Threshold Neuro Fuzzy Expert System for Diagnosis of Breast Cancer

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ABSTRACT
An Expert system is an interactive computer-based decision tool that uses both the facts and heuristics to solve difficult decision making problems. Fuzzy logic is a new way of expressing probability. Neural Networks are eminently suited for approximating and designing of fuzzy Controllers and other types of Fuzzy Expert System. Neuro-fuzzy systems are connectionist models that allow learning as artificial neural network, but their structure can be interpreted as a set of fuzzy rules.Fuzzy logic and neural networks form the basis of the majority aided diagnostic intelligent systems. It would be interesting to combine the two approaches to exploit both advantages. In this paper we propose an ARM Cortex-M3 Based Interactive Neuro Fuzzy Expert System for diagnosis of breast cancers proposed on an Ex-DBC System for benign and malignant digital mammographic findings. In order to assist physicians, Radiologists and others in clinical diagnosis, a wide set of breast cancer detection rules was designed using Digital Mammographic dataset are discussed in this paper.

General Terms: Expert system, Neural Networks, Fuzzy Logic, Digital Mammography ,Benign, Malignant

Keywords: ARMCortex-M3, Neural Networks, Fuzzy Logic, Ex-DBCSystem, Benign Malignant, Microcontroller, Multiplexer

1. INTRODUCTION
Artificial Intelligence in Medicine is new research topic plays an vital role in medicine and assist the computer scientists and Doctors, Radiologists indoctrinate medicine and nudge forward the frontiers of science and Technology. Expert system is a computer system or a computer program that uses artificial intelligence to emulate the decision-making ability of a human expert and to solve problems within a specialized domain that ordinarily requires human expertise. In order to accomplish the feats of apparent intelligence, an expert system relies on two components called knowledge base and an inference engine. A knowledge base is an organized collection of facts about the system's domain. An inference engine interprets and evaluates the facts in the knowledge base in order to provide an effective solution. Typical tasks for expert systems involve classification, diagnosis, monitoring, and design, scheduling, and planning for specialized endeavors.

Expert system is the way to separate domain specific knowledge from more general purpose reasoning and presentation technique. The inference engine is used to reason with both Expert knowledge and data to the particular problem being solved. The Expert system knowledge will typically in the form of a set of IF-THEN Rules. The Expert System tries to prove every rule generated by inference engine.Fuzzy logic is a valuable tool for depicting medical concepts by treating them as Fuzzy sets. Fuzzy Rules are can be easily comprehended and verified tuned and possibly expanded by medical experts and used for the development of Classification system s that is very precious in the process of Medical Diagnosis.

Two main factors are proved to be critical for the success of Medical Diagnosis.

1. A Fast and accurate input partitioning method that attempts to find the soft class boundaries by automatically processing a series of representative examples.
2. A Verbally interpretable knowledge representation frame work that allows the verification and integration of generated rules.

Fuzzy logic is found to have a variety of applications in various fields such as medical diagnosis. Fuzzy Logic system is based on the decisions on inputs derived from the membership functions which are formulae to determine the fuzzy set.

Neural Networks in Fuzzy Expert System are used for implementing these approximations in appropriate hardware. Although classical Networks can be employed for this purpose, attempts have been made to develop alternative approaches. Neural networks and fuzzy logic are two approaches that are widely used to solve classification and pattern recognition problems. Neural Networks more attuned to the various procedures of approximate reasoning.

The alternative Networks are usually referred to as Fuzzy Neural Networks.

A Neuro- fuzzy system is a fuzzy system that uses learning algorithm derived from or inspired by Neural Network theory to determine its parameters (fuzzy sets and fuzzy rules) and process. Here we are combining two approaches which were used widely to solve classification and pattern recognition problems in diagnosing Breast Cancer.

Breast cancer is one of the most commonly occurring cancers in women. Early diagnosis of breast cancer is crucial and important in reducing mortality rate and improving the patient's quality of life. Current breast imaging diagnosis include: Mammography, Magnetic Resonance Imaging, MRI, and Sonograms, Ultrasound images. The mammography is more effective than ultrasound in the early diagnosis of breast cancer calcification and is cheaper than MRI. Mammography offers high-quality images at a low radiation dose, and is currently the only widely accepted imaging method used for breast cancer diagnosis. Hence Mammography is the major examination of choice since it has been proven capable to detect the disease.However, analyzing a mammogram and concluding in correct diagnosis results is not a trivial medical task. An early diagnosis of this disease has more importance and considerably improves the prognosis and leads to more effective treatment for the patient.

Mammogram report includes many technical details, which will show BIRADS score. BIRADS is an acronym for Breast Imaging-Reporting and Data System, a quality assurance tool originally designed for use with mammography. The system is

designed to standardize reporting, and is used by radiologists, medical professionals to communicate a patient's risk of developing breast cancer. This indicates the radiologist's opinion of the absence or presence of breast cancer. "BI-RADS" refers to the mammography assessment categories. These are standardized numerical codes typically assigned by a radiologist after interpreting a mammogram. This allows for concise and unambiguous understanding of patient records. Through a medical audit and outcome monitoring, BI-RADS provides important peer review and quality assurance data to improve the quality of patient's care.

The recognition of abnormalities such as calcifications and masses in mammograms require a well-trained Medical Doctors or Radiologist. Often, several findings mislead the radiologist either because of fatigue or lack of experience or as a result of human error. As a solution, information technology and computational intelligence have been employed to classify findings and provide second opinion using, a wide set of breast cancer detection rules and implemented in an embedded environment. Hopefully it will become an instrument of detection and early awareness of the relevant part of the population.

This Advanced RISC Machine (ARM) Cortex-M3 based Interactive Neuro-Fuzzy Expert System is a quality assurance device designed to standardize mammographic reporting, reduce confusion in breast imaging interpretations and facilitate precise outcome monitoring.

The ARM Cortex family of processors provides a standard architecture to address the broad performance spectrum required by these diverse technologies. The ARM Cortex-M3 processor is the industry-leading 32-bit processor for highly deterministic real-time applications. With high performance and low dynamic power consumption the Cortex-M3 processor delivers leading power efficiency 12.5 DMIPS/mW based on 90nmG. Coupled with integrated sleep modes and optional state retention capabilities the Cortex-M3 processor ensures there is no compromise for applications requiring low power and excellent performance.

The Interactive Neuro Fuzzy Expert System is designed to provide an organized approach to image interpretation and reporting. It does not require a separate computer system, but the utilization of a computer in reporting is strongly encouraged. Not only does this facilitate reporting, but also data are simultaneously collected for the maintenance of a database for future review. This will permit individual radiologists or groups to monitor their own results and appraise the accuracy of their image interpretation so that they can adjust thresholds appropriately. The radiologist's attention should be focused on the interpretation of images. The simplest input utilizes a single screen with minimal interaction needed from the radiologist. The goals are to maximize the image viewing time and minimize any distractions from the reporting.

2. LITERATURE SURVEY

Existing Expert Systems diagnosing breast cancer includes

The innovative combination of electro-magnetism and back propagation algorithm using Neuro – Fuzzy classification method prepared by Ching-Hung Lee. 2010 IEEE [3].A Combination of Fuzzy inference system and wavelet transform employed to decrease the number of missing regions or unnecessary biopries. Developed by Pelin Gorgel Sertban, and Osman N.Ucan. 2012 IEEEE,[1] The primitive detection of tumor masses in Digital Mammograms make use of the characteristics of texture that simplified description of Neuro fuzzy system for early detection of Breast Cancer 2003 IEEE[9]. Arpita Das proposed profound computer aided diagnostics system based on Genetic Neuro Fuzzy model arsit the radiologist in the diagnosis of breast cancer 2008 IEEE.[13]An Advanced Fuzzy – Neuro approach is implemented using compact genetic algorithm and steady state genetic algorithm gives a new methodology to diagnose the breast cancer in Hamdi paper IEEE 2010[4]In recent advances the expert systems designed for breast cancer forecasting the forthcoming of the disease and indicates the likelihood of recovery from the disease Adaptive Neuro-Fuzzy inference System (ANFIS) facilitates to design a model for survival rate of breast cancer. This prediction is mandatory for every patient and it increases the survival rate 2011 IEEE[14] In Asharaf's study is commixture of two methods. ANFIS and information gain in creating a model for breast cancer detection through human knowledge and machine learning. Information gain and adaptive Neuro-Fuzzy inference system for breast cancer Diagnosis[11]The author Walker and Jr.,Elizabeth A.Verheggen introduces an evolutionary programmed Neural Networks with Adaptive Boosting for Computer Aided Diagnosis of Breast Cancer. This improves the the performance of both modelling paradigms without introducing unnecessary anomalies7[15] The professor Janghal Shukla proposed and proved the best method for diagnosis of Breast Cancer through a knowledge Base Approach[7].An adoptable Fuzzy c-means radial basis network proposed to diagnose the breast cancer based on Fuzzy Rules.In this study the Hierarchical fuzzy Neural Network and Fuzzy Gaussian Potential Neural Network are combined by creating a new algorithm and applied on the data set WBCD and find the category Benign and Malignant.[6].This study paper compare particle swarm optimizer based on Artificial Neural Networks based on ANFIS Algorithm and the classifier every person as patient[16]This paper develops an Expert System and design for breast cancer Knowledge based reasoning and predict the occurrence of the cancer disease [2].

In few of these existing systems for the diagnosis of the breast cancer they proposed an EX-DBC system for benign and malignant mammographic findings. However, there are various categories in BIRADS. This paper concentrates on the study of various other categories of BIRADS to design and appropriate tool to enhance the accuracy of diagnosis.

2. PROPOSED NEURO FUZZY EXPERT SYSTEM USING ARM CORTEX M3 SYSTEM FOR BREAST CANCER DIAGNOSIS

We propose an ARM Cortex M3 interactive neuro fuzzy expert model for classification digital Mammographic mass dataset. we obtain best rules to use inference engine of interactive neuro fuzzy expert system for diagnosis of breast cancer using fuzzy logic utilize various combination of rules. Neuro-fuzzy system is a acquiring machine that finds the factors of a fuzzy system (i.e., fuzzy sets, fuzzy rules) by employing approximation techniques from neural networks.

A fuzzy system appeals linguistic rules instead of learning examples as previous knowledge the input and output variables have to be narrated linguistically. If the knowledge is incomplete, wrong or contradictory, then the fuzzy system must be better functioned. The tuning of Fuzzy system is discharged in a heuristic way. This is time consuming task. Here the comparison between Neural Networks and Fuzzy systems shown Table1.

Neural Networks	Fuzzy Systems
no mathematical model necessary	no mathematical model necessary
learning from scratch	apriori knowledge essential
several learning algorithms	not capable to learn
black-box behavior	simple interpretation and implementation

Table 1: Comparison of neural control and fuzzy control

The neuro-fuzzy system has a 3 layered feed forward architecture. The units network use t-norms or t-conorms as activation function. The hidden layer represents fuzzy rules. Fuzzy sets are encoded as (fuzzy) connection weights.

- A neuro-fuzzy system is represented as special three-layer feedforward neural network.
  The first layer corresponds to the input variables.
  The second layer symbolizes the fuzzy rules.
  The third layer represents the output variables.
  The fuzzy sets are changed into as (fuzzy) connection weights.

The first layer contains five input units (x1..x5) representing the pattern features. The hidden layer holds rule units, (R1-R7) representing the fuzzy rules and the third layer consists of six output units. There are 7 fuzzy rules using BI-RADS (1-6) and five inputs Mass shape, Mass Margins, Mass density, Calcification and Calcification Distribution. Neuro fuzzy model is created for interactive expert systems to diagnose Breast Cancer Inference engine.

X1: Mass Shape X2: Mass margin
X3: Mass Density X4: Calcification
X5: Calcification Distribution

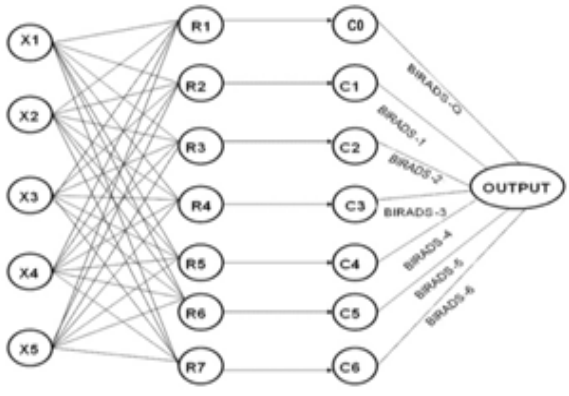

Fig: 1 The Neuro Fuzzy model created for interactive neurofuzzy expert system

According to the NCCN Guide lines to diagnosis the Breast cancer

The following rules are to be considered

The input Mass Shape contains five categories Round, Oval, Lobular and irregular, uncertain. Oval and round masses are usually benign. The data set is converted in to digital data coded in binary form. Round-0000 Oval-0001 Lobular-0010 irregular-0011 and uncertain -0100.

The Margins of the Masses are the most important indicators of likelihood of malignancy. The margins can be described as circumscribed -0000 obscured -0001 micro lobular -0010, Indistinct -0011 and speculated -0100.

The mass density contains fat density -0000, Low density -0001 Isodense-0010 High density – 0011 and Has Central Lucency-0100

The fourteen types of Calcification are digitalized in the following table

S.No	Calcification category	Digital code
1	Lucent centered -	0000
2	Parallel tracks-	0001
3	Coarse Popcorn like-	0010
4	Large Rod like -	0011
5	Round-	0100
6	Egg-shell rim-	0101
7	Milk of Calcium	0110
8	Suture Calcification	0111
9	Dystrophic	1000
10	Punctuate	1001
11	Amorphous /indistinct	1010
12	Granular sand like	1011
13	Pleomorphic /Heterogeneous/granular-	1100
14	Fine Linear branching/ casting	1101

The Calcification distribution can be categorized in five groups

1. Diffused and scattered 0000 (Not Suspicious)
2. Regional 0001 (low Suspicious)
3. Segmental 0010 (High Suspicious)
4. Linear branching 0011 (Very high Suspicious)
5. Grouped/clustered 0100 (Suspicious Malignancy)

4. MEDICAL RULES AND PROPOSED DIGITAL LOGIC RULES

In this proposed expert system we convert the medical rules into Digitized Logical rules which are implemented with the following set of Rules. This Conversion procedure helps in generating an accurate advanced and faster tool for diagnosis of Breast cancer.

R1: Rule l

If Mass shape = round and Mass margin = Circumscribed and Mass density = Fat density and Calcification: lucent centered and Calcification distribution diffused and scattered then BIRADS –0 (Re-imaging)

If Mass shape=0000 and Mass Margin=0000 and Mass Density=0000 and Calcification=0000 and Calcification distribution=0000 then BIRADS-0(Re-imaging)

R2: Rule 2

If Mass shape = round and Mass margin= Circumscribed and Mass density = Fat Density and Calcification = Lucent Centered Calcification distribution = diffused and scattered then BIRADS-1(Normal)

If Mass shape =0000 and Mass Margin=0000 and Mass density = 0000 and Calcification = 0000 Calcification distribution =0000 then BIRADS-1(Normal)

R3: Rule 3

If Mass shape = round or oval and Mass margin is circumscribed or obscured Mass density = fat density or low

density and Calcification = Lucent cantered or parallel tracks / linear lobular or Coarse / popcorn or large rod like or recent or egg shell rim or milk of calcium and Calcification distribution = diffused and scattered then BIRADS – 2 (Benign)
If Mass shape =0000 or 0001 and Mass Margin =0000 or 0001 Mass density =0000or 0001 and Calcification = 0000/0001/0010/0011/0100/0101/0110 and Calcification distribution = 0000 then BIRADS – 2(Benign)
R4: Rule 4

If Mass shape = Lobular and Mass margin = Micro lobular. Mass density = Isodense and Calcification = Suture calcification or Dystrophic or Punctuate or Amorphous / indistinct Calcification distribution = diffused and scattered or regional or segmental or linear branching then BIRADS -3(Probably Benign)

If Mass shape = 0010 and Mass margin = 0010 Mass density = 0010 and Calcification = 0111or1000 or 1001or 1010 Calcification distribution =0000 or 0001 or 0010 or 0011 then BIRADS -3(Probably Benign)
R5: Rule 5
If Mass shape = irregular and Mass margin= speculated and Mass density = Has central lucency and Calcification= pleomorphic / Heterogeneous Granular Calcification Distribution= Segmental (very suspicious) or Linear branching (high suspicious. then BIRADS – 4.(Suspicious abnormality)

If Mass shape = 0011 and Mass margin= 0100 and Mass density = 0100 and Calcification= 0010 or 0011 Calcification Distribution= 0010 or 0011 (high suspicious). then BIRADS – 4. . (Suspicious abnormality)
R6: Rule 6

If Mass shape = irregular and Mass margin= speculated and Mass density =Has central lucency and Calcification = pleomorphic / Heterogeneous granular and Calcification distribution = clustered them BIRADS -5(Highly Suggestive Malignancy)
If Mass shape = 0011 and Mass margin =0100 and Mass density=0100 and Calcification =1100 and Calcification distribution= 0100 then BIRADS -5(Highly Suggestive Malignancy)
R7: Rule 7

If Mass shape = irregular and Mass margin= speculated Mass density= Has central lucency and Calcification = fine linear branching and Calcification distribution = Clustered then BIRADS – 6 (Malignant).

If Mass Shape =0011 and Mass Margin=0100 and Mass density=0100 Calcification =1101 and Calcification distribution =0100 then BIRADS-6(Malignant)
The assessment categories of BI-RADS were developed for mammography and they are represented by C0, C1, C2, C3, C4, C5, C6 variables in the Output Layer.

1. C0-0: Incomplete –BIRADS0
2. C1-1: Negative-BIRADS1
3. C2-2: Benign finding(s)-BIRADS2
4. C3-3: Probably benign-BIRADS3
5. C4-4: Suspicious abnormality-BIRADS4
6. C5-5: Highly suggestive of malignancy-BIRADS5
7. C6-6: Known biopsy – proven malignancyBIRADS6

All these rules were trained in the ARM CORTEX M3 processor based micro controller system. These Input parameters are required to be fed in to the system which will process and gives C0,C1,C2,C3,C4,C5,C6 and finally diagnose the breast cancer for patients.

5. ARCHITECTURE OF THRESHOLD NEURO FUZZY EXPERT SYSTEM

This system is implemented using ARM Cortex-M3 processor which is the industry-leading 32-bit processor for highly deterministic real-time applications. With high performance and low dynamic power consumption the Cortex-M3 processor delivers leading power efficiency. In order to assist users in clinical diagnosis, a very convenient Graphical user interface is designed to take the necessary input parameters for BIRADS classification.

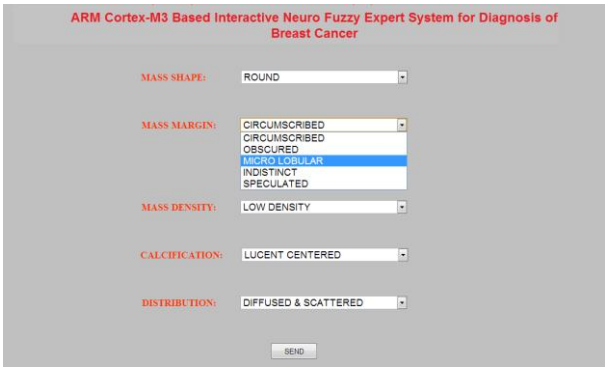

Fig: 2 Graphical User Interface of Interactive Neuro-Fuzzy Expert System

Extensive fuzzy rules are then assigned to manipulate the desired BIRADS using the Following System.

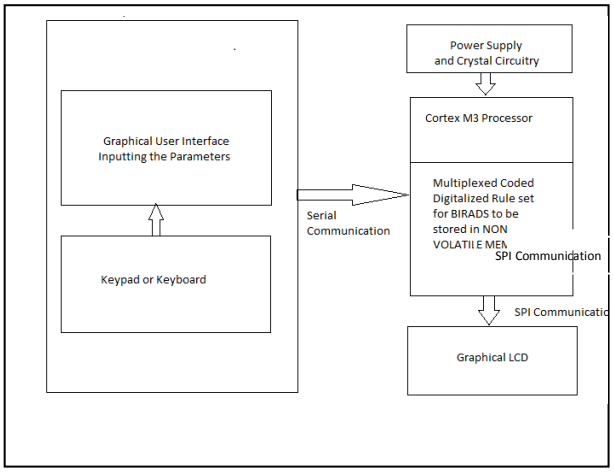

Fig: 3 Basic Schematic of Interactive Neuro-Fuzzy Expert System

Multiplexed Coding mechanism is applied for all set of rules implemented in ARM Cortex M3 Micro Controller which generates the final output that identifies BIRADS Classification.

Fig: 4 ARM Cortex M3 based Interactive Neuro Fuzzy Expert System

6. CONCLUSION

In this paper we proposed ARM-M3 based an interactive neuro Fuzzy expert system to diagnose the breast cancer. The proposed system uses a wide range of BIRADS classification which enhances the accuracy of Diagnosis.

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