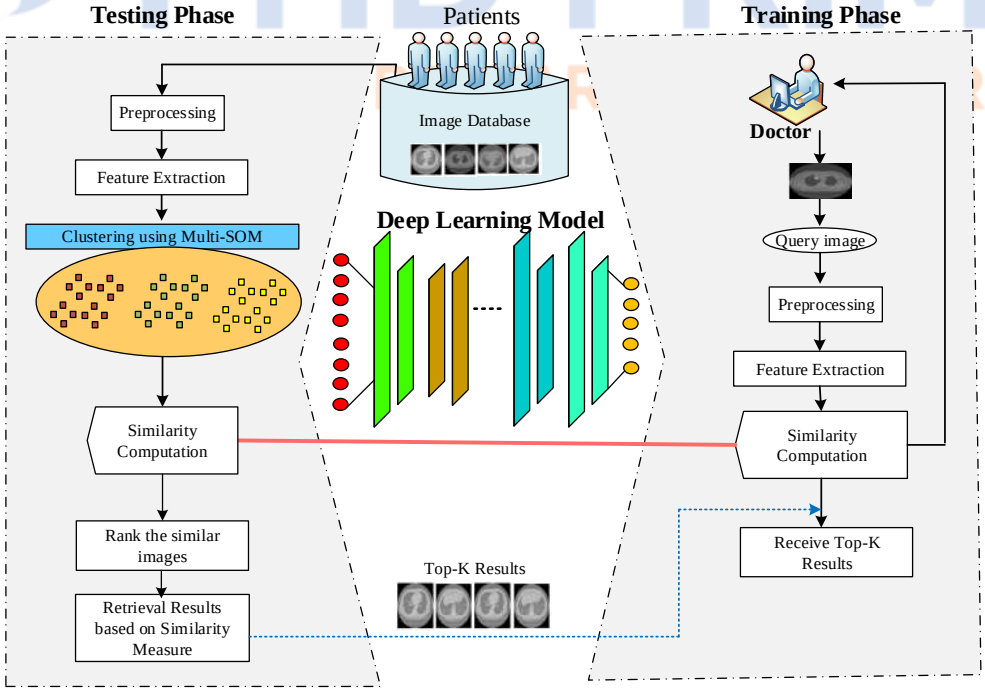
Performance Evaluation

Finally the proposed work has obtained high performance in terms of all performance metrics for LISS (Lung) and EXACT09 (Chest CT) Databases.

- Precision

- Recall
- F-Score
- Recognition Rate
- K-Positive Results
- Error Rate
- Running Time (ms)
- Precision-Recall Curve

SYSTEM ARCHITECTURE



IV. RESEARCH NOVELTIES

- It is a very new method that accomplishes effective operations for individual query images and the training set.
- In order to maximize the performance of precision, recall, f-score, retrieval accuracy, we proposed a hybrid feature extractor, which extracts the visual and semantic features effectively. The visual features are extracted by DWT, and DCT, and the semantic features are extracted by bounding-box based CNN.
- To minimize the feature vectors length, we select the optimum set of features using MINε
- We proposed an extended version of KNN, which is best in lung nodules sign detection, and outperforms than the traditional KNN algorithm.

V. PREVIOUS WORKS & LIMITATIONS

Paper 1

Title – A New Classifier Fusion Method based on Historical and On-Line Classification Reliability for Recognizing Common CT Imaging Signs of Lung Diseases

Concept – Authors of this paper is proposed a weighted sum method (multi-classifier fusion) for lung nodules recognition. The confusion matric is constructed, which shows the historical decision making reliability. There are two components are combined to find the weight of confidence value for classifier.

Limitations

- Classifier fusion process is ineffective since the range of classification is not uniform and hence normalization of confidence value is important

Paper 2

Title – Content based Medical Image Retrieval using Dictionary Learning

Concept – In this paper, K-SVD is proposed, which uses clustering method for dictionary learning for similarity analysis on group of large medical image collections. The

performance of K-SVD proves that it is better than traditional SVD algorithm. A user query image is matched using OMP (Orthogonal Matching Unit) algorithm. Supervised information is used for image retrieval.

Limitations

- OMP and K-SVD is are time consuming process

Paper 3

Title – Local Wavelet Pattern: A New Feature Descriptor for Image Retrieval in Medical CT Databases

Concept – In this paper LWP (local wavelet pattern) is proposed which characterize the query image for retrieval of similar images. The proposed LWP feature descriptor is outperforms for CT image retrieval and it is better than the LBP method. The proposed LWP addressed the issues of LBP where information determines from centre pixel information and it is matched with the LWP decomposed values.

Limitations

- LWP outperforms than the LBP, but good feature descriptor is required for medical image retrieval.

Paper 4

Title – Employing Domain Indexed to Efficiently Query Medical Data from Multiple repositories

Concept – In this paper, multiple repositories are used. Along with this domain index is constructed for various categories. For content based queries searching in domain index, KNN (k-nearest neighbor) is considered. Domain index is newly constructed and it is category of index structures. Experiment results are considered for public database (mammograms).

Limitations

- Error rate in similarity computation is large and it takes large computation time. KNN is simple technique that does not support for large database similarity computation

Paper 5

Title – Cluster based-image descriptors and fractional hybrid optimization for medical image retrieval

Concept – In this paper, two new mechanisms are proposed such as cluster based image descriptor and hybrid fractional optimization algorithm such as brain storm optimization and ant lion algorithm. Set of features such as Correlogram, Wavelet Moments and Mean, Skew, Variance, Kurtoiss, and LGP are stored in the featured database. This hybrid technique is used to generate optimal weight scores.

Limitations

- It is very time consuming operation and hence it does not suitable early diagnosis of medical research works.

PHD PRIME
YOUR RESEARCH PARTNER

Paper 6

Title – An Approach for Multimodal Medical Image Retrieval using Latent Dirichlet Allocation

Concept – This paper addressed the problem of solving insufficient feature for CBMIR. Previous works in the research of CBMIR are based on either visual or texture. However insufficient feature set leads to poor retrieval results. Hence authors of this paper have proposed combined feature sets (Visual and Textural) for CBMIR. Latent Dirichlet Allocation is proposed for visual features encoding.

Limitations

- High Semantic Gaps occurred due to the only combination of texture and visual features

Paper 7

Title – Content-Based Image Retrieval System for Pulmonary Nodules Using Optimal Feature Sets and Class Membership-Based Retrieval

Concept – Authors of this paper have designed a new content based image retrieval system for lung pulmonary nodules. There are five steps are employed in this study include volume of interest (VOI) selection, nodule segmentation, feature extraction, feature selection and class membership based image retrieval. It is designed using two techniques such as class membership based retrieval and optimal feature sets.

Limitations

- Class membership based CBMIR increases calculation and insufficient feature set is considered

Paper 8

Title – Automated and Effective Content-based Mammogram Retrieval using Wavelet based CS-LBP feature and Self-Organizing Map

Concept – In this paper, CBMIR is proposed for mammograms images on the basis of two approaches including SOM and wavelet features based CS-LBP. The segmentation of selective threshold in seeded region growing is proposed. Wavelet features are extracted in the segmented part using CS-LBP. Finally, SOM is used for cluster formation. The proposed mammorgram CBMIR is fast, effective and automatic. To improve the system performance three preprocessing steps are included: automatic labeling-scratches suppression, automatic removal of pectoral muscle and image quality improvement.

Limitations

- There are two limitations in SOM: classes/groups do not necessarily match informational categories of interest
- SOM is limited control of clusters (number of classes and identities)

Paper 9

Title – Medical Image Retrieval using Deep Convolutional Neural Network

Concept – This paper solved the major research issue in CBMIR i.e. semantic gap analysis between query image and the image database. A deep learning model (convolutional neural network) is proposed for classification of images. The proposed scheme is tested on intermodal database which consists of nearly twenty-four classes for five medical image modalities.

Limitations

- The proposed system does not extract more number of features for accurate retrieval

Paper 10

Title – A Simple Texture Feature for Retrieval of Medical Images

Concept – In this paper, a simple CBMIR scheme is proposed which primarily considered texture features for retrieval. Firstly, two filtering techniques are employed such as Schmid and Gabor. It gives extensive local texture information for medical images. Then filtered images are partitioned into patches which are non-overlapping. At lastly, bag-of-words model is presented to acquire image represented as features.

Limitations

- Low ARR and APR due to simple method for CBMIR

Paper 11

Title – Medical Image Retrieval using Self-organizing Map on Texture Features

Concept – In this paper, authors have presented SOM for CBMIR. In training stage, local texture image features are extracted for large image database. Then SOM is applied on texture features to retrieve the set of medical images. This paper only considers texture features for retrieval and it also extracts texture features in 3×3 neighborhood information.

Limitations

- Pixel wise computation for retrieval using SOM is time consuming process and also texture features alone does not provide the accurate retrieval results.

Paper 12

Title – Content-based Medical Image Retrieval by Spatial Matching of Visual Words

Concept – In this paper authors have proposed an unsupervised CBMIR scheme using visual words spatial matching. This paper majorly has two contributions including location features and skip similarity index. Here spatial similarity of visual words is matched based on the Skip Similarity Index (SSI). The proposed SSI can effectively measure the sequential location similarity between each visual word by skipping the unmatched location features.

Limitations

- Bag of visual words model is a vector based model which counts occurrence of local image features and created dictionary according to the extracted features, but one of the notorious drawback of bag of visual words model ignores the spatial relationship among features. Very poor for visual words positioned within image

PHD PRIME
YOUR RESEARCH PARTNER

Paper 13

Title – Content based Medical Image Retrieval using Topic and Location Model

Concept – In this paper, topic and location model is proposed for content based medical image retrieval. The information of topic is created using Guided Latent Dirichlet Allocation (GuideLDA) model whereas the location model is used to incorporate the spatial information of visual words. In order to find the order of images for retrieval, a new $wPrecision$ (Weighted Precision) is proposed

Limitations

- Static and fixed K i.e. the number of topics is fixed in Guided LDA. In addition, LDA topics are not information and hence it affects the quality of CBMIR system in terms of ARR and APR

- Weighted precision is used to find the top-k results for the given query image. One major problem with this weighted precision is that the infrequent feature vectors/classes are produced the less weight precision value. Infrequent classes of the weight precision may hide and also leads to poor performance. But infrequent classes are also important to retrieve the relevant images.

Paper 14

Title – Content-Based Image Retrieval System for Pulmonary Nodules: Assisting Radiologists in Self-Learning and Diagnosis of Lung Cancer

Concept – In this paper self-learning scheme is considered in this paper for lung cancer diagnosis and content based image retrieval for lung CT images (pulmonary nodules). 3D shape features considered in this work for effective retrieval. For feature selection, minimal redundancy-maximal relevance (MRMR) is used. Finally three similarity measures are considered such as Manhattan, Chebyshev and Euclidean.

Limitations

☑ These three distance metrics (Manhattan, Chebyshev and Euclidean) are poor in terms of finding similar images

Paper 15

Title – Rapid Retrieval of Lung Nodule CT Images Based on Hashing and Pruning Methods

Concept – In this paper authors experiment the proposed approach using LIDC database. This database consists of CT images. A pruning algorithm is presented such as pruning based decision rule is considered to enhance the retrieval precision. Working flow of the proposed algorithm is follows: firstly training dataset is loaded. Then spectral clusters are formed in which similar images are grouped and stored in database. Finally, KSH (Supervised Hashing with Kernel) is proposed to convert the binary code for all clusters (images).

Limitations

- Hashing technique cause serious threats in terms of storage since it required to store images as well as the hash codes into database.

BIBLIOGRAPHY

Juan-Juan Zhao, Ling Pan, Peng-Fei Zhao, Xiao-Xian Tang, "Medical Sign Recognition of Lung Nodules based on Image Retrieval with Semantic Features and Supervised Hashing", Journal of Computer Science and Technology, Vol. 32, Issue.3, PP, 457-469, 2017

Cai, Y., Li, Y., Qiu, C., Ma, J., & Gao, X. (2019). Medical Image Retrieval Based on Convolutional Neural Network and Supervised Hashing. IEEE Access, 7, 51877–51885.

Shinde, A., Rahulkar, A., & Patil, C. (2019). Content based medical image retrieval based on new efficient local neighborhood wavelet feature descriptor. Biomedical Engineering Letters, PP. 1-8

Sun Xiaoming, Zhang Ning, Wu Haibin, Yu Xiaoyang, Wu Xue, Yu shang, "Medical Image Retrieval Approach by Texture Features Fusion based on Hausdorff Distance", Mathematical Problems in Engineering, PP. 1-12, 2018

Ling Ma, Xiabi Liu, Yan Gao, Yanfeng Zhao, Xinming Zhao, Chunwu Zhou, "A New Method of Content based Medical Image Retrieval and Its Applications to CT Imaging Sign Retrieval", Journal of Biomedical Informatics, Vol. 66, PP. 148-158, 2017

Ling Ma, Xiabi Liu, Li Song, Chunwu Zhou, Xinming Zhao, Yanfeng Zhao, "A New Classifier Fusion Method based on Historical and On-Line Classification Reliability for Recognizing Common CT Imaging Signs of Lung Diseases", Computerized Medical Imaging and Graphics. Vol. 40, PP. 39-48, 2015

M. Srinivas, R. Ramu naidu, C.S. Sastry, C. Krishna Mohan, "Content based Medical Image Retrieval using Dictionary Learning", Neurocomputing, Vol. 168, PP. 880-895, 2015

Shiv Ram Dubey, Rajat Kumar Singh, "Local Wavelet Pattern: A New Feature Descriptor for Image Retrieval in Medical CT Databases", IEEE Transactions on Image Processing, Vol. 24, Issue.12, PP. 5892-5903, 2015

Paulo H. Oliveira, Lucas C. Scabora, Mirela T. Cazzolato, Willian D. Oliveira, Rafael S. Paixao, Agma J.M. Traina, Caetano Traina-Jr, "Employing Domain Indexed to Efficiently Query Medical Data from Multiple Repositories", IEEE Journal of Biomedical and Health Informatics, Vol. 99, PP. 1-10, 2018

Yadav, P. (2018). Cluster based-image descriptors and fractional hybrid optimization for medical image retrieval. Cluster Computing, 1-11

Vikram, M., Anantharaman, A., BS, S., & S., S. K. (2019). An Approach for Multimodal Medical Image Retrieval using Latent Dirichlet Allocation. Proceedings of the ACM India Joint International Conference on Data Science and Management of Data - CoDS-COMAD '19.

Mehre, S. A., Dhara, A. K., Garg, M., Kalra, N., Khandelwal, N., & Mukhopadhyay, S. (2018). Content-Based Image Retrieval System for Pulmonary Nodules Using Optimal Feature Sets and Class Membership-Based Retrieval. Journal of Digital Imaging.

Vibhav Prakash Singh, Rajeev Srivastava, "Automated and Effective Content-based Mammogram Retrieval using Wavelet based CS-LBP feature and Self-Organizing Map", Biocybernetics and Biomedical Engineering, Vol. 38, Issue.1, PP. 90-105, 2018

Adnan Qayyum, Syed Muhammed Anwar, Muhammed Awais, Muhammed Majid, "Medical Image Retrieval using Deep Convolutional Neural Network", Neurocomputing, Vol. 266, PP. 8-20, 2017

Rushi Lan, Si Zhong, Zhenbing Liu, Zhuo Shi, Xiaonan Luo, "A Simple Texture Feature for Retrieval of Medical Images", Multimedia Tools and Applications, Vol. 77, PP. 10853-10866, 2018

Shashwati Mishra, Mrutyunjaya Panda, "Medical Image Retrieval using Self-Organizing on Texture Features", Future Computing and Informatics Journal, Vol.3, Issue.2, PP. 359-370, 2018

P. Shamna, V.K. Govindan, K.A. Abdual Nazeer, "Content-based Medical Image Retrieval by Spatial Matching of Visual Words", Journal of King Saud University- Computer and Information Sciences, Open Access, PP. 1-14, 2018

P. Shamna, V.K. Govindan, K.A. Abdul Nazeer, "Content based Medical Image Retrieval using Topic and Location Model", Journal of Biomedical Informatics, Vol. 91, Issue.103112, PP. 1-42, 2019

Dhara, A. K., Mukhopadhyay, S., Dutta, A., Garg, M., & Khandelwal, N. (2017). Content-Based Image Retrieval System for Pulmonary Nodules: Assisting Radiologists in Self-Learning and Diagnosis of Lung Cancer. Journal of Digital Imaging, 30(1), 63–77.

Pan, L., Qiang, Y., Yuan, J., & Wu, L. (2016). Rapid Retrieval of Lung Nodule CT Images Based on Hashing and Pruning Methods. BioMed Research International, 2016, 1–10.

PHD PRIME
YOUR RESEARCH PARTNER