Development of a Risk-Factor System for Predicting Occurence of Breast Cancer Using Fuzzy Logic

Fabiyi A. O.
Federal Polytechnic Ede
Ede, Nigeria
fabiyiademolaebony@yahoo.com, 08025600073

Ogunleye G.O.
Federal University Oye-Ekiti, Nigeria
07066358913

Onyeka N.C.
Federal Polytechnic Ede
Ede, Nigeria
camiliaobi@live.com
07033310638

Amosa B.M.G
Allbytes Consults
Gbagada Lagos, Nigeria
*amosabmg@gmail.com
08034719314

***Abstract**: The high mortality rate associated with cancer and the inability to detect the disease early has led to a catastrophic reduction in the rate of survivability of the disease in women. We have attempted to improve on the rate of survival by using Fuzzy logic to develop a risk factor system for detection of breast cancer. The system has been implemented using the Mamdani fuzzy logic approach in MATLAB. A graphical user interface (GUI) has been developed using Microsoft Visual Studio 2012. The GUI was powered by a Fuzzy Logic Library and Visual C# was used as its programming language.*

***Keywords:** Breast Cancer, Disease, Risk factor, Fuzzy Logic.*

1. INTRODUCTION

Mortality due to breast cancer can be reduced by the early diagnosis of disease, as well as by early treatment initiation. Many symptomatic breast cancer patients experience long delays in obtaining diagnosis and treatment which can negatively affect their prognosis. Patients with breast cancer suffer distress due to the disease and its treatment. Furthermore, advances in medicine have prolonged life expectancy in these patients. Breast cancer is the second most common cancer overall, and by far the most common cancer in women. In 2012, 1.67 million new cases of breast cancer (25% of all incident cancer cases) were estimated worldwide. It is the most common cancer in women in both more and less developed regions, with slightly more cases estimated to have occurred in LMICs (883 000 cases) than in more economically developed regions (794000 cases) in 2012 [1]. Breast Cancer is the most frequent cancer among women, impacting 2.1 million women each year, and also causes the greatest number of cancer-related deaths among women. In 2018 it is estimated that 627,000 women died from breast cancer approximately 15% of all cancer deaths among women [2]. Cancer is a potentially fatal disease which is majorly caused by environmental factors that mutate genes encoding critical cell-regulatory proteins [3].

Agents that cause cancer also known as carcinogens can be seen in the air, food and water, chemicals and also sunlight that people are exposed to. According to [4], 650,000 people out of the estimated 965 million are diagnosed with cancer annually and the lifetime risk of an African woman dying from cancer is two times higher than the risk of a woman in a developed country. Cancer is known to comprise of a set of more than 200 different diseases. It can be in a widely accepted sense described as an uncontrolled growth and spread of abnormal cells in the body. A cell is the basic unit of life. Cells in living thing split to produce more cells when the living thing harboring them requires it. At some point, cells keep on splitting or dividing without control thus creating excess cells which are not needed. This in turn causes the formation of mass tissue also known as a tumor. Tumors can be found in tissues of different types. There are currently many reasons that make cancer prevail.

These reasons can vary from increased ability to take care of diseases which will cause a delay in their progression to inability to diagnose and treat a disease which leads to death and disability [5]. Predicting the future occurrence of cancer is a very much wanted technique which will be a very great help in providing early detection of cancer and in like manner increase the rate of survivability.

The rise in the incidence of breast cancer in recent years should have prompted women with an awareness and knowledge to seek medical advice with minimal breast symptoms. However, only a small number of women are still aware of this internationally. Due to the conservative nature of many societies, many women refrain from seeking medical advice out of shyness or stigma until their disease becomes advanced. Research conducted has shown that there is high mortality rate and there has been a great lapse in the early detection of cancer hence, a catastrophic reduction in the rate of survivability.

This is a major problem since cancer is a kind of disease that is painless at its early stages and might not be noticed until it has become a big problem to contend or deal with and sometimes ends with the death of the individual hosting it. This research is aimed developing a risk factor system for detection of breast cancer using fuzzy logic. This will be used to enlighten people if they are at the risk of getting cancer hence, encouraging early detection which will in turn increase the rate of survivability. There are different types of cancers in which this study can be applied to but the study would be limited to only breast cancer.

II. RELATED LITERATURES

In 2009, breast cancer became the most frequently diagnosed form of neoplastic disease in women in India and is now the most common cause of cancer death in the country, accounting for more than a fifth of all female cancer mortality The main risk factors for breast cancer include individual factors like race and ethnicity, overweight and obesity, physical inactivity, alcohol use, and smoking.
Breast cancer risk can also significantly increase for women with first-degree relatives with breast cancer and women with increased breast density. Reproductive risk factors include early age at menarche, nulliparity, late age at first birth, lack of breast feeding, oral contraceptive use, menopausal status, and menopausal hormone therapy. In many LMICs, changes in reproductive factors, lifestyle and increased life expectancy have led to a sharp rise in the incidence of breast cancer. Presently, national and international health authorities like the U.S. Preventive Services Task Force (USPSTF), the Canadian Task Force on Preventive Health Care (CTFPHC) or the World Health Organisation share the opinion that not enough scientific evidence exists to show that breast self-examination (BSE) can save lives or made women to detect breast cancer at an earlier stage and therefore, should not be taught on population-wide level. They also recommend that BSE should not be promoted since there is evidence suggesting that such public health interventions may actually cause harm. However, in countries where mean tumour sizes are above [1].

Computing, in its regular ideology, is situated on manipulation of numbers and symbols [6]. To explain better, computing with linguistic variables is a methodology in which the object of computation are words and propositions drawn from a natural language, e.g., significant increase in water consumption, small, large, far from recommendations, etc.

Soft Computing is a branch or study under computing that involves the building of machines that are termed wise and intelligent [7]. Intelligence gives the ability or provides the power to derive an answer and not simply arrive at the answer. Intelligence can also be more generally and widely defined as the ability to perceive, identify and retain knowledge or information and apply it to itself or other instances of knowledge or information providing referable understanding models of any size, complexity, or density, due to any conscious or subconscious imposed will or instruction to do so (www.wikipedia.com).

Soft computing gives a highly noticeable paradigm shift in the field of computing, which mirrors the fact that human minds, unlike computers in the present day, embody an outstanding ability to store and process information which is pervasively imprecise, uncertain and lacking [8]. Soft computing has been regarded as a fast coming collection of methodologies, which shoots at exploiting tolerance for impression, partial truth to achieve robustness, total low cost and uncertainty. It mimics consciousness and cognition in several important respects [7]. Soft computing aims at developing a computer or machine which will work in the same way or manner as humans do. The knowledge and wisdom of humans can be re-enacted in computers and systems in some artificial manner.

The combination of the principal constituents of soft computing which are FL, NC, EC, ML and PR has been found to be very effective in solving problems. An example of this can be found in Neuro-fuzzy Systems. Neuro-fuzzy systems are on a daily basis becoming known as consumer products such as washing machines, air conditioners etc. and are also used in industrial applications. The incorporation of soft computing in consumer products and industrial systems leads to the development of systems which have high Machine Intelligence Quotient (MIQ) [8]. The high MIQ of systems which have soft computing incorporated in them is responsible for the fast growth in the number variety of applications of soft computing. Therefore, these successful applications of soft computing implies that the impact of soft computing will be highly felt the next couple of years.

A. Expert Systems (Es)

An expert system is a computer program that represents and reasons with knowledge of some specialists' subject with a view to solving problems or giving advice [9]. Expert Systems are computer programs that are derived from a branch of computer science research called Artificial Intelligence (AI) in [10]. The scientific goal of an AI is to understand intelligence which in turn leads to the building or development of computers that exhibit intelligent behaviour.

AI is deals with the concepts and methods of symbolic inference, or reasoning, by a computer, and how the knowledge used to make those inferences will be represented inside the machine.Expert systems are also known as knowledge based systems. The usage of ES has been largely successful because ES limits the field of interest to a narrowly defined specific domain area that can be naturally described by explicit verbal rules. An ES's knowledge base is embedded with the human expert's knowledge (e.g. skilled doctor or lawyer). This human expert knowledge is what is used by the ES in its computerized consulting service.An ES gives advice to its users by combining facts in its Working Memory (WM) (WM contains facts about a problem that are discovered during a consultation) with domain knowledge in its knowledge base to draw conclusions about a problem.

B.Fuzzy Logic

Fuzzy logic is generally an expansion of deterministic logic, i.e. the truth value is ranged from 0 to 1 other than a binary value. The supposition of fuzzy logic is mainly intended at turning a black and white problem into a grey problem [11]. In the context of set theory, deterministic logic is matching to crisp sets, this means that each element in a set has a full membership to the set, i.e. the element totally feel right to the set. In contrast, fuzzy logic is equivalent to fuzzy sets, which means that each element in a set only has a half-done membership to the set, i.e. the element belongs to the set to a certain degree. The degree of a fuzzy membership is determined by a particular membership function such as trapezoidal membership function, triangular membership function and Gaussian membership function [12].

C. Fuzzy Logic as a Prediction Tool

Prediction according to the Encarta dictionary is defined as the statement about the future i.e. a statement of what somebody thinks will happen in the future. Predicting the occurrence of an event requires imprecise and uncertain knowledge. Predicting a system is normally done by getting knowledge from past events for which historical data is gotten and analyzed to get to know the resulting sequence or pattern in the market [13].

Knowledge from the past is applied mainly to acquire the patterns that formally existed. Getting knowledge about the past can provide to some extent knowledge about the future.

Fuzzy logic has emerged overtime as a valuable technique in predicting the occurrence of future events [14]. It has been used and still being used as a prediction toolfor many systems since its inception in 1965. Fuzzy logic is almost perfect for the predictionof an event because prediction requires knowledge that is rather imperfect and uncertain.

The accuracy of a fuzzy logic prediction system is highly dependent on the variable whichincludes the system, expert rules and the membership functions [15]. A fuzzymodel operates on the level of linguistic terms and it also represents and processesuncertainty. Various application of fuzzy logic for prediction is presented in [16], [17], [18], [19], [20]. Literatures in Artificial Intelligence in Breast Cancer Research are discussed in [21], [22], [23]. Benefits of Fuzzy logic as a prediction system are presented in [24].

III. DEVELOPMENT OF A RISK-FACTOR SYSTEM FOR PREDICTING OCCURENCE OF BREAST CANCER USING FUZZY LOGIC

Breast cancer is often known as the most commonly diagnosed cancer in women today in the world. Most women at various stages undergo different tests to determine if they will develop breast cancer. These tests are commonly used to determine if these women have the BRCA1 and BRCA2 cancer genes. BRCA1 and BRCA2 are human genes that produce tumor suppressor proteins. These proteins help repair damaged DNA and therefore, play a vital role in ensuring the stability of the cell's genetic material. When either of these genes is mutated, such protein product is either not made or does not function correctly.

However, since mutations in these genes account for just a small fraction of all breast cancers, a negative test result doesn't mean the women who go for these tests will be in the clear. Likewise, testing positive doesn't mean the woman might have breast cancer in the future. Early detection of breast cancer improves the chances of a curative treatment and a lot of progress has been made in this field during the last decade. Screening and diagnosis techniques have enhanced early detection of breast cancer over the years. Some of these screening and diagnostics techniques include:

i. Breast self-examination: The American Cancer Society (ACS) stated that every woman should start monthly breast self-examination at the age of 20. An analysis carried out on 12 studies involving 8,118 patients with breast cancer correlated the performance of breast self-examination with tumor size and regional lymph node status. Women who performed breast self-examination were more likely to have smaller tumors and less likely to have axillary node metastases than those who did not. This technique has been flawed due to the fact that it is rarely performed well.
ii. Clinical breast examination: Women are recommended to begin clinical breast examination at age 20. This was stated by the American Cancer Society. They are also recommended to have an examination every 3 years between ages 20 and 39.
iii. Mammography: The American Cancer Society, the American College of Radiology, and the American Medical Association each have since updated their guidelines since 1997 and recommend annual mammography beginning at age 40. The National Cancer Institute (NCI) also updated their guidelines in 1997. They recommended that women should undergo screening mammography every 1-2 years beginning in their 40s.

A. Fuzzy Logic Model

The proposed fuzzy logic model will use the Mamdani fuzzy logic approach. The Mamdani approach was chosen because it is widely accepted for capturing expert knowledge, flexible, uses defuzzification technique, and has output membership functions.

The Mamdani model in this research was designed based on various potential breast cancer risk factors. Some potential breast cancer risk factors include:

i. Age: The risk of developing breast cancer increases with age. It has been found that rates are generally low in women younger than 40. This rate increases after age 40 and are highest in those 70 and above.
ii. Sex: Majority of breast cancer cases are normally associated with females. Breast cancer also occurs in males but it is very rare.
iii. Family History: Women who have relations like a mother or sister with breast cancer have a greater risk of getting breast

cancer. The risk is multiplied if the woman has multiple relatives who have the disease.

iv. Alcohol: Research consistently shows that drinking alcoholic beverages -- beer, wine, and liquor -- increases a woman's risk of hormone-receptor-positive breast cancer. Alcohol can increase levels of estrogen and other hormones associated with hormone-receptor-positive breast cancer. Alcohol also may increase breast cancer risk by damaging DNA in cells.

v. Menarche Age: Early menstruation in a woman can increase the risk of breast cancer. This is possible because an early period exposes a woman's body to greater amounts of estrogen (reproductive hormone in a woman) over her lifetime. Increased levels of estrogen in a woman over a long period of time can increase the risk that cells in the breast will become cancerous.

vi. Age at Menopause: Women who have menopause at a later age have higher risk of being diagnosed with breast cancer. This is possible because an early period exposes a woman's body to greater amounts of estrogen (reproductive hormone in a woman) over her lifetime. Increased levels of estrogen in a woman over a long period of time can increase the risk that cells in the breast will become cancerous.

vii. Number of Births: Women who have less than 2 children have a higher risk of breast cancer. The reason is that pregnancy changes hormone levels and breast tissue in a way helps to protect breast cells from becoming cancerous. The more pregnancy a woman has, the more her breast tissue changes and the more protection she gets.

viii. Birth Weight: A woman who weighs more when she gives birth has a higher risk of breast cancer before menopause. Researchers are not sure yet why this occurs but studies are being conducted on different influences like pregnancy hormones and other prenatal factors to learn more about breast cancer development.

ix Tumor Size: Tumors occur as a result of formation of mass tissue which is caused by the continuous splitting and dividing of cells without control thus creating excess cells which are not needed. Tumor size measured in centimeters (cm) ranges from 0.1 – 5.0cm. Women with tumor size < 1.0cm have lower risk than women with tumor size >= 5.0cm

After reviewing the above potential risk factors, a few factors were chosen to be incorporated in the model. These factors are: age, menarche age, family history, alcohol intake, and tumor size. In accordance to these chosen factors, membership functions were created using the Triangular Membership Function. The architecture of the breast cancer system which involves the input variables, membership functions, rules and the defuzzification process which produces the crisp value is presented in Figure 1

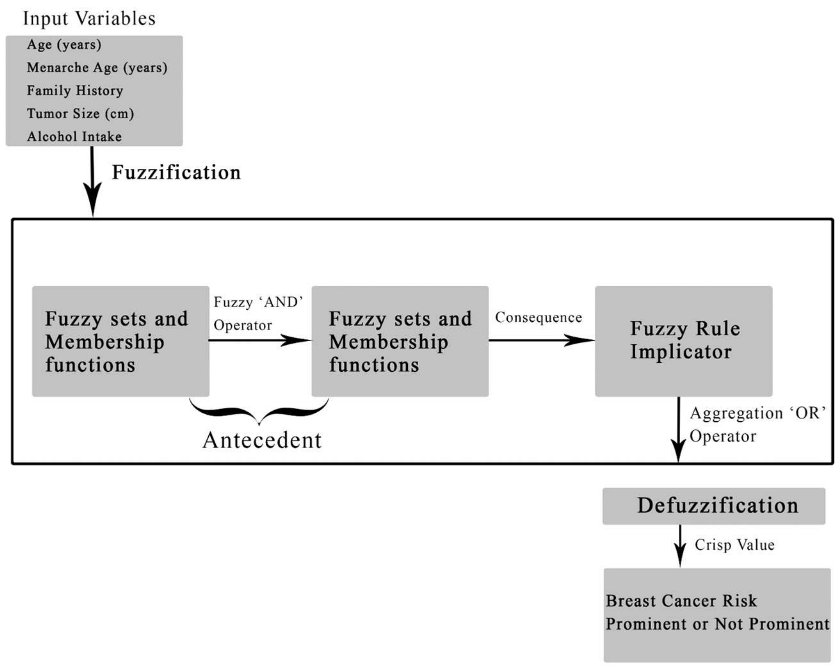

Figure 1: Architecture of the Breast Cancer Fuzzy Inference System

B Linguistic Variables

Tables showing the various linguistics variables for the design are in Tables 1 – 4.

TABLE 1: LINGUISTIC LABELS FOR FUZZY VARIABLES

S/NO	PARAMETERS	LINGUISTIC LABELS
1	Age	Range one(R1), range two(R2), range three(R3), range four(R4)
2	Menarche Age	Early(EL), normal(NM), late(LT)
3	Family History	YES, NO
4	Tumor Size	Small(SM), medium(MD), large(LG)
5	Alcohol Intake	Less(LS), more(MR)
6	Breast Cancer Risk	Low risk(LR), risky(RS), high risk(HR)

TABLE 2: NUMERICAL VARIATION INTERVAL FOR INPUT VARIABLES

INPUT VARIABLES	MIN VALUE	MAX VALUE
Age	40	100
Menarche Age	10	15
Family History	0.1	1.0
Tumor size	0.1	5.0
Alcohol intake	0.1	1.0

TABLE 3: NUMERICAL VARIATION INTERVAL FOR OUTPUT VARIABLES

OUTPUT VARIABLES	MIN VALUE	MAX VALUE
Breast cancer risk	0%	100%

TABLE 4: LINGUISTIC LABELS AND THEIR RANGES

S/NO	PARAMETERS	RANGE
1	Age	Range one: 40 – 49 Range two: 50 - 59 Range three: 60 - 100
2	Menarche age	Early: 10 – 11

		Normal: 12 - 13 Late: 14 - 15
3	Family History	Yes: 0 - 0.5 No: 0.6 - 1
4	Tumor size	Small: 0.1 - 1.0 Medium: 1.1 - 2.0 Large: 2.1 - 5.0
5	Alcohol intake	Less: 0.0 - 0.5 More: 0.6 - 1
6	Breast cancer risk	Low risk: 1 – 33.3% Risky: 33.4 – 66.6% High risk: 66.7 – 100%

C. Rule Base

The defined rules for the risk-factor system for predicting the occurrence of breast cancerusing fuzzy logic is presented in Table 5

TABLE 5: DEFINED RULES FOR THE FUZZY MODEL

Rule number	Age	Tumor size	Menarche age	Alcohol intake	Family History	Output: breast cancer risk
1	R1	SM	EL	LS	YES	LR
2	R1	SM	EL	LS	NO	LR
3	R1	SM	EL	MR	YES	RS
4	R1	SM	EL	MR	NO	LR
5	R1	SM	NM	LS	YES	LR
6	R1	SM	NM	LS	NO	LR
7	R1	SM	NM	MR	YES	RS
8	R1	SM	NM	MR	NO	LR
9	R1	SM	LT	LS	YES	LR
10	R1	SM	LT	LS	NO	LR
11	R1	SM	LT	MR	YES	RS
12	R1	SM	LT	MR	NO	LR
13	R1	MD	EL	LS	YES	HR
14	R1	MD	EL	LS	NO	RS
15	R1	MD	EL	MR	YES	HR
16	R1	MD	EL	MR	NO	HR
17	R1	MD	NM	LS	YES	RS
18	R1	MD	NM	LS	NO	RS
19	R1	MD	NM	MR	YES	HR
20	R1	MD	NM	MR	NO	RS
…	…	…	…	…	…	…
60	R2	MD	LT	MR	NO	RS
61	R2	LG	EL	LS	YES	HR
62	R2	LG	EL	LS	NO	HR
63	R2	LG	EL	MR	YES	HR
64	R2	LG	EL	MR	NO	HR
65	R2	LG	NM	LS	YES	HR
66	R2	LG	NM	LS	NO	RS
67	R2	LG	NM	MR	YES	HR
68	R2	LG	NM	MR	NO	HR
69	R2	LG	LT	LS	YES	HR
70	R2	LG	LT	LS	NO	RS
71	R2	LG	LT	MR	YES	HR
72	R2	LG	LT	MR	NO	HR
73	R3	SM	EL	LS	YES	RS
74	R3	SM	EL	LS	NO	RS
75	R3	SM	EL	MR	YES	HR
76	R3	SM	EL	MR	NO	RS
77	R3	SM	NM	LS	YES	RS
78	R3	SM	NM	LS	NO	RS
79	R3	SM	NM	MR	YES	HR
80	R3	SM	NM	MR	NO	RS

IV IMPLEMENTATION OF A RISK-FACTOR SYSTEM FOR PREDICTING OCCURENCE OF BREAST CANCER USING FUZZY LOGIC

We presented the necessary development and implementation requirements for actualizing the Breast Cancer Prediction System, it also describes and explains the necessary procedures to be followed. These procedures are to be followed for the development, testing, and implementation of the proposed system and other development and/or implementation related issues. The development tools used for the design and implementation of the system are; Matrix Laboratory (MATLAB), Microsoft Visual Studio and C# based fuzzy logic library.

A. Implementation of the Model with Matlab

The Mamdani Fuzzy Logic for the Model is in Figure 2

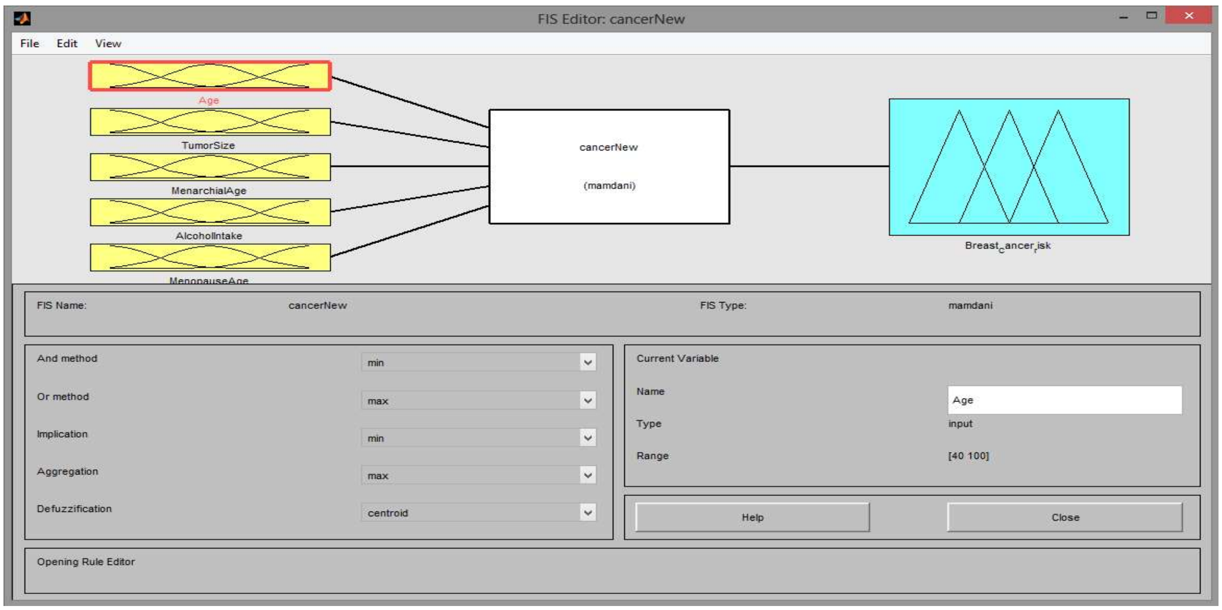

Figure 2: Mamdani Fuzzy Logic for the Model

B. Creating Membership Functions

Membership functions are created using the membership function editor. The following steps are used for the specification of the input/output membership functions:

i. Select each of the input/output membership variables
ii. Set both the range and display to the vector
iii. Select add MF's from the edit menu. (Hint: this adds MF's to the
iv. chosen input variable)
v. Select membership function type for the added MF's e.g. trimf, which is the triangular membership function
vi. Pick each MF and give appropriate linguistic variables with their corresponding ranges

C. Membership Functions

The input membership functions used for the design are presented in figures 3 – 7

i. Age

The age input variable which comprises of three triangular membership functions. The display range ranges from [40-100] is as presented in Figure 3.

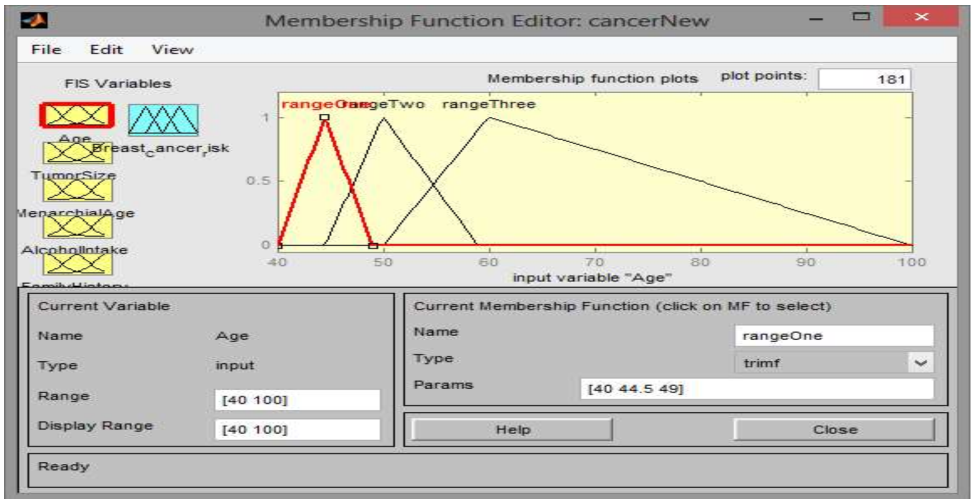

Figure 3: Age input variable

ii. Menarche Age

Figure 4 shows the menarche age input variable which comprises of three triangular membership functions and the display range ranges from [10-15]

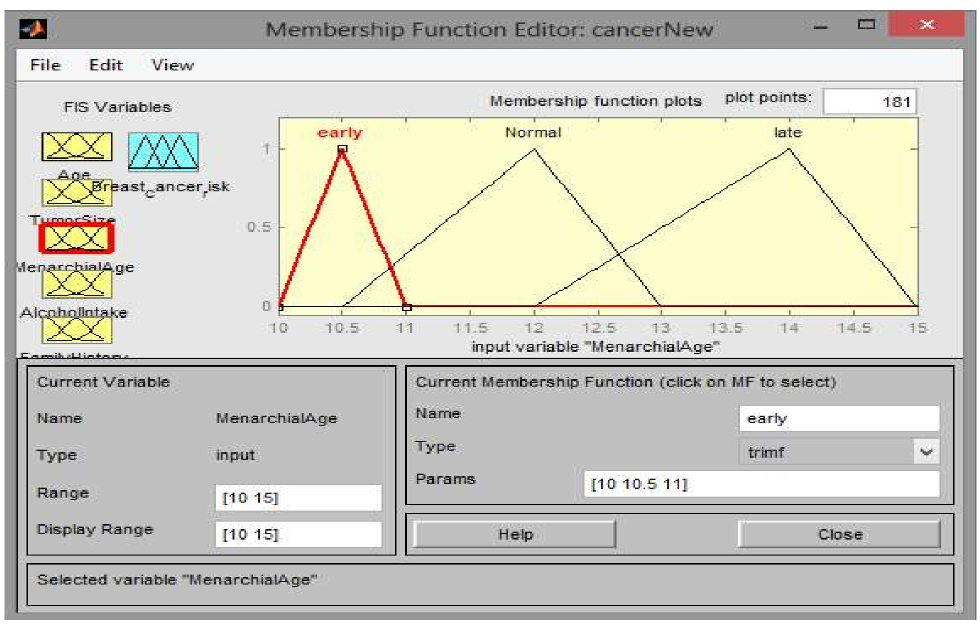

Figure 4: Menarche age input variable

iii.Family History

The family history input variable which comprises of two triangular membership functions. The display range ranges from [0-1] is in Figure 5

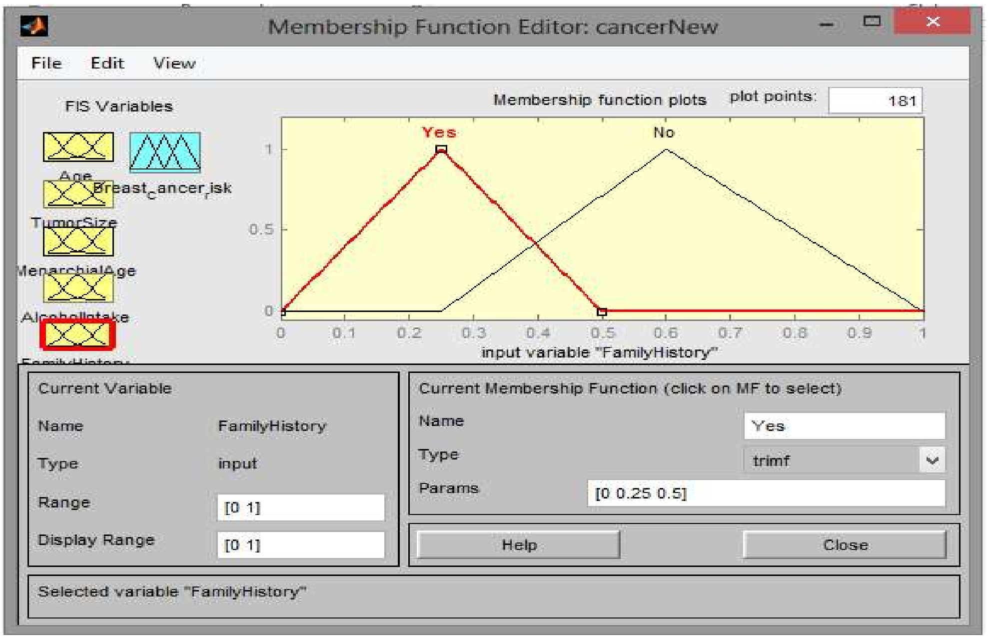

Figure 5: Family history input variable

iv. Tumor Size

The tumor size input variable which comprises of three triangular membership functions and the display ranges from [0-5] is as shown in Figure 6.

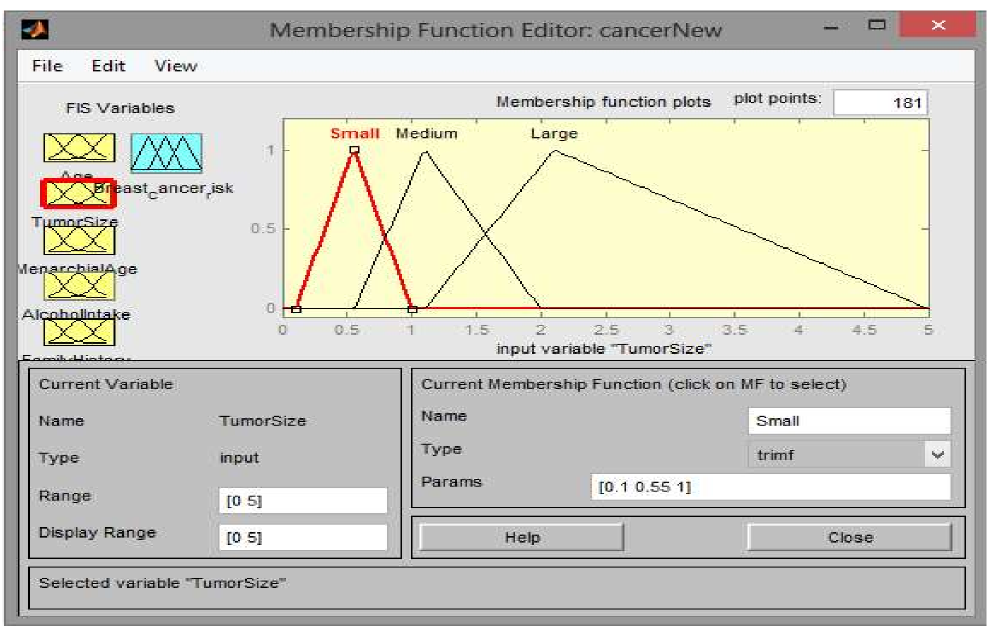

Figure 6: Tumor size input variable

v.Alcohol Intake

The alcohol input variable which comprises of two triangular membership functions and the display ranges from [0-1] is in Figure 7.

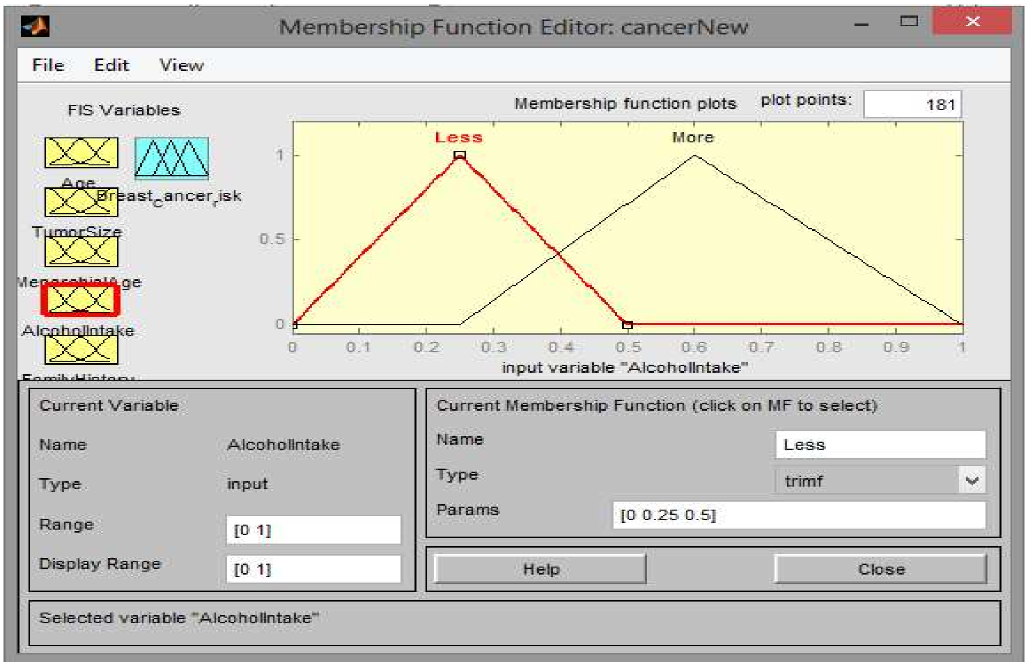

Figure 7: Alcohol intake input variable

d.Output Membership Function

The breast cancer risk-output variable which comprises of three triangular membership functions and the display ranges from [0-100] is presented in Figure 8.

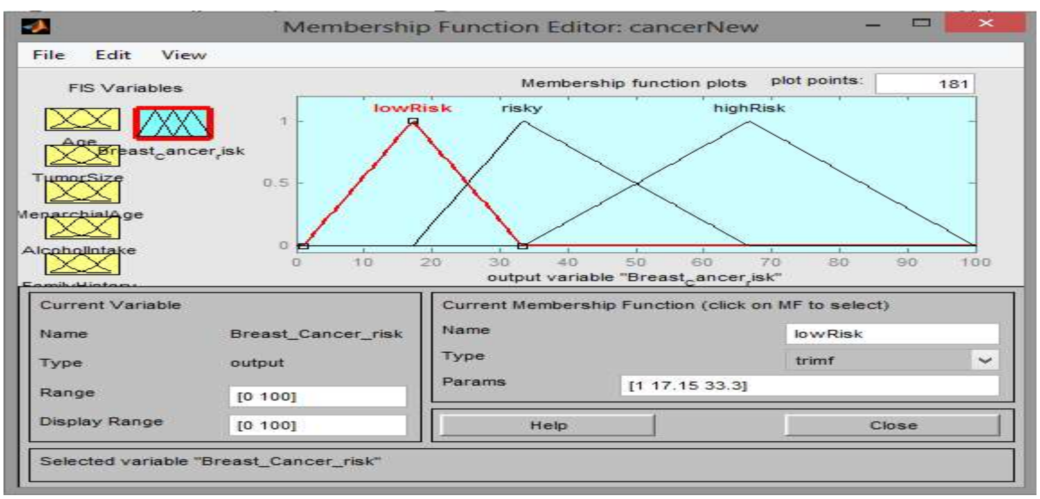

Figure 8: Breast cancer risk output variable

e.Rule-Base

After the determination of membership functions and membership degrees for the system, fuzzy logic model formed. Rules of the fuzzy logic model were determined using acquired data and expert opinions. A total of

108 rules were generated. The Fuzzy model rule editor and Fuzzy model rule viewer are presented in Figures 9 and 10 respectively.

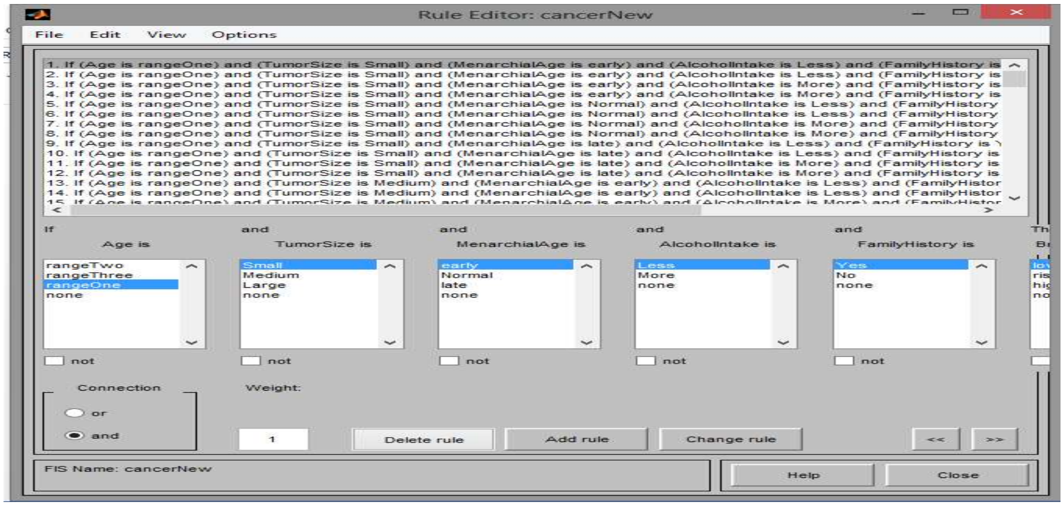

Figure 9: Fuzzy model rule editor

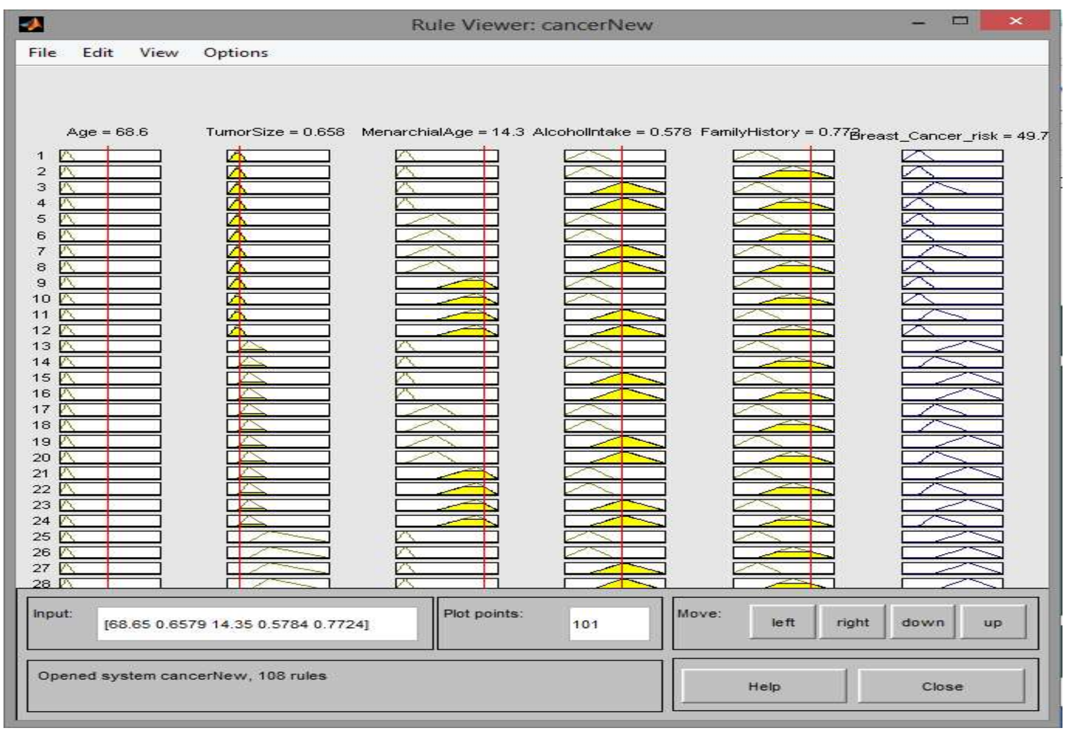

Figure 9: Fuzzy model rule editor

f. Graphical User Interface Documentation

The interfaces of the Breast Cancer Risk Expert System application are in Figure 11. The Risk Analysis Form is the form that is used to determine the breast cancer risk of a patient. The form is powered using a fuzzy logic library. Users are required to fill in all fields appropriately. After all fields have been filled appropriately, the user is then required to click the 'Check Risk' button which shows the user the risk value of the patient being analyzed.

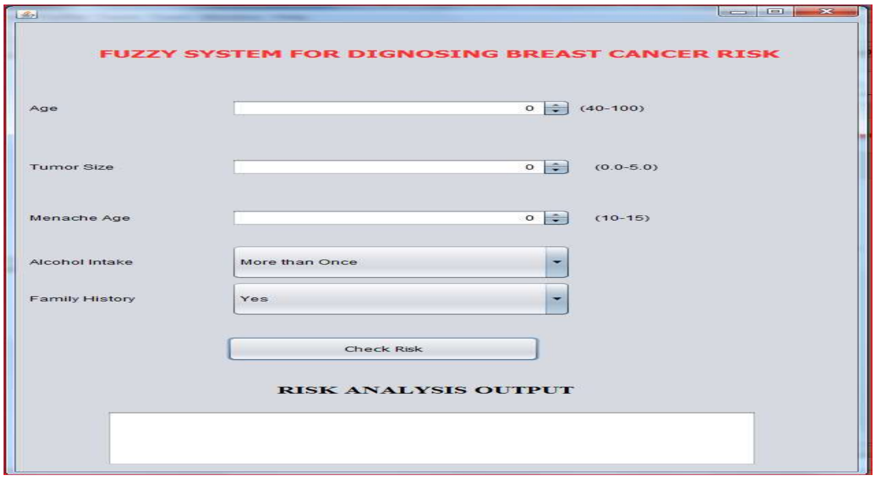

Figure 11: Risk Analysis form

g. System Test

The validity of the presence of breast cancer in a patient is done through the risk analysis dialog box (Fig .12).

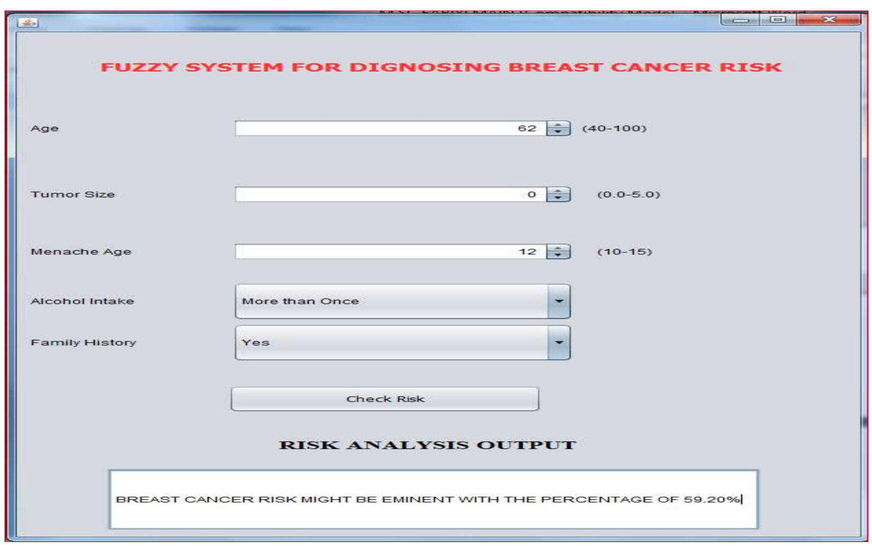

Figure 12: Risk analysis form test

V. CONCLUSION

The dramatic rise in the incidence of breast cancer in the recent time has necessitated the government to initiate specific measures to increase awareness and educate women to seek early medical advice when they experience breast symptoms. Given that most women display positive attitudes towards breast cancer screening, therefore there is an opportunity to develop a system for early detection of the ailment.
This simple, inexpensive technique would be more acceptable to diagnose patients early, rather than the expensive and resource-intensive mammography procedures recommended in high-income countries in addition to breast self-examination and clinical breast examination. Early detection of breast cancer is one of the most important means or tools for successful treatments. In this research work, a desktop based medical expert system using the Mamdani fuzzy logic approach for standardized prediction has been developed and implemented to predict the presence of breast cancer in a woman. The system alongside other medical examinations and tests would help medical practitioners predict the presence of breast cancer.

This research work has been designed to help its users to predict the future occurrence of breast cancer in women but it's still dependent on some other medical examinations. The fuzzy logic model used in this research work utilizes only a few risk factors for its prediction. The system can be improved further by considering other relevant risk factors which can be beneficial to the improvement of the system. Other models for prediction can also be used to enhance this research work. One of these models is known as the Artificial Neural Fuzzy Inference System (ANFIS).

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