Image Incorporated Mammogram and Ultrasound Based Expert System for Breast Diseases

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Abstract

Every woman in the world is at risk for breast cancer. In Malaysia alone, recent statistics show that breast cancer is the number one cause of cancer-related deaths among women. Early detection is most vital for good prognosis and mammography proves to be the best method of detection. Women who are in the high risk group should consider having their first baseline mammograph taken. Most Asian countries have not implemented mass screening as yet. If so, radiologists would be faced with an increased caseload, thereby elevating the chances of improper diagnosis. In practice, both mammography and ultrasound investigations are frequently used to assess breast lesions after undergoing the first assessment i.e. physical examination as the three investigations typically give complementary information. Diagnosticians with the training and experience to interpret mammographic and breast ultrasound images are scarce. An expert system would make diagnostic expertise more widely and readily available in the clinical community. The design and development of an image incorporated mammograph and breast ultrasound expert system has been detailed in this paper. Possible extension to this would be to embed image processing modules on the image based mammograph and breast ultrasound expert system.

Keywords

Expert System, Breast Cancer, Mammogram, Breast Ultrasound

1. Introduction

In Malaysia alone, approximately one in twenty women will be inflicted with breast cancer by the age of seventy. By the age of 85, women have a one in eight chance of developing breast tumour. In the year 2000, almost 4,000 newly diagnosed cases emerge in the country. Of these, nearly 45 % result in deaths, making it the number one cause of cancer-related deaths in Malaysian women [1].

Mass screening as a first baseline mammograph for women above a certain age has been implemented as a health policy and practice in other parts of the world. The practice has resulted in a decrease in severe breast cancer and an increase in mortality due to earlier detection and treatment. Should Malaysia decide to follow suit i.e. embark in implementing mass screening, radiologists would be faced with an increased caseload, thereby increasing the chances of improper diagnosis.

Diagnosticians with the training and experience to interpret mammographic and breast ultrasound images are scarce. An expert system would make diagnostic expertise more widely and readily available in the clinical community.

In the early period of a doctor's professional activity, an expert system would prove valuable in minimizing the troubles that he might face due to inexperience. The existence of such facilities could be helpful especially for young radiologists or non-specialists.

As the expert system contains specific rule base for the differentiation of breast diseases, it may be utilized both to help train physicians in mammography and breast ultrasound to promote a more consistent mammographic and ultrasound interpretation.

The criteria for interpreting imagery is subjective and variable. With the help of an expert system, the diagnostic criteria can be made more explicit. This would serve as a basis for consistent and reproducible diagnoses. At the same time, it would also form the basis

for discussion and further research to improve the validity of the diagnostic criteria.

In this paper, an image incorporated mammograph and breast ultrasound expert system has been described and detailed.

2. The Methodology in Developing the Mammogram and Ultrasound Based Expert System

In practice, mammography and ultrasound investigations are both frequently used to assess breast lesions after undergoing the first assessment i.e. physical examination. This is because the three investigations typically give complementary information [2]. Hou et al has also advocated this in Taiwan [3].

Medical images in digital format enable analysis with computer vision and artificial intelligence techniques. Computer-aided diagnosis acts as a second opinion in detecting lesions and in making diagnostic decisions. The radiologist can then make the final diagnosis and decisions on patient management. Computer analysis methods uses lesion features extracted by either a computer or radiologists. Artificial intelligence techniques include feature selection methods and in CAD schemes include rule-based methods, discriminant analysis, Baysian methods, artificial neural networks and fuzzy logic [4].

Cook and Fox's study had been confined to specifically one characteristic of mammography feature, namely circumscribed breast lesions [5]. This paper further expands this concept. Other manifestations and features seen in mammograms[6] and also features encountered in breast ultrasound has been included in this study. In addition, another capability has been added i.e. while the expert system is being executed, images of mammogram and ultrasound can be referred and called upon to be viewed and assessed by users to assist in answering the queries displayed by the expert system.

The basis of development of the whole system is summarized in Figure 1.

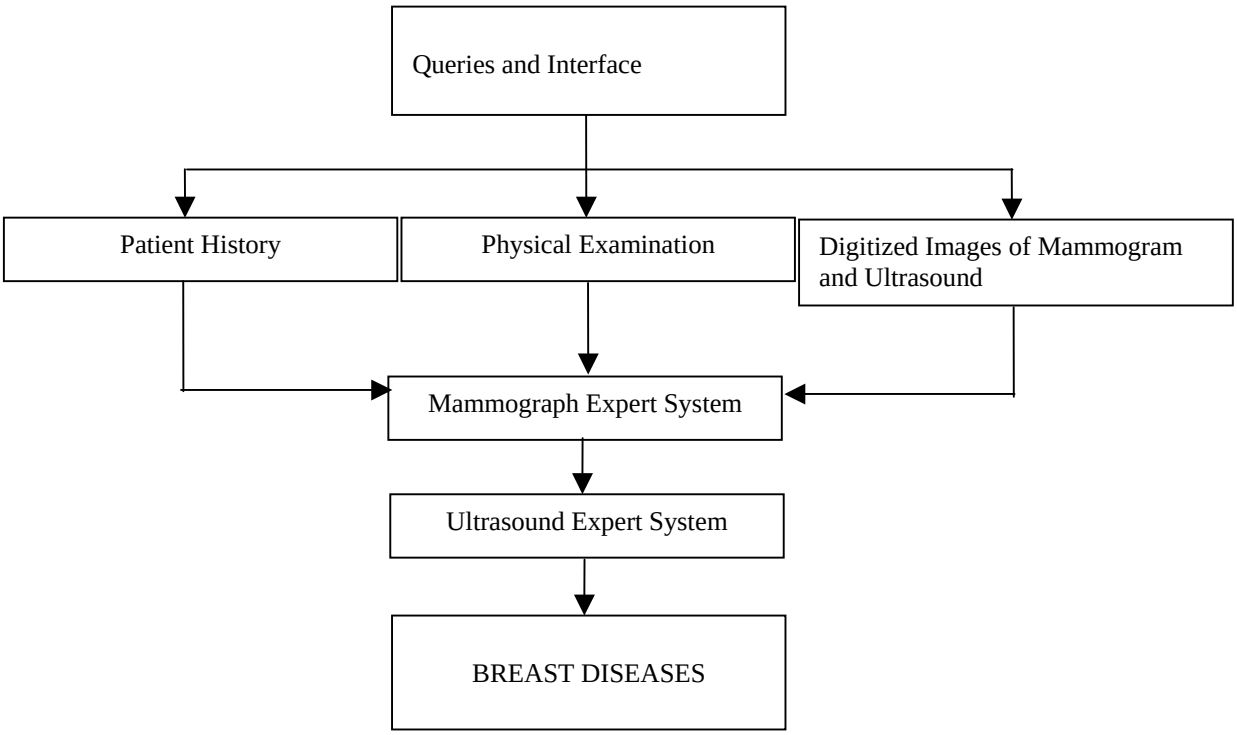

Figure 1. The Expert System Functional Architecture

3. The Development of the Rule-Base for the Expert Systems

Careful medical history and physical examination are the first and most important steps in identifying patients' risk factors. These form part of the rule base system.

The factors assessed by doctors during charting the patient's history would include the patient's reproductive history, history of breast diseases, history of trauma, hormonal manipulations and the patient's own symptomatic complaints. The physical examination would ascertain symptoms based on visual inspection and on palpation by the health provider.

Physical examination has its limitations in that a tumor has to be of a certain size to be felt and is of a certain consistency from the adjacent tissues to be differentiated from them. Therefore other modalities are to be included for assessment in the expert system that is namely, mammography and the breast ultrasound.

The results of patients' history, physical findings, mammographic signs together with findings from the ultrasound are combined together to differentiate further in the diagnosis of the breast disease.

The different criteria for observation on the two modalities i.e. mammography and ultrasound will be listed.

a. Signs pertaining to mammography

There are certain mammographic signs that help to indicate and differentiate whether an abnormality is benign or malignant [7].

Each mammogram is assessed for:-

- signs of asymmetry
- presence of mass/masses
- presence of calcifications
- skin, nipple and trabecular changes
- axillary nodal abnormalities

b. Signs pertaining to the breast ultrasound

As in mammograms, certain characteristics observed in the breast ultrasounds indicate classification features.

Table 1 shows the criteria for differentiating cystic and solid lesions while Table 2 lists the criteria for classifications of normal soft tissues [7,8].

Table 1. The criteria for differentiating cystic and solid lesions

	Characteristics	Cystic	Solid
1	internal echoes	no	yes
2	posterior details	enhancement	shadowing
3	echoes from boundaries	smooth	jagged
4	shape of mass	spherical	irregular
5	surrounding tissues	compressed	reactive

Table 2. The criteria for classifications of normal soft tissues

	Characteristics	Properties
1	magnitude	strong, medium, small
2	texture of echoes	coarse, medium, fine
3	overall distribution	uniform, granular, complex
4	Internal structures	present, absent
5	attenuating property	High, medium, low

4. Developing Prototypes

Diagnosis of breast diseases requires a more thorough investigation of all possibilities and procedures. Moreover, there is a poorly structured collection of many isolated facts and it is unclear what kinds of distinctions between the facts are the important ones. It is necessary to solve the possibilities by heuristic or appropriate methods which do not require perfect data and the solutions derived by the system may be proposed with varying degrees of certainties. Also, it is important to obtain explanations that indicate how the expert system arrived at the answer and justifications to be made for the knowledge itself. Therefore the use of rules or assertions is preferred to represent the knowledge.

The creation of the rule base proceeds from discussions with practicing clinicians and radiologists and from the extraction of rules from texts and journals on mammography and ultrasound.

In the development of the initial version of the **Mamm**ograph **Ex**pert System (MAMMEX) and **B**reast Ultras**ound Ex**pert System (BOUNDEX), several key decisions regarding the components which make up a knowledge base are addressed including the selection of a certainty system. This system provides the range of certainty values which can be assigned to each rule in the knowledge base. To make results easy to interpret, a certainty system provides groupings between 1 and 10 with 10 as a base. The certainty values are based on six classes indicating varying degrees of successes that could

be expected when consultation takes place. The six certainty classes are given in Table 3.

Table 3. Certainty classes

very unlikely	-0, 1
unlikely	-2, 3
uncertain	-4, 5
certain	-6, 7
definite	-8, 9
most definite	

-

1
0

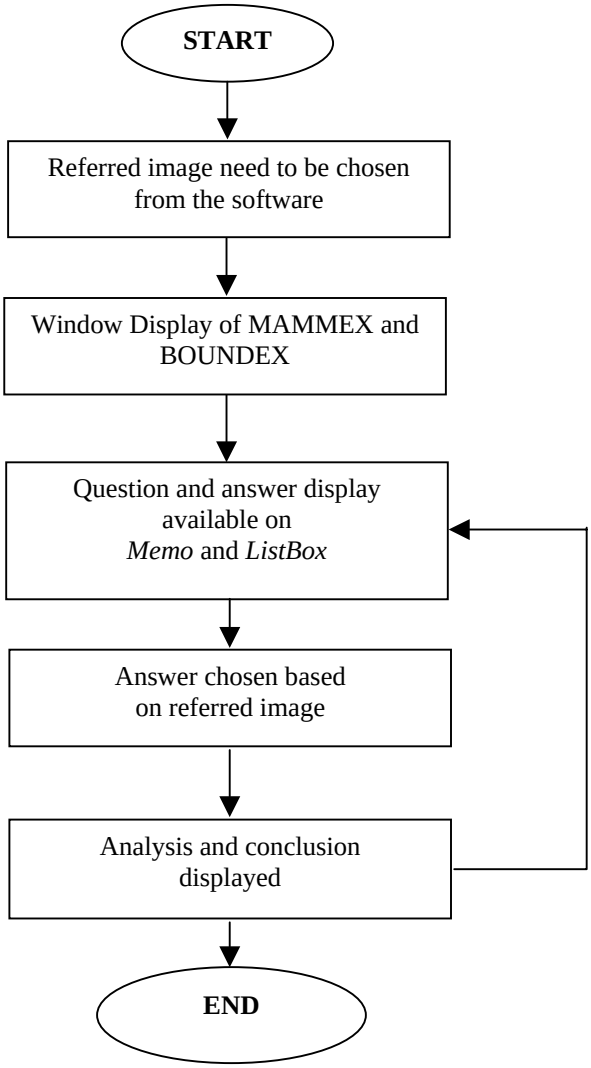

Figure 2. The MAMMEX and BOUNDEX Expert System Usage

5. The Execution Process of the Mammograph and Breast Ultrasound Expert System

In a simplified way, the execution process of the mammograph expert system (MAMMEX) and breast ultrasound system (BOUNDEX) is shown in Figure 2 below.

It was envisaged that the expert systems have the following features, namely

a. Referred Image - images of patients that would be necessary to be referred while running the expert system, can be chosen and would be made available in the *Patient Image* window.

b. Patient's Name - the patient's name whereby the image being referred is made available and noted automatically by the software.
c. Question Window - questions pertaining to the mammograph or ultrasound features observed will be displayed automatically at the beginning of the Medical Expert consultation session. This is followed by the multiple answers ListBox.
d. Answer - the answers displayed in the ListBox can be chosen by clicking the correct choice of answers of the mutiple choice given. The image of the particular patient is readily available for viewing and analysis purposes.
e. Conclusion - the diseases that are highly likely to be associated with the answer given will be displayed together with a percentage of certainty.
f. Analysis - the listing of answers chosen during the program execution will be displayed.

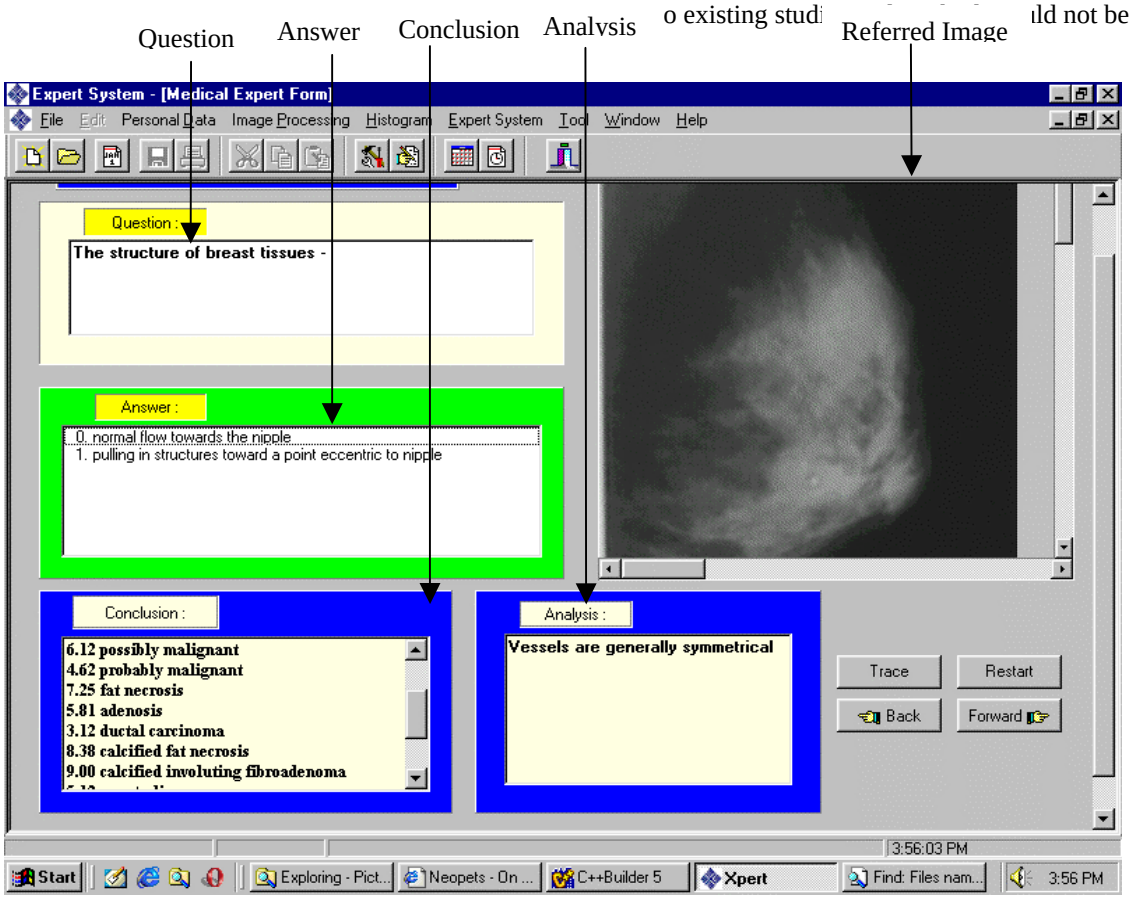

Figure 3.The front -end interface for MAMMEX

In addition to these, it options and buttons are

i. Restart - for analysing purposes and to accommodate the user to redo the whole process from the very beginning,
ii. Trace - this enables the user to examine the answers, the particular image being referred and the conclusion of the whole process of execution of the expert system.
iii. Back - to return to the previous question.
iv. Forward – to return to the question answered prior to the activation of the back button.

6. Discussion

As the design of the mammography and breast ultrasound expert system is still in its prototype stage, many improvements and adjustments are to be made. Discussions and consultations with radiologists are being continued. Specifically, efforts to accumulate available data in the form of digitized images of the same patients who have undergone both mammography and ultrasound simultaneously are being intensively carried out and documented. This involves a lot of effort and time as these data are found to be scarce. As such, comparisons o existing studi ld not be made as yet.

ing modules are intended to be used and executed on the collection of data images to further assist users of the expert system in answering the queries in the expert system. Plans to incorporate a knowledge base have also been considered.

Having decided upon all the necessary features of the expert systems, the front end was designed accordingly. A sample of the opening display for MAMMEX is shown in Figure 3. Figure 4 illustrates the sample display for BOUNDEX.

7. Results

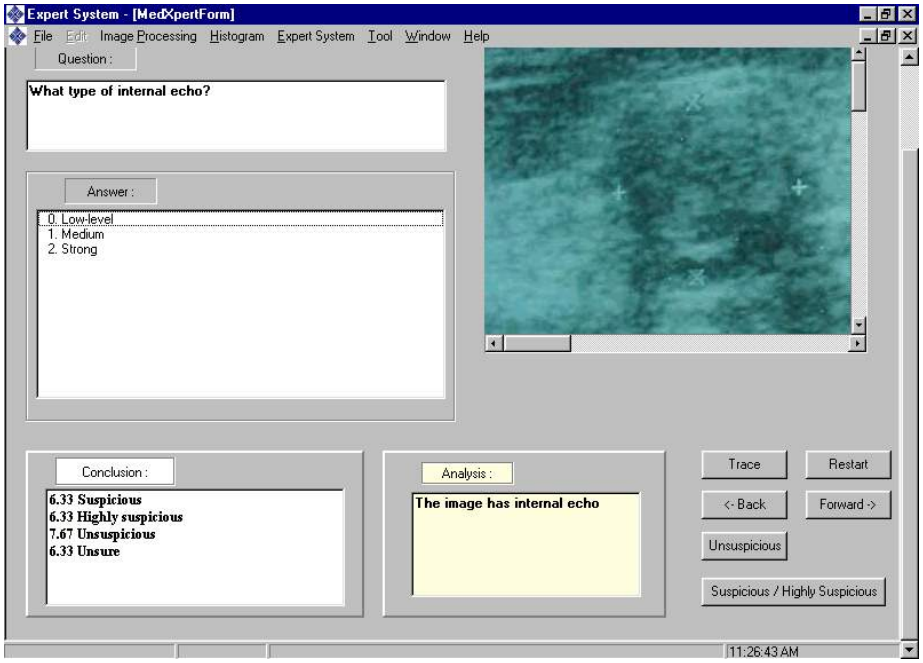

Figure 4. The front end of the BOUNDEX interface

8. Conclusion

As mammography and ultrasound investigations are both frequently used in practice to assess breast lesions after undergoing the first assessment i.e. physical examination, an attempt has been made to design an experts system based on these modalities. This would facilitate diagnostic expertise more widely and readily available in the clinical community whereby diagnosticians with the training and experience to interpret mammographic and breast ultrasound images are scarce. The design of an image incorporated mammograph (MAMMEX) and breast ultrasound expert system (BOUNDEX) has been detailed in this paper. Work ensued will include the usage of image processing modules to further enhance and highlight characteristic features that will be able to assist the end user in identifying and answering the questions forwarded by the expert system. The incorporation of a knowledge base would also prove to be valuable.

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