Lecture Notes in Networks and Systems 613

Sandeep Kumar · Harish Sharma ·
K. Balachandran · Joong Hoon Kim ·
Jagdish Chand Bansal *Editors*

Third Congress on Intelligent Systems

Proceedings of CIS 2022, Volume 2

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Preface

This book contains outstanding research papers as the proceedings of the 3rd Congress on Intelligent Systems (CIS 2022), held on September 05–06, 2022, at CHRIST (Deemed to be University), Bangalore, India, under the technical sponsorship of the Soft Computing Research Society, India. The conference is conceived as a platform for disseminating and exchanging ideas, concepts, and results of researchers from academia and industry to develop a comprehensive understanding of the challenges of the advancements of intelligence in computational viewpoints. This book will help in strengthening congenial networking between academia and industry. We have tried our best to enrich the quality of the CIS 2022 through the stringent and careful peer-review process. This book presents novel contributions to Intelligent Systems and serves as reference material for advanced research.

We have tried our best to enrich the quality of the CIS 2022 through a stringent and careful peer-review process. CIS 2022 received many technical contributed articles from distinguished participants from home and abroad. CIS 2022 received 729 research submissions from 45 different countries, viz., Algeria, Australia, Bangladesh, Belgium, Brazil, Bulgaria, Colombia, Cote d'Ivoire, Czechia, Egypt, Ethiopia, Fiji, Finland, Germany, Greece, India, Indonesia, Iran, Iraq, Ireland, Italy, Japan, Kenya, Latvia, Malaysia, Mexico, Morocco, Nigeria, Oman, Peru, Philippines, Poland, Romania, Russia, Saudi Arabia, Serbia, Slovakia, South Africa, Spain, Turkmenistan, Ukraine, United Kingdom, United States, Uzbekistan, and Vietnam. After a very stringent peer-reviewing process, only 120 high-quality papers were finally accepted for presentation and the final proceedings.

This book presents second volume of 60 research papers data science and applications and serves as reference material for advanced research.

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Patch Extraction and Classifier for Abnormality Classification in Mammography Imaging

Parita Oza, Paawan Sharma, and Samir Patel

Abstract Breast cancer is a fatal disease that affects millions of women worldwide. The number of cases of breast cancer has risen over time. Although it is difficult to prevent this disease, the survival rate can be improved with early detection and proper treatment planning of the disease. Thanks to breakthroughs in deep learning, the progress of computer-assisted diagnosis (CAD) of breast cancer has seen a lot of improvement. Deep neural networks have advanced to the point where their diagnostic capabilities are approaching those of a human specialist. Mammograms are crucial radiological images used to detect breast cancer at its early stage. Mammogram image scaling at the input layer is required for training deep convolutional neural networks (DCNNs) directly on high-resolution images. This could result in the loss of crucial information for discovering medical abnormalities. Instead of developing an image classifier, the idea is to create a patch classifier. The technique for extracting abnormal patches from mammography images is proposed in this research. Patches are extracted from a benchmark and publicly available MIAS dataset. These patches are then used to train deep learning classifiers such as VGG-16, ResNet-50, and EfficientNet-B7. With the patches already included in the CBIS-DDSM dataset, we contrast the results of the MIAS patches. EfficientNet-B7 on CBIS-DDSM patches produced good results (92% accuracy) when compared to other classifiers such as VGG-16 and ResNet-50. We also discovered that ResNet-50 is demonstrated to be quite robust on both datasets.

Keywords Mammogram · Deep learning · Patch extraction · Classification

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1 Background

Breast cancer is one of the most common abnormal neoplasms in the female population. Mammography is a referral examination for breast cancer screening [1]. Furthermore, it has been established that the breast cancer survival rate is highly influenced by the stage at which the disease is detected [2]. Computer-aided diagnostic (CAD) systems are being developed for automated breast cancer diagnosis. This approach improves finding accuracy and the capacity to recognize irregularities such as breast mass, calcification, focal distortion, asymmetries. Only professional doctors make final decisions; thus, CAD systems can operate as a second reader designed to aid a radiologist.

DCNNs are extensively utilized for cancer detection, classification, and segmentation in medical imaging. Unfortunately, training a network from scratch can take days or weeks and requires a significant amount of computing power [3]. In addition, to avoid overfitting the training dataset, the training procedure for supervised deep CNNs typically necessitates a high number of annotated samples. The most common method for dealing with this issue is transfer learning (TL). The goal is to fine-tune a model that has been pre-trained [4]. In most cases, TL-based convolutional neural networks (CNNs) are utilized to categorize the entire image. Instead, in patch-based classification, we categorize individual patches of an image belonging to a given class before categorizing the whole image based on the patches' categorization. For training DCNNs directly on high-resolution images, image scaling at the input layer is necessary. This might lead to the loss of vital information to detection medical anomalies. Patch-based classification seeks to answer the following question: "What are the prominent traits of a specific patch that indicate that it belongs to one of two classes?". Furthermore, image scarcity is a prevalent problem in medical imaging studies. As a result, making several patches from a single image might significantly expand the training set.

We present a method for extracting patches from mammograms in this paper. For patch extraction, we used the MIAS [5] dataset. We created a patch-based classifier that uses DCNNs to classify breast mammography images into benign and malignant categories. We employed transfer learning with pre-trained models like VGG-16 [6], ResNet-50 [7], and EfficientNet-B7 [8] to classify patches. We utilized CBIS-DDSM [9] mammography patches as a comparison.

The rest of the paper is organized as follows: Sect. 2 presents the literature of the domain. Then, the proposed methodology is showcased in Sect. 3. We discussed the results in Sect. 4. We finally end with the conclusion in Sect. 5.

2 Related Work in the Domain

The fields of AI such as machine learning and deep learning have made potential advancements in biotechnology and medical research domain [10]. Despite the fact that several authors have proposed using traditional machine learning and computer vision techniques to classify breast abnormalities [11], due to the scarcity of publicly available datasets, the use of deep learning approaches has been limited in the field of breast imaging [12–14]. Due to privacy and regulatory concerns, having significant and correctly annotated picture data is the most frequent problem in the medical research arena [15–17]. In the majority of situations, this issue also results in an overfitting scenario. The majority of the time, convolutional neural networks (CNNs) based on transfer learning are used to classify the entire image. To fit the model input size, we must resize the picture when utilizing the transfer learning approach for the whole mammography. The loss of certain significant picture information during image scaling is undesirable for medical image analysis. This issue may be resolved, and the model performance can be enhanced, by extracting accurate ROI patches similar to model's input size from whole mammograms and utilizing them for training. While including additional patch samples in the training set, the accuracy of transfer learning technique may also be improved.

A patch-based method is proposed by authors of [2] to detect and segment microcalcifications from mammograms. This model comprises two convolutional neural network-based blocks: the detector and the segmentation. The model might be particularly beneficial in the screening situation, where the high number of exams may cause the reader's attention to be diverted to support diagnosis or restrict the differential diagnosis. Another study [1] proposes a patch-based CNN approach for breast mass detection in full-field digital mammograms (FFDM). Authors look into using transfer learning to adapt to a specific area. Transfer learning is an effective way of transferring knowledge from one visual domain to another. The majority of current research is now based on this concept. Issues like ignorance of semantic characteristics, analysis limitations to the present patch of pictures, missing patches in low-contrast mammography images, and segmentation ambiguity are addressed in [18]. An ensemble learning strategy is presented in the work employing machine learning techniques like random forest and boosting to improve the classification performance of breast mass systems while reducing variance and generalization error. To categorize breast cancer images, [19] proposed a CNN model which can do feature extraction, feature reduction, and classification. The model can classify breast cancer images into three categories: malignant, normal, and benign. A recent survey [20] provided the study of publicly available mammographic datasets and dataset-based quantitative comparison of the most modern approaches. Authors of [21] presented an end-to-end model to identify and classify masses inside the whole mammographic image. They expanded on that work by categorizing local image patches using a pre-trained model on a labeled dataset that offers ROI data. ResNet-50 and VGG-16 are used as a pre-trained models in this work. For mammogram classification, a CNN-based patch classifier is proposed in [22]. A curriculum learning technique was applied in the study to attain high levels of accuracy in classifying mammograms. Authors of [23] examined several classification strategies for mammogram classification, divided into four categories based on function, probability, rule, and similarity. Furthermore, the research concentrated on various issues relating to mammography datasets and classification algorithms. Patch-based classifiers are also used for other imaging modalities such as breast histopathology imaging. For the automatic categorization of histological breast image, authors of [24] suggested a patch-based classifier utilizing convolutional neural network (CNN). One patch in one decision and all patches in one decision are two operating modes used in the proposed classification system. Additionally, on the concealed test dataset of histopathology images, authors achieved an accuracy of 87%.

3 Methodology

3.1 Dataset

MIAS: MIAS [5] is an ancient and benchmark mammography dataset with 322 images divided into three categories: standard, benign, and malignant. The images in the datasets are all 1024 × 1024 pixels in size. The (x, y) image coordinates of the anomaly's center and the estimated radius (in pixels) of a circle encompassing the abnormality are supplied as ground truth.

CBIS-DDSM: CBIS-DDSM [9] is a standardized and upgraded version of DDSM mammography [25]. The dataset contains roughly 10,000 images of various abnormalities, including normal, benign, and malignant conditions. The dataset is separated into training and testing sets to compare and contrast different methodologies. Due to a lack of memory during training, we picked 6700 images for our work.

3.2 Patch Extraction

We adopted a patch-based technique to analyze the input mammograms, anticipating that local information would be adequate to categorize such tiny and limited areas. Furthermore, a patch-based method allowed us to significantly expand the training set and do a proper data augmentation simply. The dataset we utilized is supplied with information on the abnormality's approximate radius and center. The region of interest was initially extracted using these parameters, and several patches containing benign or malignant information were then extracted. First, we extracted squared patches with $N \times N$ dimension and took their annotated labels from the corresponding mammograms. Next, we slide the patch mask over the mammogram with uniform step size and took only those region of interest (ROI) with a certain number of suspicious pixels (see Fig. 1). Then, we used a sliding window algorithm to create multiple patches from the extracted region of interest. We are able to feed models with varied inputs since every patch that is ultimately chosen has a unique visual detail. Algorithm 1 presents the entire process for extracting patches from mammograms.

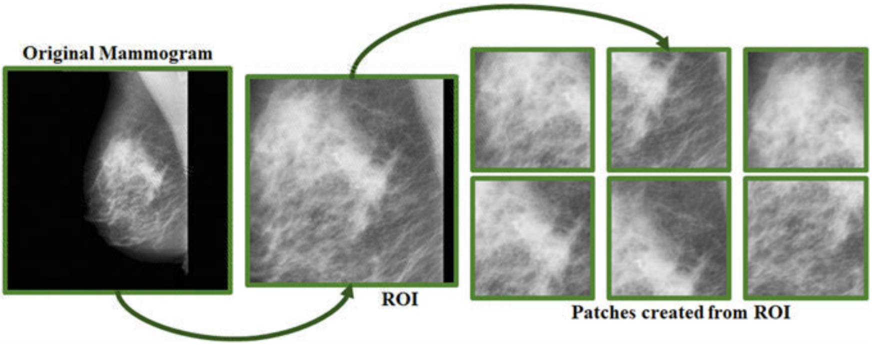

Fig. 1 Mammogram with ROI and extracted patches

Algorithm 1 Patch extraction from mammograms

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Require: Mammogram Images, Annotation file
Ensure: Extracted ROI from abnormal mammograms
  Data: MIAS mammogram datasets
  Initialization: Patch size, width, height, $(X, Y)$ coordinates of abnormalities, $R$ (Approximate center of coordinates), cropped ROI
  for each image detail in annotation file do Do
      Read images from Benign and Malignant Folders
      Read width and height of image
      Find new $(x, y)$ coordinates pairs to generate cropped ROI
      $x1 = X + R -$ Patch Size
      if $x1 > 0$ then $x1 = x1$ else $x1 = 0$
      $y1 = Y + R -$ Patch Size
      if $y1 > 0$ then $y1 = y1$ else $y1 = 0$
      $x2 = X - R +$ Patch Size
      if $x2 \leq$ width then $x2 = x2$ else $x2 =$ width
      $y2 = Y - R +$ Patch Size
      if $y2 \leq$ height then $y2 = y2$ else $y2 =$ height
      ROI = im.crop($x1, y1, x2, y2$)
  end for
  Use sliding window algorithm to create multiple patches from the extracted region of interests
```

3.3 *Transfer Learning (TL)*

We adopt transfer learning to develop a patch classifier. We used three pre-trained DCNN models; VGG-16, ResNet-50, and EfficientNet-B7. As shown in Fig. 2, we employed a recent implementation of deep neural networks that features TL to start a new model with specified modifications utilizing parameters from a pre-trained model for a specific purpose. We began by building a foundation model and populating it with weights that had already been trained. The underlying model's layers are then locked. The output of one (or multiple) layer from the base model is then used to build a new model on top of it. Finally, the new model is trained using MIAS and CBIS-DDSM patches, and the results are compared either.

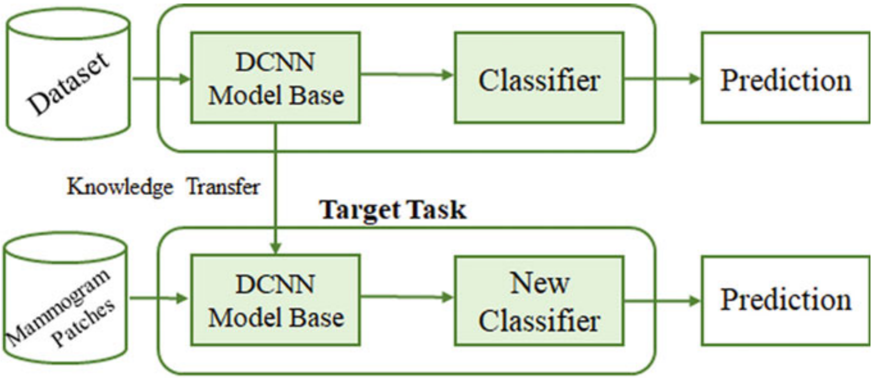

Fig. 2 Patch classifier using transfer learning

4 Result Analysis and Discussion

We split the dataset into train and test random splits using the ratio of 70:30. The experiments were run for 100 epochs with a batch size of 128. We considered accuracy and loss as performance parameters for our models. Figures 3 and 4 depict the training and validation performance of all the models, respectively. The graphs show that, in comparison to CBIS patches, none of the three models could perform well with MIAS patches. We also found that the performance of EfficientNet-B7 on CBIS-DDSM

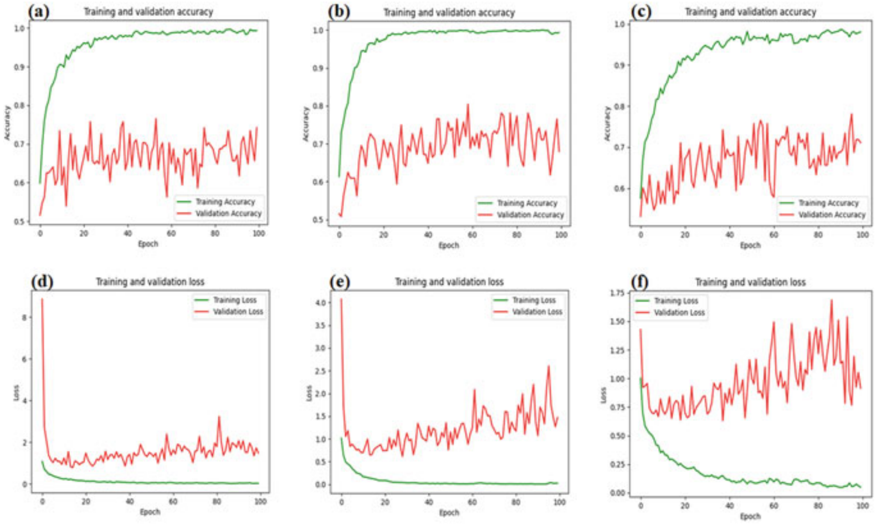

Fig. 3 Model performance on MIAS patches. **a**, **d** Accuracy and loss of VGG-16. **b**, **e** Accuracy and loss of ResNet-50. **c**, **f** Accuracy and loss of EfficientNet-B7

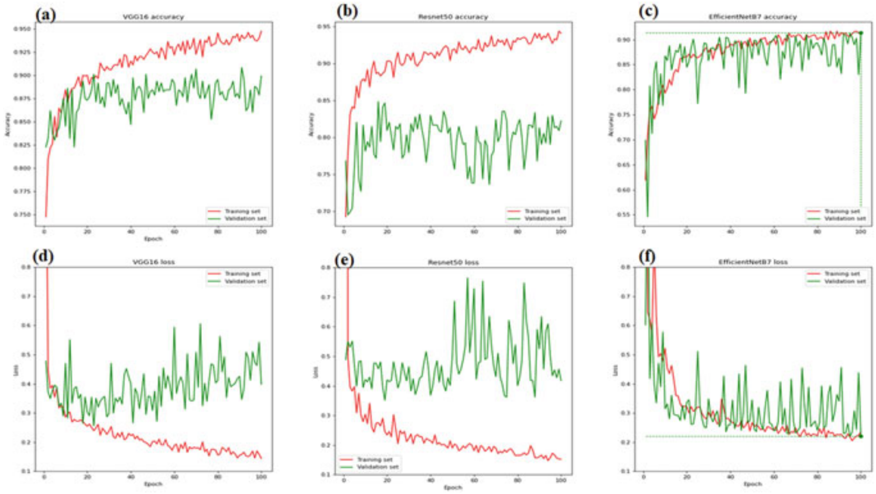

Fig. 4 Model performance on CBIS-DDSM patches. **a**, **d** Accuracy and loss of VGG-16. **b**, **e** Accuracy and loss of ResNet-50. **c**, **f** Accuracy and loss of EfficientNet-B7

patches is quite good compared to other models used in this study. The models were built up to have the best accuracy and loss. To keep track of the validation loss, early stopping was used. As a result, EfficientNet-B7 has the best accuracy and loss at almost the final epoch on CBIS-DDSM patches (see Fig. 4c, f). Still, the model is suffering from a very classic problem of oscillation, which can be handled by controlling the value of the learning rate. We solely gave further performance characteristics for all the models on CBIS-DDSM and MIAS patches (see Tables 1 and 2). When compared to MIAS patches, the comparison reveals that all models performed better on CBIS-DDSM patches.

Table 1 Performance measures of various models on CBIS-DDSM patches

	Sensitivity	Specificity	Precision	Recall	Test accuracy	Test loss
VGG-16	0.86	0.89	0.88	0.86	0.88	0.44
ResNet-50	0.69	0.93	0.90	0.69	0.82	0.44
EfficientNet-B7	0.90	0.92	0.91	0.90	0.91	0.38

Table 2 Performance measures of various models on MIAS patches

	Sensitivity	Specificity	Precision	Recall	Test accuracy	Test loss
VGG-16	0.82	0.79	0.79	0.82	0.84	0.52
ResNet-50	0.61	0.84	0.77	0.61	0.76	0.69
EfficientNet-B7	0.84	0.77	0.78	0.84	0.83	0.50