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Bayesian Network Based Intelligent Pediatric System

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***Abstract*—**In this paper, a Bayesian Network (BN) based system is presented for providing clinical decision support to healthcare practitioners in rural or remote areas of India for young infants or children up to the age of 5 years. The government is unable to appoint child specialists in rural areas because of inadequate number of available pediatricians. It leads to a high Infant Mortality Rate (IMR). In such a scenario, Intelligent Pediatric System provides a realistic solution. The prototype of an intelligent system has been developed that involves a knowledge component called an Intelligent Pediatric Assistant (IPA); and User Agents (UA) along with their Graphical User Interfaces (GUI). The GUI of UA provides the interface to the healthcare practitioner for submitting sign-symptoms and displaying the expert opinion as suggested by IPA. Depending upon the observations, the IPA decides the diagnosis and the treatment plan. The UA and IPA form client-server architecture for knowledge sharing.

***Keywords*—**Network, Based Intelligent, Pediatric System

I. Introduction

INTELLIGENT systems are considered a subset or an application of the branch of computer science known as artificial intelligence. In turn, artificial intelligence is broadly defined as comprising certain techniques that allow computers to take on the characteristics of human intelligence. A medical intelligent system is a computer program that, when well-crafted, gives decision support in the form of accurate diagnostic information or, less commonly, suggests treatment or prognosis. Diagnostic, Therapeutic, or prognostic advice is given after the program receives information (input) about the patient, usually via the patient's physician. Intelligent systems have characteristics which make them dissimilar from other kinds of medical software because it deals with uncertainty. Because clinical medicine often does not deal in certainty, intelligent systems may have the capability of expressing conclusions as a probability. It is generally agreed that intelligent software must contain a large number of facts and rules about the disease or condition in question in order to deliver accurate answers.In this paper, a Bayesian Network based system is presented to help healthcare professionals to diagnose the disease of young infant/child, classify it and identify the treatment plan. The Intelligent Pediatric Assistant (IPA) has been developed for deciding the diagnosis as per the sign-symptoms provided by the healthcare professional. It also keeps track of the number of diseases diagnosed from a particular rural/remote site.

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The GUI of User Agent (UA) provides the practitioner a user interface to feed in the measured values and observations. The UA and IPA use the disease ontology that specifies the vocabulary and semantics for understanding the child related diseases. The GUI of IPA is used to display the activity of PHC practitioners. The system works without the direct involvement of a pediatrician as IPA is responsible to emulate a child specialist in dealing with some childhood diseases. The system has been designed to support even a naïve healthcare practitioner in dealing with child diseases.

A. Healthcare Scenario of infants in India

A majority of the Indian population is living in rural or remote areas. The healthcare practitioners in these areas are not specialized in dealing with infant or childhood diseases. They simply refer child related critical cases to specialized doctors in urban areas. There is also an acute shortage of funds and adequate trained child specialists in India. The first ever report tracking global progress against pneumonia, the leading killer of children under five years of age, finds that India is witnessing the highest number of pneumonia-related child deaths in the world. The infection is killing 16 lakh children under five every year, more than 3.7 lakh in India alone. According to the National Commission on Population (India), in 2002, approximately Rs. 643.1 million was needed for infrastructure and services of 1,774 more pediatricians were required. Hence, the government is unable to appoint child specialists in rural areas. All this leads to high Infant Mortality Rate (IMR) i.e. 68/1000 live births. The National Commission on Population observes that main contributors to high IMR in India are states having majority of population residing in rural areas as shown in Table I.

TABLE I
IMR WITHIN INDIAN STATES (1999) PER THOUSAND

STATES	Orissa	Madhya Pardesh	Uttar Pardesh	Rajasthan
IMR	98	98	85	83

B. Origin of the Research Problem

The responsibility of providing treatment to young infants/children in rural India is with the general health care practitioner posted in Primary Health Center (PHC) or rural dispensaries. Because of the shortage of funds and inadequate trained specialists, the government appoints a child specialist at Community Health Care Center (CHC) only. Therefore, CHC serves as a first referral center to PHC and dispensaries. At some rural places, even less qualified health care professionals are somehow managing the situation. They lack proper knowledge to diagnose and treat the patient. Whenever they face any critical problem related to childhood diseases, they refer these patients to CHC. This increases the number of patients for the child specialist at CHC. The main diseases that young infants and children suffer from include: Pneumonia, Diarrhea, Measles, and Malaria etc. These are often curable at local levels if proper diagnosis and treatment plans are administered timely. The situation demands a system that works beyond these limitations. One can think of incorporating the concept of client-server architecture with an expert system on the server and a dumb client or a telemedicine system. But the problem with this system is the loss of collaborative and proactive behavior that is often required in such cases and limits the scope for future expansions. The problem with the telemedicine is that, it needs direct involvement of a pediatrician to diagnose the disease. Because of these limitations Bayesian Network based intelligent software are more suitable in this domain. This system will help healthcare professionals to diagnose the disease of young infant/child, classify it and identify the treatment plan. A number of research papers supporting the usage of software agents to handle such circumstances have been produced in recent years. Some of the health care applications based on agent metaphor are discussed in section II.

II. Related Work

Software agents are proving to be promising because of their reactive, proactive, autonomous, collaborative and knowledge-sharing capabilities.[2] have discussed the potential and application of agents to assist in a wide range of activities in health care environments. [3] discuss a browsing assistant agent ‘Letizia’ that has been developed to find serendipitous connections when a user searches something related to medicine, and a software agent ‘Aria’ that has been developed to integrate the annotation and retrieval of images into a single, integrated application. [4] simulate an agent oriented environment for German hospitals with the objective to improve or optimize the appointment scheduling system, Resource allocation and cost benefit of clinical trials. [5] employ the Multi agent system for providing diagnosis and advice to health care personnel dealing with traumatized patients. An Emergency Medical Assistant (ERMA) using Intelligent Monitoring agents has been developed to demonstrate the system for the trauma environment with particular emphasis on types of shock and stabilization of arterial blood gases. [6] develops agent based system to improve vaccination rates in Germany. Agents have been developed to maintain consistency of patient’s medical record at pharmacy level, specialist level and at family doctor level. [7] are concerned with the accurate dosage advice for diabetic patients and aim to produce a Personal Digital Assistant based system into which patients enter various details about their diet and physical condition.[8] discuss various applications of MAS in health care e.g., coordination of organ transplants among Spanish hospitals, patient scheduling, senior citizen care etc. [9] have worked on a research project, called PalliaSys. It incorporates information technology and multi-agent systems to improve the care given to palliative patients. [10] has developed TOMAS (Telemedicine-Oriented Medical Assistant) which is used by each specialist to transfer microscopic images and data of a patient for collaborative diagnosis in the department of pathology. [11] have developed an Intelligent Healthcare Knowledge Assistant which uses multi agent system for dynamic knowledge gathering, filtering, adaptation and acquisition from Health care Enterprise Memory unit. [12] created a Multi agent system that aims to enhance monitoring, surveillance and educational service of a Medical Contact Center (MCC) for chronic disease management in Greece. [13] discuss a case study involving various agents for providing consultation and therapy to patients suffering from diabetes. [14] developed an interaction mechanism among the agents that diagnose the disease, suggests the treatment plan as per supplied symptoms and also keep the track of number of disease diagnosed.

The use of Multi-Agent systems in healthcare domain has been widely recognized. But, due to uncertainty in medical domain, it is difficult to decide the appropriate agent with whom to collaborate in order to find the proper diagnosis for a given set of sign-symptoms. To overcome this problem, a Bayesian Network (BN) based decision making framework is presented. The proposed methodology is applied to an Intelligent Pediatric Agent (IPA), a part of MAS for child care. The simulated results suggest that BN can be applied effectively to this type of decision making problem.

More precisely, we try to explore the efficacy of expert-systems in this application area so that proper and effective diagnose and delivery of treatment plan for the young infants and children up to the age of five years can be taken care off at the PHCs in India.

III. Bayesian Network based Childcare System

Bayesian network based system is concerned with intelligent systems that interact and decide for themselves what they should do in order to achieve the design objectives. Software with specific abilities is developed and deployed in the domain of our problem. In the following section, a brief introduction to the functional model and its implementation is provided.

A. Functional Model

An intelligent system is designed according to the requirements for effective diagnosis and delivering the treatment plans for young infant/child in the child-care setting described above. It provides an interaction mechanism with the healthcare professional at a rural site and delivers diagnosed disease and suggests treatment plans as per the supplied sign symptoms. Figure 1 illustrates the abstract interaction model of the system.

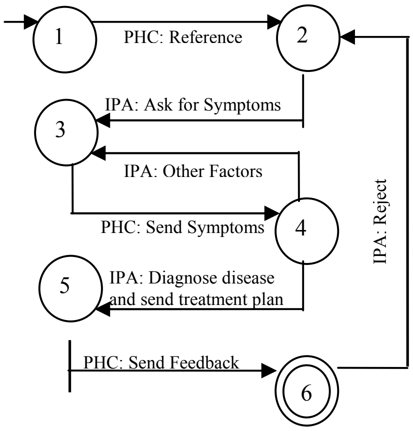

Fig. 1 Interaction Model of the System

The UA is located at PHC while IPA is located at various CHCs. The IPA is behaving as a server to User Agents. The sequence of interactions that takes place between the UA and IPA is discussed in the following algorithms.

B. Algorithms

1) Description

a) Diagnosis_Disease is a global Boolean variable that records whether PHC or IHS can provide consultancy or not. Feedback is a global Boolean variable that records, whether the treatment plan provided by IHS or PHC suits the patient or not.

b) Symptoms and Case History are the variables that contain the symptoms of the disease and the case history of the patient and they are recorded by the PHC.

c) Diagnosed Disease and Treatment Plan are global string variables that store the disease and the treatment suggested to the patient.

d) Environment Factors is a string variable that contains the information regarding other ef that can affect the patient and in turn the treatment plan as well.

IHS_ID is a unique identification number allocated to the IHS.

2) Operators Description

:= Assignment
= Equal to
<> Not equal to

```
Treat_PHC()
begin
Set Feedback := False
  while (Feedback <> True)
  begin
    Read Symptoms and CaseHistory of the patient
    Set Diagnosis_Disease
    if (Diagnosis_Disease = True) then
    begin
      Set DiagnosedDisease
      Set TreatmentPlan
    else
      Read other related EnvironmentFactors
Call Treat_IHS( Symptoms,
               CaseHistory, EnvironmentFactors IHS_ID)
    end if
      Read Feedback from patient
  end while
end
Treat_IHS(Symptoms, CaseHistory, EnvFactors, IHS_ID)
begin
  Set Diagnosis_Disease
  if (Diagnosis_Disease = True) then
  begin
    Set DiagnosedDisease
    SetTreatmentPlan
    Return
  else
    Treat_IHS( Symptoms, CaseHistory EnvFactors, IHS_ID)
  end if
end
```

The main problem is posed before the patient in the form of questions denoted as qi ε Q , where Q = {q1, q2… qk}, set of all possible questions. The qi is passed by the UA to the IPA. 'S' is a set that contains all possible symptoms that a child may be suffering from. i.e. S = {Symptom1, Symptom2… SymptomN}. Now depending on qi, IPA intelligently selects some of the sign-symptoms to be answered by the health care. First of all the preliminary observations regarding the patient are to be recorded in order to move towards the diagnosis. It is shown in the following figure 2.

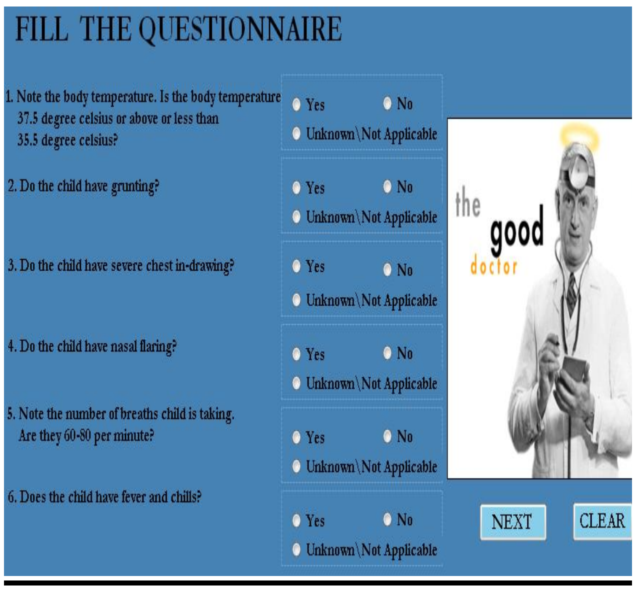

Fig. 2 Preliminary observations regarding the patient

These investigations that are recorded at the PHCs are sent to the IPA. Depending upon these investigations the IPA asks for the specific sign symptoms from the PHCs as shown in the following figure 3.

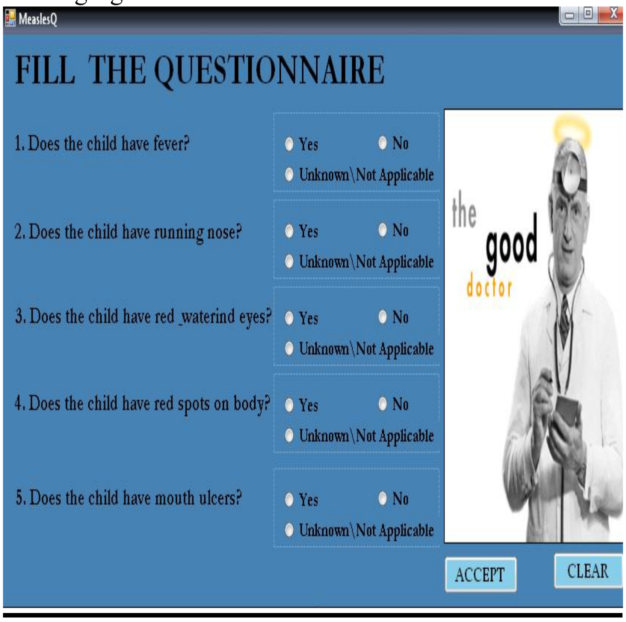

Fig. 3 Disease specific sign symptoms

Once all the symptoms are gathered, the Bayesian Network based engine diagnose the disease it is sent to the PHCs as shown in the following figures 4 and 5.

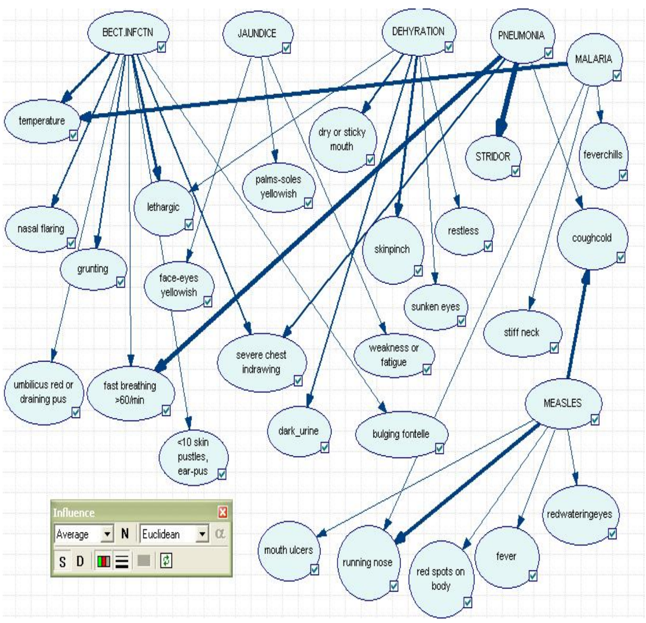

Fig. 4 Bayesian Network Based Diagnosis engine

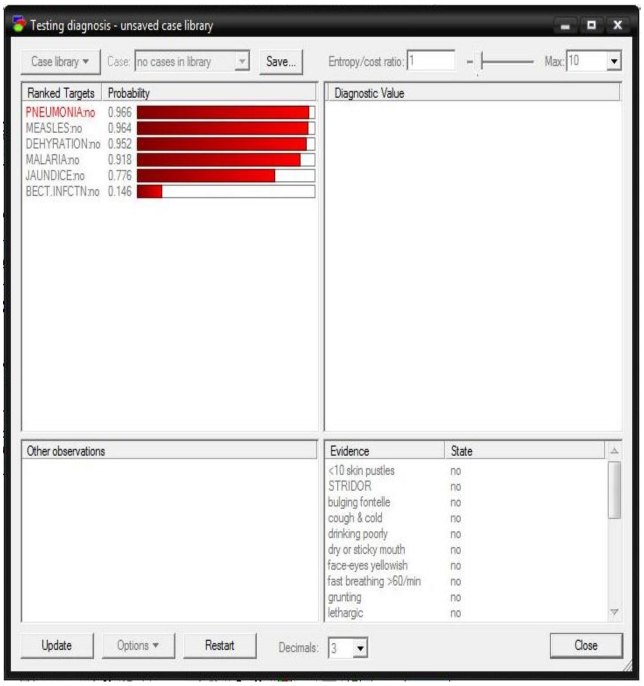

Fig. 5 Diagnosis by the Bayesian Network Based Diagnosis Engine

IV. Discussions and Scope for Future Work

The rural healthcare delivery system in India can be improved by integrating it with the advancements of information technology. For that we need a system that demonstrates features such as, autonomy, reasoning, knowledge-sharing and cooperation. A promising solution to this requirement is an intelligent system. The system based on Bayesian theorem can be used to sense a particular situation, analyze it and make a search for the desired goals. The prototype system that has been discussed above is suitable to the prevailing situation of healthcare in rural India for tackling some diseases being handled by a pediatrician at CHC. There are situations where a pediatrician seeks help from other domain specialists like Neonatologist, Cardiologist, Neurologist, and Endocrinologist. The future work includes the incorporation of such systems. To incorporate reasoning capabilities, Java Expert System Shell (JESS) that works well with JADE [15] can also be considered. To make the system fault tolerant, a replication or cloning of IPA will also be considered in future. A higher level health is center, e.g. Civil Hospital at district level, can be kept in mind for replication and monitoring purposes. JADE supports cloning as well as mobility of agents. Porting the system to mobile devices is also an attractive option.

V. Conclusion

The prototype Bayesian Network Based Childcare system will assist the PHC practitioner in tackling cases that are outside his/her expertise. It will also help the rural patients to reduce their traveling efforts to visit CHC at long distances. The objective of this system is to exhibit the strength of information technology in handling healthcare problems of young infants/children. The system is to provide assistance to the PHC practitioner for diagnosis of childhood diseases and generation of timely treatment plan so as to reduce the IMR. The medical personnel at PHC are supposed to treat most of the cases themselves effectively, and not refer them to CHC unnecessarily. The pediatrician at CHC can monitor the specific cases at PHC also.

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