IJEEC

International Journal of Electrical Engineering and Computing
Vol. 7, No. 1 (2023)

Original research paper
UDC 004.65:618.19-073
DOI 10.7251/IJEEC2301034M

Web-Based System for Remote Mammogram Processing

Marina Milošević , Dejan Vujičić, Đorđe Damnjanović, Marija Vujović

Department of Computer and Software Engineering, University of Kragujevac, Faculty of Technical Sciences, Čačak, Serbia

E-mail address: marina.milosevic@ftn.kg.ac.rs, dejan.vujicic@ftn.kg.ac.rs, djordje.damnjanovic@ftn.kg.ac.rs, marija.vujovic@ftn.kg.ac.rs

Abstract— **This paper presents a web-based system for remote processing of mammographic images (mammograms) using Matlab Web Service. The Matlab Web Service is a toolbox for accessing Matlab applications from the internet. We created an image processing system that combines the computational and graphical abilities of Matlab with remote access through the internet. Our system for mammogram processing is a Matlab application stored on a local workstation. By using a web browser users can upload their data (mammogram and parameters necessary for image processing) and view the results obtained after processing (notification about the breast cancer existence). The presented computer system for mammogram processing includes three modules: image preprocessing, feature extraction, and classification. The preprocessing phase consists of the image de-noising, region of interest extraction and image contrast enhancement. The second phase is based on feature extraction techniques for detecting abnormalities in digital mammograms. A total of 20 texture features based on gray-level co-occurrence matrices are used to evaluate the effectiveness of textural information possessed by mass regions. To investigate the ability of the feature set in differentiating abnormal from normal tissue, we employed three different classifiers: Support vector machine classifier, Naive Bayes classifier and K-Nearest Neighbor classifier. The efficiency of classification is provided using a cross-validation technique. The main characteristics of the proposed web-based diagnostic system are that users can use application written in Matlab without installing Matlab software, and they do not need to have any knowledge about programming in Matlab to run application.**

Keywords- breast cancer; image processing; mammography; Matlab; web service;

I. INTRODUCTION

Breast cancer is the most common malignancy in women. It is often characterized by a lack of early symptoms, which results in late detection of the disease. Breast cancer screening with mammography has been proven very effective in preventing breast cancer death. Nonetheless, due to the very complex anatomy of the breast and small differences in the density of various breast tissues, the analysis of mammographic images is significantly hindered. Thus, the software support for the mammographic detection of tumors (Computer-Aided Diagnosis - CAD) has become very important.

There are many commercial and non-commercial CAD systems based on image processing to assist in diagnosis and therapy. However, most of these systems are available only as local applications that run on high-performance workstations. In that case, the processing power of the application is not available to other workstations. Using web-based tools, users can access the CAD system functionalities wherever the internet is available, without taking into account operating system and processing power limitations.

There are many web-based medical software tools for accessing DICOM (Digital Image Communication in Medicine) images through the web [1]-[3]. Presented web applications are usually picture archiving and communication systems (PACS) or Medical Informatics Systems (MIS). Various studies have focused on medical image processing web-based tools available for research and diagnosis purposes. Mahmoudi with the group of authors in [4] presented a web-based, interactive, extendable, 2D and 3D medical image processing and visualization application. Medical image preprocessing, registration, and segmentation methods are implemented. They used a four-layered software design consisting of an algorithm layer, web-user-interface layer, server communication layer and wrapper layer. Jiménez with the group of authors in [5] presented a web platform for computing and analyzing the 3D fractal dimension of magnetic resonance images (MRIs) of the brain. The presented web platform is successfully applied in a study where an analysis and characterization of groups of 3D MR images are performed for three neurodegenerative diseases: Multiple Sclerosis, Intrauterine Growth Restriction and Alzheimer's disease. Paper [6] presents a method for integration of image processing and display into a web-based image distribution server to enable users to access, view and manipulate PACS DICOM images using Web browsers. A Web-based platform that allows registered users to upload, visualize, process and comment on medical images is developed by Millan and Yunda [7]. The system contains a social network module, a video conference and webinar module and an image visualization, annotation and

This paper is a revised and expanded version of the paper presented at the XXII International Symposium INFOTEH-JAHORINA 2023 processing module. Cai with the group of authors developed a system that provides efficient and flexible digital medical image data access and manipulation over the Internet [8]. The presented system has the potential to integrate and associate data from multiple vendors' systems and multiple imaging modalities at a regional level. The authors of [9] reviewed advantages of cloud computing applications in medical image processing. They also presented tools and methods for medical image processing using the cloud. Yuan with the group of authors in [10] proposed a web-based platform Rayplus for medical image processing. The system allows access to applications written in C ++ through the internet. Jacinto with the group of authors in [11] proposed a platform for the visualization and processing of medical images. They offered 2D/3D images obtained using three forms of processing including volume slicing, segmentation and surface meshing, which were completed on the server side. The authors of [12] presented a web-based system for retinal image analysis. The system contains special processing modules for retinal diseases.

A computer system for tumor diagnosis in mammograms described in this paper includes three modules: image preprocessing, feature extraction, and classification. The preprocessing phase consists of the image de-noising, region of interest (ROI) extraction and image contrast enhancement. In the second phase, we analyzed the texture measures based on gray-level co-occurrence matrices (GLCM) for the classification of preprocessed mammograms. Support vector machine (SVM) classifier, Naive Bayes classifier, and K-Nearest Neighbor (k-NN) classifier were employed to estimate the classification performances of the extracted textural features in the final stage of mammogram processing.

The significance of the realized CAD system increases if it is available to a larger number of users at any time. Matlab web service application enables access to CAD system for the detection of breast cancer in mammograms from remote locations at every moment.

CAD system for breast cancer detection is available as a Matlab application, stored on a local workstation. User can upload the mammographic image and enter the necessary data that is sent to a server for processing. After executing the Matlab application on the server, user receives a notification of the classifier's estimates about the breast cancer existence.

The rest of this paper is structured as follows. Section 2 describes modules of the CAD system for breast cancer detection: image preprocessing, feature extraction, and classification, as well as classification performance. Section 3 gives a general description of the Matlab web service. The user interface of the Matlab web service application is described in Section 4. Conclusions are given in Section 5. The last section contains a literature review.

II. CAD SYSTEM FOR DETECTION OF TUMOR IN DIGITIZED MAMMOGRAMS

A. Image preprocessing

Preprocessing of mammograms aims to provide better conditions for the extraction of desired objects. The preprocessing phase of the presented CAD system consists of three segments: image de-noising, region of interest extraction, and enhancement of image contrast.

Image noise removal is an important part of many CAD systems based on image processing. A 2D adaptive median filter [13] is used to remove noise from mammograms. Each pixel in the image compares with its surrounding neighbor pixels. A pixel that is different from the majority of its neighbors is considered as noise and replaced by the neighborhood median value. The size of the neighborhood is adjustable.

The region of interest extraction in mammogram processing involves background and pectoral muscle removal. It is a necessary step of preprocessing phase, especially in the case of scanned analog mammograms that often contain undesirable objects. ROI extraction procedure provides extraction of relevant characteristics of mammograms. We extracted the region of interest using the algorithm presented in [14]. The mentioned algorithm includes skin line detection, detection of MLO (mediolateral oblique) view type, extraction of the breast region and pectoral muscle removal procedure.

Detection of MLO view type

The skin line detection is necessary to detect the type of MLO view, whether it is a Left sided (LMLO) or Right sided (RMLO). The MLO projection is one of the two standard projections in screening mammography, that usually reflects most of the breast tissue, with emphasis on the upper-outer quadrant, which statistically is the most common place for pathological changes. An algorithm for skin line detection contains the following notations:

I - original mammographic image;

B1 and B2 - binary images obtained from the original image, with different thresholds; Threshold values were selected experimentally;

I(i,j), B1(i,j) and B2(i,j) – pixel value in the *i*th row and *j*th column of image I, B1 and B2, respectively.

Algorithm for skin line detection

```
If I(i,j)>5
    Then, B1(i,j)=1
    Else, B1(i,j)=0
If I(i,j)>15
    Then, B2(i,j)=1
    Else, B2(i,j)=0
Skin line image = B1-B2.
```

An algorithm for the RMLO test checks whether it is a RMLO projection. This algorithm is applied to the Skin line image.

Algorithm for RMLO test

```
Start with the first row, scan from left to right side
If the pixel is black
    Then, move to the next pixel
    Else, replace the current pixel with white and move to the next pixel while the current column is not the last
Repeat this procedure for each row, the result is image I1
R=|I-I1|
```

The algorithm for the LMLO test is the same as the algorithm for the RMLO test, with the difference that scanning is performed from right to left side. L=|I-I2| is an image obtained using an Algorithm for the LMLO test. If *mR* is the mean value of *I1* and *mL* the mean value of *I2*, then the view type is determined as follows:

If *mL>mR*
View is Left
Else, the View is Right.

When the type of MLO view is known, the background removal procedure and pectoral muscle removal procedure can be applied automatically.

Background removal procedure

The background removal procedure for the Right MLO view of the mammogram and the Left MLO view is very similar. This procedure starts with an image contrast enhancement based on a simple logarithmic operation. A logarithmic operation as

$$\gamma(\xi,\psi)=\lambda o\gamma[7+\phi(\xi,\psi)] \qquad (1)$$

is applied to the original image *f(x, y)*, and *g(x, y)* is the transformed image with significantly enhanced contrast of the regions near the breast boundary. Those regions are characterized by low density and poor definitions of details. The value 7 was chosen experimentally, and *log* presented the logarithm with base 10.

In the continuation of the background removal procedure, a binarization procedure is applied to the transformed image *g(x, y)*. A binary image (an image composed of black and white pixels) is obtained by replacing a pixel value greater than 128 and less than 255 with a value "1", and a pixel value outside of this range with a value "0".

To remove a breast background, it is necessary to create and apply a mask. A mask is created by applying an algorithm for mask formation to the binary image. The algorithm for the mask formation for RMLO mammograms is explained below.

Algorithm for the mask formation

Start with the first row, scan from left to right side
If the pixel is black
Then, move to the next pixel
Else, move to the next pixel while the pixel is white
If the pixel is black again
Then, replace the current pixel with black and move to the next pixel while the current column is not the last
Repeat this procedure for each row

The breast region without background is obtained by multiplying the binary mask and the original mammogram.

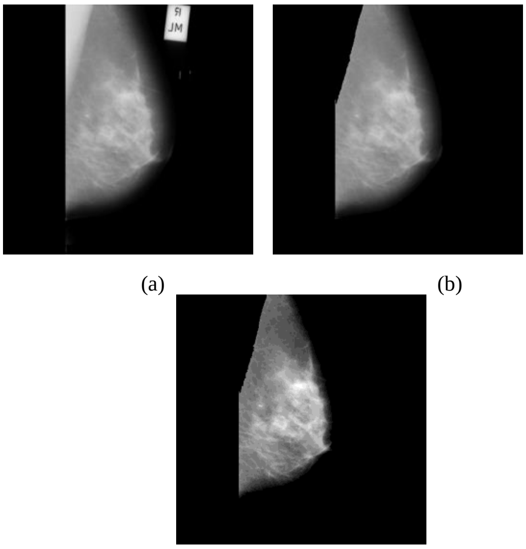
Pectoral muscle removal

The density of pectoral muscle tissue is usually greater than the density of the rest of the breast tissue. If a threshold operation is applied to the mammogram with removed background, the result will be an image with extracted pectoral muscle and some central part of the breast. The threshold value is defined based on the intensity of the pectoral muscle. Pixel values greater than the threshold are retained, while values less than the threshold are set on value "0".

Algorithm for the pectoral muscle removal

Start with the first row and *n*th column, *n* is the column of the first non-zero pixel in the current row. Scan from left to right side.
If the pixel is non-zero
Then, replace the current pixel with zero and move to the next pixel. Repeat this procedure until the current pixel is not black.
Else, start from the next row and *n*th column and repeat the previous step.
Stop the procedure when all rows are exhausted. The result is the image with the extracted central part of the breast.
Subtract the central part of the breast from the image with extracted pectoral muscle and the central part of the breast. The result is isolated pectoral muscle.
Subtract the isolated pectoral muscle from the mammogram with the removed background. The result is a mammogram without background and pectoral muscle - ROI.

The pectoral muscle removal procedure for the LMLO type of mammogram is the same as here explained procedure, with the difference that scanning is performed from right to left side. Original mammograms from the Mini-MIAS database [15] after de-noising and output of the ROI extraction procedure are depicted in Fig.1 (a) and Fig.1 (b), respectively.



(a) (b) (c)

Figure 1. Mammogram preprocessing: (a) Mammogram mdb266 from mini-MIAS database after de-noising; (b) Detected region of interest; (c) Contrast enhancement operation result.

In the third part of the preprocessing stage, an adjustment of pixel intensity values is performed. Values between low and high intensities of the input image are mapped to values between low and high intensities of the output image. Values below the low intensity of the input image are mapped to the low intensity of the output image and those above the high intensity of the input image are mapped to the high intensity of the output image. The result of the contrast enhancement operation is shown in Fig.1 (c).

B. Features extraction and classification

Architectural distortion in the breast tissues arises as a consequence of the presence of tumor masses. As a result, textural information of mammograms that contain masses and mammograms without masses are significantly different. In the present study, the classification of ROIs as normal or abnormal is based on the GLCM texture measures.

The GLCM is a method based on calculation how often two pixels with specific values and in a specified spatial relationship occur in an image. The spatial relationship of the pixels is defined by orientation θ and distance d. Each element in the GLCM is the sum of the number of times that the pixel with one specific value occurred in the specified spatial relationship to a pixel with another specific value in the input image. GLCM can be calculated in four different angles θ (0°, 45°, 90°, 135°) and for different values of distance d. The size of the GLCM is determined by the number of gray levels in the image.

In this study, 4 matrices corresponding to 4 directions θ = 0°, 45°, 90°, 135° and pixel distance d = 1 were computed for each ROI. A large number of co-occurrences derived from ROI is achieved using distance d = 1. Four values corresponding to the four matrices were obtained for each feature. Texture feature is represented by an average value.

We used a total of 20 GLCM features: Angular Second Moment (Energy), Contrast, Correlation, Variance, Inverse Difference Moment (Homogeneity), Sum Average, Sum Variance, Sum Entropy, Entropy, Difference Variance, Difference Entropy, Information Measure of Correlation 1 and Information Measure of Correlation 2 proposed by Haralick [16], Autocorrelation, Dissimilarity, Cluster Shade, Cluster Prominence and Maximum Probability proposed by Soh [17], and features Inverse Difference Normalized and Inverse Difference Moment Normalized proposed by Clausi [18].

The classification process consists of two phases: the training and the testing phase. The classifier is trained using the known data. Then, a trained classifier performed classification of the unknown data. Support Vector Machine [19], K-Nearest Neighbor classifier [20] and Naive Bayes classifier with diagonal covariance matrix estimate [21] were employed to classify the normal and abnormal cases.

SVM is a kernel method that transforms the input data space to optimize the fit to the optimal hyper-plane. This method is based on the principle of structural risk minimization, which aims at minimizing the bound on the error made by the learning machine on data unseen during training, rather than minimizing the mean square error over the data set. As a result, an SVM tends to perform well when applied to data outside the training set.

K-Nearest Neighbor is a simple yet robust classifier where an object is assigned to the class to which the majority of the nearest neighbors belong. All objects are considered to be present in the multidimensional feature space and are represented by position vectors where these vectors are obtained by calculating the distance between the object and its neighbors. The multidimensional space is divided into regions utilizing the locations and labels of the training data. An object in this space will be labeled with the class that has the majority of votes among the k-Nearest neighbors.

A Naive Bayes classifier with diagonal covariance matrix estimate is a simple probabilistic classifier based on Bayes' theorem with strong independence assumptions. He assumes that the presence of a particular feature of a class is unrelated to the presence of any other features. The small amount of training data required to estimate the parameters necessary for classification is the main advantage of this classifier.

C. Classification performance

Mammogram classification results presented in [14] confirm the effectiveness of the applied method for two-class mammogram classification. A five-fold cross-validation method, confusion matrix, and receiver operating characteristic analysis were performed to evaluate the classification performance. Using five-fold cross-validation the data set is divided at random into a set of K = 5 distinct sets. Training is then performed on K – 1 sets and the remaining set is tested. This is then repeated for all of the possible K training and test sets. The classification results are the average of all K results. The data set used in this study consists of 300 randomly selected mammograms from the local database, 150 abnormal and 150 normal patterns. Masses of varying size and location are present in abnormal mammograms.

The performance in recognition is evaluated by three factors: Accuracy (AC), Sensitivity (SE) and Specificity (SP) of detection. Classification accuracy is dependent on the number of samples correctly classified, and it is defined as AC=(TP+TN)/(TP+FP+TN+FN). Sensitivity is a proportion of positive cases that are well detected by the test. It is defined as SE=TP/(TP+FN). Specificity is a proportion of negative cases that are well detected by the test. It is defined as SP=TN/(TN+FP). TP is the number of true positives, FP is the number of false positives, TN is the number of true negatives, and FN is the number of false negatives. The classification performances are given in Table I.

TABLE I. CLASSIFICATION PERFORMANCE ACHIEVED USING THE SVM CLASSIFIER, K-NN CLASSIFIER, AND NAIVE BAYES CLASSIFIER IN THE TEST WITH THE MAMMOGRAMS FROM THE LOCAL DATABASE

Performance Measures	**Classification schemes**		
	SVM	***k-NN***	***Naive Bayes***
TP	121	84	114
FP	20	71	32
FN	29	66	36
TN	130	79	118
Accuracy	83.7%	54.3%	77.3%
Sensitivity	80.7%	56%	76%
Specificity	86.7%	52.7%	78.7%

An accuracy ratio of 83.7% indicates that a SVM classifier can be trained to effectively classify mammograms from the local database. Results in Table I also indicate that there is no significant difference in classification accuracy between the SVM classifier (83.7%) and the Naive Bayes classifier (77.3%). Classification results obtained using the SVM classifier and Naive Bayes classifier are much better than the classification results obtained using the k-NN classifier, with an accuracy ratio of 83.7% and 77.3% according to 54.3%.

III. MATLAB WEB SERVICE

Matlab Web Service (MWS) is a toolbox for the MATLAB software package that allows users to run Matlab applications remotely over the internet using standard web technologies. MWS is not part of the standard Matlab installation. It is installed subsequently as a separate toolbox. In this paper, the Modelit Matlab Webservice Toolbox [22] was used.

Modelit Matlab Webservice Toolbox provides utilities for [23]:

- Implementation of web services;
- Creation of XML (eXtensible Markup Language) output;
- Encapsulation of Matlab figures in HTML (HyperText Markup Language);
- Conversion of JSON (JavaScript Object Notation) strings to Matlab;
- Serialization and deserialization of encoded ASCII (American Standard Code for Information Interchange);
- Parallelization of tasks by making asynchronous calls to web services.

In the simplest MWS configuration, the user enters the input values using the web browser and then runs the Matlab applications. Web browser runs on a client computer while Matlab application runs on another (server) machine. After executing the Matlab application, the server computer sends the output of the application to the user-designed HTML (HyperText Markup Language) document in the web browser. In this way, users can access Matlab applications over the internet, from any remote location in an easy manner at the lowest possible cost and without software installation.

The MWS application is a combination of Matlab executable files (m-files), HTML files, and graphics. Knowledge of Matlab programming and HTML programming are the only requirements to design a Matlab application that runs on a Matlab Web Service. The realization of the MWS application can be divided into the following steps:

- Creating a user interface in the form of HTML documents for the collection of input data from the user and display of results obtained after the execution of the Matlab application,
- Writing the Matlab application as an executable m-file that:
  - Receives the data entered by the client into an input HTML document;
  - Processes the entered data and generates the required output data (numerical values, text, images, etc.);
  - Forwards the output data to the output HTML document.
- Specifying the name of the main executable m-file and associated configuration data in the configuration file.

Fig. 2 shows the interaction between a client application (client) and Matlab over the internet. The client application (usually a web browser) opens the input HTML document (web page) to upload the input parameters, both numeric and graphical (images). After entering the required input values in the input HTML document, the client request is forwarded to the *matweb* component via the HTTP service. The *matweb* component is a TCP/IP (Transmission Control Protocol/Internet Protocol) client that communicates with the Matlab server. It uses the Common Gateway Interface (CGI) to extract data from the input HTML document and transfer them to the Matlab server.

The Matlab server is a multithreaded TCP/IP server that manages communication between the client application and Matlab. It is configured to listen the requests on the TCP/IP ports that are defined in the *matlabserver.conf* file. The Matlab server loads the requested m-file into Matlab. After execution has been completed the Matlab server gives the received output data to the *matweb* component. After that, the *matweb* sends them to the client in an output HTML document through HTTP service. During the execution of m-file, images or any other data files can be created and sent to the output HTML document. The web browser will download them from the HTTP service.

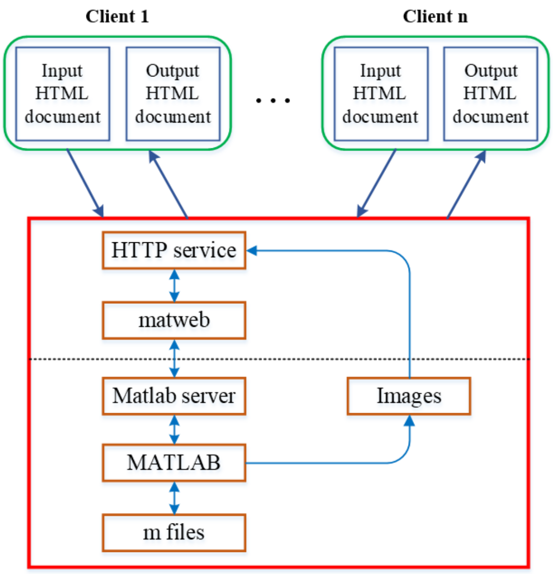


Figure 2. Communication between clients and Matlab over the internet.

In order to make web service to work with Matlab, the installation of Apache Tomcat is necessary [24]. Before starting Tomcat, in its installations directory, the corresponding JAR (Java ARchive) file and Matlab executable code is necessary, to make a connection between Matlab and Tomcat.

An XML file has to be made to establish a connection. This XML file includes the servlet name, port, and URL (Uniform Resource Locator) address to the server.

From the Matlab command line, the *createMatlabServer()* function has to be called, with port number passed as an argument. After that, the server has to be started and it will automatically execute *HTMLCallback()* function, if there isn't any other argument set.

IV. Results

The user interface of the MWS application consists of two basic HTML documents: one for uploading mammograms and entering values of the input parameters and the other for displaying results obtained after executing the Matlab code. Every internet user can use the MWS application on their computer with the appropriate web browser.

The user interface for uploading mammograms and entering values of the input parameters is shown in Fig. 3. Button “Browse” gives users the ability to choose a mammogram to be processed. After a successful mammogram upload and its display that confirms that the mammogram is correctly uploaded, it is necessary to specify values of the four input parameters: contrast-correction value, binary image enhancement value, the threshold for pectoral muscle removal, and length of the pectoral muscle.

The contrast-correction value is the value from the logarithmic operation applied in the Background removal procedure**.** In most cases, the value of this parameter is 7. The parameter binary image enhancement value can be selected from a drop-down menu. This value represents the radius of a disk-shaped structuring element, which is an essential part of the morphological dilation operation. The dilation operation uses a structuring element for expanding the objects contained in the input image, by adding pixels on object boundaries. None, 5, 10, 15, 20, 25, and 30 are possible values to choose from drop-down menu. The value of this parameter used to extract the ROI from mammogram mdb266 (Fig. 1) is 10. The third parameter - threshold can have a value from a range of values [0 - 255]. If the tissue is denser, the intensity of the pixels is higher, so it is necessary to enter a higher threshold value. To extract the ROI from the mammogram mdb266, a threshold value of 150 was entered in the form shown in Fig. 3. The length of the pectoral muscle represents the number of rows of the image, expressed in percentages, where the pectoral muscle is located. It is not necessary to process all rows of the image in the Pectoral muscle removal procedure. For example, if the pectoral muscle stretches on 50% of the image rows, then a value of 0.5 should be entered for this parameter. For mammogram mdb266, the value of this parameter is 0.4.

The user can enter different values of the input parameters until he finds the optimum values that provide a satisfactory result. By clicking the “Submit” button, the uploaded image and the entered values are sent to the application for processing. The “Reset” button allows the user to clear all entered values, including the selected mammogram.

After processing the input data, a new web page is opened showing the detected region of interest - a mammogram with removed background and pectoral muscle, and a notification about estimations of all three classifiers (Fig. 4). Each classifier estimates whether the mammogram is positive (there's a sign of cancer) or negative (there's no sign of cancer). The set of input values (7, 10, 170, 0.19) was used for processing of mammogram mdb013 shown in Fig. 4.

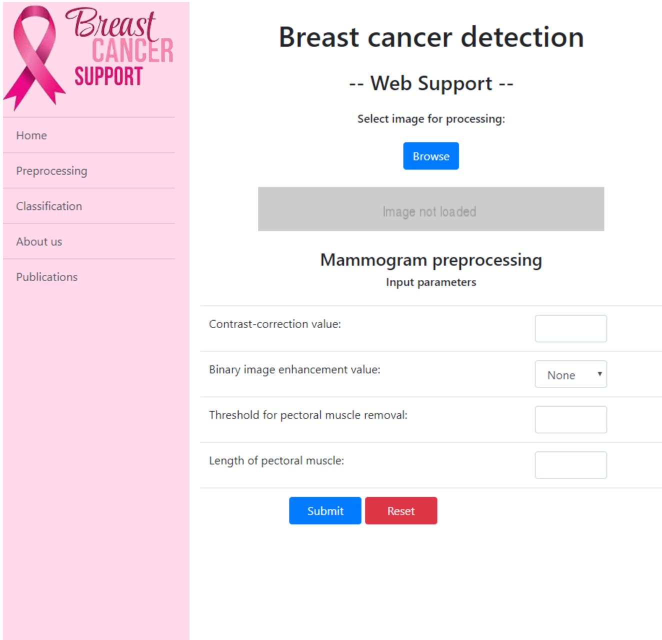


Figure 3. Web page for uploading mammograms and entering values of input parameters.

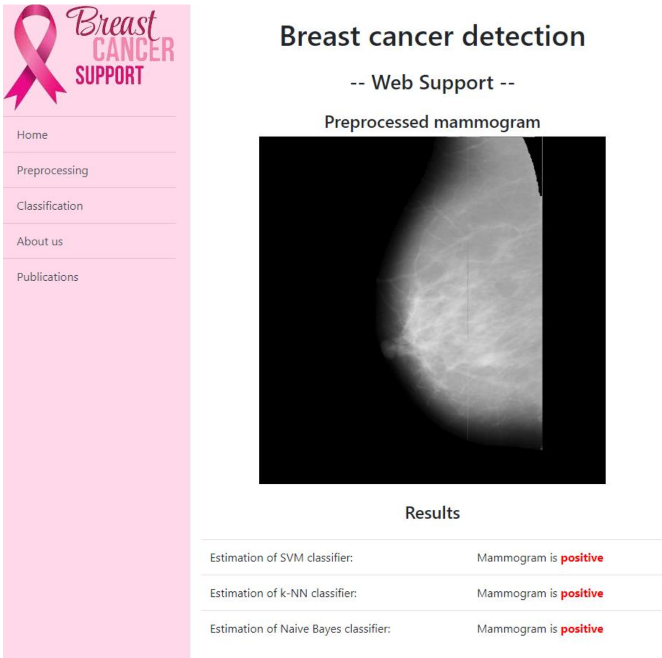


Figure 4. Web page for displaying mammogram processing results.

On the left side of the HTML documents shown in Fig. 3 and Fig. 4 are links that provide information for easier use of the application. This information is especially useful when the user first encounters an application. A description of the mammogram preprocessing procedure is provided on the web page referenced by the “Preprocessing” link. Information about image de-noising, region of interest extraction, and enhancement of image contrast is displayed on this web page. The method for mammogram ROI detection, composed of several steps, is described in detail. To set optimal values of the input parameters, users must read this informative text. A link “Classification” leads the users to information about texture feature extraction and classification of patterns. Basic information about the authors of the application is given on the link "About us". The authors of the presented application are authors of several published scientific papers whose topic is the mammogram classification. A list of mentioned scientific papers is provided on the link "Publications". Papers [25], [26] and [27] are part of this list.

V. CONCLUSION

The paper describes a mammogram processing system that is available through the internet using Matlab Web Services. The user interface consists of web pages for data entry and display of results. Therefore, in addition to a web browser, users do not need additional software to use this web-based application.

Users of the MWS application for breast cancer detection can upload their own mammogram and enter different values of the input parameters until they find the optimum values that provide a properly determined region of interest. After processing the input data, users get a notification about estimations of three different classifiers. The notification contains information on whether the ROI extracted from their mammogram is positive or negative.

The most important advantage of MWS is that users can use applications written in Matlab without installing Matlab software, whose license price is quite high. Besides, users don't need to have any special knowledge about programming in Matlab to run applications. To execute the MWS application, it is enough to have a suitable web browser and be familiar with the purpose of the Matlab application, to set the correct values of the input parameters. The system can be used on almost every main web browsers available today. We have tested the system on Mozilla Firefox, Google Chrome, Microsoft Edge, Opera, Vivaldi, and Safari web browsers.

MWS applications are available through the standard HTTP protocol. This allows users to connect with Matlab through any application that implements this protocol, such as Java applets.

The advantages of the proposed CAD system for breast cancer detection in mammographic images are the good classification results and very short processing time (less than 10 seconds in our testing cases, from image upload to obtaining results). The accuracy of the detection algorithm is good but not satisfactory. Therefore, it is not possible to rely on their diagnosis. In other words, the result of a detection algorithm should be used only as help in deciding, confirming the diagnosis, or to remark on the oversight.

In addition to numerous advantages, the presented MWS application has some disadvantages. One of the disadvantages is the fixed structure of the Matlab application. In some cases, the ability to change the application structure would be useful.

Future work will focus on the further improvement of classification performance by reducing the number of input texture features and using the other classification methods, such as neural networks. In addition, the focus will be on the discrimination between benign and malignant masses. Also, while the current system is served on local computers and is not publicly offered, the idea is to publish the system online. Of course, this step has to be done carefully, and after many tests of the system's stability.

ACKNOWLEDGMENT

This study was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia, and these results are parts of Grant No. 451-03-47/2023-01/200132 with the University of Kragujevac - Faculty of Technical Sciences Čačak.

REFERENCES

[1] D. Klimes, M. Kubasek, R. Smid and L. Dusek, "Internet-based system for anti-tumor chemotherapy evaluation," Computer Methods and Programs in Biomedicine, vol. 93, no. 3, pp. 292–296, 2009.

[2] D. N. Kennedy et al., "WebParc: a tool for analysis of the topography and volume of stroke from MRI," Medical & Biological Engineering & Computing, vol. 48, no. 3, pp. 215–228, 2010.

[3] H. Shen et al., "MIAPS: a web-based system for remotely accessing and presenting medical images," Computer Methods and Programs in Biomedicine, vol. 113, no. 1, pp. 266– 283, 2014.

[4] S. E. Mahmoudi et al., "Web-based interactive 2D/3D medical image processing and visualization software," Computer Methods and Programs in Biomedicine, vol. 98, no. 2, pp. 172-182, 2010.

[5] J. Jiménez et al., "A Web platform for the interactive visualization and analysis of the 3D fractal dimension of MRI data," Journal of Biomedical Informatics, vol. 51, pp. 176-190, 2014.

[6] J. Zhang, J. Sun and J. N. Stahl, "PACS and Web-based image distribution and display," Computerized Medical Imaging and Graphics, vol. 27, no. 2–3, pp. 197-206, 2003.

[7] J. Millan and L. Yunda, "An Open-Access Web-based Medical Image Atlas for Collaborative Medical Image Sharing, Processing, Web Semantic Searching and Analysis with Uses in Medical Training, Research and Second Opinion of Cases," Nova, vol.12, no.22, pp. 143-150, 2014.

[8] W. Cai, D. Feng and R. Fulton, "Web-based digital medical images," IEEE Computer Graphics and Applications, vol. 21, no. 1, pp. 44 - 47, 2001.

[9] A. Mirarab, N. G. Fard and M. Shamsi, "A cloud solution for medical image processing," International Journal of Engineering Research and Applications, vol. 4, no. 7, pp. 74-82, 2014.

[10] R. Yuan, M. Luo, Z. Sun, S. Shi, P. Xiao and Q. Xie, "RayPlus: a Web-Based Platform for Medical Image Processing," Journal of Digital Imaging, vol. 30, no. 2, pp. 197–203, 2017.

[11] H. Jacinto, R. Kechichian, M. Desvignes, R. Prost, S. Valette: A web interface for 3D visualization and interactive segmentation of medical images. Proceedings of the 17th International Conference on 3D Web Technology, ACM, 2012, pp. 51–58.

[12] M. Ortega, N. Barreira, J. Novo, M. G. Penedo, A. Pose-Reino, F. GomezUlla: Sirius: a web-based system for retinal image analysis, International Journal of Medical Informatics, Vol. 79, No. 10, 2010, pp. 722–732.

[13] H. Hwang and R. A. Haddad, "Adaptive median filters: New algorithms and results," IEEE Transactions on Image Processing, vol. 4, no. 4, pp. 499-502, 1995.

[14] M. Milosevic, D. Jankovic and A. Peulic, "Comparative Analysis of Breast Cancer Detection in Mammograms and Thermograms," Biomedical Engineering/ Biomedizinische Technik, vol. 60, no. 1, pp. 49-56, 2015, DOI: 10.1515/bmt-2014-0047.

[15] J. Suckling et al., "The mammographic images analysis society digital mammogram database," Exerpta Medica, vol. 1069, pp. 375–378, 1994.

[16] R. M. Haralick, K. Shanmugam and I. Dinstein, "Textural features for image classification," IEEE Transactions on Systems, Man, and Cybernetics, vol. 3, no. 6, pp. 610–621, 1973.

[17] L. K. Soh and C. Tsatsoulis, "Texture analysis of SAR sea ice imagery using gray level co-occurrence matrices," IEEE Transactions on geoscience and remote sensing, vol. 37, no. 2, pp. 780–795, 1999.

[18] D. A. Clausi, "An analysis of co-occurrence texture statistics as a function of grey level quantization," Canadian Journal of Remote Sensing, vol. 28, no. 1, pp. 45–62, 2002.

[19] B. E. Boser, I. M. Guyon and V. N. Vapnik, "A training algorithm for optimal margin classifiers," Proceedings of the Fifth Annual ACM Workshop on Computational Learning Theory, pp. 144–152, 1992.

[20] N. S. Altman, "An introduction to kernel and nearest-neighbor nonparametric regression," The American Statistician, vol. 46, no. 3, pp. 175–185, 1992, DOI: 10.1080/00031305.1992.10475879.

[21] I. Rish, "An Empirical Study of the Naive Bayes Classifier," Proceedings of the IJCAI-2001 Workshop on Empirical Methods in Artificial Intelligence, vol. 3, no. 22, pp. 41-46, 2001.

[22] Modelit Webserver Toolbox for Matlab, available at: https://www.modelit.nl/index.php/webserver-toolbox-for-matlab

[23] N. J. Van der Zijpp, K. J. Hoogland, User Guide for the Modelit Matlab Webservice Toolbox, 2016.

[24] Apache Tomcat, available at: http://tomcat.apache.org/ (accessed on: October 2018)

[25] M. Radovic, M. Milosevic, S. Ninkovic, N. Filipovic, A. Peulic, "Parameter optimization of a computer-aided diagnosis system for detection of masses on digitized mammograms," Technology and Health Care, vol. 23, no. 6, pp. 757-774, 2015, DOI: 10.3233/THC-151034.

[26] M. Radovic, M. Djokovic, A. Peulic, N. Filipovic, "Application of Data Mining Algorithms for Detection of Masses on Digitalized Mammograms," Proceedings of the 5th International Conference on Information Society and Technology (ICIST 2015), Kopaonik, Serbia, March 8-11, pp. 13-18, 2015.

[27] M. Radović, M. Đoković, A. Peulić, N. Filipović, "Application of data mining algorithms for mammogram classification," Proceedings of the 13th International IEEE Conference on Bioinformatics and Bioengineering (BIBE), Chania, November 10-13, pp. 1-4, 2013.

Marina M. Milošević received her B.Sc. degree in Computer science from the Faculty of Technical Sciences Čačak, University of Kragujevac, Serbia, in 2010 and Ph.D. degree in Computer science from the Faculty of Electronic Engineering, University of Niš, Serbia, in 2016. She is currently an assistant professor at the Department of Computer and Software Engineering, Faculty of Technical Sciences Čačak. Her research interests include digital signal processing, image processing, biomedical engineering, and medical informatics.

Dejan S. Vujičić received his B.Sc. and M.Sc. in Computer Science at the University of Kragujevac, Faculty of Technical Sciences in 2011 and 2012, respectively. He also received M.Sc. in Astronomy in 2016, at the Faculty of Mathematics, University of Belgrade. He is currently a PhD student in the field of Computer Science, at the Faculty of Technical Sciences in Čačak, where he is employed as a teaching assistant since 2014. His research interests include computer architecture, parallel computing, wireless sensor networks, neural networks, and applications of computer science in astronomy.

Đorđe M. Damnjanović received his B.Sc. degree in Computer science in 2010 and M.Sc. degree in Computer engineering in 2011, both from the Faculty of Technical Sciences Čačak. Finished Ph.D. thesis at the Faculty of Electronic Engineering, University of Niš, Serbia, in 2022. Currently, he is an assistant professor at the Department of Computer and Software Engineering, Faculty of Technical Sciences Čačak. His research interests include digital signal processing, image processing, remote control, and human-computer interaction.

Marija S. Vujović received her B.Sc. degree in Computer science from the Faculty of Technical Sciences Čačak, University of Kragujevac, Serbia, in 2021. She is currently a student of the master studies in the field of Computer Science, at the Faculty of Technical Sciences in Čačak, where she is employed as a teaching associate since 2022. The next step in education and professional advancement is enrolling in doctoral studies. Her research interests include digital signal processing, image processing, remote control and biomedical engineering.