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Developing a Knowledge-Based System for Diagnosis and Treatment Recommendation of Neonatal Diseases Using CLIPS

Nida D. Wishah, Abed Elilah Elmahmoum, Husam A. Eleyan, Walid F. Murad Samy S. Abu-Naser

Department of Information Technology,
Faculty of Engineering and Information Technology,
Al-Azhar University, Gaza, Palestine

Abstract: *A newborn baby is an infant within the first 28 days of birth. Diagnosis and treatment of infant diseases require specialized medical resources and expert knowledge. However, there is a shortage of such professionals globally, particularly in low-income countries. To address this challenge, a knowledge-based system was designed to aid in the diagnosis and treatment of neonatal diseases. The system utilizes both machine learning and health expert knowledge, and a hybrid data mining process model was used to extract knowledge from a clinical dataset. The PART algorithm achieved the highest performance result with 98.06% accuracy under 10-fold cross-validation, and the generated rules were used to develop the knowledge-based system. The system achieved 90.9% accuracy in system performance testing and 89.2% in user acceptance testing, and is intended to serve as an assistant tool for healthcare experts.*

Keywords: data mining, neonatal diseases, design science research, knowledge-based system , clips , Artificial Intelligence.

1. Introduction :

The first few weeks of a newborn's life are crucial for adjusting to a new environment, experiencing rapid growth, and achieving developmental milestones. However, many infants across the world face health risks during this period. In fact, 2.5 million newborns die within their first month of life, with the leading causes of death being perinatal asphyxia, respiratory distress syndrome, and sepsis (Ahuja, 2019).

One of the most promising and ambitious areas of artificial intelligence for improving healthcare service delivery is knowledge-based systems (KBS). KBS combines automatic knowledge acquisition through machine learning and manual knowledge acquisition through interviews with healthcare experts to develop a system that can diagnose and recommend treatment for newborn diseases (Ahuja, 2019).

Machine learning algorithms have been effective in drawing insights from large medical datasets and accelerating medical research. Through the development of a KBS prototype, healthcare management can improve the quality and accessibility of healthcare services, and help achieve the Sustainable Development Goal of reducing newborn mortality to less than 12 per 1000 live births by 2030 (O, 2021).

The primary contribution of this study is to produce an innovative KBS model, which can serve as a model for the development of related systems. This paper contributes to the healthcare industry by enhancing the effectiveness and efficiency of service delivery and improving the existing policies of the country.

This paper presents a knowledge-based system developed using a combination of automatic knowledge acquisition through machine learning and manual knowledge acquisition through expert interviews. The system aims to diagnose and recommend treatment for newborn baby diseases, thereby improving the effectiveness and efficiency of healthcare service delivery. The ultimate goal is to contribute to the global effort of reducing newborn mortality to less than 12 per 1000 live births by 2030, as outlined in the Sustainable Development Goals.

Expert System:

The proposed Expert System for diagnosis and treatment recommendation of neonatal diseases. emulates the decision-making ability of a human expert in a neonatal diseases . It utilizes knowledge and rules acquired from human experts to provide accurate and consistent recommendations . ES for the diagnosis and treatment recommendation of neonatal diseases was implemented using the CLIPS Rule-Based Programming Language. The ES utilizes a knowledge-based system (KBS) approach, which combines automatic knowledge acquisition using machine learning algorithms with manual knowledge acquisition through interviews with healthcare experts.

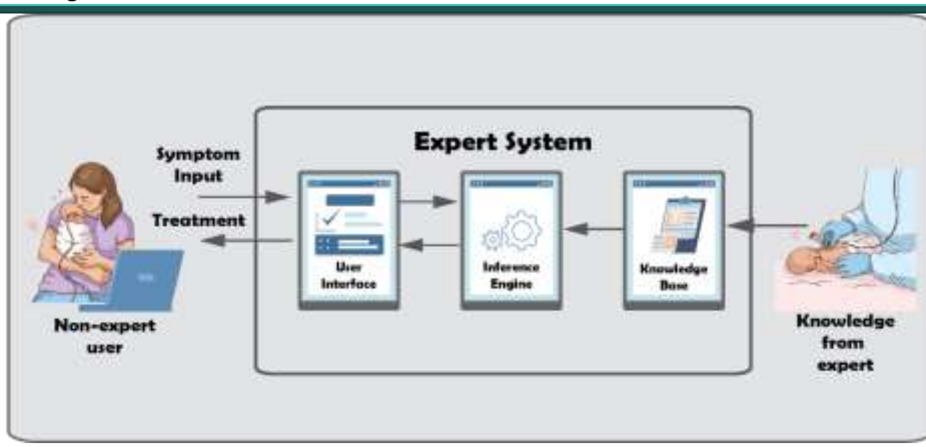

Figure 1: The figure presents the Main Components of an Expert System

2. Methodology and data preprocessing

This paper applies Design Science Research (DSR) as a research methodology to design a knowledge-based system. DSR is a problem-solving approach that has enabled engineers and computer scientists to enhance their work and push the limits of human capabilities by creating innovative artifacts. The methodology is driven by the relevance to the environment and the rigor of the knowledge base. According to Peffers et al. (2008), the DSR process model consists of six activities: identifying and motivating the problem, defining solution objectives, designing and developing, demonstrating, evaluating, and communicating.

2.1 Design and development

The process referred to as "designing an artifact" involves specifying the desired functionality of the innovative artifact and proposed systems, followed by the creation of a model based on the intended solution. The framework of the proposed system is depicted in Figure 1, as described by Ramírez-Gallego et al. (2015).

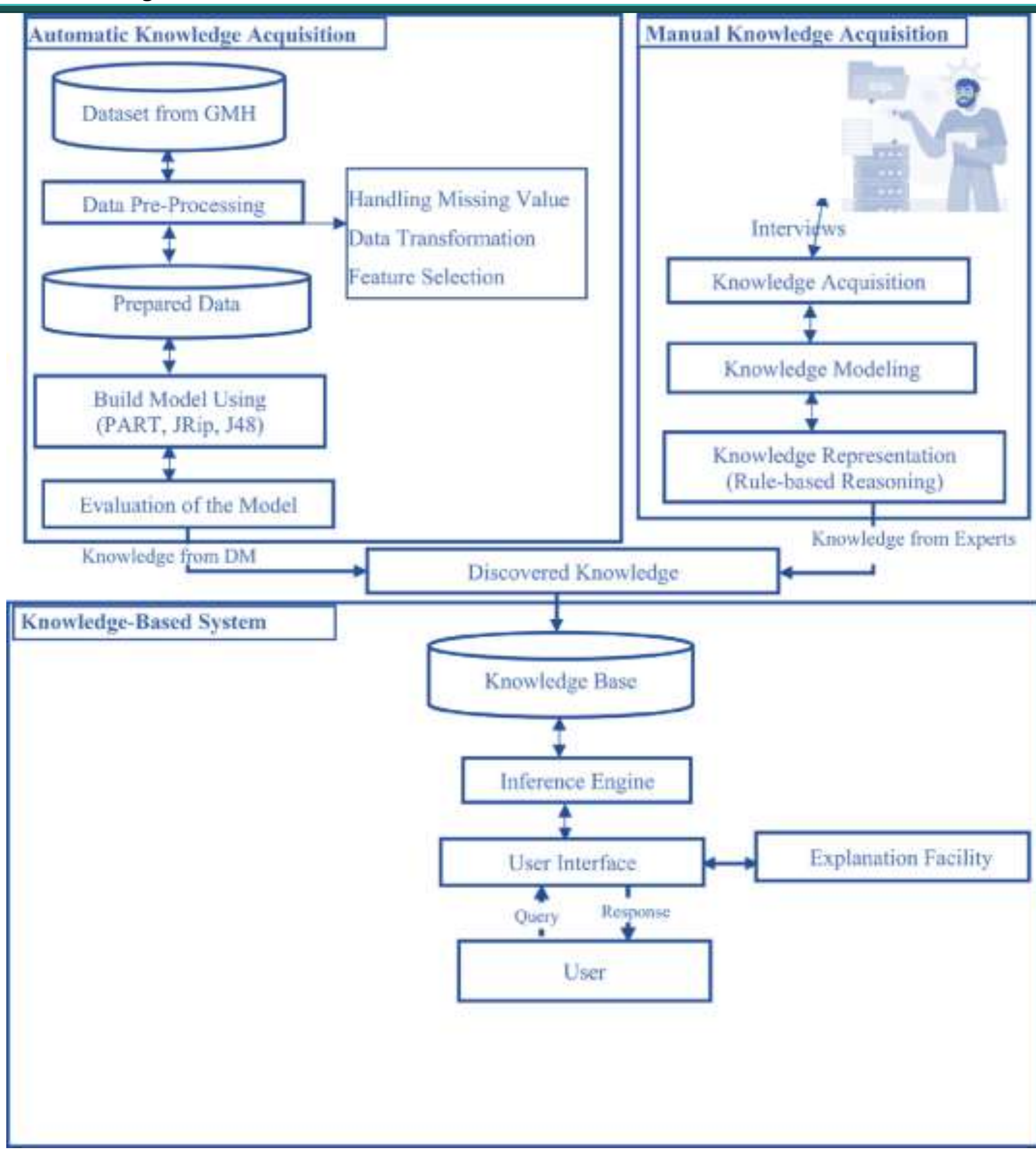

Figure 1

2.2 Automatic knowledge acquisition

Obtaining the required knowledge from healthcare professionals poses a significant challenge in the development of expert systems. To overcome this traditional knowledge gathering hurdle and enhance knowledge-based systems, automatic knowledge acquisition becomes essential. With the exponential growth of healthcare datasets, leveraging machine learning techniques in the healthcare industry provides the most effective solution for extracting valuable knowledge from these vast volumes of data.

2.3 Manual knowledge acquisition

To gather implicit knowledge from medical experts, both structured and unstructured interviews were conducted. The author interviewed healthcare professionals to obtain insights and recommendations aimed at improving existing practices and addressing problems. The selection of medical experts for the study was based on the author's purposive sampling technique, allowing for a targeted gathering of implicit knowledge. The acquired knowledge was then modeled using a decision tree and represented using a rule-based knowledge representation approach in this paper.

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2.4 Knowledge-based system

In machine learning applications in healthcare, dataset preprocessing plays a crucial role. Even minor adjustments to data quality can lead to higher effectiveness, resulting in improved validity and quality of the discovered knowledge (Hailemariam, 2012). To enhance the performance of the predictive model, various techniques were employed during the preprocessing phase. These techniques include handling missing values through imputation, selecting relevant features, and transforming the data. The application of these preprocessing techniques aims to improve the overall performance of the predictive model.

2.5 Data preprocessing

In healthcare machine learning applications, dataset preprocessing plays a crucial role as it helps ensure higher effectiveness and improved validity and quality of the discovered knowledge (Hailemariam, 2012). To enhance the performance of predictive models, several techniques are employed during the preprocessing phase. These techniques include addressing missing values through imputation, selecting relevant features, and transforming the data. By applying these preprocessing techniques, the predictive model's performance is enhanced, leading to more accurate and reliable outcomes.

3. Experimentation and implementation

Model building is the core task in machine learning, and the model is developed by providing the processed data to the selected machine learning classification algorithms (Micheline et al., Citation2012).

Knowledge Acquisition:

In the artificial intelligence field, knowledge acquisition and representation are important activities in knowledge-based systems development. The knowledge gained during the first stages of the development of knowledge-based systems has determined the success of the intelligent system (Mohammad & Al Saiyd, Citation2010).

Knowledge Modeling:

Models are employed to capture the fundamental aspects of real systems by breaking them down into more manageable parts that are easier to understand and manipulate. In line with this, Figure 2 showcases the knowledge obtained from the healthcare expert in the form of a decision tree. This decision tree is utilized for diagnosing and providing treatment recommendations for diseases in newborn babies.

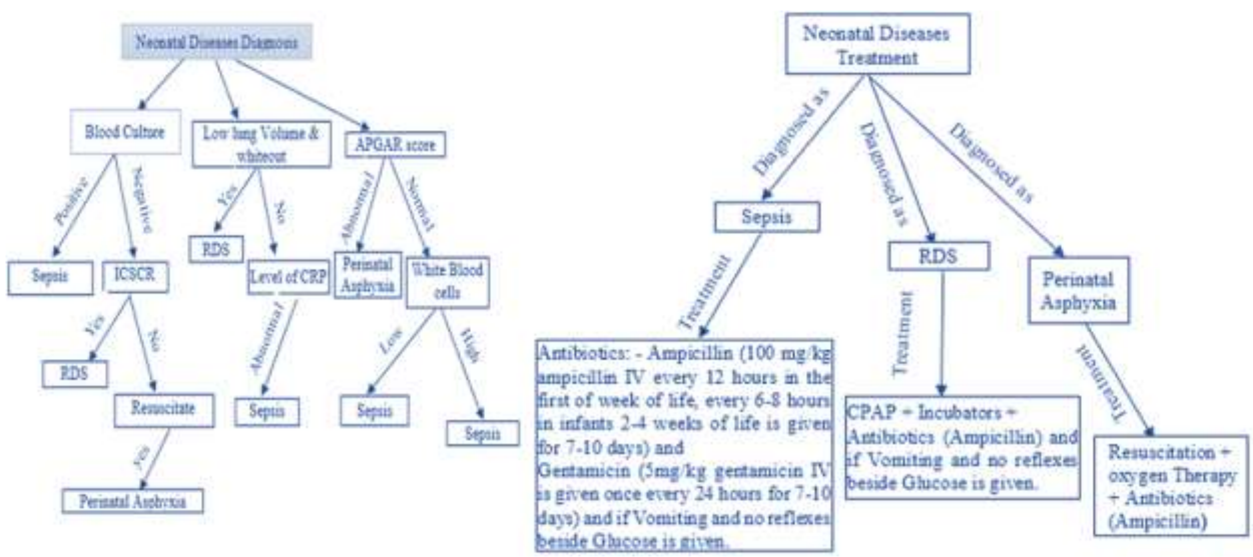

Figure 2

Knowledge Representation:

Once the knowledge is acquired and modeled, it is represented using rule-based knowledge representation techniques. In this study, the knowledge obtained from healthcare experts was represented in IF-THEN format. Here are some sample rules for the diagnosis of newborn diseases

Rule 1: IF newborn patients' blood culture is Positive, THEN the Disease = Sepsis.

Rule 2: IF newborn patients' blood culture is Negative the intercostal subcostal retraction is Yes THEN the Disease = RDS.

Rule 3: IF newborn patients' blood culture is Negative the intercostal subcostal retraction is No and the Resuscitate is Yes THEN the Disease = Perinatal Asphyxia.

Rule 4: IF newborn patients have low lung volume with whiteout color is Yes THEN the Disease = RDS

4.1. Developing knowledge-based system

Following the completion of the knowledge acquisition, modeling, and representation tasks, the subsequent activity is the design of expert systems. In the context of diagnosing neonatal diseases like sepsis, RDS, and perinatal asphyxia, a total of 16 rules were generated from the PART classification algorithms, while an additional 8 rules were provided by domain experts. Furthermore, for each disease, the knowledge extracted from domain experts was utilized to ensure the functionality of the expert systems in managing the respective conditions.

Then, the acquired knowledge is programmed in the knowledge base as facts about the subject and knowledge relationships in terms of if-then rules. Beyond the knowledge representation or rule-based reasoning approach.

5.1. Material and Methods

The goal of the expert system is to diagnose neonatal diseases by presenting all the relevant symptoms. The system will prompt the user to select the type of symptoms observed. After gathering the necessary information, the expert system will provide a diagnosis, identify the specific illness, and offer recommendations for the user's benefit.

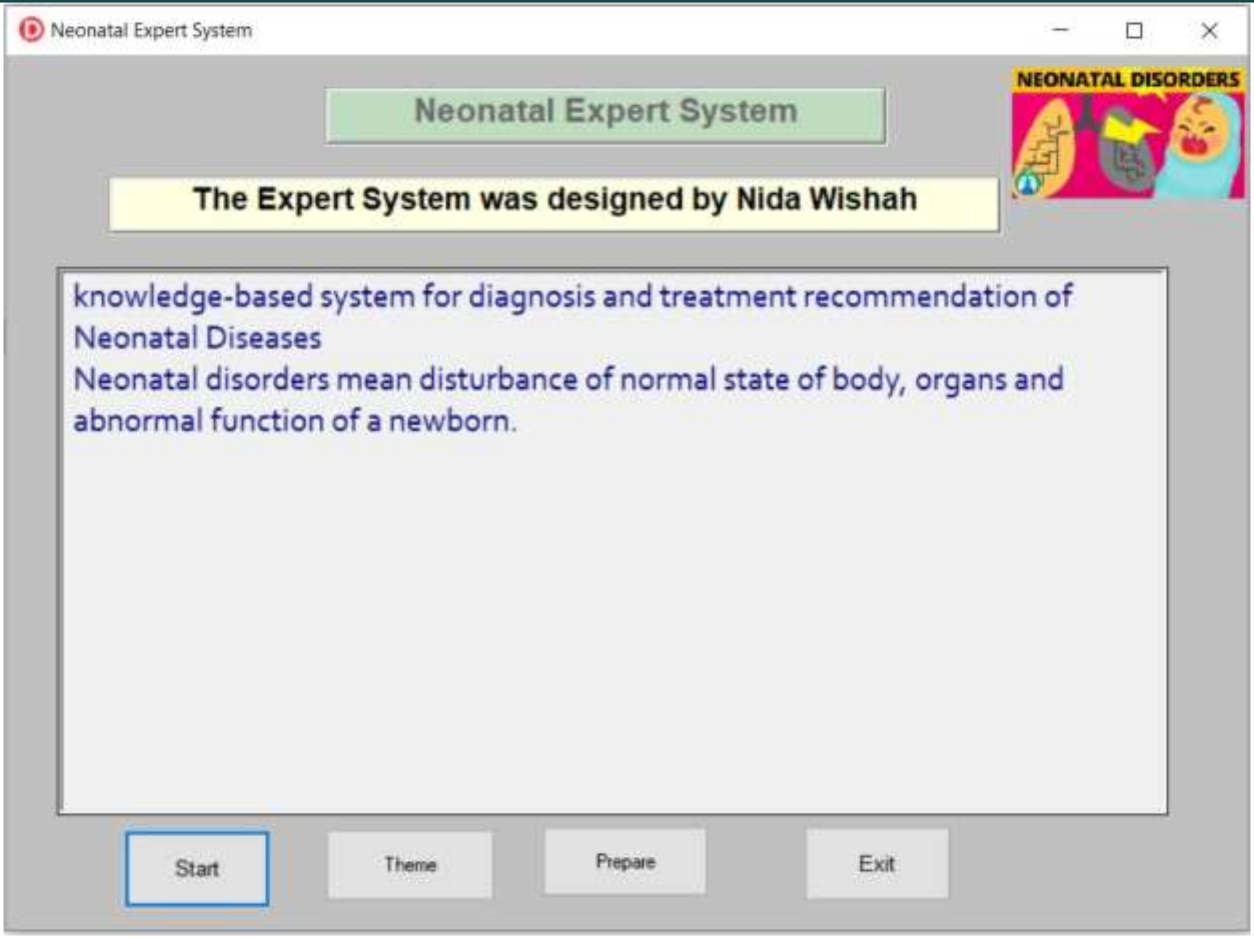
Neonatal Expert System
NEONATAL DISORDERS
Neonatal Expert System
The Expert System was designed by Nida Wishah
knowledge-based system for diagnosis and treatment recommendation of Neonatal Diseases
Neonatal disorders mean disturbance of normal state of body, organs and abnormal function of a newborn.
Start
Theme
Prepare
Exit

Figure 3 : shows the main interface of the system

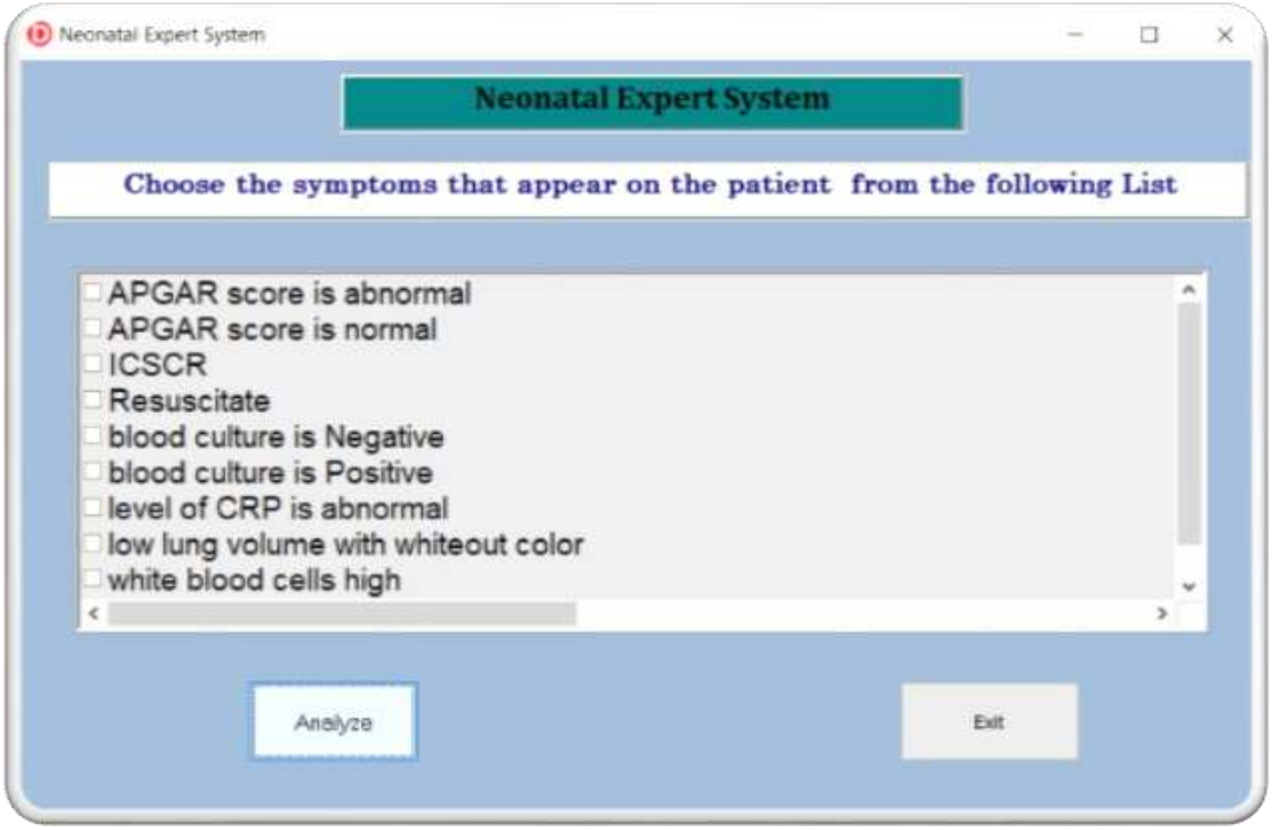

Figure 3: Dialogue between the expert system and the user

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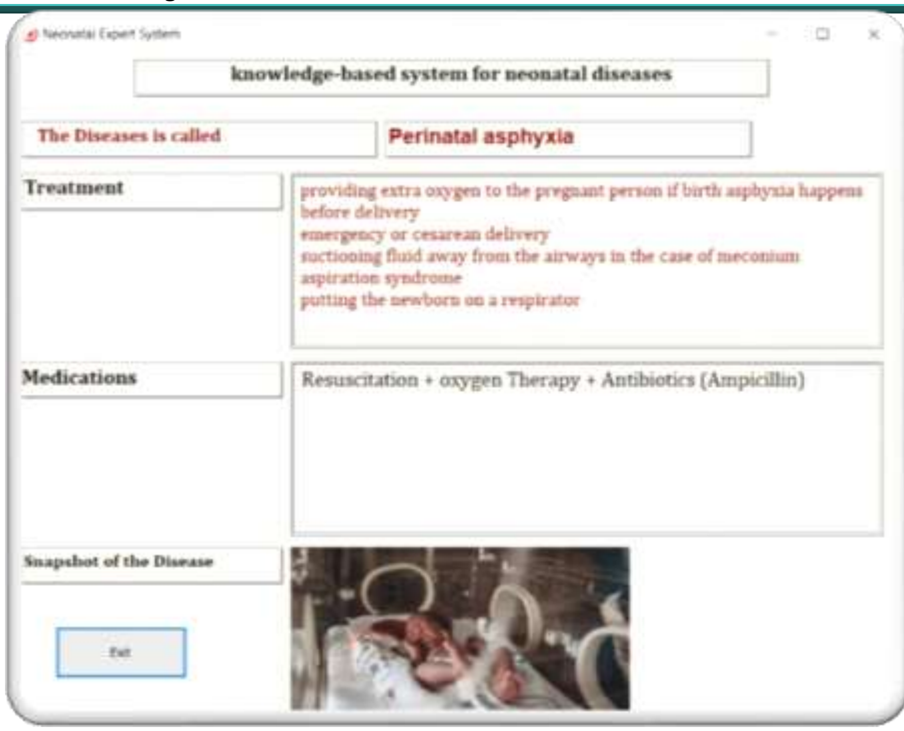

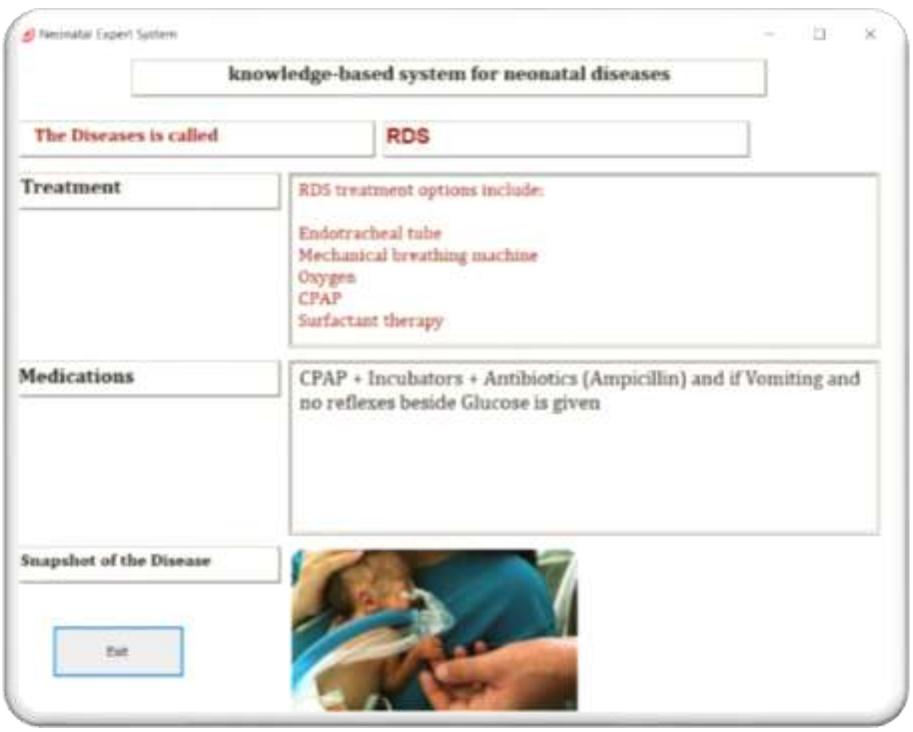

Figure 4: Diagnosis and recommendation

Here some overview about above diagnosis:

Perinatal asphyxia: is a lack of oxygen to the fetus or newborn during the perinatal period (the time from 24 weeks of pregnancy to 7 days after birth). It can be caused by a number of factors, including[1]:

- Umbilical cord prolapse
- Placenta previa
- Abruptio placentae
- Prolonged labor
- Meconium aspiration
- Birth trauma

The diagnosis of perinatal asphyxia is based on a number of factors, including [2]:

- The baby's Apgar score
- The baby's blood gas levels
- The baby's neurological exam
- The baby's imaging studies

The Apgar score is a test that is given to newborns to assess their health immediately after birth. A low Apgar score may be a sign of asphyxia. Blood gas levels can be used to check for signs of oxygen deprivation, such as low blood oxygen levels and high blood carbon dioxide levels. A neurological exam can be used to look for signs of brain damage caused by asphyxia. Imaging studies, such as a CT scan or MRI, can be used to look for signs of brain damage or other injuries caused by asphyxia. [3]

The treatment of perinatal asphyxia depends on the severity of the condition. Mild cases may only require supportive care, such as oxygen and fluids. More severe cases may require treatment in the neonatal intensive care unit (NICU), such as mechanical ventilation and medications to protect the brain. [4]

The long-term outcome of babies with perinatal asphyxia varies depending on the severity of the condition. Some babies make a full recovery, while others may have long-term problems, such as cerebral palsy, learning disabilities, or seizures.[5]

There are a number of things that can be done to prevent perinatal asphyxia, including:

- Getting regular prenatal care
- Identifying and managing risk factors
- Having a healthy pregnancy
- Having a safe delivery

Respiratory distress syndrome (RDS), also known as hyaline membrane disease, is a common respiratory disorder primarily affecting premature infants [6]. It occurs due to insufficient production of surfactant, a substance that helps keep the air sacs in the lungs open and prevents their collapse. Without enough surfactant, the lungs become stiff, making it difficult for the baby to breathe properly.

RDS is more prevalent in infants born before 34 weeks of gestation as their lungs are not fully developed and have lower levels of surfactant [6]. Other risk factors for RDS include maternal diabetes, cesarean delivery without labor, multiple pregnancies, and a family history of RDS.

The symptoms of RDS typically manifest shortly after birth and may include rapid, shallow breathing, retractions (visible pulling of the chest wall during breathing), grunting sounds, and cyanosis (bluish tint to the skin) [6].

The diagnosis of RDS involves clinical evaluation, assessment of symptoms, and imaging tests such as chest X-rays to evaluate lung maturity and rule out other respiratory conditions [6].

Treatment for RDS focuses on providing respiratory support and ensuring adequate oxygen supply. This may involve placing the baby on a ventilator to assist breathing and administering surfactant replacement therapy to enhance lung function [6].

The prognosis for infants with RDS depends on various factors such as the severity of the condition, gestational age at birth, and the availability of appropriate medical interventions. With advancements in neonatal care, the survival rates for infants with RDS have significantly improved over the years [6].

Neonatal sepsis is a serious infection that affects newborns. It can be caused by bacteria, viruses, or fungi. Sepsis can be life-threatening, so it is important to seek medical attention immediately if you think your newborn may have it.
The symptoms of neonatal sepsis can vary, but they may include[7]:

- Fever
- Low body temperature
- Rapid breathing
- Fast heart rate
- Pale or mottled skin
- Poor feeding
- Vomiting
- Diarrhea
- Convulsions
- Lethargy
- Seizures

If your newborn has any of these symptoms, it is important to call your doctor or take them to the emergency room right away.
The diagnosis of neonatal sepsis is based on a number of factors, including [8]:

- The baby's symptoms
- The baby's medical history
- The baby's physical examination
- Blood tests
- Urine tests
- Cerebrospinal fluid tests
-

Blood tests can be used to check for signs of infection, such as an elevated white blood cell count. Urine tests can be used to check for signs of infection, such as bacteria or white blood cells. Cerebrospinal fluid tests can be used to check for signs of infection in the brain and spinal cord.

If your newborn is diagnosed with sepsis, they will be treated with antibiotics. The type of antibiotic that is used will depend on the type of infection that is causing the sepsis. Antibiotics are usually given intravenously (IV).

In addition to antibiotics, newborns with sepsis may also need fluids, oxygen, and other supportive care.

The prognosis for newborns with sepsis depends on the severity of the infection and the baby's overall health. Most babies with sepsis make a full recovery, but some babies may have long-term complications, such as brain damage or hearing loss.

There are a number of things that can be done to prevent neonatal sepsis, including [9]:

- Getting regular prenatal care
- Washing your hands thoroughly before and after touching your newborn
- Keeping your newborn's environment clean
- Breast-feeding your newborn

Conclusion:

In this paper, we have presented the development of a knowledge-based system for the diagnosis and treatment recommendation of neonatal diseases using CLIPS. The aim of this research was to leverage the power of artificial intelligence and knowledge representation techniques to improve the accuracy and efficiency of diagnosing and treating neonatal diseases.

Through the utilization of CLIPS, a widely recognized expert system tool, we were able to construct a knowledge-based system that incorporates domain-specific knowledge and rules. The system was designed to emulate the decision-making process of healthcare professionals, enabling it to analyze symptoms, medical records, and other relevant information to arrive at accurate diagnoses and treatment recommendations.

The development process involved the acquisition of medical knowledge from experts in the field of neonatology, the representation of this knowledge in a structured format, and the implementation of inference rules within the CLIPS environment. The system's performance was evaluated through extensive testing and validation, using real-world clinical cases and expert assessments.

The results of our evaluation demonstrated the system's effectiveness in accurately diagnosing neonatal diseases and providing appropriate treatment recommendations. The knowledge-based system achieved high levels of accuracy and demonstrated the potential to assist healthcare professionals in making informed decisions, particularly in cases where time is of the essence or when expert consultation may not be readily available.

The integration of a knowledge-based system like the one developed in this research has the potential to significantly enhance the quality of care provided to neonatal patients. By leveraging artificial intelligence techniques, healthcare professionals can benefit from the system's ability to rapidly process large volumes of data, consider complex relationships, and provide evidence-based recommendations.

However, it is important to acknowledge that the knowledge-based system presented in this paper is not intended to replace healthcare professionals. Instead, it should be viewed as a complementary tool that can assist in the decision-making process.

Furthermore, ongoing refinement and expansion of the system's knowledge base will be necessary to ensure its relevance and accuracy as medical knowledge evolves.

In conclusion, the development of a knowledge-based system for the diagnosis and treatment recommendation of neonatal diseases using CLIPS represents a significant step towards improving healthcare outcomes in neonatology. The system's ability to harness domain-specific knowledge, analyze complex medical data, and provide accurate recommendations holds great promise for enhancing clinical decision-making and ultimately improving the well-being of neonatal patients. Further research and collaboration between experts in the fields of medicine and artificial intelligence will be crucial in advancing the capabilities of such systems and their integration into clinical practice.

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