Relational Model Based Multi-Disease Diagnosis Expert System

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Abstract: Biomedical expert systems are kind of expert systems designed especially for biomedical decision purposes. In present research work a relational model based multi-disease diagnosis biomedical expert system is implemented which helps users in diagnosis of 30 common human diseases (i.e. Anemia, Appendicitis, Athletes foot, Bunions, Chicken-pox, Croup, Dengue Fever, Fungus Nails, Hammer Toes, Hematuria, Hemophilia, Hookworm, Hypertension, Hypotension, Influenza, Jaundice, Leprosy, Leukemia, Malaria, Metatarsalgia, Parkinson Disease, Peripheral Vascular Disease, Pneumonia, Ringworm, Shin-splints, Sinusitis, Tetanus, Typhoid Fever, Typhus, Whooping Cough) based on patient’s disease symptoms. The system also extends its facilities for users to get them locality and language preference based registered doctors’ details for further confirmation and real treatment of the disease. The system is implemented using Oracle & Java technology, and presently encompasses 31 different symptom categories and total 166 symptoms under them. The system is tested on a close data set and recognition efficiency is 100%, and a positive feedback was received from the users when tested on an open data set.

Keywords: Artificial Intelligence; Disease Diagnosis; Medical Expert System; Knowledge Base; Relational Model

1. INTRODUCTION

Human disease is an impairment of the normal state of a human being that interrupts or modifies its vital functions. Human health can be defined theoretically in terms of certain measured values like pulse rate, breathing rate, body temperature, blood pressure, sensitivity of various organs of the body, height, weight, acuity of vision etc [10]. When a human being is diseased, then the value of one or more of these measures deviates from normal range which generally appears with special signs and symptoms.

Human disease diagnosis is a complex process and requires high level of expertise. In most of the remote areas, the population is deprived of the facilities of having experts to diagnose diseases. The problem can be mitigated by implementing expert systems which can emulate the decision-making ability of human experts. With the advancement in computer technology and introduction of AI field several medical expert systems have been developed which help in disease diagnosis. Some early well known expert systems are, MYCIN written in Lisp to identify bacteria causing severe infections, PUFF for diagnosis of lung disease, BABY expert system to monitor patients in Newborn Intensive Care Unit, CASNET for diagnosis and treatment of glaucoma, ONCOCIN to assist physicians in treating cancer patients receiving Chemotherapy, INTERNIST for diagnosis of complex problems in general internal medicine, CLOT for coagulation problems [9], etc.

In literature review, Chang, C.C. et al. developed a web-based decision support system for chronic diseases’ diagnosis [3]. Hasan, M.A. et al. developed a Fuzzy expert system for human disease diagnosis [5], Biswas, D. et al. developed a system for diagnosis of 13 different human diseases using Matlab, MS Excel and Visual Basic [1], Shukla, A. et al. developed Neuro-Fuzzy based expert system for breast cancer diagnosis [6], Prasad, B.D.C.N. et al.
developed an expert system for diagnosis of Asthma using machine learning algorithms [8], Maseleno, A. et al. developed an expert system for skin diseases using Dempster-Shafer Theory [7], Borgohain, R. et al. developed an expert system for Diagnosis of neurological diseases using Prolog, MS Visual Studio.Net and MySQL [2]. Eze, A.O. et al. developed an expert system in visual basic.net for disease diagnosis and prescribing medication [4].

These expert systems help in diagnosis of various human diseases but following real life aspects need to be addressed as well, (i) A patient can have one or more diseases at a time, (ii) Probability of different diseases in a patient can vary based on signs and symptoms observed on his/her body, (iii) A symptom can be associated with one or more diseases and vice versa, (iv) A symptom can have different significance for different diseases, (v) A doctor can diagnose one or more diseases, (vi) A disease can be diagnosed by one or many doctors, (vii) A disease can be cured by one or many therapies, (viii) recommendation of preferred doctors for further confirmation in case of doubt and real treatment. In present research work a relational model based multi-disease diagnosis expert system has been implemented using Oracle and Java technology which addresses all these aspects. The system can diagnose 30 different diseases in human beings, and recommend locality and/or language preference based registered doctors for further contact and real treatment.

Rest of the paper is organized as follow. In section 2, objectives of the system are specified. In section 3, the expert system model is explained. In section 4, knowledge acquisition for the system is explained. In section 5, expert system’s knowledge-base representation is elaborated. In section 6, expert system’s implementation is explained. In section 7, expert system is evaluated and result is shared. In section 8, expert system’s scope and limitations are specified. In section 9, paper is concluded.

2. OBJECTIVES
Main objectives of the present expert system are:
• To assist doctors and medical students in diagnosis of various diseases associated with symptoms i.e. to be a personal assistant for them,
• To help patients in early diagnosis of diseases based on signs and symptoms,
• To help patients to get registered doctors’ contact details according to their preferences,
• To help doctors, medical staff, medical students to get other registered doctors’ contact details according to their preferences,
• To provide facility of easy addition of new diseases/symptoms/treatments in the system’s knowledge base,
• To provide facility of easy editing of the system’s knowledge base.

3. THE EXPERT SYSTEM MODEL
To meet the specified objectives, a relational model based interactive human multi-disease diagnosis expert system is implemented. Working of the system can be divided into 5 main modules (complete model of the system is shown in figure 1), where, in the first module, relationship is established among symptoms, diseases, treatments and their expert doctors. Medical committee or expert doctors can define relationship among symptoms, diseases and their treatments. System admin can establish relationship between diseases and their expert doctors.

![Figure 1: Relational Biomedical Expert System Model](image-url)
In the second module, user interacts with the system and selects one or more symptom categories (like eye, nose, pain etc.) displayed by the system. Then, system displays a set of symptoms under selected symptom categories and user further selects signs/symptoms observed on his/her body. Selected symptoms become input for the third module.

In the third module, the system takes selected symptoms as input and uses them for multi-disease probability calculation. After calculating diseases' probability, system displays up to 5 top most probable diseases in decreasing order of probabilities along with all associated symptoms, their treatments, and prevention methods. These help user in confirming diseases and follow appropriate treatment/prevention methods. If the user is not able to confirm diseases, then he can consult doctors.

In the fourth module, user specifies diseases on which doctor's consultation is required. The user can also specify his locality and/or language preferences in registered doctors’ selection for further consultation. These all user specifications become input for the next module.

In the fifth module, the system uses the user inputs to determine preferred doctors for him and displays doctors’ contact details on the screen. Complete flow of the expert system user interaction is shown in figure 2.

**4. KNOWLEDGE ACQUISITION**

Expert system’s domain knowledge was acquired from expert doctors, patients, relevant books and various e-resources [11-13]. This acquired knowledge can be considered as the heart of the system which forms its base. Presently, knowledge-base consists of 31 different symptom categories and total 166 symptoms under them for diagnosis of specified 30 diseases.

**5. KNOWLEDGE REPRESENTATION**

The expert system is based on real life facts like (i) A patient can have one or more diseases at a time, (ii) A symptom can be associated with one or more diseases and vice versa, (iii) A symptom can have different significance for different diseases, (iv) A doctor can diagnose one or more diseases, (v) A disease can be diagnosed by one or many doctors, (vi) A disease can
Figure 3: ER Diagram of the Expert System’s Knowledge-base

Figure 4: Disease-Symptom Association Illustration
be cured by one or many therapies. To hold such highly relational data, RDBMS system has been used, and knowledge has been represented in form of entities and relationships among them. ER diagram of the system’s knowledge-base is shown in figure 3.

6. The Expert System Implementation

The expert system has been implemented using Oracle and Java technology. Java is an object-oriented, robust, secure, platform independent, high performance programming language used for the system’s front-end development. Oracle is an object relational, high performance, secure, and reliable database used for system’s back-end implementation to store knowledge base. Inference engine has been implemented in Oracle Structured Query Language (SQL) using analytic functions. There are two main functions of the inference engine explained below:

6.1. Multi-Disease Probability Calculation

It is based on a fact that, a disease can have multiple symptoms associated with it and these symptoms can be further associated with many other diseases. But, weightage of a symptom in multi-disease probability calculation can vary disease to disease (as shown in figure 4).

Inference engine calculates probability of all suspected diseases \( d \) using below formula.

\[
\text{Disease Probability} (d) = \sum_{i=1}^{n} \left( \frac{w_{di}}{c_d} \right) \times 100\%
\]

where, \( n \) is number of symptoms observed in a patient, \( w_{di} \) is weightage of \( i \)th symptom in disease \( d \), \( c_d \) is cumulative score of disease \( d \).

6.2 User Preferred Doctors’ Determination

To determine preferred doctors for a user, the expert system takes patient diseases’ list as input along with preferences on doctors' communication language, country, and locality (distance) range and gives back preferred doctors’ list as output. Distance between the user and doctors’ locations are calculated using longitude and latitude of their locations.

7. The Expert System Evaluation and Result

The expert system has been evaluated as below:

7.1 Close Dataset Evaluation of Multi-Disease Probability Calculation

Close dataset is a subset of the expert system’s knowledge base itself taken for evaluating the system. Disease ‘Malaria’ was chosen for evaluating the expert system. Table 1, shows related symptoms and symptom categories for disease ‘Malaria’ in the close dataset.

Table 1: Symptoms and Symptom Categories in Close Dataset for Disease ‘Malaria’

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Symptom Category</th>
<th>Symptom</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body</td>
<td>Chills</td>
</tr>
<tr>
<td>2</td>
<td>Body</td>
<td>Fever</td>
</tr>
<tr>
<td>3</td>
<td>Body</td>
<td>Nausea</td>
</tr>
<tr>
<td>4</td>
<td>Body</td>
<td>Tiredness</td>
</tr>
<tr>
<td>5</td>
<td>Oral</td>
<td>Vomiting</td>
</tr>
<tr>
<td>6</td>
<td>Pain</td>
<td>Headache</td>
</tr>
<tr>
<td>7</td>
<td>Pain</td>
<td>Muscle Aches</td>
</tr>
</tbody>
</table>

The expert system takes these symptoms as input and calculates multi-diseases’ probability. In this scenario, for expert system to be accurate, disease ‘Malaria’ should have highest probability among other suspected diseases in the expert system’s output.

Figure 5 shows, the inference engine output, after multi-disease probability calculation, where the probability of disease ‘Malaria’ is 100%. Thus the expert system successfully identified the expected disease ‘Malaria’ for which symptoms was fed in it. Similarly, when the expert system was tested for other diseases using close dataset symptoms, then it was able to identify expected diseases 100% accurately.
7.2 Open Dataset Evaluation of Multi-Disease Probability Calculation

Open dataset is a dataset taken from open world directly. For evaluating the system, symptoms (shown in Table 2) were taken from a patient who was diagnosed by an expert doctor as ‘Malaria’ patient. Further, these symptoms were fed to the expert system for multi-disease probability calculation and expectation was to get the same output i.e. highest probability for disease ‘Malaria’ as diagnosed by the expert doctor.

The expert system takes these symptoms as input and calculates multi-diseases’ probability. In this scenario, for expert system to be accurate, disease ‘Malaria’ should have highest probability among other suspected diseases in the expert system’s output.

Figure 6 shows, the inference engine output after multi-disease probability calculation, where the probability of disease ‘Malaria’ is highest among other suspected diseases. Thus the expert system successfully identified the expected disease ‘Malaria’ for which symptoms was fed into it. Similarly, when the expert system was tested for other 29 diseases using open data set symptoms, then a positive feedback was obtained.

Table 2: Symptoms and Symptom Categories in Open Dataset Sample for Disease ‘Malaria’

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Symptom Category</th>
<th>Symptom</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Body</td>
<td>Chills</td>
</tr>
<tr>
<td>2</td>
<td>Body</td>
<td>Fever</td>
</tr>
<tr>
<td>3</td>
<td>Body</td>
<td>Nausea</td>
</tr>
<tr>
<td>4</td>
<td>Body</td>
<td>Tiredness</td>
</tr>
<tr>
<td>5</td>
<td>Pain</td>
<td>Headache</td>
</tr>
<tr>
<td>6</td>
<td>Pain</td>
<td>Muscle Aches</td>
</tr>
</tbody>
</table>

7.3 Dummy Dataset Evaluation of User Preferred Doctors’ Determination

For evaluating this functionality, 1000 dummy expert doctors across the world with diverse expertise were registered with the system. Then, for a dummy patient profile and preferences (as specified in Table 3) attempt was made to find out preferred doctors’ list. In user preferred doctors’ determination process, the expert system first of all, identifies all the doctors who have expertise in specified diseases, and further filters them based on patient’s preferences criteria. At the end, the expert system also determines preference order using internal logic and displays it to the patient. Pictorial representation of user preferred doctors’ determination is shown in figure 7 on map [14]. Table 4 shows, preferred registered doctors’ list selected from the database for the specified patient profile.
Table 3: Dummy Patient Profile and Preferences

<table>
<thead>
<tr>
<th>Patient Disease</th>
<th>Malaria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patient’s Location</td>
<td>City: Patna, State: Bihar, Country: India</td>
</tr>
<tr>
<td>Patient Location Latitude</td>
<td>25°36’ N</td>
</tr>
<tr>
<td>Patient Location Longitude</td>
<td>85°06’ E</td>
</tr>
<tr>
<td>Language Preference for Doctor</td>
<td>English</td>
</tr>
<tr>
<td>Country Preference for Doctor</td>
<td>India</td>
</tr>
<tr>
<td>Doctor’s Location Distance Range</td>
<td>550 Kilo-Meters</td>
</tr>
</tbody>
</table>

Table 4: Preferred Registered Doctors’ List for Specified User Profile and Preferences

<table>
<thead>
<tr>
<th>Doctor ID</th>
<th>City</th>
<th>Country</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Language</th>
<th>Distance</th>
<th>Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>P00101</td>
<td>Patna</td>
<td>India</td>
<td>25°36’ N</td>
<td>85°06’ E</td>
<td>English</td>
<td>0</td>
<td>1st</td>
</tr>
<tr>
<td>P00431</td>
<td>Varanasi</td>
<td>India</td>
<td>25°27’ N</td>
<td>83°00’ E</td>
<td>English</td>
<td>212</td>
<td>2nd</td>
</tr>
<tr>
<td>P00025</td>
<td>Ranchi</td>
<td>India</td>
<td>23°19’ N</td>
<td>85°19’ E</td>
<td>English</td>
<td>255</td>
<td>3rd</td>
</tr>
<tr>
<td>P00034</td>
<td>Dharan</td>
<td>Nepal</td>
<td>26°49’ N</td>
<td>87°17’ E</td>
<td>English</td>
<td>257</td>
<td>X</td>
</tr>
<tr>
<td>P00940</td>
<td>Dhaka</td>
<td>Bangladesh</td>
<td>23°46’ N</td>
<td>90°23’ E</td>
<td>English</td>
<td>545</td>
<td>X</td>
</tr>
<tr>
<td>P00609</td>
<td>Raipur</td>
<td>India</td>
<td>21°14’ N</td>
<td>81°38’ E</td>
<td>English</td>
<td>601</td>
<td>X</td>
</tr>
</tbody>
</table>

Figure 7: User Preferred Doctor’s Determination
8. Scope and Limitations

There are two main limitations of the expert system in present work:


2. The expert system can provide contact details of system registered doctors only.

9. Conclusion

In this paper, we presented a generic relational model based biomedical expert system for diagnosis of multiple diseases in human beings, which can also assist patients in identification of preferred doctors for further confirmation and real treatment of the disease. The system can be used by doctors as well as their personnel assistant in disease diagnosis and by medical students in training purposes.

Presently, the expert system encompasses 31 different symptom categories and total 166 symptoms under them to diagnose 30 specified common human diseases. The system has been tested on a close data set and recognition efficiency is 100%, and a positive feedback was received from the users when tested on an open dataset. In future, the expert system accuracy (for open dataset) and capability can be further enhanced by adding more diseases, symptoms categories, symptoms, and treatments into the system’s knowledge base.

References


