An Expert System To Determine The Bone Diseases

by

Shuhada Binti Md. Rifin

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

SHUHADA BINTI MD. RIFIN

ABSTRACT

An expert system named BONNEX to diagnose bone diseases, being one of artificial intelligence (AI) applications, has been developed in this work. This expert system is utilizing the expertise from orthopedics and other resources. BONNEX is used to perform diagnoses based on patient's data, clinical examination data and other relevant sources in the same way as an expert can do. With the help of the expert system, the non experts can perform the decision making process in the same way as the experts.

BONNEX would make experts' diagnostic capability more widely available in the clinical community. BONNEX will aid inexperienced orthopedics or general practitioners working in small medical centers and rural areas to diagnose the nature and conditions of the bone diseases amongst patients before it can be referred to the expert doctors and orthopedic who will be normally be available in the big hospitals or medical centers which are far away from patients' location. It is hoped that with the early detection of the bone diseases, further and immediate therapies can be taken to cure the diseases

The elements needed in developing the expert system are user interface, database, knowledge base, explanation facility and inference engine. The users interact with the system through a user interface.

The database of the system contains expert-level knowledge on bone diseases and the information is obtained from interviews with the expert orthopedics and research from books, websites and journals. After the bone diseases are determined, the signs and symptoms of the diseases are verified and classified into three categories. The data is re-arranged into systematic representation. The decision table is prepared for the system. The decision table is the representation of the findings to ease the expert system development. It lists out the diseases in one axis and the corresponding symptoms into another axis.

The knowledge that the expert system uses is made up of set of IF-THEN rules. It serves as the heart of the 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 five classes indicating varying degrees of successes that could be expected when consultation takes place. The expert system shell, EXSYS will then generate the rules and perform the platform of the system. The system will ask the set of questions needed to the users, store the results, perform the heuristic search procedure and display the results.

The explanation facility provides the reasoning facility and justifies the system's conclusion. Inference engine helps the programmer to locate and correct bugs in the program's performance, assists in the addition of new knowledge, helps to maintain correct rule syntax, and perform consistency checks on the updated knowledge base.

The doctor has to refer to x-rays to diagnose the bone diseases. But raw x-rays will contain lot of noises and the features of particular diseases may not be clear. So, the x-ray image will be digitized and the digitized image is used by the doctor in diagnosing the bone diseases.

However, BONNEX, an expert system to determine the bone diseases is an expert system developed with limited capability of diagnosing the wide range of bone diseases. BONNEX is only capable of diagnosing 25 types of common bone diseases in Malaysia. It still cannot be represented as the powerful tool in accurately diagnosing the bone diseases. The expert system need to be redeveloped and more effort should be put to increase its level of precision.

It is hope that the system can be beneficial to the society. Despite its limitations, it is hoped that the system could be a breakthrough to many inventions of the other expert system in the medical applications, especially in diagnosing the bone diseases.

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In the name of Allah, the Most Gracious, the Most Merciful. To Prophet Muhammad Bin Abdullah, leader of anbiya' and shalihin, peace be upon him. My greatest gratitude goes to the Creator, Allah s.w.t. for showering His invaluable strength in the completion of this two-semesters Final Year Project. Together, I am able to present this final report as a part of the assessment.

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ABBREVIATIONS AND NOMENCLATURES

AI - Artificial Intelligence

IS - Information System

PC – Personal Computer

CHAPTER 1

INTRODUCTION

1.1. BACKGROUND

Bones perform a number of essential functions such as support and protect internal organs, act as levers and braces for muscles to help the body moving as well as produce and store blood cells in the bone marrow. Bones are actually living and growing tissue. Throughout a person's lifetime, old bone is removed (resorption) and new bone is added to the skeleton (formation). According to the National Institutes of Health, three types of tissue can combine to make up mature bones:

- compact tissue (the hard outer portion of most bones)
- cancellous tissue (spongy tissue inside the bones that contains bone marrow, which makes blood cells)
- subchondral tissue (smooth bone tissue of the joints) -a layer of cartilage covers subchondral tissue to cushion the movement of joints. [29, 31, 33]

However, bones are exposed to various kinds of bone diseases. There are many common types of bone diseases recognized in Malaysia. Some of the classification and the corresponding types of bone diseases are described in Table 1.1. People in Malaysia are at risk of suffering the various kinds of bone diseases and necessary action should be taken to implement the periodic monitoring and health-care advisories for upwards of 20 million Malaysians.

Osteoporosis, for example, is a silent disease in which bones become fragile and more likely to break. Bone loss usually occurs slowly over time. Any bone can be affected, but of special concern are fractures of the hip and spine. It can impair a person's ability to walk unassisted and may cause prolonged or permanent disability or even death. [27, 28]

Table 1.1. The Classification and the Corresponding Types of Bone Diseases

Classification of Bone Diseases	**Examples of Bone Diseases**
Infectious Bone Diseases *Inflammation of bone or joint, usually accompanied by pain.*	Spinal Infections, Chronic Osteomyelitis, Osteoarthritis
Congenital Deformity *Bone deformity present at birth; as a result of either heredity or environmental influences.*	Kyphosis, Lordosis, Scoliosis
Degenerative Bone *Marked by gradual deterioration of bones along with loss of function; sometimes related to degenerative diseases of old age.*	Osteoporosis, Osteochondritis Dissecans
Metastases Bone Diseases *Malignant ("cancerous") deposits from cells*	Spinal Turbeculosis
Bone Tumor and Cancer *Abnormal growth of cells within the bone that may be benign or malignant (cancerous).*	Spinal Tumour, Osteosarcoma, Osteochondroma, Aneurysmal Bone Cyst
Paediatric Bone Diseases *Bone diseases that infected baby or children.*	Legg-Perthes' Diseases, Rickets
Muscle Strain and Dislocated Bone *The bone diseases caused by the muscle stain and slipped disk*	Lumbago, Sciatica, Slipped And Herniating Disk, Muscle Spasms, Spondylolisthesis

1.2. PROBLEM STATEMENT

The wide range of environmental conditions and complex dependencies of the practice of medicine have always being used for test bed for various advanced technologies. The research expansion on the bone diseases area has also spurred, but widespread dissemination and clinical application have not kept pace with the research findings. The reason is because there is lack of expertise in the bone diseases area; especially in the remote area.

The purpose of this study is to develop a system that can utilize the expert's knowledge in the small to medium medical premises to diagnose the various kinds of bone diseases. It is hoped that with the early detection of the bone diseases, further and immediate therapies can be taken to cure the diseases.

There will be highly qualified experts on various subjects in big organizations. However, it may not be possible to pay for such experts in small to medium organizations. It would be desirable to have a simulated expert using the easily available computer systems. This is because the bone diseases are in the increasing trends and the orthopaedic with the training and experience are scarce.

Expert system is one of the methods that can assist the medical practitioner in diagnosing the bone diseases. Expert system would make diagnostic expertise more widely available in the small to medium clinical community. This expert system will aid inexperienced orthopaedics and general practitioners working in small centres, rural areas or developing countries to diagnose the nature and conditions of the bone diseases amongst patients before it can be referred to the expert doctors and orthopaedics that will normally be available in the big hospitals or cities.

1.3. OBJECTIVES AND SCOPE OF STUDY

In this study, an expert system to diagnose bone diseases is developed. An important application could potentially be to facilitate the x-ray diagrams and identify the group of patients susceptible to the types of bone diseases. However, the expert system developed is limited to only diagnose 25 common types of bone diseases. This is because there are various kinds of bone diseases and the time for the project completion is restricted.

Amongst the goals of the development of the expert system are:

- Substituting for an unavailable human expert in bone area; human experts are expensive and scarce.
- Assimilating the knowledge and experiences of several bone experts; so that the idea of experts can be integrated together to enhance and boost up the diagnostic processes.
- Providing equal rights of getting the treatment of bone diseases among the people in the urban and rural areas.
- Training new bone experts; for aiding diagnosticians in some routine and difficult task to improve productivity and effectively manage the complexities
- Providing requisite expertise of bone area on projects that do not attract or retain experts [4, 5, 14]

A consultation system could diminish the troubles the doctor faces due to inexperience, in the early period of his professional activity. The assistance of such facilities could be helpful especially for young orthopaedics or non-specialists. Therefore, the focus of this research is the application of expert systems to elevate the awareness of certain factors that are associated with bone diseases amongst patients and thus determines the degree of suspicion and the necessity for further therapeutics.

Chapter 1 outlines the introduction of the study, which includes the background of the study, problem statement and the objective and scope of study. The study aims to supports and automates decision making in determining the bone diseases to help the people who are suffering those diseases.

Chapter 2 clearly defines the literature review of the expert systems and the key elements to develop the system. In the chapter, the elements needed in developing the expert system are also defined.

Chapter 3 describes the methodology in developing the system. The work on the system begins with the attempt to gain some familiarity with the problem domain by initial interviews with the experts, extracting and collecting information from journals, books and websites, designing the system, and building and testing the prototype.

Chapter 4 outlines the results and discussion of the project progress. The findings include the data collected in the means of information gathered and image.

Chapter 5 outlines the conclusion of the report. It is anticipated that the system could be a breakthrough to many inventions of the other expert system especially in the medical applications.

CHAPTER 2

LITERATURE REVIEW

Human experts are able to perform at high level because they know a lot about their area of expertise. An expert system, for example, uses knowledge specific to a problem domain to provide 'expert quality' performance in that application area. Generally, expert system designers acquire this knowledge with the help of human domain experts, and the system emulates the human expert's methodology and performance.

As with skilled humans, expert systems tend to be specialists, focusing on a narrow set of problems. Also, like humans, their knowledge is both theoretical and practical: the human experts that provide the system's knowledge have generally augmented their theoretical understanding of the problem domain with tricks, shortcuts, and heuristics for using the knowledge they have gained through problem solving experience.

2.1. THE CHARACTERISTICS FEATURES OF AN EXPERT SYSTEM

Expert system differ form conventional systems and have distinctive characteristics, which differentiate them from classical computer systems. These features are described in the following important ways:

- Bounded knowledge domain – the expertise is limited to a specific, narrow domain

- Deductive reasoning is typical – Problems use rules or heuristics to express knowledge. Collection of IF-THEN antecedents and conclusions represent the knowledge. Knowledge rather than data are used to control the solution process.
- The knowledge base and reasoning mechanism are separate – These entities are distinct such that the program executing the reasoning mechanism can analyze different types of knowledge bases. This knowledge is encoded and maintained as an entity separate from the control program.
- Explain it's reasoning – this explanation facility provides a means of describing "Why?" in an understandable way to users. It is capable of explaining how a particular conclusion was reached and why requested information is needed during a consultation.
- Expert systems use symbolic representation for knowledge for example, rules to perform their inference through symbolic computations that closely resemble manipulations of natural language.
- Qualitative aspects – the information processing and output are qualitative or non-algorithmic as opposed to quantitative
- Modular design – an expert system is modular and so growth is incremental and changes are easy to carry out. [4, 5, 14, 15]

Expert systems are most suitable for problem domains when the following conditions exist:

- No procedural algorithm exists but there are heuristics.
- Only limited experts exist or are available.
- Noise exists in available data or it is imprecise.
- The problem is characterized as diagnostic or interpretive.
- Formal reasoning provides a mechanism for solution. [4, 5, 14, 15]

Once a problem satisfies the above criteria, the major advantage for using an expert system is the problem solving aspect. This help to further the understanding of the domain interest.

2.1.1. The Structure of the Expert System

The expert system developed for this project is composed of a user interface, a database, a knowledge base, an explanation facility and an inference engine. Figure 2.1 shows the simplified block diagram of the Expert System architecture. [5]

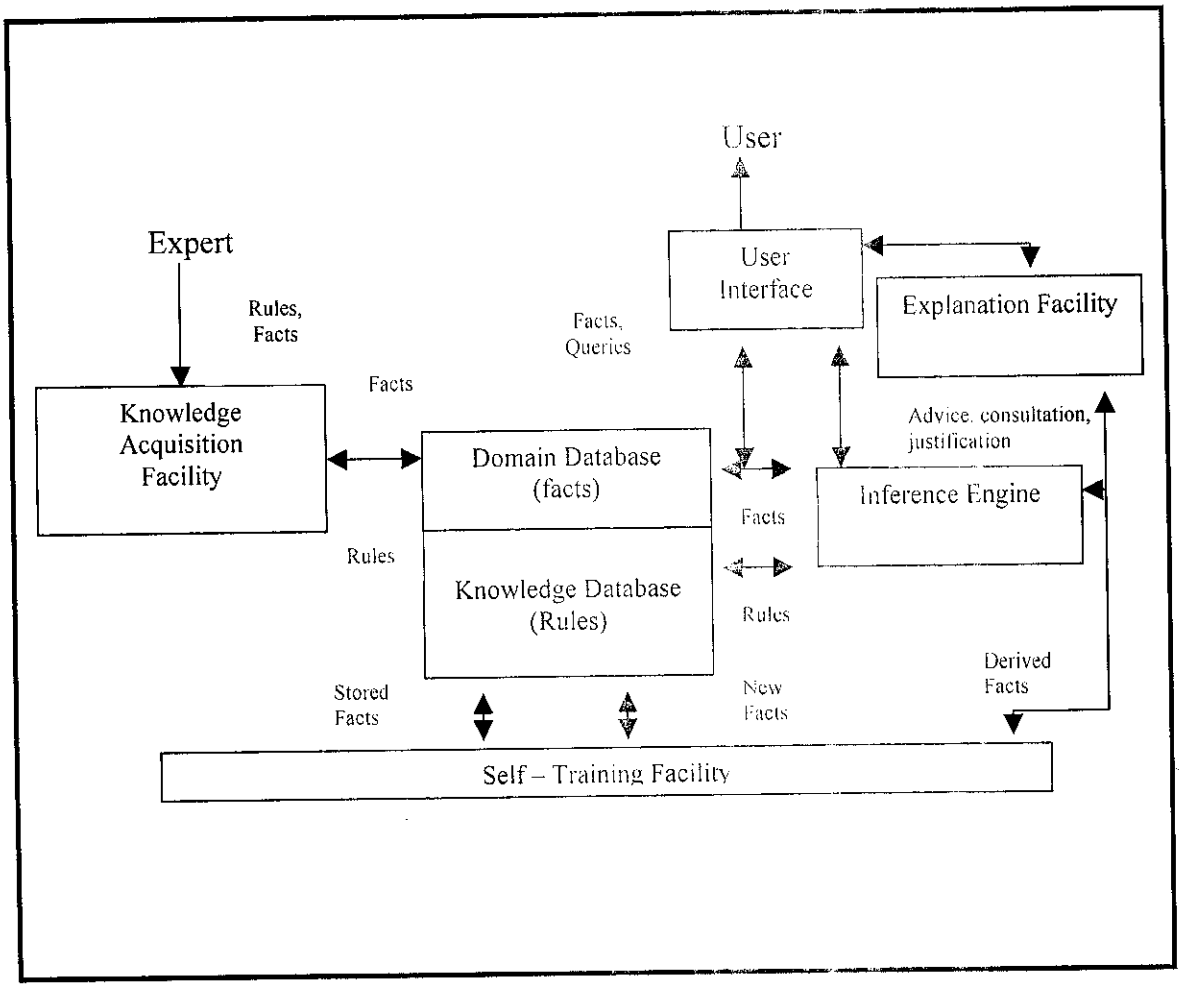


Figure 2.1. Expert System Architecture

2.1.2. The User Interface

The users interact with the system through a user interface that simplifies communication and hides much of the complexity, such as the internal structure of the rule base. The final decision of the interface type is a compromise between user needs and the requirements of the knowledge base and inference system. [4]

2.1.3. The Database

The database contains expert-level knowledge on particular subject. This knowledge is obtained from one or more human experts, books, journal and from other databases and is stored in a knowledge- representational form that is inherent to the expert system design

The database normally contains two types of data; the static data and the dynamic data. In the static data, facts and relations found in the problem domain are stored. Even though these data are fixed, software engineer has capability to upgrade the data in future after few finding in the area available. In other hand, dynamic data is the data, which collected during a consultation session [4].

2.1.4. The Knowledge Base

The heart of the expert system is the knowledge base, which contains the knowledge of a particular application domain. The knowledge base contains both general knowledge as well as case-specific information. The knowledge that the expert system uses is made up of either a set of rules or experience of information about the behaviour of the elements of a particular subject domain. The inference engine applies the knowledge to the solution of actual problems. It is essentially an interpreter for the knowledge base. [4]

2.1.5. The Explanation Facility

The expert system must keep track of case-specific data: the facts, conclusions and other information relevant to the case under consideration. This includes the data given in a problem instance, partial conclusions, confidence measures of conclusions, and dead ends in the search process. This information is separate from the general knowledge base.

The explanation subsystem allows the program to explain its reasoning to the user. These explanations include justifications for the system's conclusion, in response to explanations of why the system needs a particular piece of data and tutorial explanations or deeper theoretical justifications of the program's actions. [5]

2.1.6. The Inference Engine

Many systems also include a knowledge-base editor (or known as the inference engine). Knowledge-base editors help the programmer locate and correct bugs in the program's performance, often accessing the information provided by the explanation subsystem. They also may assist in the addition of new knowledge, help maintain correct rule syntax, and perform consistency checks on the updated knowledge base. {5}

2.1.7. The Expert System Shell

In this project, the development of an expert system is based on EXSYS, an expert system shell which runs on microcomputers. Several criteria guided the selection of EXSYS shell as the expert system used in this work:

- The software can run under the Windows environment on a portable computer

- It is important that the software developed be simple enough so that an end-user can learn to run the program and perform sensitivity analysis with minimum amount of training time
- It has the ability to exhibit high performance in terms of speed and reliability in order to be a useful tool
- It is able to propose right and consistent solutions in a reasonable time
- It makes the expert system capable of explaining and justifying the solution or recommendations to convince the user that it's reasoning is correct
- Its working is rather more transparent i.e. a representation scheme that may be easily read and understood
- It has the ability to allow interface calls to external programs

2.2. THE IMAGE PROCESSING SYSTEM

2.2.1. The Need for Digital Image Processing

For diagnosis of bone diseases, the doctor has to refer to x-rays. But raw x-rays will contain lot of noises and the features of particular diseases may not be clear. So, the x-ray image will be digitized and the digitized image is used by the doctor in diagnosing the bone diseases.

Using the digitally processed image, the doctor has to answer the questions asked by the expert system.

2.2.2. Image Processing Techniques

Certain image features can be accentuated with the use of image processing techniques for subsequent analysis and image display. The image processing task to diagnose the bone diseases are emphasizing on certain specified image characteristics and features specifically associated with signs of abnormality. However, since the display mechanism used in analyzing the bone diseases will be used primarily by the doctor, it have simple, adaptable user interface that can be tailored to suit the requirements.

The image processing techniques are shown in Figure 2.2 below. The image processing tasks performed on the unprocessed x-ray is targeted to help the doctor to enhance the visibility of the clear desired features so that the questions asked by the expert system can be easily answered. The image processing tasks are performed using MATLAB Image Processing Tools

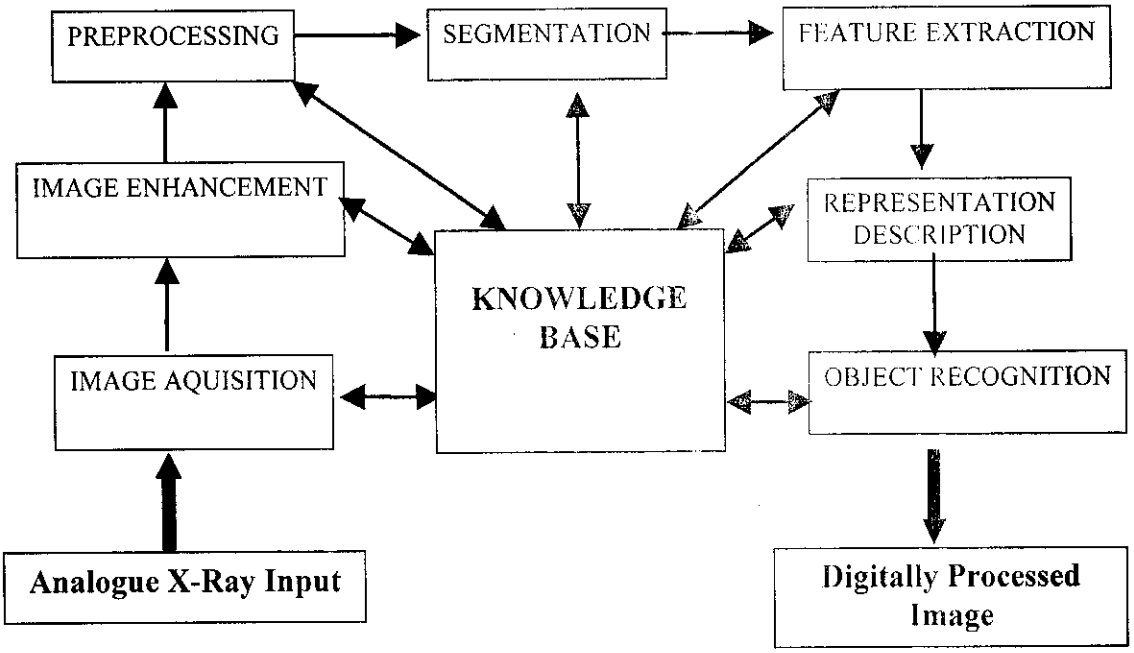


Figure 2.2. Image Processing Techniques

2.2.2.1. Image Acquisition

Image acquisition is the process of acquiring the unprocessed images into the image processing system. The image acquisition can be done using the devices such as camera, scanner or video player. [6, 7]

2.2.2.2. Image Enhancement

Image enhancement techniques are used to emphasize and sharpen image features for display and analysis. The image enhancement techniques can be operated to the unprocessed images in the spatial domain by manipulating the pixel data or in the frequency domain by modifying the spectral components. [6, 9]

2.2.2.3. Pre-processing

The pre-processing algorithms, techniques, and operators are used to perform initial processing that makes the primary data reduction and analysis task easier. They include operations related to extracting regions of interest, performing basic algebraic

operations on images, enhancing specific image features and reducing data in both resolution and brightness. [7, 9]

2.2.2.4. Segmentation

Image segmentation is important to find regions that represent objects or meaningful parts of objects. Before any processing can be done at a level higher, division of the image corresponding to objects of interest is necessary. [6, 8]

2.2.2.5. Feature Extraction

The information useful for solving application-based problems is extracted using the feature extraction technique. This is done by intelligently reducing the amount of image data with image processing techniques such as image segmentation and transforms. [6]

2.2.2.6. Representation Description

The human visual receives an input image as a collection of spatially distributed light energy called an optical image. The image are represented in the form of analogue electrical signals and sampled to generate the digital image. The digital image is represented as a two-dimensional array of data, where each pixel value corresponds to the brightness of the image and can be modelled by a different function corresponding to each separate band of brightness information. The image types are such as binary, gray-scale, colour and multispectral. [6, 9]

2.2.2.7. Object Recognition

Object recognition process is the techniques used to find complex object boundaries by marking potential edge points corresponding to places in an image where rapid changes in brightness occur. [8, 9]

CHAPTER 3

METHODOLOGY

The work on the system begins with the attempt to gain some familiarity with the problem domain. This is obtained with initial interviews with the experts and collecting data and facts from experts during the discussion and by researching. The process of extracting the data can be done from various sources such as books, websites and journals.

After the familiarization of the general overview of the problem domain, the process of designing the system is performed. The way to represent the knowledge is selected; determining the search strategy and designing the user interface.

After the design commitments, the prototype is built and it should be able to solve problems in a small area of domain and provide a test bed for preliminary design assumptions. The system should be tested and refined its knowledge by giving it typical problems to solve and correcting its shortcomings.

For the system, the various types of bone diseases are considered. The system targeted to diagnosis 25 types of common bone diseases in Malaysia. After the bone diseases are determined, the diseases are then classified into three categories to ease the diagnosis process of the bone diseases. For the corresponding bone disease, the signs and symptoms of each disease are verified. This is done with the help of the experts.

The data is then re-arranged into systematic representation. The decision table is prepared for the system. The decision table is the representation of the findings to ease

the expert system development. It lists out the diseases in one axis and the corresponding symptoms into another axis (Please refer to Attachment 1-1 to Attachment 1-5 for the sample of decision tables).

After the completion of the decision table development, the expert system is developed. The system works base on the heuristic search capability. It can search for the required output base on the inputs entered by the users into the system. To acquire for the needs, the IF-THEN rules are developed. The expert system shell, EXSYS will then generate the rules and perform the platform of the system. The system will ask the set of questions needed to the users, store the results, perform the heuristic search procedure and display the results.

In the mean time, the preparation for the image processing of the x-ray diagram is done. The samples of x-rays are collected from the hospitals. This will ease the usage of the system since the image processing will enhance the clarity and quality of the diagrams; it is beneficial for the user of the system especially for the young clinicians and the non-experts.

3.1. KNOWLEDGE ACQUISITION

Knowledge acquisition is the phase of expert system development dedicated to the identification of the rules and facts that comprise the knowledge base. Some have termed this phase development as the bottleneck of expert system development because of the challenges involved and that has to be faced as well as the time-consuming process. Fortunately, there are certain guidelines that can ease the process.

The three steps in the Knowledge Acquisition Process are shown in Figure 3.1.

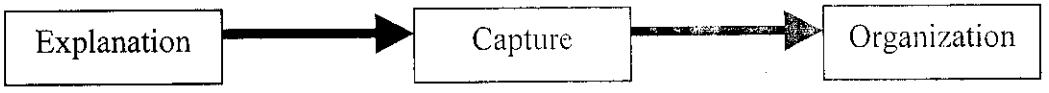


Figure 3.1. The three steps in the Knowledge Acquisition Process

3.1.1. Explanation

The explanation stage includes:

- Knowledge acquired from consultations and interviews with the experts
- Knowledge that can be obtained from books, journals etc.

The expert supplies the knowledge required to solve a specific problem. The expert usually avails himself of various sources of knowledge in his work; monographic sources, knowledge acquired from textbooks, but first and foremost, from his individual experience, which comes after years of practice. Experience shows that only part of this knowledge documented. Most of the knowledge is in the expert's head. The best method to obtain all the knowledge is through interviews. Interview sessions are important because it is the most commonly used method to gather knowledge. However, it is the most difficult way due to consideration of factors like time and convenience.

Knowledge that exists in the written forms has already undergone the explanation stage and exists in articulated forms. Thus, most other knowledge sources can be seen as a subset of the knowledge acquisition process based on the interview format. [4, 5]

3.1.2. Capturing

The capturing stage is the process of documenting the objects, relations and actions that make up the knowledge. [5]

3.2.3. Organization

The organization stage is the process of ordering the knowledge. which are facts and other information in such a form such as knowledge base that it is ready for mapping into rules. [5]

3.2. THE CREATION OF THE KNOWLEDGE BASE

It was certainly helpful to represent the data in a tabular form or a decision table prior to actually creating the rule base for the expert system. For example, all details such as the patients' history, the clinical examinations such as the bone density tests and physical tests, and observation of the abnormalities in the x-ray diagrams are indicated for each disease. The decision table represented as a method for visualizing the large number of possible situation (Please refer to the Attachment 1-1 to Attachment 1-5 for the sample of decision tables).

However, since the expert system deals with the delicate and critical information of the bone diseases aspects, the decision table needed to be revised many times with the help from the ingenuous resources and references such as the medical journals and from the opinion of the orthopaedics itself. This is to ensure the high level of precision of the result produced by the expert system

Facts and information has to be gathered in order to facilitate enough knowledge to be incorporated in the expert system. The information gathered is based on three categories

3.2.1. The Patient's History

The patient's history is the personal information acquires from the patients. The information is such as the general question about their lifestyles, family history of the diseases, the age of the patients and the symptoms of the diseases.

3.2.2. Clinical and Physical Examination Findings

The doctor must perform the necessary clinical examination that to determine the bone diseases. Some of the clinical tests performed are such as visual examination and other clinical examination using the medical devices.

3.2.2. The X-ray Findings

The doctor has to refer to the x-ray to diagnose the condition of the bone. From the x-ray, the doctor can determine if there are abnormalities to the bone's condition. If the abnormalities occur, future action can be taken.

The sample x-rays are collected from the hospital. However, raw x-rays will contain lot of noises and the features of particular diseases may not be clear. So, the x-ray image will be digitized to clear all the noise and the digitized image is used by the doctor in diagnosing the bone diseases.

3.3. DEVELOMENT OF BONNEX

Diagnosis of bone diseases requires a more thorough investigation of all possibilities and procedures. Moreover, there is a poorly structured collection of many isolated facts. It is necessary to solve the possibilities by heuristic or appropriate methods that 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 get explanations that tell how the expert system arrived at the answer and justifications 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 orthopaedics and from the extraction of rules from medical texts and journals. The information is represented in the decision table form (Please refer to Appendix 1-1 to Appendix 1-5 for the sample of decision table).

In the development of the initial version of BONNEX, 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 five classes indicating varying degrees of successes that could be expected when consultation takes place. The certainty classes are given in Table 3.1.

Table 3.1. Certainty Classes

Certainty Classes		
▪ Unlikely	-	0,1,2
▪ Likely	-	3,4,5
▪ Certain	-	6,7
▪ Definite	-	8,9
▪ Most Definite	-	10

3.3.1. The Production Rules

Rules are chosen as the method of representation of the knowledge base. Rule-based modes of knowledge representation employ what are termed production rules, or simply rules. Such rules are typically of the IF-THEN type. The designation for IF-THEN rules is that of condition-action or premise-conclusion or qualifier-choice statements.

3.3.2. The Rule Status

The expert system BONNEX deals with knowledge rather than data and the files that are used are often referred to as knowledge bases. The rules that the program uses are IF-THEN type rules. A rule is made up of a list of IF conditions (normal English sentences) and a list of THEN conditions (more sentences) or statements about the certainty of a particular choice being the appropriate solution to the problem. If the system determines that the entire IF conditions in a rule are true, it adds the rules of THEN conditions to what it knows to be true.

Sample of IF-THEN rule is as shown in Figure 3.2. In the figure, it is shown that IF particular symptoms and the certainty classes are determined to be true, THEN it will produce that the particular bone diseases together with the values of the corresponding certainty class to be true.

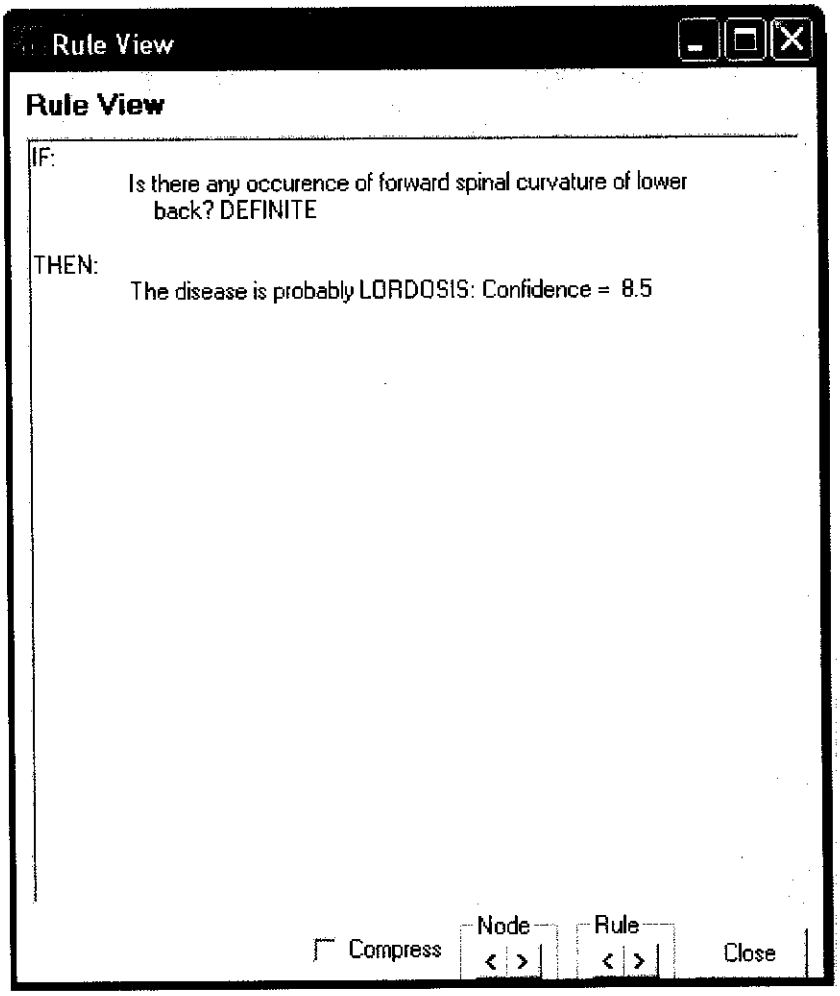


Figure 3.2. Sample of IF-THEN rule

3.4. SYSTEM DESCRIPTION AND OPERATION

The expert system is available on a Personal Computer (PC). When the system is run on WINDOWS mode, the system will start asking relevant questions to match the conditions of bone diseases. The system will ask many questions based on three categories. The first category of the questions asked will deal with the history of the patients collected by the doctor by questioning the patient. The second category phase of the questions asked will deal with the clinical and physical examinations done by the clinical doctor on the patients. The third category of the questions relate to the x-ray features, which will be answered by the clinical doctor using the processed x-ray image.

This is how BONNEX obtains data needed to make a decision. The type of question asked is multiple choices. A question will display a statement followed by a numbered list of possible choices to complete the sentence. The user is requested to click on the radio buttons' choices that is correct for the question statement and press the {ENTER} button.

The sample of question and answering format is as shown in Figure 3.3 (Please refer to Appendix 2-2 to Appendix 2-3 for sample of questions and answering format).

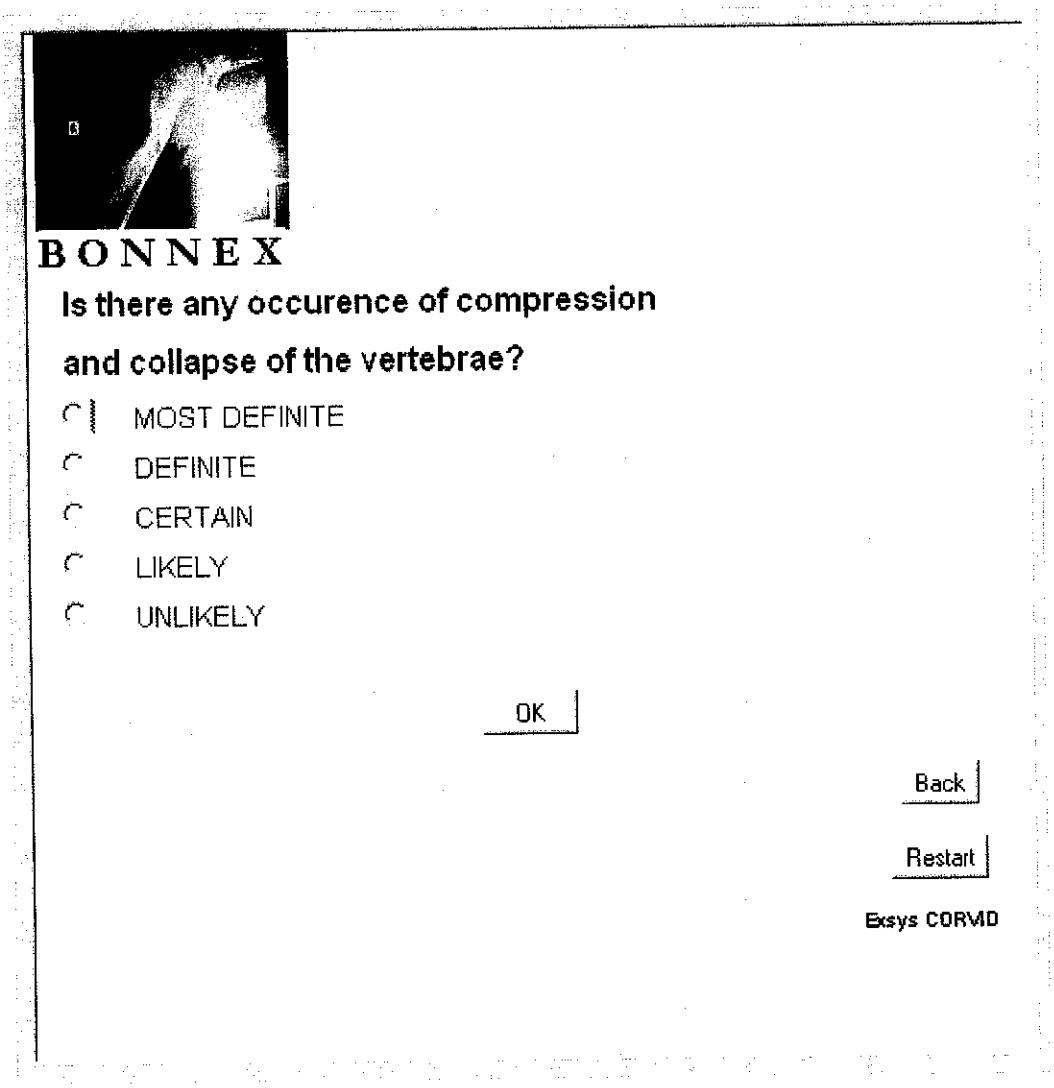


Figure 3.3. Sample of Question and Answering format

The system will continue to ask questions until it has reached a conclusion. When the user has answered the last question, the system will process all the answers given by the user and come to a conclusion. The conclusion may be the selection of a single solution or a list of possible solutions arranged in order of likely hood based certainty.

Then the system will ask the user to press the "RESULT' key to see the results on the screen. Based on the information that has been provided, a set of outputs that includes one or more diagnoses will be displayed with the relevant certainty values and also the necessary follow-up measures to be carried out further. The system can also give reasons how and why it has arrived at that conclusion in a sophisticated system.

The sample of the result displayed by BONNEX is as shown in Figure 3.4.

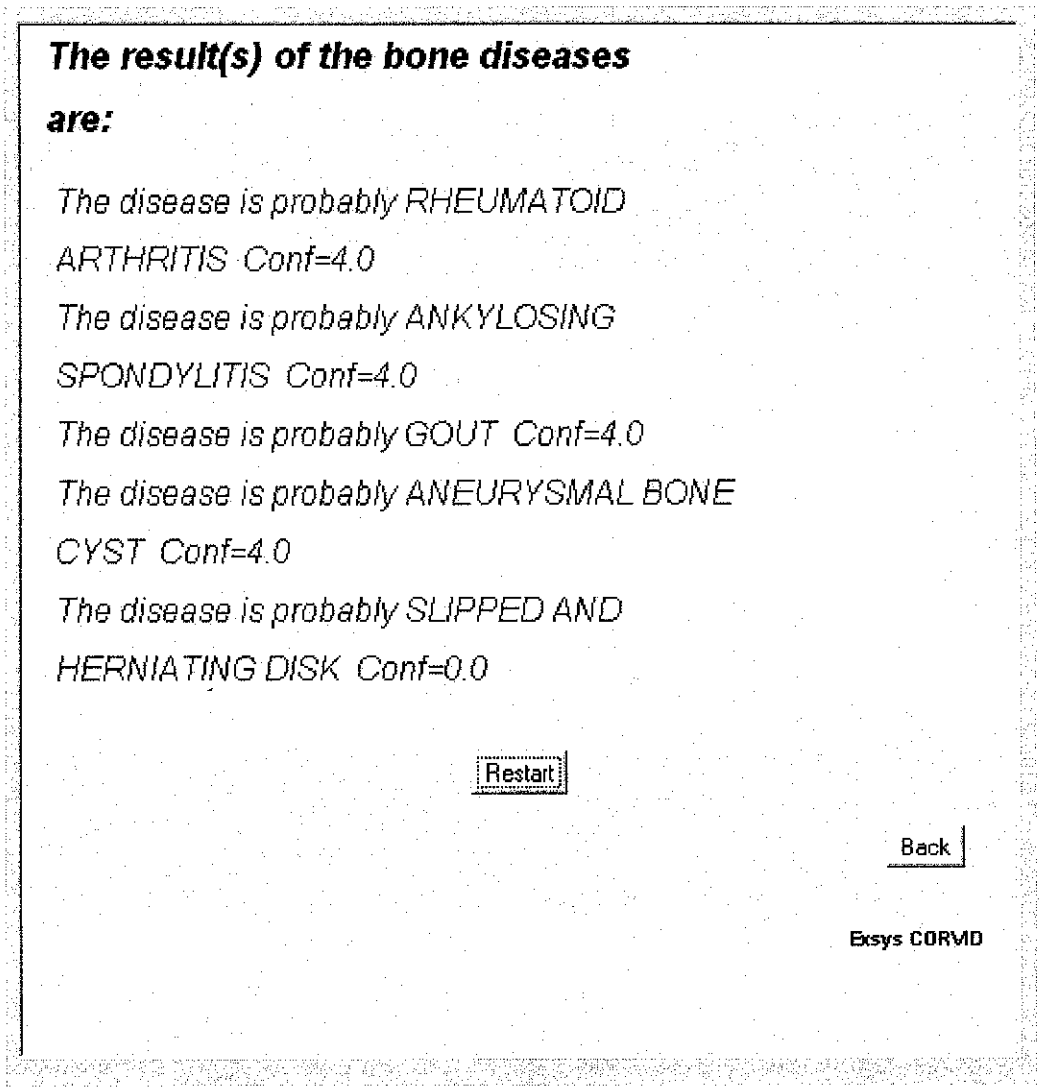


Figure 3.4. Sample of the displayed results on BONNEX

CHAPTER 4

RESULTS AND DISCUSSION

The system is tested by acquiring the details of patients and diagnosed by the doctor. BONNEX requires three types of information, which are the patient's personal history, the clinical examination and the x-ray examination. The doctor will answer the questions provided by BONNEX and the system will display the result based on the answers provided by the doctor.

The three samples of the diagnosis process done by acquiring the help of the doctor is shown in this chapter. Acquiring the information from the patient on three categories, which are the patient's history, clinical examination and x-ray examination, does the diagnosis process. For each category, there are several steps should be taken by the doctor to obtain the answer for the questions. The doctor will then answer the questions provided by BONNEX and BONNEX will consequently provide the probability of the bone disease based on the answers.

The three samples of the diagnosed patients are shown below.

4.1. PATIENT 1

4.1.1. Personal History

- The patient is at the age of 18.
- The patient shows the symptom of losing weight.
- Sometimes, there is symptom of fever, chills, nausea and vomiting.
- The patient shows the symptom of losing appetite on food.

4.1.2. Clinical Examination

- There is inflammation and swelling at the part of the body.
- The part will be checked using x-ray.

4.1.3. X-ray Examination

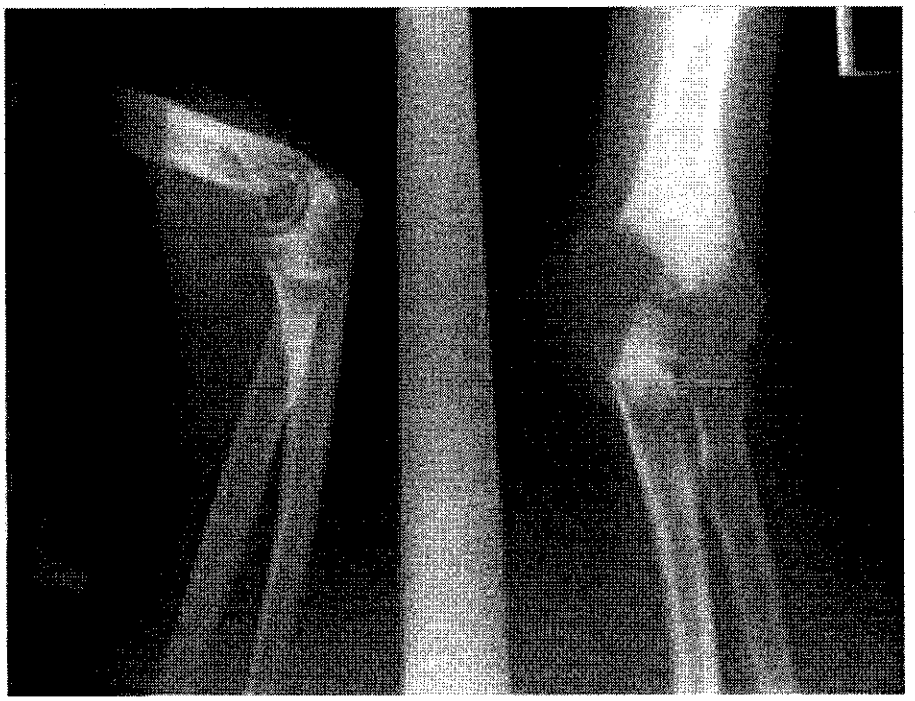


Figure 4.1. The unprocessed x-ray of Patient 1

Figure 4.2. The processed x-ray of Patient 1

4.1.3.1. X-ray Analysis

From the x-ray diagram, it is shown that there is lucency of bone at the affected area.

4.1.4. BONNEX Analysis

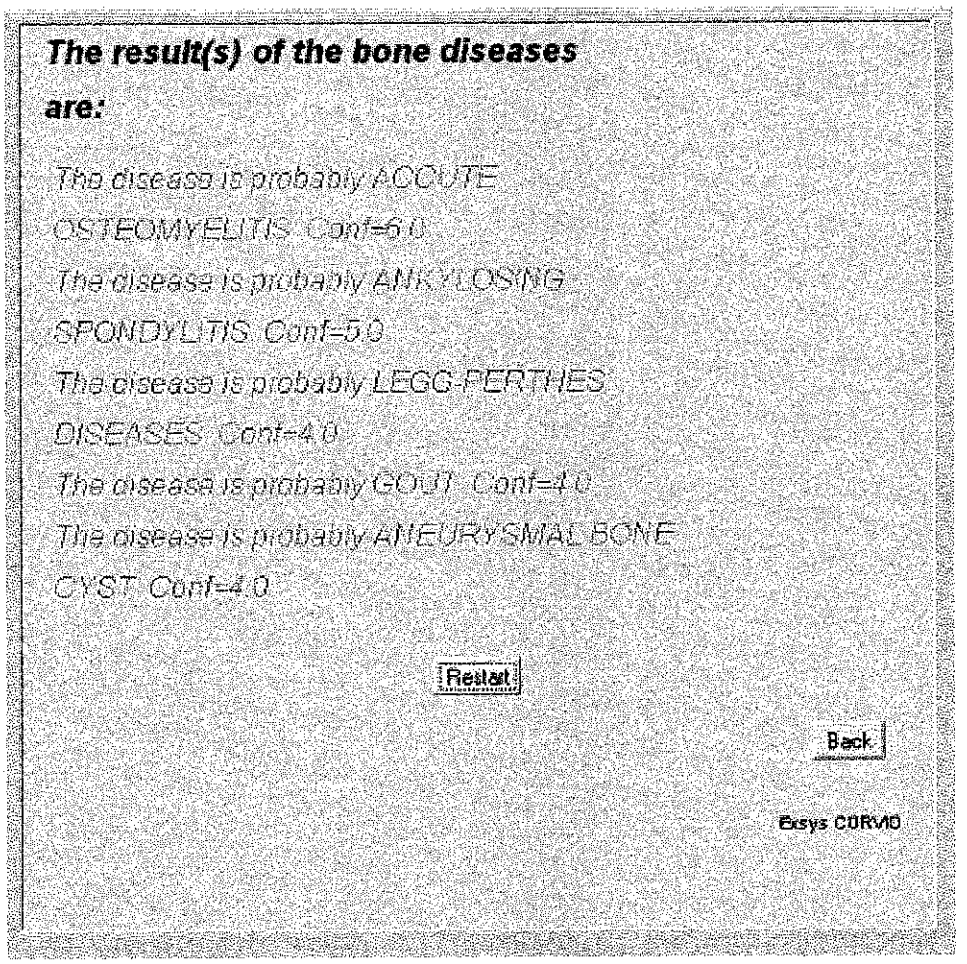


Figure 4.3. Result shown by BONNEX for diagnosis process of Patient 1

4.1.5. Discussion

From the result shown by BONNEX, it is determined that the patient has the probability of having Acute Osteomyelitis, which is rated as high. However, there is also the probability of having other diseases as well. The doctor should refer the patient to the expert orthopaedic to continue the treatment of the disease.

4.2. PATIENT 2

4.2.1. Personal History

- The patient is at the age of 42.
- There is family history of having the same disease.

4.2.2. Clinical Examination

- There is inflammation and swelling at the affected part of the body.
- The part will be checked using x-ray.

4.2.3. X-ray Examination

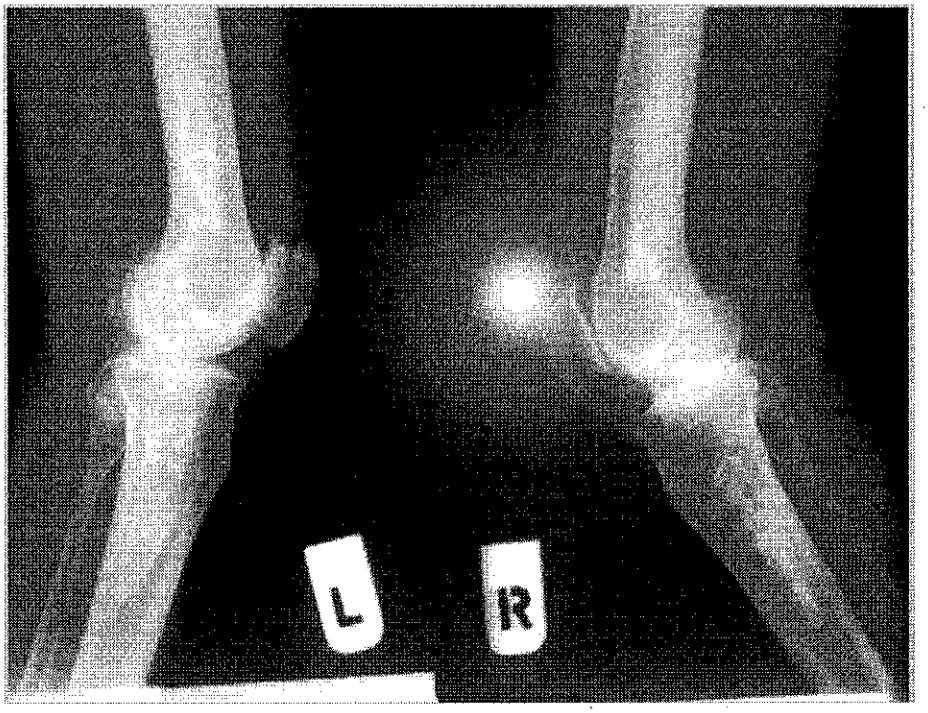


Figure 4.4. The unprocessed x-ray of Patient 2

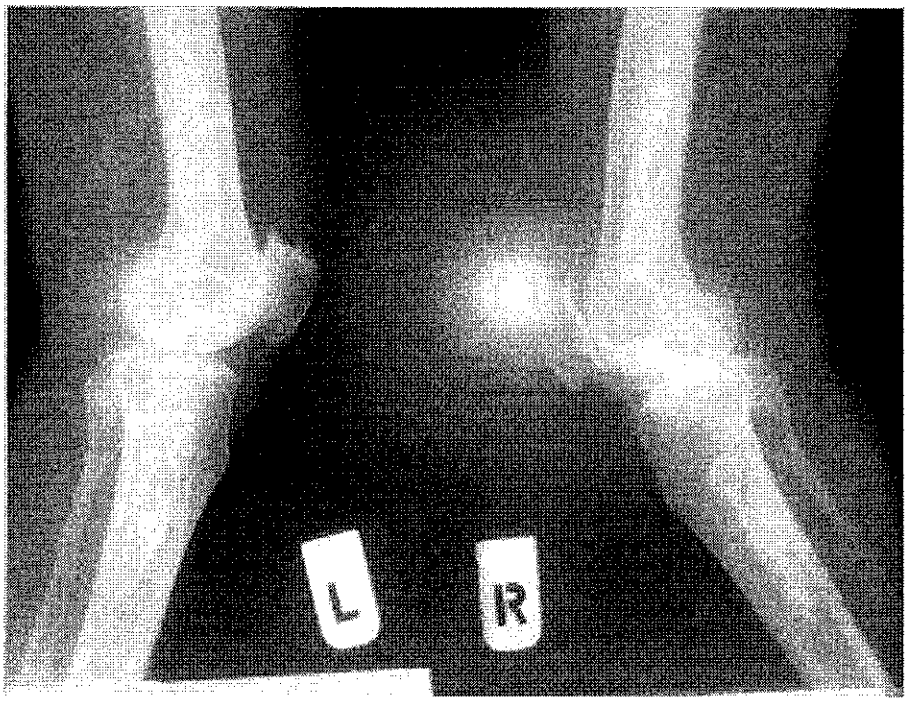


Figure 4.5. The processed x-ray of Patient 2

4.2.3.1. X-ray Analysis

From the x-ray diagram, it is shown that there is additional stalk of bone grows from the side of the affected area.

4.2.4. BONNEX Analysis

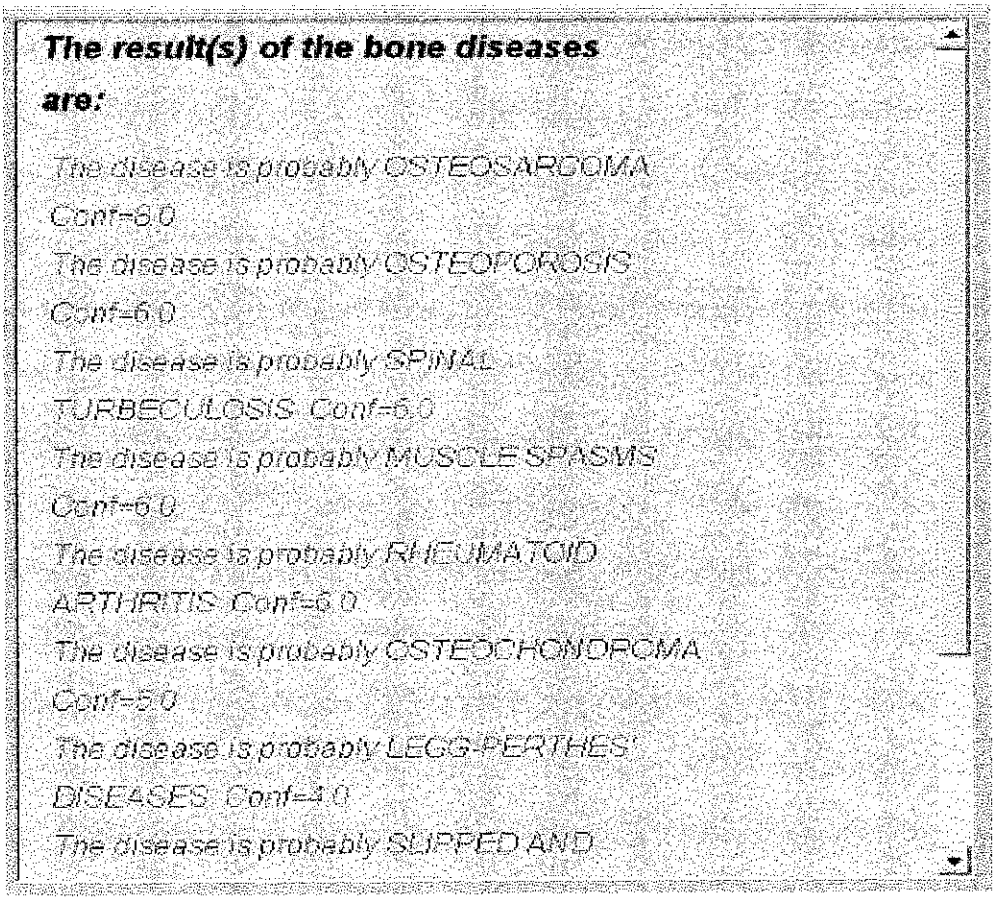


Figure 4.6. Result shown by BONNEX for diagnosis process of Patient 2

4.2.5. Discussion

From the result shown by BONNEX, it is determined that the patient has the probability of having Osteosarcoma, which is rated as high. However, there is also the probability of having other diseases as well. The doctor should refer the patient to the expert orthopaedic to continue the treatment of the disease.

4.3. PATIENT 3

4.3.1. Personal History

- The patient is at the age of 54.
- The patient has pain and discomfort at the joints of hand.
- The patient feels excessive warmth at the affected joint.

4.3.2. Clinical Examination

- There is soft nodules develop beneath the joints.
- There is inflammation and swelling at the affected part of the body.
- The part will be checked using x-ray.

4.3.3. X-ray Examination

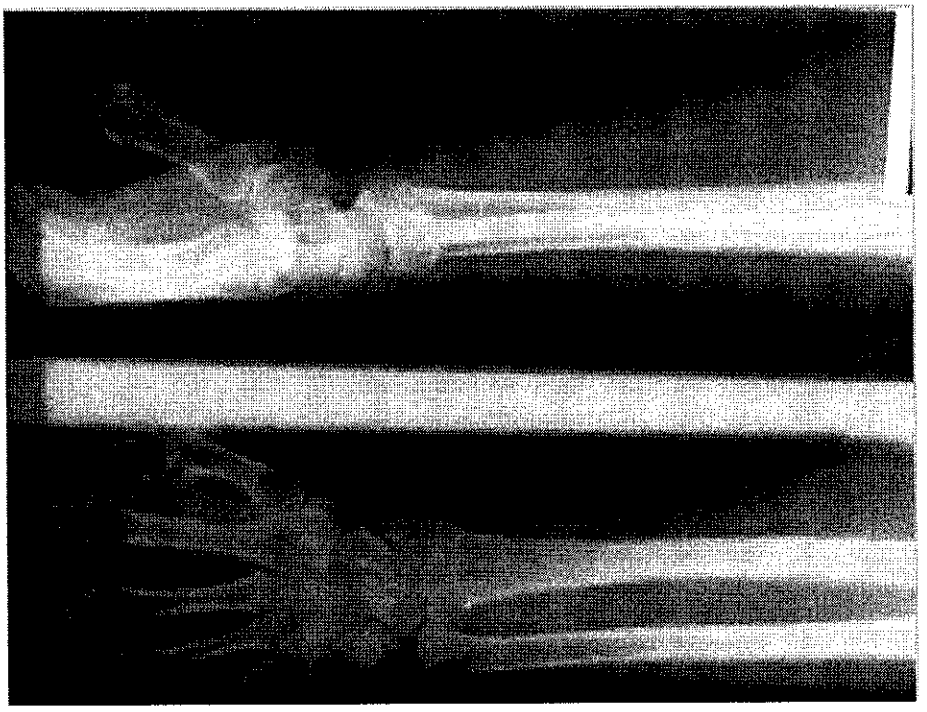


Figure 4.7. The unprocessed x-ray of patient 2

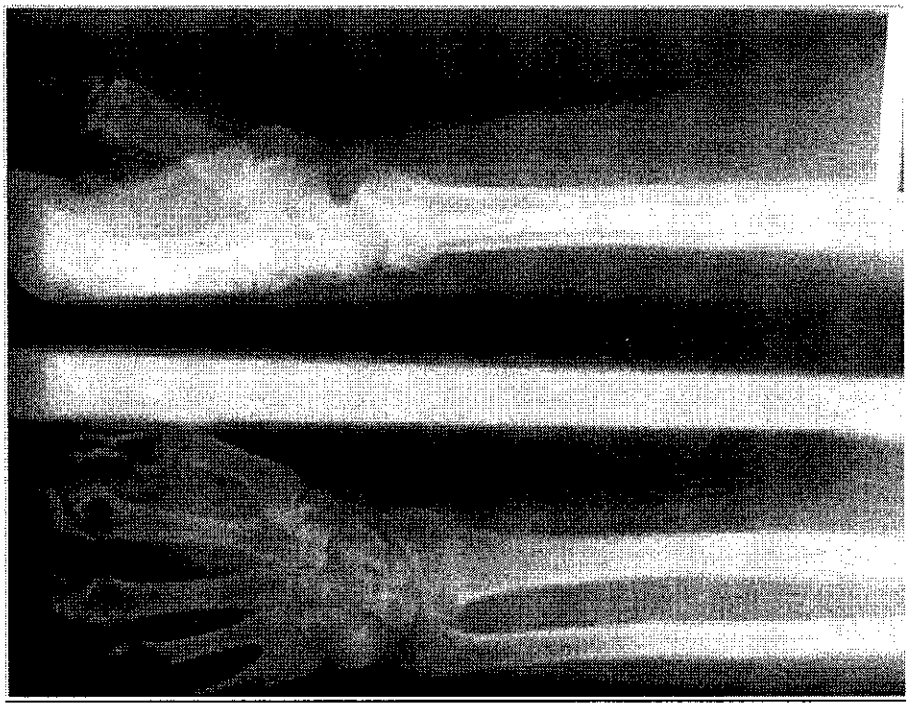


Figure 4.8. The processed x-ray of Patient 3

4.3.3.1. X-ray Analysis

From the x-ray, it is shown that there are abnormalities shown at the joints of hand.

4.3.4. BONNEX Analysis

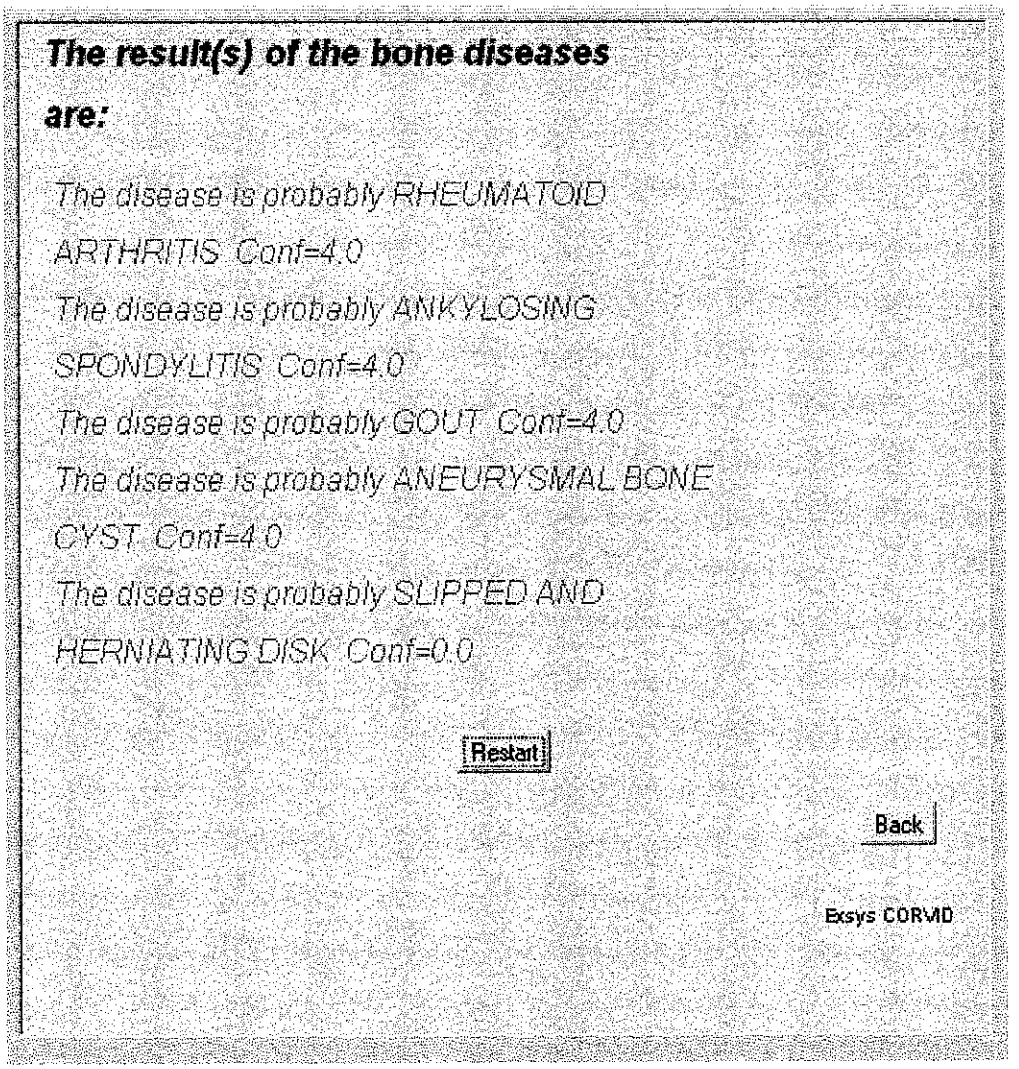


Figure 4.9. Result shown by BONNEX for diagnosis process of Patient 3

4.3.5. Discussion

From the result shown by BONNEX, it is determined that the patient has the probability of having five diseases with the same range. The patient should be referred to the expert orthopaedic for the confirmation of the disease. The doctor should refer the patient to the expert orthopaedic to continue the treatment of the disease.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The wide range of environmental conditions and complex dependencies of the practice of medicine has always being used for test bed for various advanced technologies. As a consequence, the medical technologies have rapidly changing, accumulating faster than we can use it. The recent medical technologies are applying the knowledge of several relatively mature technologies such as artificial intelligence (AI), multimedia communication and information systems (IS). The technologies are intended to be an application for the periodic monitoring and health-care advisories for upwards of 20 million Malaysians.

Health maintenance and illness prevention play a crucial role not only to an individual's quality of life but also to societal well-being. This medical-based project is anticipated to establish healthcare system that is capable in leveraging advanced information and multimedia technologies so as to deliver hitherto unattainable healthcare services at the individual, family and community-level, especially to the people in the rural areas.

The development of the knowledge base is the most important task that the expert system developer performs. There is a need to employ a systematic, thoughtful procedure in knowledge-base construction. In the development of an expert system, the process of knowledge acquisition and knowledge representation are phases that proceed virtually hand in hand are absolutely vital to the integrity of the end result. Based on these understanding, the complete knowledge base for the expert system is gradually

developed in an incremental manner. The system development based on production rules and decision tables are considered.

It is hoped that the study can attain the objective to successfully support and automate decision making in determining the bone diseases. The problem solving power exhibited by an intelligent agent's performance is primarily the consequences of its knowledge base, and only a consequence of the inference method employed. In the same time, the system is hoped to reduce the risks of suffering the bone diseases by performing the diagnosis at the early stage. The non-experts who employ the capability of the experts can do this.

During this project, several problems and difficulties occur. Some of the problems can be solved by taken certain steps. The major problem faced was to gather case with the x-ray samples. This is due to safety consideration of the hospitals. We were allowed to get some cases during clinical consultation and during the time there were only few cases that are of interest. Most of them are not in the scope of study. So, more time needs to be spent to complete finding the related cases in the study.

Knowledge-based was developed with reference to review books, journals and consult orthopaedics. Availability of orthopaedics is always in constant demand by their patients. We have to find the suitable time with orthopaedics before we could consult to acquire knowledge for the expert system. This requires more time consuming. Nevertheless, we were able to get support from helpful staff of the General Hospital, Ipoh.

The results of the expert system developed in this project have been compared with the diagnoses of orthopaedics for a few diseases. It was shown that there was good consistency. In the same extent, the expert system could provide alternative cases of diseases with certain probability (Please refer Chapter 4). In certain situations, the orthopaedic cannot identify any other diseases in short period of diagnosis. This is the advantage of expert system. User will gain new knowledge every time they consult the

expert system. This will provide a computerized expert in orthopaedic as a platform for doctors in training to improve their diagnostic skills in orthopaedic.

However, BONNEX, an expert system to determine the bone diseases is an expert system developed with limited capability of diagnosing the wide range of bone diseases. This is because the system is only capable of diagnosing 25 types of bone diseases. The number of the diseases that can be diagnosed by BONNEX should be increased so that the user of BONNEX can rely totally on the expert system to diagnose the bone diseases.

In addition, further enhancement to the text archive, a dictionary on medical terms can be included and activated at any time during the consultation and should be included in the system. Great vocabulary can be associated with each medical term by developing a natural language processor to handle input instead of menu selection.

BONNEX still cannot be represented as the powerful tool in accurately diagnosing the bone diseases. The expert system needs to be redeveloped and revised to increase the level of precision so that the system can be beneficial to the society.

As a conclusion, it is anticipated that the system could be a breakthrough to many inventions of the other expert system in the medical applications especially in diagnosing the bone diseases.

REFERENCES

[1] *"The New Complete Medical and Health Encyclopedia (Volume Two)"*, Ferguson Publishing Company, United States of America, 2002.

[2] *"Family Medical Guide to Health & Fitness (Volume Three – The Systems of the Body and Their Disorders)"*, Pacific Press Publishing Association, United States of America, 1991.

[3] *"The British Medical Association- Complete Family Health Encyclopedia"*, British Medical Association, London, Great Britain, 1990.

[4] Syed Sahal Nazli Alhady B. Syed Hassan (1999), *"Design of Noiseless ECG Monitoring System with In-Built Expert System"*. M. Sc. Thesis, University Science Malaysia.

[5] Umi Kalthum Ngah (1995), *"An Expert System With Integrated Image Processing Features For The Diagnoses Of Breast Diseases"*. M. Sc. Thesis, University Science Malaysia.

[6] Awcock, G.W and Thomas, R. *"Applied Image Processing"*, Mc-Graw Hill, New York, 1996.

[7] Gonzalez, R.C., and Woods, R.E., *"Digital Image Processing"*, Reading, MA: Addison Wesley, 1992.

[8] Jain, A.K., *and "Fundamentals of Digital Image Processing"*, Englewood Cliffs, NJ: Prentice Hall, 1989.

[9] Russ, J.C., *"The Image Processing Handbook"*, Boca Raton, F.L: CRC Press, 1992.

[10] Sid-Ahmed, M.A., *"Image Processing: Theory, Algorithms and Architectures"*, New York: McGraw Hill, 1995.

[11] Umbaugh, S.E, Moss, R.H., and Stoecker, W.V., "An Automatic Colour Segmentation Algorithm with Application to Identification of Skin Tumours Borders," *Computerized Medical Imaging and Graphics*, Vol. 16, No.3, pp. 227-285, 1992.

[12] Ellam S.V. and Maisen M.N., *"A Knowledge-based System to Assist in the Diagnosis of Thyroid Disease from a Radioisotope Scan"*, in Pretschner D.P. and Urrutia B., (Eds), Knowledge-based systems to aid medical image analysis, vol.1, Commission of the European Community, 1990.

[13] Fathi-Torbaghan M and Meyer D, *"MEDUSA: a fuzzy expert system for medical diagnosis of acute abdominal pain"*, Methods of Information in Medicine, 33(5), 1994.

[14] Gallant S. I., *"Neural Network Learning and Expert Systems"*, MIT Press, 1993.

[15] Hatzilygeroudis I., Vassilakos P. J. and Tsakalidis A., *"An Intelligent Medical System for Diagnosis of Bone Diseases"*, Procs MPBE'94, 1994.

[16] Huges C. A., Gose E. E. and Roseman D. L., *"Overcoming deficiencies of the rulebased medical expert system"*, Computer Methods and Programs in Biomedicine 32(1), 1990.

[17] Leao B. D., Reategui E. B., Guazzelli A and Mendonca E. A., *"Hybrid systems: a promissing solution for better decision support tools"*, Proceedings of the 8th World Conference on Medical Informatics, 1995.

[18] Reiber J.H.C., Bloom G., Gerbrands S.S., Backer E., van de Herik H.J., Reijs A.E.M., van der Feltz I. and Fioretti P., *"An Expert System Approach for the Objective Interpretation of Thallium-201 Scintigrams"*.

[19] http://www2.med.umich.edu

[20] http:// www.sciencedirect.com/science/journal

[21] http://www.sightquest.com/health

[22] http://www.osteofound.org

[23] http://www.testsymptomsathome.com/SYM_osteo.asp

[24] http://www.miacalcin.com/info/about/signsSymptoms.jsp

[25] http://www.beat-your-health-condition.com/osteoporosis-treatments.html

[26] http://www.womenshealthmatters.ca/centres/osteo/diagnosis

[27] http://orthoinfo.aaos.org/images

[28] http://www.noah-health.org/english/illness/orthop

[29] http://www.uihealthcare.com

[30] http://www.lpch.org/DiseaseHealthInfo/HealthLibrary/orthopaedics

[31] http://www.hopkinsmedicine.org

[32] http://www.covenanthealth.com/features/health/bones

[33] http://www.healthcentral.com

[34] http://edcenter.med.cornell.edu/CUMC_PathNotes/Skeletal/716.GIF

BONNEX - AN EXPERT SYSTEM TO DETERMINE THE BONE DISEASES

DECISION TABLE WITH THE CERTAINTY VALUES (DISEASES VS. SYMPTOMS

Note that:

1. Certainty Classes

BONNEX - AN EXPERT SYSTEM TO DETERMINE THE BONE DISEASES

DECISION TABLE WITH THE CERTAINTY VALUES (DISEASES VS. SYMPTOMS

Note that:

1. **Certainty Classes**
   - Unlikely - 0,1,2
   - Likely - 3,4,5
   - Certain - 6,7
   - Definite - 8,9
   - Most Definite - 10

2. **O = Occurrence of the symptoms**

3. **V = Certainty values of the symptoms**

		S29		S30		S31		S32		S33		S34		S35		S36		S37		S38		S39		S40		S41		S42	
		O	V	0	V	0	V	0	V	0	V	0	V	0	V	0	V	0	V	0	V	0	V	0	V	0	V	0	V
1.	OSTEOPOROSIS																											√	8
2.	KYPHOSIS																												
3.	LORDOSIS																												
4.	SCOLIOSIS																												
5.	LUMBAGO																												
6.	SCIATICA																												
7.	SLIPPED AND HERNIATING DISK																												
8.	SPONDYLOTISTHESIS																												
9.	SPINAL TURBECULOSIS																												
10.	MUSCLE SPASMS																												
11.	SPINAL INFECTIONS																												
12.	SPINAL TUMOR																												
13.	SLIPPED EPIPHYSIS																												

BONNEX - AN EXPERT SYSTEM TO DETERMINE THE BONE DISEASES

DECISION TABLE WITH THE CERTAINTY VALUES (DISEASES VS. SYMPTOMS

Note that:

SYMPTOMS OF THE BONE DISEASES WITH THE CORRESPONDING CODES to accompany the decision table of BONNEX (Diseases Vs. Symptoms)

No.	Code	Description
1.	S1	X-ray showing osteopenia (decrease in bone mass)
2.	S2	Back pain
3.	S3	Compression and collapse of the vertebrae
4.	S4	Forward bending of the spine
5.	S5	Pain / discomfort / stiffness across the affected area
6.	S6	Forward spinal curvature of lower back
7.	S7	Prominence of the buttocks
8.	S8	Spine leaning more to one side than the other
9.	S9	Pain and tenderness across lower part of the back / lower lumbar
10.	S10	Difficulty in bending forward and leaning back
11.	S11	Spasmodic/ persistent pain in the affected leg
12.	S12	Muscle weakness
13.	S13	Tenderness to palpation over the sciatic nerve
14.	S14	Bent bone
15.	S15	Straight leg raising test positive
16.	S16	Disabling muscle spasm
17.	S17	Buttocks and lower leg pain
18.	S18	Pain in the hip and knee
19.	S19	Painful of movements
20.	S20	Par spinal abscesses or sinuses
21.	S21	Bone destruction / deformity
22.	S22	Pressure on spinal cord
23.	S23	Paralysis of the lower limb
24.	S24	Lack of control over bowel and bladder function
25.	S25	Head of femur slips from normal position
26.	S26	Limitation in joint movement (limping gait)
27.	S27	Pain at the thigh and groin
28.	S28	Inflammation and swelling over affected area
29.	S29	Fever, chills, nausea and vomiting
30.	S30	Lucency of bone on x-ray
31.	S31	Arrest of growth
32.	S32	Sequestrum (dead bone) on x-ray
33.	S33	Degeneration of bone under joint surface
34.	S34	Pain and deformity of the joints
35.	S35	Excessive warmth of the infected area
36.	S36	Weakness of ligaments, tendons and surrounding muscles
37.	S37	Soft nodules develop beneath skin
38.	S38	Uric acid accumulates in joints
39.	S39	Additional stalk of bone capped with cartilage that grows from the side of the bone
40.	S40	Malignant and commonly occurred on proximal tibia/ distal femur
41.	S41	Head takes on square shape, bowlegs / knock-knees, protruding abdomen, constipation, pelvis become deformed
42.	S42	Other member in the family having similar problem
43.	S43	The patient is having other disease

No.	Code	Description
44.	S44	The patient is a child
45.	S45	The patient is an adolescent
46.	S46	The patient is an old man / woman
47.	S47	Loss of appetite
48.	S48	Loss of weight
49.	S49	Do not exercise regularly
50.	S50	Imbalance diet
51.	S51	The patient does not have good posture habit
52.	S52	Take any medical treatment before
53.	S53	The patient is a man
54.	S54	The patient is a woman
55.	S55	The patient is obese

BONNEX - AN EXPERT SYSTEM TO DETERMINE THE BONE DISEASES

DECISION TABLE WITH THE CERTAINTY VALUES (SYMPTOMS VS. DISEASES)

Questions Based On Patient's History

Symptoms vs. Diseases			D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20	D21	D22	D23	D24	
1.	S2	Back pain	√	√	√	√																					
2.	S4	Forward bending of the spine		√																							
3.	S5	Pain / discomfort / stiffness across the affected area										√							√	√		√	√				
4.	S9	Pain and tenderness across lower part of the back / lower lumbar					√		√	√																	
5.	S10	Difficulty in bending forward and leaning back					√																				
6.	S11	Spasmodic/ persistent pain in the affected leg						√																			
7.	S12	Muscle weakness						√																			
8.	S17	Buttocks and lower leg pain								√																	
9.	S18	Pain in the hip and knee													√												
10.	S19	Painful of movements									√	√															
11.	S22	Pressure on spinal cord											√														
12.	S23	Paralysis of the lower limb											√	√													

Symptoms vs. Diseases			D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8	D 9	D 10	D 11	D 12	D 13	D 14	D 15	D 16	D 17	D 18	D 19	D 20	D 21	D 22	D 23	D 24	
13.	S24	Lack of control over bowel and bladder function												√													
14.	S27	Pain at the thigh and groin														√											
15.	S29	Fever, chills, nausea and vomiting															√						√				
16.	S35	Excessive warmth of the infected area																			√						
17.	S36	Weakness of ligaments, tendons and surrounding muscles																			√						
18.	S42	Other member in the family having similar problem	√																	√					√		
19.	S43	The patient is having other disease								√	√																
20.	S44	The patient is a child														√										√	
21.	S45	The patient is an adolescent				√	√																				
22.	S46	The patient is an old man / woman	√																	√							
23.	S47	Loss of appetite															√										
24.	S48	Loss of weight															√					√					
25.	S49	Do not exercise regularly	√																								
26.	S50	Imbalance diet																					√				

Symptoms vs. Diseases			D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20	D21	D22	D23	D24	D
27.	S51	The patient does not have good posture habit		√	√																						
28.	S52	Take any medical treatment before											√														
29.	S53	The patient is a man																					√				
30.	S54	The patient is a woman	√																								
31.	S55	The patient is obese													√												

BONNEX - AN EXPERT SYSTEM TO DETERMINE THE BONE DISEASES

DECISION TABLE WITH THE CERTAINTY VALUES (SYMPTOMS VS. DISEASES)

Questions Based On Clinical Examination

Symptoms Vs. Diseases			D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8	D 9	D 10	D 11	D 12	D 13	D 14	D 15	D 16	D 17	D 18	D 19	D 20.	D 21	D 22	D 23	D 24
1.	S7	Prominence of the buttocks			√																					
2.	S13	Tenderness to palpation over the sciatic nerve						√	√																	
3.	S15	Straight leg raising test positive																								
4.	S16	Disabling muscle spasm							√																	
5.	S20	Par spinal abscesses or sinuses									√															
6.	S26	Limitation in joint movement (limping gait)													√	√										
7.	S28	Inflammation and swelling over affected area															√					√	√			
8.	S31	Arrest of growth																√								
9.	S37	Soft nodules develop beneath skin																			√					
10.	S41	Head takes on square shape, bowlegs / knock-knees, protruding abdomen, constipation, pelvis become deformed																								√

BONNEX - AN EXPERT SYSTEM TO DETERMINE THE BONE DISEASES

DECISION TABLE WITH THE CERTAINTY VALUES (SYMPTOMS VS. DISEASES)

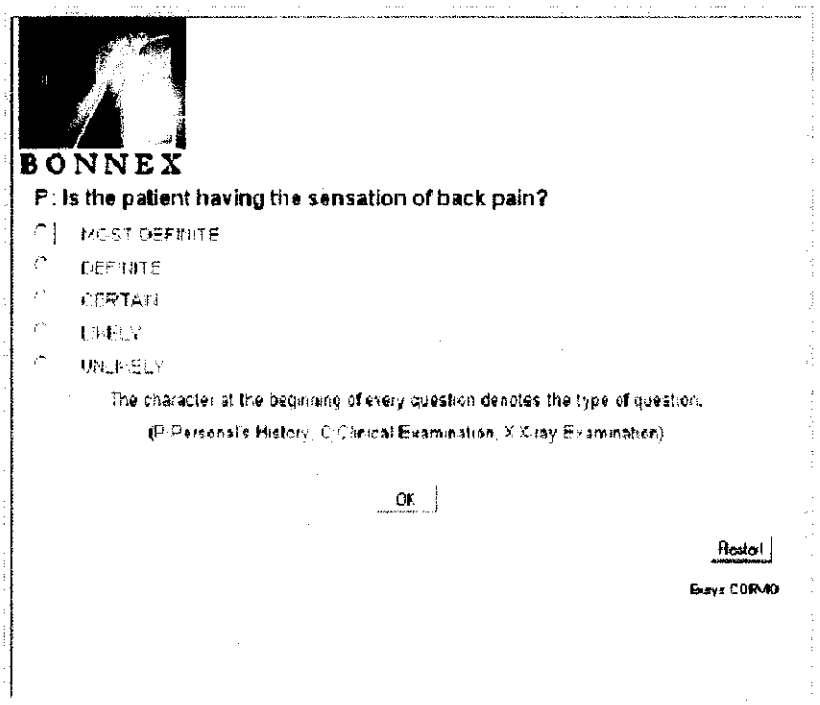
Questions Based On X-Ray Examination

	Symptoms Vs. Diseases		D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20	D21	D22	D23	D24	D25
1.	S1	X-ray showing osteopenia (decrease in bone mass)	√																								
2.	S3	Compression and collapse of the vertebrae	√																								
3.	S4	Forward bending of the spine		√							√																
4.	S6	Forward spinal curvature of lower back			√																						
5.	S8	Spine leaning more to one side than the other				√																					
6.	S14	Bent bone																								√	
7.	S21	Bone destruction / deformity											√					√									√
8.	S25	Head of femur slips from normal position													√												
9.	S30	Lucency of bone on x-ray															√										
10.	S32	Sequestrum (dead bone) on x-ray																√									
11.	S33	Degeneration of bone under joint surface																	√								
12.	S34	Pain and deformity of the joints																		√							

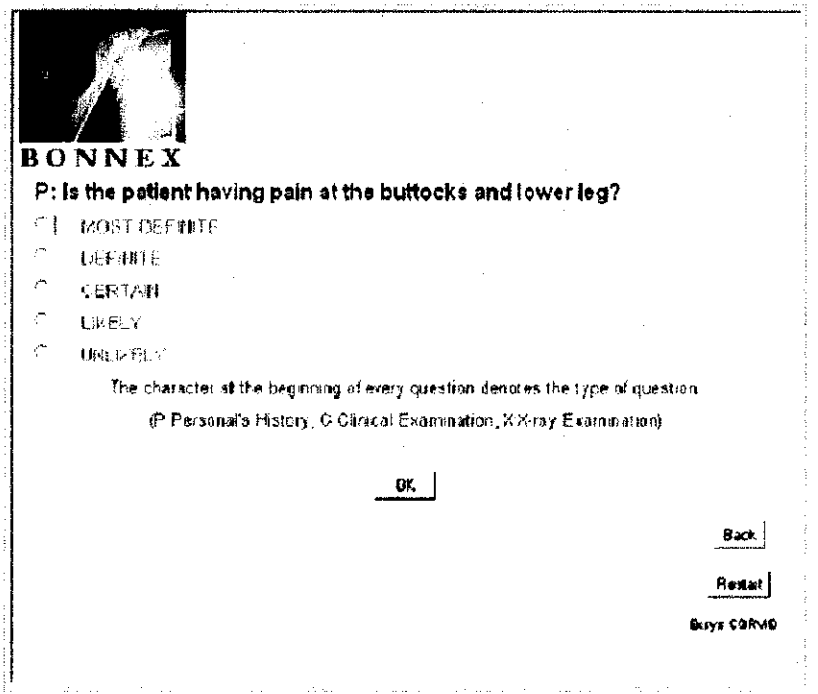
Symptoms Vs. Diseases			D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15	D16	D17	D18	D19	D20	D21	D22	D23	D24	D25
13.	S38	Uric acid accumulates in joints																					√				
14.	S39	Additional stalk of bone capped with cartilage that grows from the side of the bone																						√			
15.	S40	Malignant and commonly occurred on proximal tibia/ distal femur																							√		

SAMPLE QUESTIONS ON PATIENT'S HISTORY

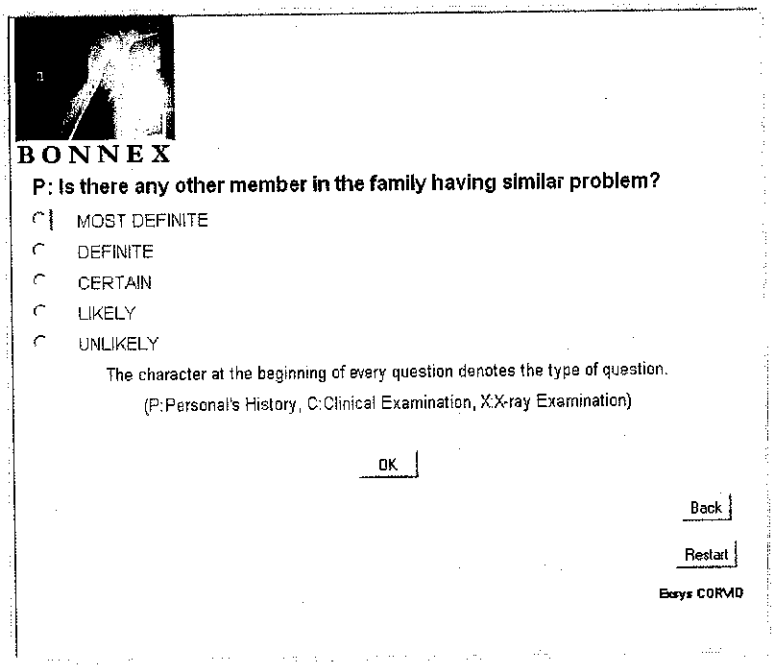
Question 1



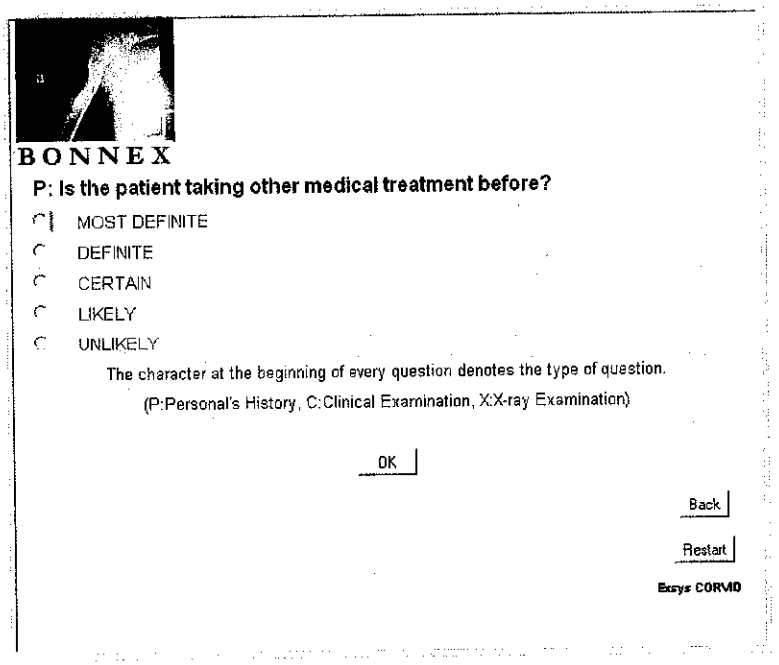
Question 2



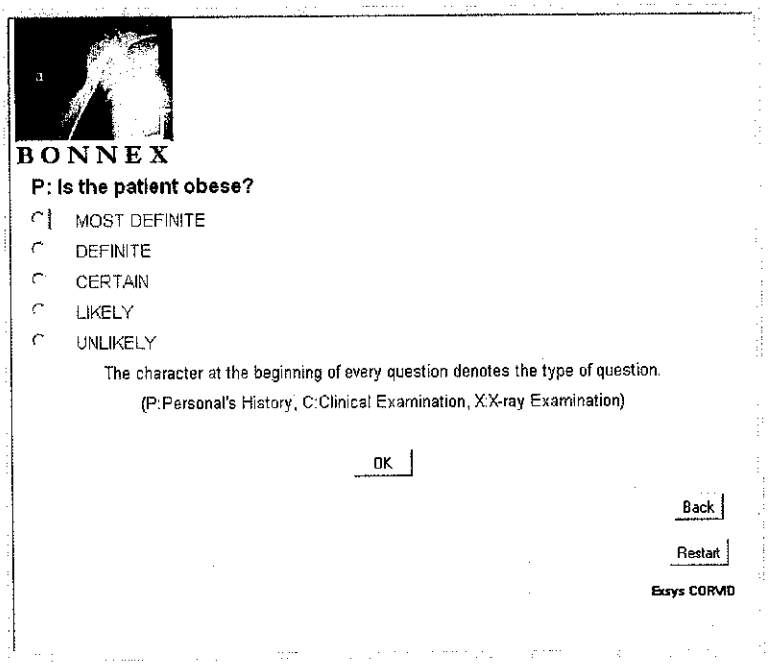
Question 3



Question 4

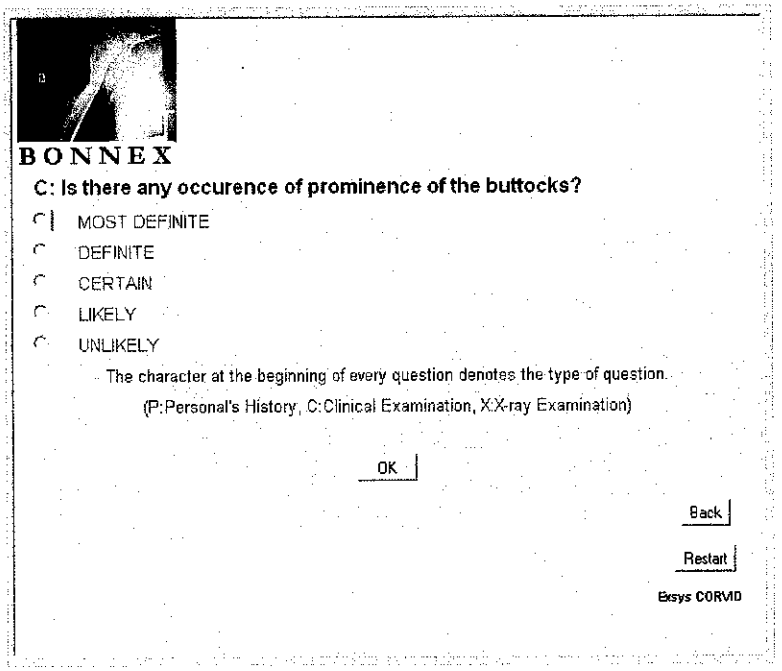


Question 5

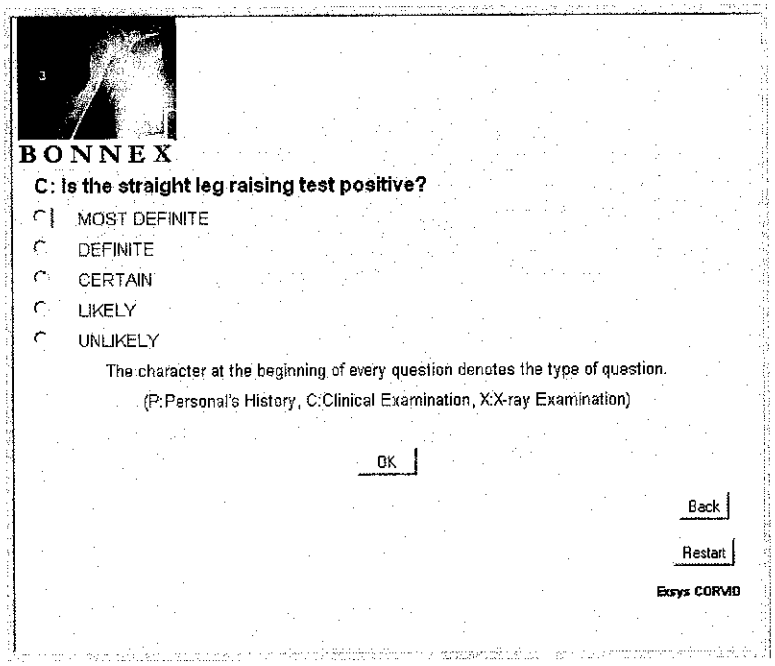

BONNEX
P: Is the patient obese?
MOST DEFINITE
DEFINITE
CERTAIN
LIKELY
UNLIKELY
The character at the beginning of every question denotes the type of question.
(P:Personal's History, C:Clinical Examination, X:X-ray Examination)
OK
Back
Restart
Exsys CORVID

SAMPLE QUESTIONS ON CLINICAL EXAMINATIONS

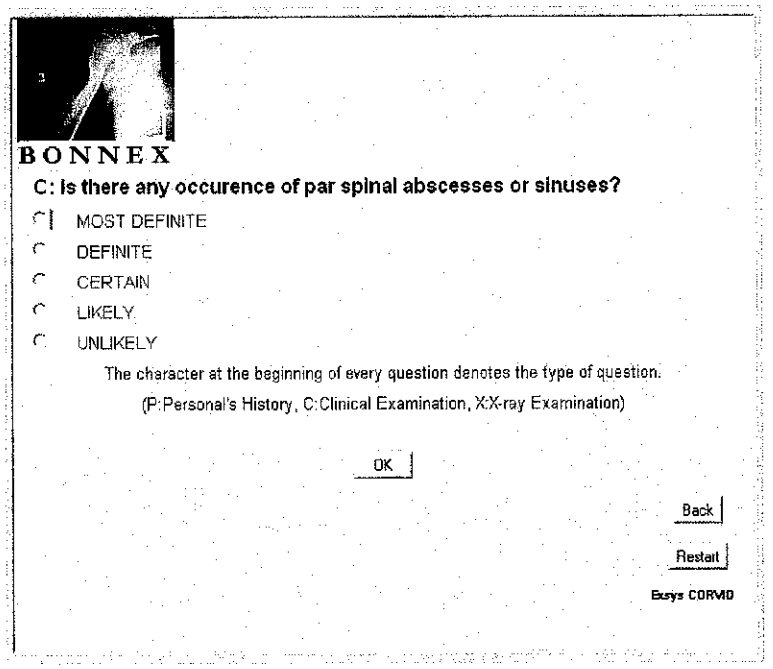
Question 1



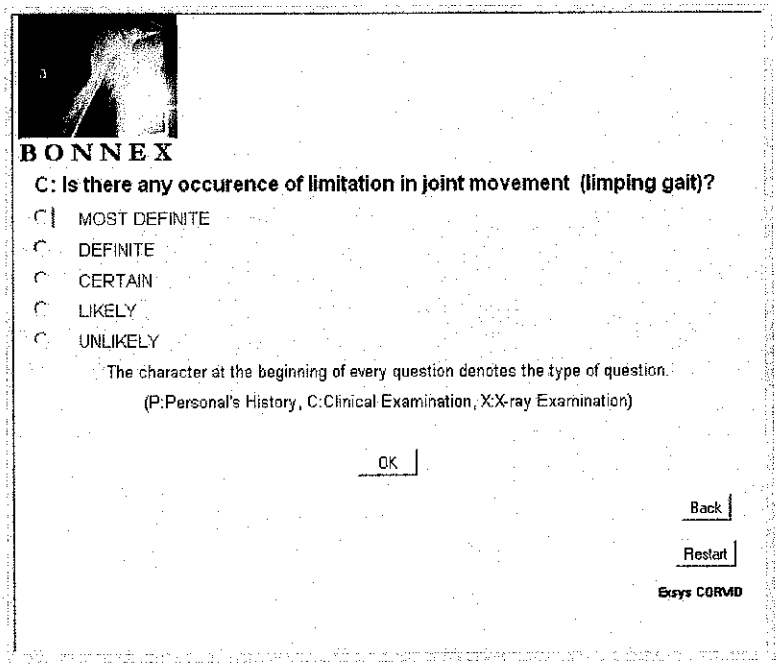
Question 2



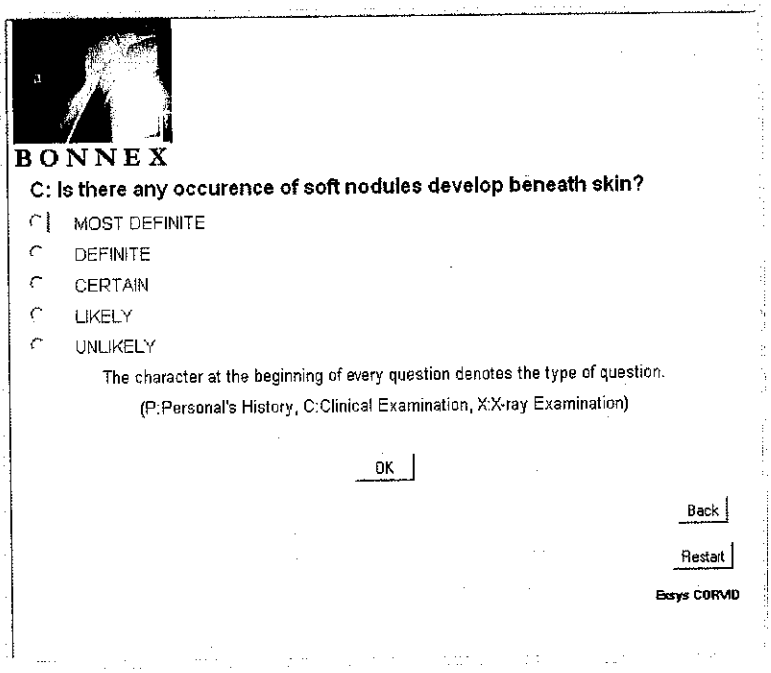
Question 3



Question 4

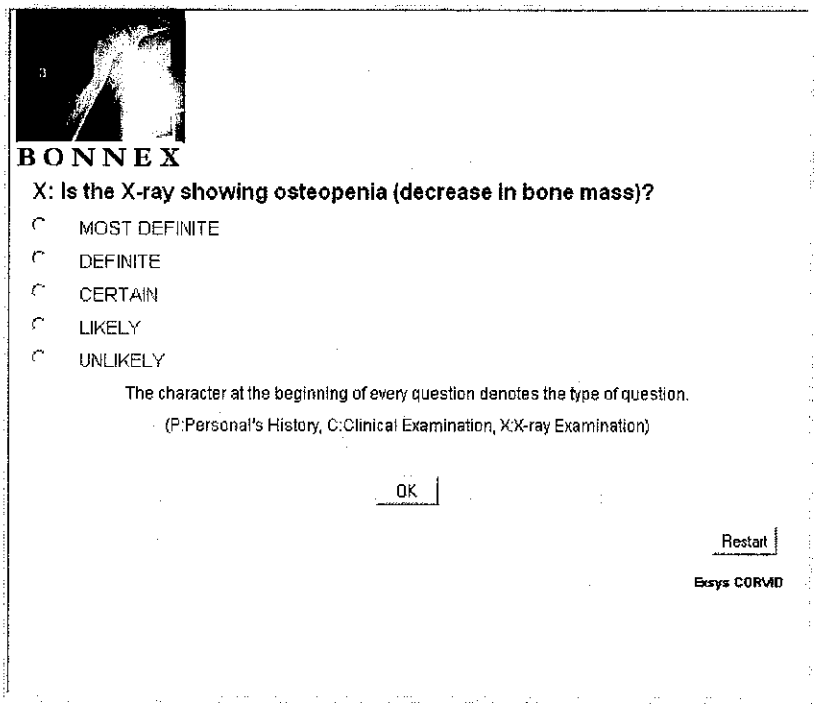


Question 5

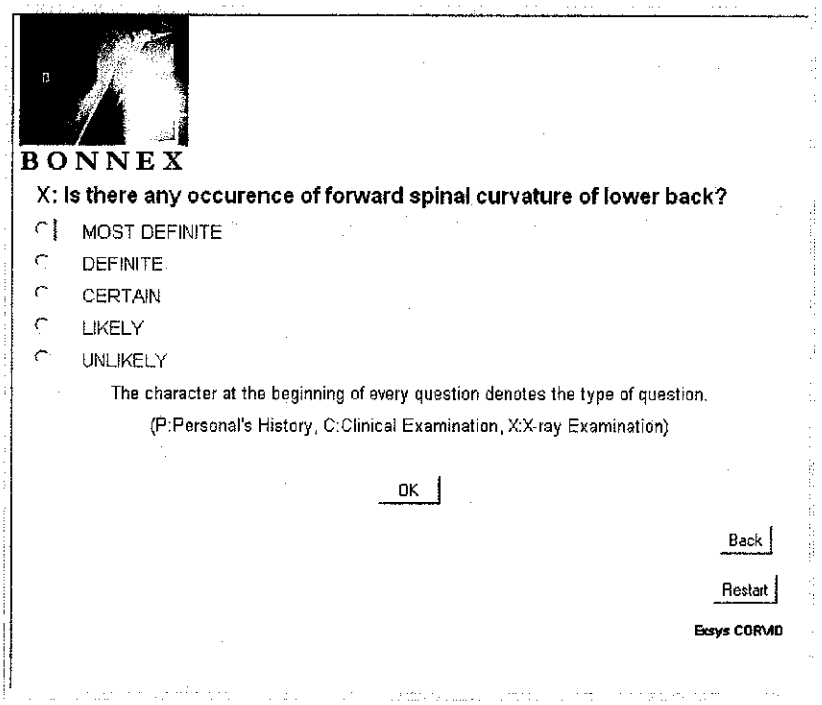

BONNEX
C: Is there any occurence of soft nodules develop beneath skin?
MOST DEFINITE
DEFINITE
CERTAIN
LIKELY
UNLIKELY
The character at the beginning of every question denotes the type of question.
(P:Personal's History, C:Clinical Examination, X:X-ray Examination)
OK
Back
Restart
Ecsys CORMD

SAMPLE QUESTIONS ON X-RAY EXAMINATIONS

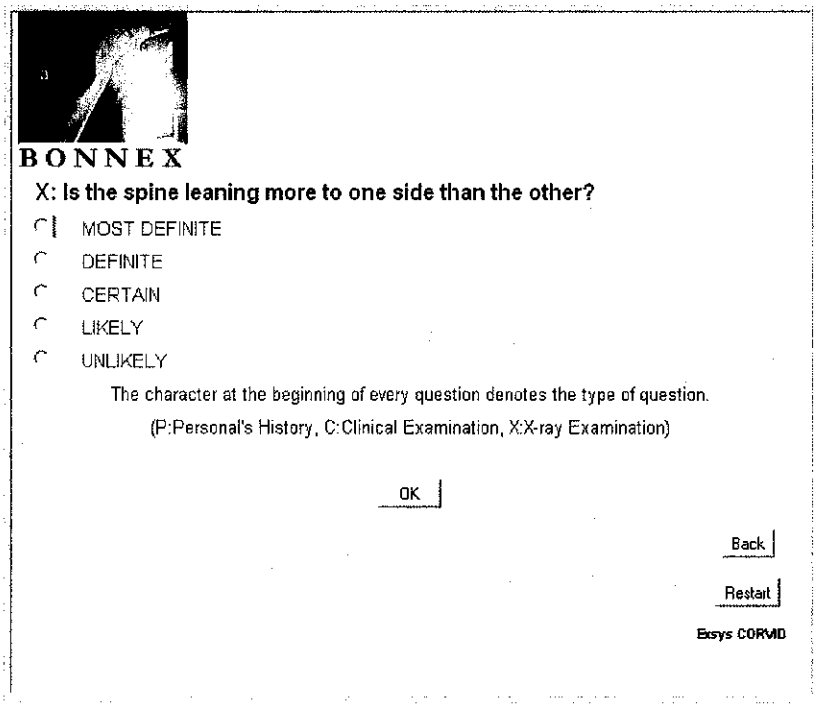
Question 1



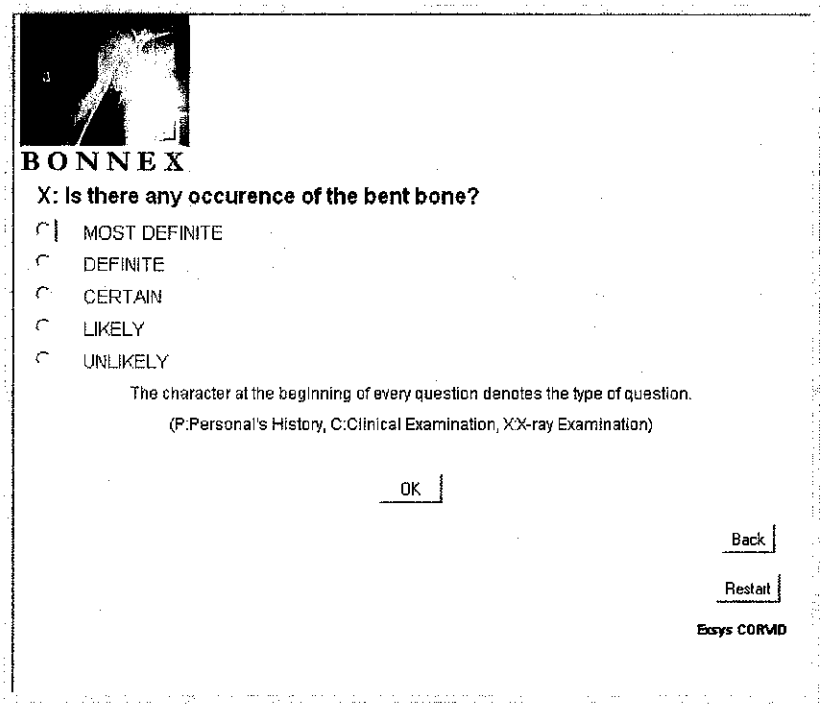
Question 2



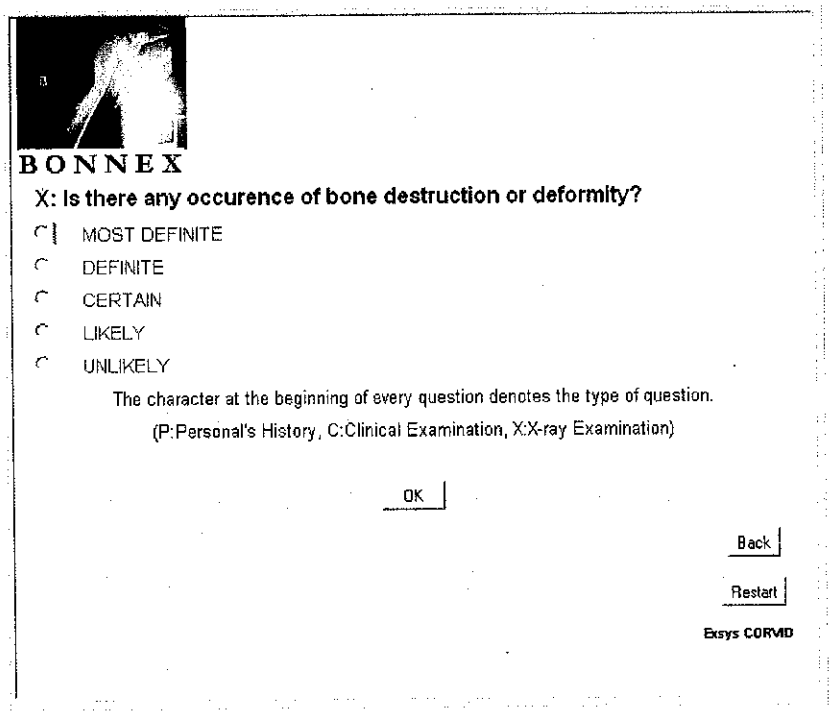
Question 3



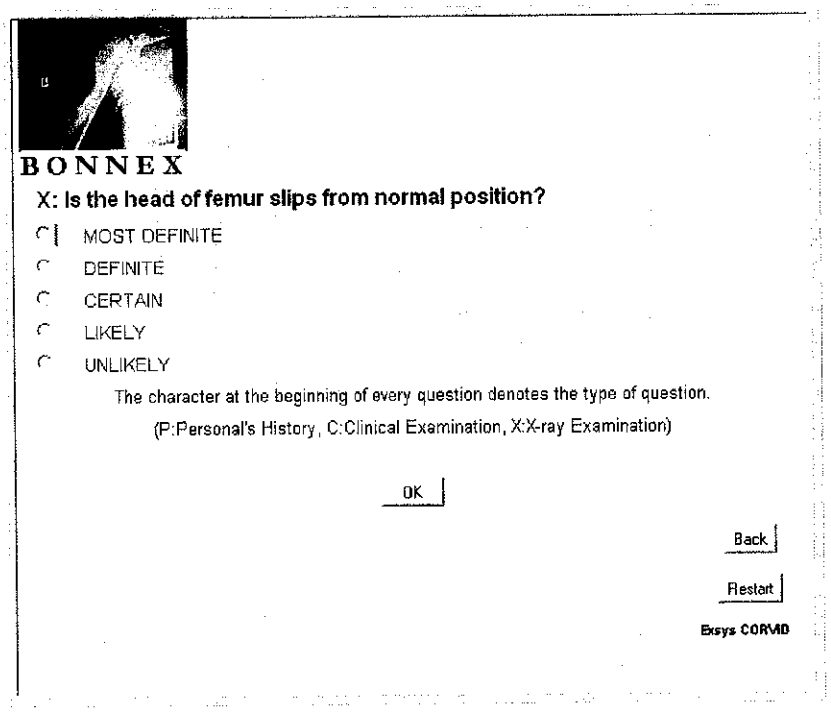
Question 4



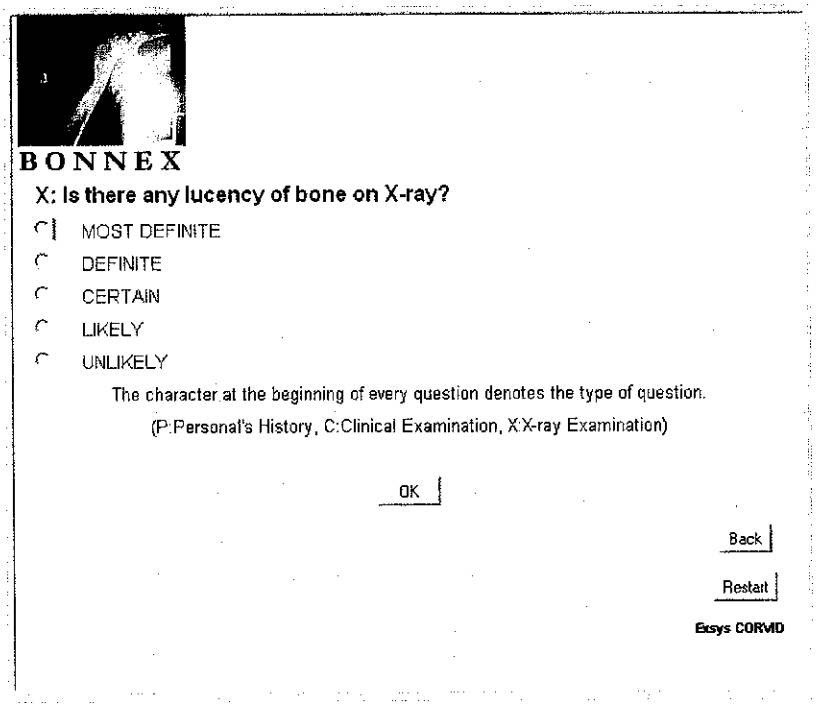
Question 5



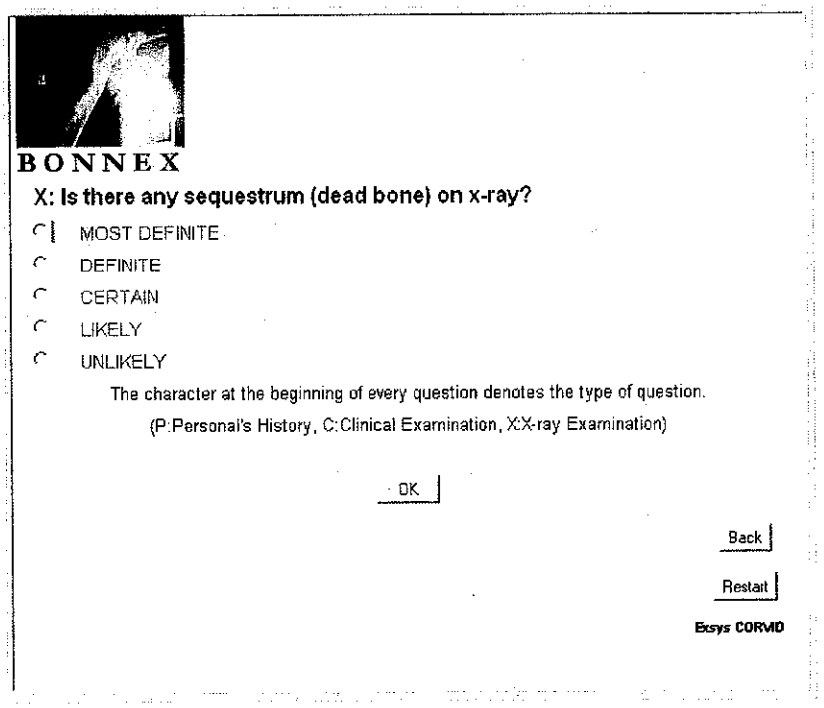
Question 6



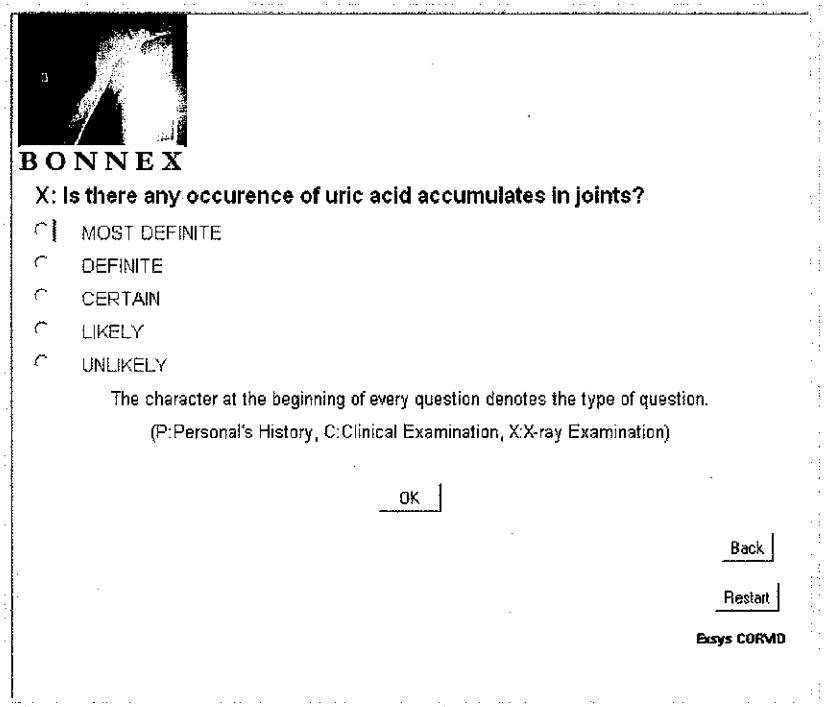
Question 7



Question 8



Question 9



Question 10