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# A Novel Approach to Web-Based CADx Application for Analysis of Breast Ultrasound Images

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**ABSTRACT**

There have been many studies on computer-aided detection/diagnosis (CADe/CADx) systems that assist the specialists in the evaluation of radiological images. Such systems increase the success rate of disease detection and decrease the time spent for detection. In recent years, some of the academicals and commercial CADx applications for mass detection/diagnosis on breast ultrasound images were developed as web applications. In this study, a novel, high success-rate CADx web application with a novel classifier architecture was developed and a specialist can track the patients without time and location restrictions with the help of internet connection. Different from commercial applications, the developed application can also be used as an educational tool for junior doctors or medical students to increase their practice in the field of radiology.



***Keywords:*** breast cancer; cad; web based

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## Introduction

According to a recent studies Breast cancer is an important disease that causes women to lose their lives [1]. Benign and malignant type of breast tumors are caused by uncontrolled growth of breast cells [2]. X ray imaging and ultrasound imaging are the most basic medical imaging methods in the early identification of breast cancer [3,4]. Specialists working with mammograms tend to make more misdiagnosis than those working with ultrasound. That is, the rate of false positives is higher for mammograms [5]. Most of the unnecessary biopsies (65%-85%) are caused by the low specificity of mammography [6]. Unnecessary biopsy leads to emotional pressure on the patients and increases the cost.

There have been many studies on computer-aided detection (CADe)/diagnosis (CADx) systems that help specialists in the interpretation of radiological images. Such systems both increase the success rate of detection and reduce the identification time [7,8]. A typical cad software consists of several different layers. These layers are called the image preprocessing layer, the region of interest (ROI) determination layer, and the classifier layer [7,9]. Classification is the most important part of a CAD system. It classifies the ROI as benign or malignant using the selected features with different methods. Artificial intelligence techniques are widely used as classifiers [10,11,12,13,14].

In recent years, some of the academicals and commercial CADx applications for mass detection/diagnosis on breast ultrasound images were developed as web applications [15]. Grandinetti and Pisacane [16] developed a web application which predicts the blood sugar levels of the patients in a specific period in the future. The method they used for prediction depends on the control of patient's variable conditions in the treatment process and the applied diet program. Al Mamun et al. [17] detected and followed up Parkinson patients using smart devices connected to the Internet with a cloud-based system. Markiewicz et al. [18] designed and developed a web-based software application to analyze microscopic images and assist pathological diagnosis. Remeseiro et al. [19] have developed a web-based application to assist specialist personnel in the diagnosis of dry eye disease. Ruiz et al. [20] introduced a web-based decision support platform designed to organize the treatment of patients with gestational diabetes. They aimed to improve access to private health care, to prevent unnecessary displacement of patients, to reduce evaluation time per patient, and to reduce the negative consequences of gestational diabetes. Antoniou et al. [21] designed a web-accessible database and CAD system called the MIRaCLe DB. They collected 204 mammograms from 196 patients. Their study can also be used for evaluation of education of radiologists. George et al. [22] introduced a CAD system that uses web services for detection and diagnosis of breast cancer using Cytological Images. They used artificial neural networks and support vector machines (SVM) as the classifiers. Silva et al. [23] introduced a web-based system that detects the lesions on mammogram images using an SVM classifier. Love et al. [24] proposed a stand-alone software system called Triage Cad, which classifies the masses in the breast ultrasound images. They had a sensitivity success-rate of 92% with the classifier structure they used in their CAD system. Huang et al. [25] to detect breast cancer proposed a web-based education system that consists of a CAD sub-system and a web database. The proposed system relies on the scoring of 25 features one by one (0: oval, 1: round, 2: irregular etc.) by the specialist who interprets the ultrasound image on the browser. Therefore, the subjective decisions of the specialist determine the result of the classification. However, the objective of the CAD systems is to help the specialist in the decision process by analyzing the details which are difficult for the specialist, using a computer with a high-computing power and a software.

In this study, a novel web-based CAD application was developed that contains a novel classifier architecture proposed by Uzunhisarcıklı and Göreke [26]. MATLAB code of the proposed CAD architecture runs in the background of the web-based CADx application developed in ASP.NET platform. Matlab Compiler SDK extends the functionality of the MATLAB Compiler and generates .NET assemblies from the MATLAB code. In this study, MATLAB function files of the CAD system were first converted to .NET assemblies (dll: dynamic-link library). Then, a web interface was designed and these dll files were referenced from the .NET project. Web interface was developed using C# and JavaScript programming languages. MS SQL database management system was used to store the interpretations of the images which would be examined by the specialists. The proposed application in this study reduces the time that experts spend on analyzing, reduces the cost of preparations by storing physical preparations images on the server, reproducibility, comparability and objectivity increase in quantitative evaluations.

## Classifier

The fuzzy set theory belonging to L.A Zadeh was put forward in 1965. It is suggested based on a concept of a classical set to reflect an uncertain knowledge. This type of set expresses the state of the objects belonging to the set with a float value between 0 and 1 [27]. A fuzzy inference system uses fuzzy rules, membership functions, and inference mechanisms to handle given inputs to outputs. In the Mamdani inference method, which is the most basic inference method, membership levels from the fuzzy unit are associated with the output membership function using the minimum relationship operator [28]. After Zadeh revealed Type 2 fuzzy clusters in 1975, the previous structure was called Type 1 [29]. A fuzzy inference system is called Type 2 if it contains at least one Type 2 fuzzy structure. The structure of the membership functions of these two types of systems using the same rule structure is different. In addition, the Type 2 system includes a type reducing unit which is not present in the Type 1 system [30]. The new classification architecture developed by Uzunhisarcikli and Goreke [26] includes a fuzzy inference system of Type 2 structure and has achieved 100% sensitivity performance. The block diagram representing architecture is shown in Figure 1.

X =(X1-X6) expresses the input vector applied to the first layer where X1,...,X6 is defined respectively as mean, contrast, spiculation, roundness, area and rate of area to perimeter. X7 is the input parameter given to the second layer and represents the ratio of the axes. The output of Layer 1 is the classification result which is expressed as B or M. Here, B represents benign while M represents malignant.

The rule for Layer 1 is as follows.

If (X3 ∈ M31) and (X5 ∈ M51) then (R1 ∈ O11)
If (X3 ∈ M32) and (X5 ∈ M52) then (R1 ∈ O12)
If (X5 ∈ M51) and (X2 ∈ M21) then (R1 ∈ O21)
If (X5 ∈ M52) and (X2 ∈ M22) then (R1 ∈ O22)
If (X3 ∈ M31) and (X6 ∈ M61) then (R1 ∈ O31)
If (X3 ∈ M32) and (X6 ∈ M62) then (R1 ∈ O32)
If (X3 ∈ M31) and (X2 ∈ M21) then (R1 ∈ O41)
If (X3 ∈ M32) and (X2 ∈ M22) then (R1 ∈ O42)
If (X4 ∈ M41) and (X1 ∈ M11) then (R1 ∈ O51)
If (X4 ∈ M42) and (X1 ∈ M11) then (R1 ∈ O52)

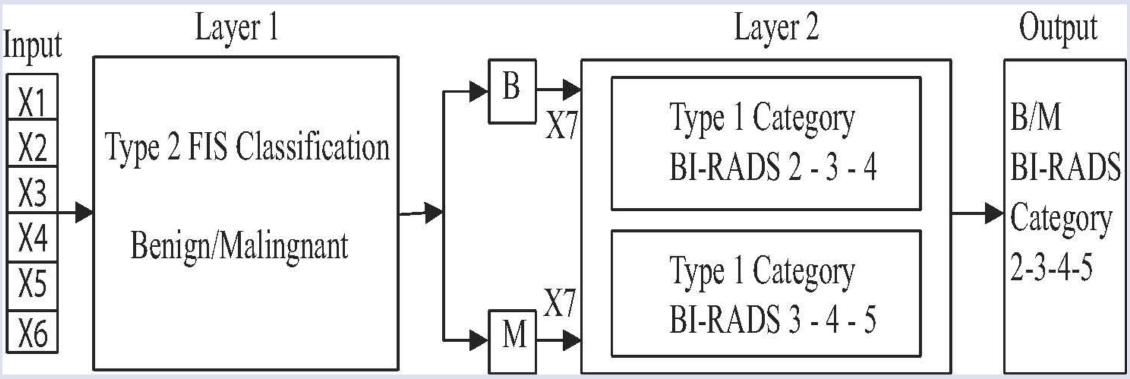


*Figure 1. CADx system architecture.*

Here, M variables refer to the membership functions of the relevant entry. There are two membership functions for each input parameter. These are named low and high.

For example, M31 for X3 input parameter refers to membership functions named high and M32 low. It refers to the membership function specifying the benign (O12) and malignant (O11) class.

The mathematical model of the fuzzy inference part of the designed software system in layer 1 and layer 2 is as summarized below. The software for both Type 1 and Type 2 fuzzy inference part was developed according to Mamdani methodology. The rule structure of the Type 2 fuzzy inference system is the same as Type 1, except for the structure of membership functions. Unlike Type 1, type reduction operation is carried out in Type 2 system.

The mathematical expression of membership functions is given by Equation 1.

$$\overline{\mu}(x;a,b,c) = \begin{cases} 0, & x < a \\ \frac{x-a}{b-a}, & a \le x \le b \\ \frac{c-x}{c-b}, & b \le x \le c \\ 0, & c \le x \end{cases} \quad (1)$$

$$\underline{\mu}(x;a,b,c) = \begin{cases} 0, & x < a + a1 \\ \frac{x-(a+a1)}{b-a}, & a + a1 \le x \le b \\ \frac{(c-c1)-x}{(c-c1)-b}, & b \le x \le (c-1) \\ 0, & (c-c1) \le x \end{cases}$$

Here $\overline{\mu}$ is the parent membership function and $\underline{\mu}$ is the sub-membership function.

x denotes the input parameter value. The a1 and c1 values are the values that determine the footprint of uncertainty (FOU) range. These values are calculated using the Artificial Bee Colony (ABC) optimization algorithm.

The mathematical expression of FOU is given by Equation 2. The diagram of fuzzy inference system is given in Figure 2.

$$FOU = \bigcup_{\forall x \in X} \left[ \underline{\mu}(x), \overline{\mu}(x) \right] / x \quad (2)$$

Equation 3 gives the mathematical expression for the output of the fuzzy inference system.

$$\left[ \underline{b}(y), \bar{b}(y) \right] = \left[ \max\left( \underline{b}1(y), \bar{b}1(y) \right), \max\left( \underline{b}2(y), \bar{b}2(y) \right) \right] \quad (3)$$

The value obtained from the second layer is used for category information [26].

## Web-based CADx application

MATLAB Compiler SDK is a very useful toolbox for developers who want to use .NET and MATLAB platforms together. Using these two software platforms, Kaçar et al introduced a web-based image processing application that implements fundamental image processing functions such as filtering, scaling and contrast equalization [31]. Guney et al. [32] introduced a web-based ECG simulator using the same methods.

A dll is a library that contains code and data that could be used simultaneously by more than one program Mathworks [33]. MATLAB function files with .m extensions were converted to .NET assemblies using the Compiler SDK as shown in Figure 3. Furthermore, these dll files may include many m function files that can be used by the main m file. To realize it using the compiler, .NET assembly option is selected from a select box that asks for the type of file to be generated. m file is added by clicking the plus button (Add exported function to the project) and the process is started by clicking the package button. If no error occurs, dll file is generated in the for_redistribution_ files_only folder. The generated dll files and functions are as follows:

- resim2using.dll: Takes the image to be processed and pixel coordinate data of the marked suspicious region perimeter as the inputs, then returns the morphological and texture-based features after obtaining the ROIs, image filtering and enhancement.
- webtip2using.dll: Includes Type 2 fuzzy inference software that takes Layer 1 parameters of the CADx architecture and classifies the suspicious region as benign or malignant.
- tip2MCatusuing.dll: Includes the fuzzy inference system software that takes the X7 parameter of CADx Layer 2 and determines the BI-RADS category.

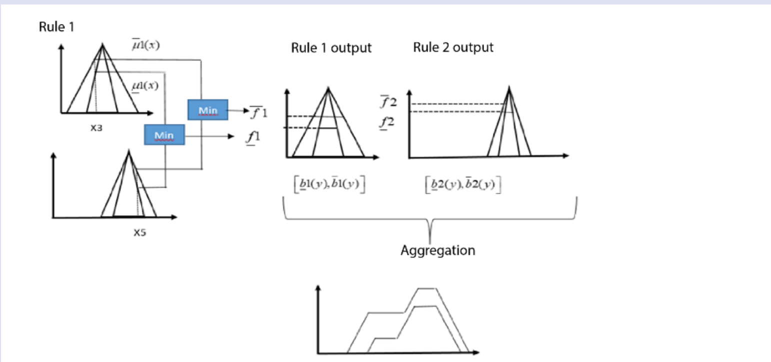


*Figure 2. The diagram of the Type 2 fuzzy inference system*

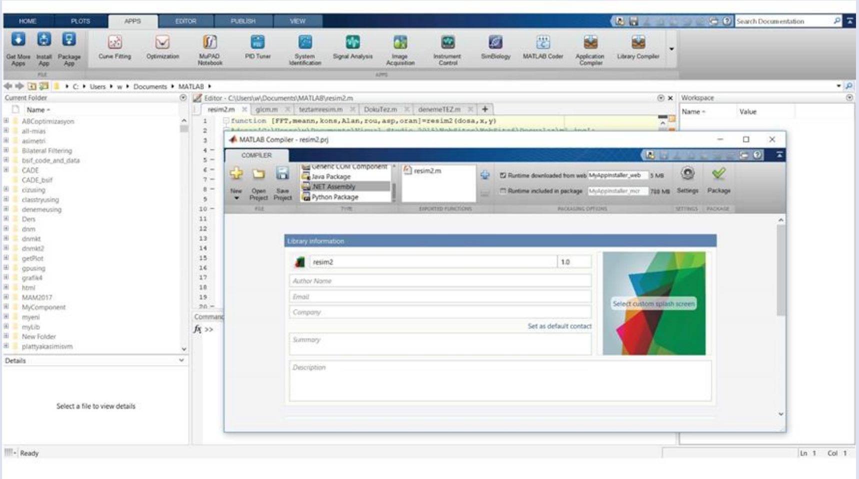

Figure 3. Dll file generation.

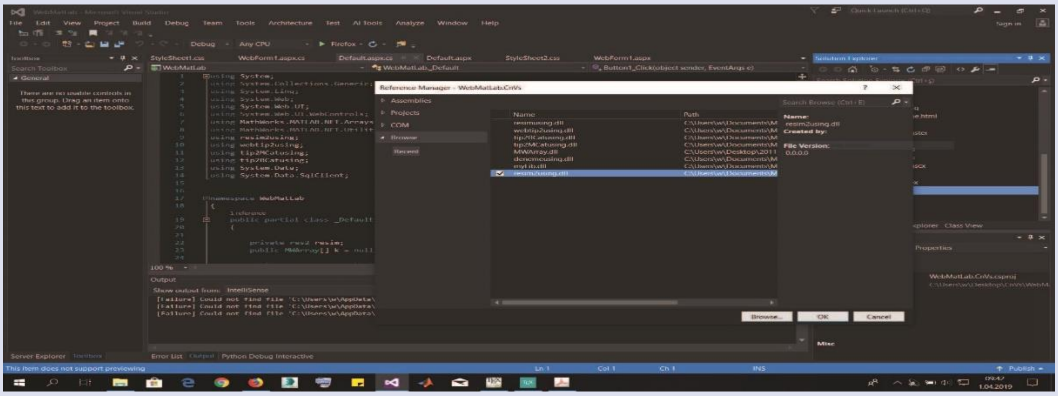

Figure 4. Visual studio environment.

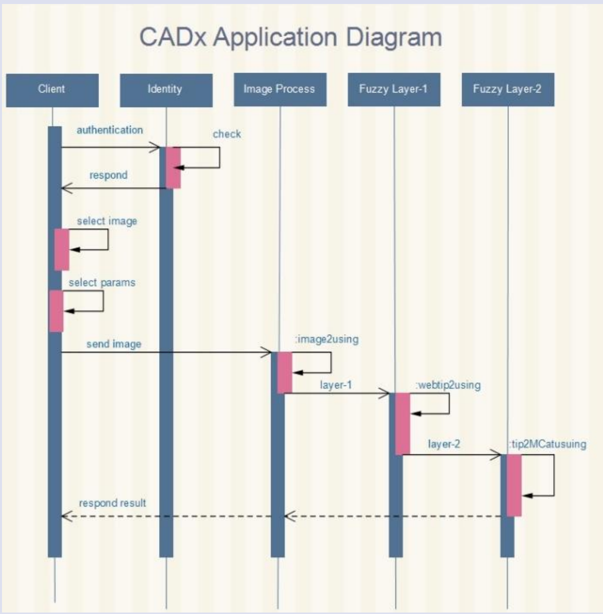


Figure 5. The system architecture of the software

Visual Studio platform that allows software development in various programming languages was used in web application development process. The dll files explained above were referenced to the project generated in Visual Studio environment as shown in Figure 4.

It can be seen from Figure 4 that there is a file named MWArray.dll. This file includes the classes that perform conversions between MATLAB and .NET platforms. Thus, data coming from MATLAB were processed without any problems.

The system architecture of the software is given in Figure 5. Here, the pixel-based coordinates of mass perimeter marked on the browser are captured using JavaScript. Coordinate information is used as the input of the object's method (resim2.m) generated using resim2using library. The function returns an array of feature values. Then these parameters are used as the inputs of the object's method that was generated from webtip2using library, and the CADx system Layer 1 output is obtained. The classification result obtained from Layer 1 output is labelled as "1" for malignant and "0" for benign. If the value equals "1" then the object's method generated from tip2MCatusuing library is called. This method takes the MF4 feature value as the input and returns the BI-RADS category for malignant type as the output. If the value equals "0", then the object's method generated from tip2BCatusuing library is called and BI-RADS category for benign type is returned.

The Add Comment text-area shown in the interface is used for storing medical information and comments for images examined by the specialists in a database. Thus, the verbal statements obtained from different users should be used as a reference for the improvement of CADx system's fuzzy rule structure.

In addition, when clicked on the Read Comment button, comments saved in the database can be moved to the text-area. Thus, specialist physicians will be able to exchange views by accessing different expert opinions about medical images.

In addition, junior specialists who have access to these opinions will be able to increase their medical knowledge and have the opportunity to practice.

By clicking the Browse button, the selected image file can be uploaded to the system by clicking the Upload Image button. Thus, any ultrasound images that are not in the database can also be loaded and analyzed. The system model of the transaction is given in Figure 6.

In this study, 70 ultrasound images obtained from the open access Biomedical Engineering Research Unit of SIIT (BioMed SIIT) database were examined by a radiology specialist and the regions containing masses were marked in computer environment. The system designed in tests performed on the specified ROI areas achieved 98.5% accuracy. The graphical interface visual of the software of the system proposed in this study is given in Figure 7 below.

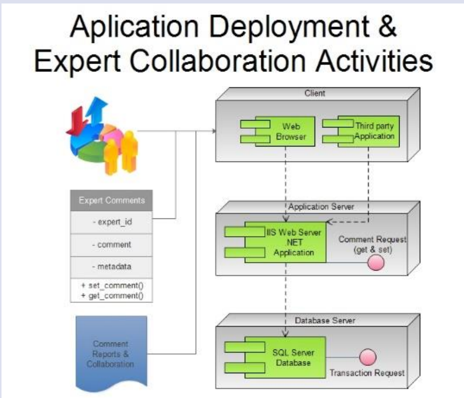


*Figure 6. The system model of the transaction*

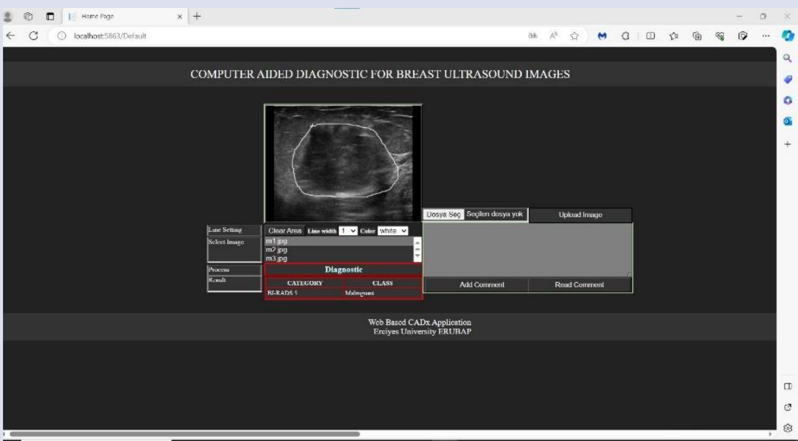


*Figure 7. The graphical interface visual of the software of the system*

## Results and conclusion

Many of the CADx/CADe studies in the literature do not include the development of a software. Some of the developed software (academical or commercial) are desktop applications. Therefore, the specialist must be able to access to the computer where the software is installed. In this study, the CADx system for the designed architecture was developed as a web-based system using different software technologies. Thus, the specialist can track his/her patients without time and location restrictions. He/she can access to the system from everywhere with an Internet connection. Different from commercial applications, the developed application can also be used as an educational tool for junior doctors or medical students to increase their practice in the field of radiology. Additionally, the information about the examined images and the experiences of the specialists will be stored in a database. It's also foreseen that the rule structure of the inference system will be improved using the obtained linguistic statements by programmer.

The single-user system was converted to a multi-user system by adding a login page. In the literature, the same medical image is analyzed by two different physicians is called double reading. This structure was converted into a multi-reading system by adding multiple users and CADx system. In addition, an online messaging module can be added to the system, and an interactive training platform can be established between the specialist and the medical student.

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