Chapter 8

A Medical Expert System for the Diagnosis of Ear Problems

8.1 Introduction

In the recent years, computers have rapid stride in the field of biomedical electronics. It has already become an indispensable tool in various medical applications. Because of this, the growth of medical field is occurring at an exponential rate. Computer assisted medical diagnosis has already become a routine feature in most of the medical diagnostic centers and such systems are generally intended to support physicians, complimenting their natural abilities to make judgments with the computers memory, reliability and processing capabilities [77]. Development of expert system in medical field has already emerged as a major area in the application of computers in medicine [125]. Medical expert system for management, diagnosis and treatment of diseases are gaining importance in the practice of modern medicine. The expert systems represent today the major part of artificial intelligence domain. This sub domain leads over 70% of real life applications. Expert system is a program to provide solutions to difficult questions requiring specialized training to answer. Majority of expert system developed to date have rule-based [79]. Most of the expert systems developed during 1960s and 1970s, including classic such as MYCIN, Dendral and R1, are rule-based. MYCIN [110] was developed to assist in the treatment of infection diseases in particular bacterial infections in the blood. The rule-based expert systems use human expert knowledge to solve real-world problems. That normally would require human intelligence.
The most important ingredient in any expert system is knowledge. The power of the systems resides in the specific high quality knowledge, they contain about task domain. The knowledge base stores all relevant information, data, rules, cases, and relationships used by the expert system. A knowledge base can combine the knowledge of multiple human experts. A rule is a conditional statement that links given conditions to actions or outcomes. The inference engine is next important block of an expert system, its purpose is to seek information and relationships from the knowledge base and to provide answer, predictions, and suggestions in the way a human expert would. In an expert system comparison, classification, identification is essential requirements. The expertise comes from education, experience, intelligence and intuition. The effective and efficient integration of the above qualities makes the decision making process more meaningful. The steps in the expert system development process include determining the actual requirements, knowledge acquisition, construction of expert system components, implementing results, and formulating a procedure for maintenance and review [21]. Diagnostic expert system help the doctors to determine arrange of alternative diagnosis or a definite diagnosis [30]. This clinical expert system will be useful for both patients and physicians.

Audition is the scientific name for the perception of sound. The ear is responsible for hearing and balance and made up of three parts outer ear, middle ear, inner ear. Hearing loss is the most occurring handicap in the world. Because of several reasons there are large numbers of abnormalities to hearing organ of human beings [20]. Some people are born with hearing impairments, for others hearing loss results from infection, biochemical insult, and exposure to intense sound, head injury, tumor growth, wax, problem with middle ear ossicular chain, cochlear, other inner ear problems [87] and aging etc. The vast array of symptoms and the multitude of clinical results associated with a disease impose a tedious assignment to
medical experts spending considerable time to analysis and arrive at reliable diag­nosis. Providing all possible symptoms and corresponding disease conditions in computer, through program it can make sufficiently sound solution to a particular problem, perhaps as good as the case an expert doctor would have made in that con­text; based on the domain expert’s (doctor) contribution and knowledge engineer’s skill in the development of the system. Medical expert systems help the doctors to determine a definitive diagnosis. The objective of the work is to develop a model expert system for the diagnosis of ear problems.

8.2 Expert System

The architecture of a typical expert system is shown in Figure 8.1; there are mainly three subsystems: knowledgebase, working memory and inference engine. The knowledgebase contain the domain specific knowledge in the form of rules. The working memory or data base contains the problem-specific facts and conclu­sions derived by the inference engine. The inference engine uses the information in the working memory along with the rules in the knowledge base to derive the conclusions.

The user interface is the means of communication between a user and expert system. The explanation module enables the user to as expert system how a particular conclusion is reached and why a specific fact is needed. The development interface is needed to modify the knowledge base and store the knowledge in an external database. This database contains patients details including blood pressure, body temperature etc. The most commonly used method for representing knowl­edge in expert system today is in the form of rules [116]. We used IF-THEN rules for knowledgebase building.

There are two basic ways a rule-based system operates backward chaining or
goal driven inference and forward chaining or data driven inference [80]. Backward chaining starts with the system given some goal(s) to prove. Forward chaining is good for problems where it is describe to learn as much as possible from available problem specific facts. In this work, backward chaining procedure is applied. The system attempts to prove the goal by using the rules along with the information provided by the user. Along the way, it derives the intermediate conclusions that help to support the quest for the goal. Backward chaining is well suited for problems that naturally start with some hypothesis to prove, such as attempting to prove

Figure 8.1: Architecture of a typical expert system
whether or not a patient has some particular disease. Diagnostic and prescription type problems can be managed well with a backward chaining system.

8.3 Knowledgebase Building

Knowledge acquisition is the most important element in the development of an expert system [99]. The knowledge has been built based on the opinions from a set of ENT doctors. There are two types of entries in our knowledge base: generic data and case specific data. In generic data, the common symptoms are handled. The case specific part of the knowledgebase possesses certain ENT diseases with unseen symptoms. For building the knowledgebase, a graphical user interface (GUI) is provided which will be helpful to doctors. They can enter diseases and remarks (causes, type of tests required and treatment) through the GUI. To incorporate the details of a new disease to the knowledge base, it is possible to select from already available symptoms in the knowledgebase and can also add additional new symptoms. For example, the diseases like meniere’s has 11 symptoms and furunculosis has only 6 symptoms. In our knowledgebase there are 132 symptoms and 28 ear diseases from three categories, ie., 13 diseases that are "very common", 6 diseases that are "common" and 9 diseases that are "uncommon".

In this work, a rule-based system is used in the inference engine for decision making. A rule-based system consists of IF-THEN rule, a bunch of facts, and an interpreter controlling the application of the given rules, given facts. These IF-THEN rule statements are used to formulate the conditional statements that comprise the complete knowledge base. For example, the rules like
IF \( s_1, s_2 \) and \( s_3 \) THEN \( C_1 \)

IF \( s_4 \) and \( s_7 \) THEN \( C_2 \)

........................

........................

IF \( s_N \) THEN \( C_N \)

where \( s_1, s_2, \ldots, s_N \) are symptoms, \( C_1 \) is the conflict set 1 containing set of diseases, \( C_2 \) is the conflict set containing a subset of diseases in \( C_1 \) and \( C_N \) is target disease obtained by diagnosis using symptoms. Some meta-rules are provided for some diseases, because the diagnosis statements are collected from different ENT specialists. Each meta-rule is verified by a knowledgebase engineer, before knowledgebase acquisition.

8.4 Inference Engine

Inference engine is the heart of the expert system; it uses information in the working memory along with the rules in the knowledgebase to derive the conclusions. Since expert system is intended for diagnosis for symptoms, a backward chaining inference strategy is adopted. Backward chaining by architecture means that no rules are fired upon assertion of new knowledge.

Backward chaining attempted to derive as much information as possible from available problem specific facts. These facts are placed in the working memory and act as a catalyst for the system by causing the firing rules that add further information to the working memory. The new information turned to firing of more rules and the process continues until no rules can fire from the working memory. So the working memory contains both initial facts and all of information inferred by the system. The working memory contains problem specific facts and conclu-
sions derived by the inference engine. Figure 8.2 shows the working of inference engine for the expert system developed. There are two subsystems in the working memory: knowledgebase and database. The knowledgebase contains a set of applicable rules developed for the system, mainly IF-THEN rules for firing, while the database contains patient’s historical details such as blood pressure, blood sugar, body temperature etc. These data are treated as facts. Many of the rules make use these parameters, before firing.

![Figure 8.2: Inference engine cycles via a match-fire procedure](image)

The inference engine accepts user input queries and responses through the I/O interface. Using knowledgebase, if a consistent match is found corresponding rules are fired into the conflict set. The inference process is carried out recursively for resolving its conflict set. If an appropriate match is found, then the inference engine is ready to the explanation part. The contents of the working memory are necessary for a match stage by a set of facts and rules contained in the knowledgebase. The
steps involved in the inference life cycle are given below.

1. Let \( M_i = \{s_1, s_2, \ldots, s_N\} \)
   where \( M_i \) is the symptom subset and \( s_1, s_2, \ldots, s_N \) are symptoms.

2. Let \( D_i = \{D_1, D_2, \ldots, D_R\} \)
   where \( D_i \) is the disease subset and \( D_1, D_2, \ldots, D_R \) are diseases.

3. Select \( M_i \), map \( M_i \) with \( D_i \), store into the working memory.

4. Conflict set \( C_i \) is identified based on the mapping \( M_i \) with \( D_i \).

5. Select a new set \( M_i \), for \( C_i \) by set of rules.

Repeat steps 3 to 5 until a single element exists in \( D_i \).

8.5 Results

Investigations are carried out, identified ear diseases and their symptoms with the help of expert doctors and audiologist. A total of 132 symptoms and 28 diseases are identified. The prototype of clinical expert system for the diagnosis of ear diseases (EDMx-Ear Diagnosis Medical Expert System) is developed. A rule based backward chaining algorithm is used to implement the system and is developed in Java. Since Java is platform independent, EDMx provided good portability. Therefore this model becomes very useful for patients and doctors for basic diagnosis of hearing problems. Figure 8.3 shows the structural organization of the EDMx system. The system has two modes of operation, administrative mode and user mode. Administrative mode is for adding further diseases and symptoms to the system and user mode for diagnosis purposes.

The evaluation of the system is performed using data of 52 patients with the help of physician's diagnosis. The performance of the system is found good. Since it is fully menu driven one, the user need not be given prior training to use the system. Similarly the expert system can also easily use, update as well as modify
Table 8.1 shows few diseases and typical symptoms of external ear. A detailed list of diseases and symptoms are shown in Appendix B.

A Turing test to measure the performance of the expert system is conducted[2]. Turing test is one of the methods used to evaluate the performance of an intelligent system. Three ENT specialists verified our knowledge base and the method of diagnosis. The doctor’s diagnosis and expert system diagnosis are similar and produced correct results for all 52 cases. These cases are previously prepared.

In the real test cases, doctors can avoid some of the steps in diagnosis process. But our expert system performs all the diagnosis steps. This is because of the difference in human intelligence. For example, the patient says "I have fever", the doctor will not measure the current body temperature of the patient. The designed expert system’s knowledgebase contains four rules. IF patient have fever and/or IF patient’s body temperature$< 38^\circ C$ (low grade) / IF patient’s body temperature
### Table 8.1: Few diseases of external ear and their typical symptoms

<table>
<thead>
<tr>
<th>Symptoms</th>
<th>Diseases</th>
<th>Otitis externa</th>
<th>Perichondritis of auricle</th>
<th>Otomycosis</th>
<th>Furunculosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ear pain</td>
<td>Mild</td>
<td>Severe</td>
<td>Moderate</td>
<td>Severe</td>
<td></td>
</tr>
<tr>
<td>Ear discharge</td>
<td>Sticky yellow</td>
<td>Watery</td>
<td>Whitish yellow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ear itching</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Ear sensitive to pressure</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Ear lobe sensitive to touch</td>
<td>Yes</td>
<td>yes</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Hearing loss</td>
<td>yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Fever</td>
<td>low grade</td>
<td>High grade</td>
<td>No</td>
<td>mild</td>
<td></td>
</tr>
<tr>
<td>Ear redness</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Ear swelling</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Continuous irritation</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Blocked sensation</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Nasal discharge</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Scaling</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Boils in the ear canal</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td></td>
</tr>
</tbody>
</table>

≤ 40°C (mild) / IF patient’s body temperature > 40°C (high grade). Any one of the rule is fired based on the facts.

### 8.6 Conclusions

This clinical expert system provides greater diagnostic accuracy to physicians across a wide range of medical specialty. By adding more symptoms and more diseases, the proposed expert system for auditory system can be made more versatile and efficient. The EDMx indicates that the results are compatible to doctor’s diagnosis with substantial reduction of time and resources. It is a potential tool to diagnosis the ear problems, if those are detected at earlier period, the patient can be saved from impairment.