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A Fuzzy-Based Expert System for Prenatal Care Advice

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Abstract

Prenatal care refers to medical attention that a woman receives to maintain her health and the health of her unborn child. The traditional methods of medical experts in prenatal care advice can sometimes be inadequate and less efficient due to a number of factors. One major issue is the lack of knowledge in the area of prenatal care for most medical experts, which hinders quality advice to pregnant women. In order to overcome some of these challenges, computer-based methods for any health issue have been proposed, which have shown to be more effective and are being utilized more frequently to raise the standard of medical care. This research work proposes the use of an expert system approach based on a forward-chain inference engine. Java programming language was used in the implementation of the proposed expert system. The expert system for prenatal care recommendations had a mean satisfaction level score of 3.87 out of a possible 5.0, according to the assessment results based on survey opinions. This suggests a 77.5% level of user satisfaction. The performance level of the expert system in providing quality advice to pregnant women indicates that it is faster, more sensitive, and more reliable than the traditional method of using medical experts to provide prenatal care advice.

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1. Introduction:

A woman receives prenatal care when she is pregnant, which helps to keep an expectant mother and her baby healthy [1]. The United Nations (UN) reports that maternal complications cause over 287,000 deaths in the world each year, or one fatality every two minutes. In 2020, developing nations accounted for 99% of all deaths which could have been avoided [2]. According to the World Health Organization (WHO), pregnancy and childbirth-related complications claim the lives of almost 830 women each day [3]. One of the major factors identified is the lack of qualified medical experts that can monitor and give first-hand advice to pregnant women. The World Health Organization advises all expectant mothers to have four prenatal consultations in order to identify, address issues, and receive vaccinations.

Compared to their care-seeking counterparts, pregnant women who do not receive care are five times more likely to die and are three times more likely to have low birth weights [4]. One of the main benefits of prenatal care is that regular medical checkups allow doctors to identify and address health issues early [5]. Additionally, pregnant women can get advice from physicians on how to give their unborn child a healthy start. Prenatal testing for a range of genetic and other abnormalities is becoming more and more prevalent [6]. The increase in prenatal testing raises the degree of medicalization and monitoring during pregnancy and gives parents and society at large additional tools for controlling the kinds of children that are born [7].

Pregnancy is portrayed as a dangerous and risky procedure by prenatal testing and a plethora of other cultural pressures [8]. Based on all these beliefs about putting pressure on women to produce quality babies, many women are reluctant to enroll in prenatal care. Understanding women's preferences and wants about care is essential to providing women-centered services. One of the best methods to lower the risk of death for pregnant women is to make important healthcare services more accessible and use them, and to raise women's understanding of the warning signs and symptoms of birth-related problems.

Computer-based methods for any health issue have proven to be more efficient and are increasingly used to improve the quality of medical services [9]. The special focus of this research is to develop an expert system application that will assist an expectant mother in the early detection of prenatal risks. A number of works have been done, particularly in the area of early pregnancy disorder prediction.

Using Artificial Neural Networks (ANNs), a decision support system was created by [10] to aid in clinical decision-making about fetal delivery requirements. This method can be used to predict fetal health, delivery, and prenatal fetal periods, among other things. It can also be used to detect blood pressure and heart attacks. In terms of diagnosing fetal labour, the Radial Basis Function Network (RBFN) technique has the best accuracy (99%) followed by the Basic Probability Assignment (BPA) technique (93%) and the Learning Vector Quantization Networks (LVQN) approach (87.5%). Reference [11] has used ANN to calculate the risk of preeclampsia occurrence. It was concluded that the neural structure would be a useful and reliable predictor. Reference [12] developed a system that can predict hydatidiform mole, preeclampsia, ectopic pregnancy, eclampsia, and hyperemesis gravidarum with an accuracy of 78.248%. But since it's a crucial system, there's a need for more precise result prediction. Reference [13] successfully created a system that uses ANN to identify preeclampsia risk early. The system was able to predict with high accuracy and also shows acceptance tests among pregnant women. However, because the weighted data needs to be trained, the system takes a lengthy time. For this research to produce the best weight results, additional parameter adjustments are required. An expert solution was put forth by [14] to enhance prenatal care in areas with restricted resources. The findings demonstrated that antenatal care access is still hampered by a number of conventions and restrictions. A machine learning-based clinical decision support system for prenatal care was proposed by [15]. The authors used an organized procedure for literature search, paper selection and filtering, data extraction, and synthesis, and a systematic review of the body of current literature. They discovered an overall lack of explainability in the proposed models. They also noted that most studies used data from a single center or nation, there was a general lack of awareness regarding the applicability and generalizability of the Clinical Decision Support Systems (CDSSs) regarding different populations, and there was a lack of experimentation, external validation, and discussion around culture, ethnicity, and race from the source data. Ultimately, they discovered a discrepancy in the application of clinical decision support systems for pregnancy care and machine learning techniques. This research aims to design a fuzzy-based expert system (computer-based method) that can be used to provide prenatal care advice to expectant women in order to prevent pregnancy-related hazards and enhance safe delivery. Bidika et al. [16] proposed a fuzzy expert system in order to monitor pregnancy for the mother's safety and provide linguistically described risk information. The research employed a seven-input-variable Mamdani fuzzy inference system. Eight closed-and open-ended questions were employed in the user acceptance evaluation used in the study, which involved five evaluators chosen from the hospital. According to the assessment's findings, the system has a 90.20% prediction accuracy. Based on a pregnancy sample dataset, the Random Forest algorithm was used to forecast the likelihood of pregnancy risk, which was then stated as seven linguistic phrases in the system testing evaluation technique. The results indicated that the study can help expectant moms reduce their chance of becoming pregnant during their pregnancy and raise awareness about the use of intelligent technology. Gebremariam et al. [17] proposed a rule-based expert system for the diagnosis of maternal complications during pregnancy. Literature reviews and local healthcare facilities were among the many sources from which the risk variables linked to each disease were gathered. After that, characteristics and guidelines were developed for the disease diagnosis, with an inference engine based on a fuzzy inference system in the Mamdani style. An online user interface for the expert system has also been created to improve accessibility and usability. Users may easily enter pertinent data and receive an accurate diagnosis of an illness thanks to this interface, which facilitates smooth system interaction. When utilizing a set of risk indicators to identify the three maternal problems (preeclampsia, GDM, and maternal sepsis), the suggested expert system showed a 94% accuracy rate. To make the system easier to use, a specially created web-based user interface was used for deployment. Filipović et al. [18] proposed a rule-based system for pregnancy monitoring. According to the study, expert systems and doctors can collaborate through software, which can enhance prenatal care. Better and safer prenatal care can be provided, and the infant mortality rate can be decreased, by incorporating the knowledge and experience of the expert system into the rule-based system to direct physician decision-making. The suggested approach identifies chromosomal anomalies based on several factors and diseases based on symptoms. It also computes and records the results of cardiotocography. Based on rules, this system functions as an expert system. Runtime modifications allow for the alteration of rules without compromising the functionality of the application. It can be viewed as a support system for medical personalities rather than a means of displacing physicians. Tahir et al. [19] developed an expert system for the diagnosis of prenatal illnesses. The author used a variety of methods to gather data, such as literature reviews, interviews, and observation. Rapid Application Development (RAD) methodology and object-oriented paradigms form the foundation of the developed system. The process of developing RAD involves several stages, including requirement planning, workshop design, and implementation. The results of the study showed that an expert system for diagnosing disorders in expecting mothers was developed using the PHP programming language, MySQL database management system, Apache web server, UML tool, and RAD system development methodology. The developed expert system was created using the forward chaining method, where the initial steps involve establishing rules and building an inference tree. The consistency test is also computed by this system using the Bayes theorem technique. The established expert system can be utilized as a diagnosis tool for pregnancy-related diseases, with an accuracy rate of 80%. As per the survey findings, the built system achieved a user-friendliness rating of 80% from the users. Fernández et al. [20] proposed a decision support system based on a three stages classifier. The goal of the proposed approach is to identify diagnostic errors by allowing each stage to function as a filter and reevaluate the classification established in the previous stage. Multilayer Perceptron, Deep Learning, Support Vector Machine, and Naives Bayes were the four assistance algorithms that were used in the study's implementation and testing. The outcomes demonstrated that Support Vector Machine and Multilayer Perceptron can be helpful in assisting gynecologists in making judgments for the first course of therapy. Support Vector Machine in particular provides results regarding accuracy, sensitivity, and specificity that are approximately 96.1, 96%, and 98%, respectively. The findings indicated that it is possible to use the algorithms with improved precision to create a clinical decision support system. The authors also stated that Gynecologists would benefit from the study by being able to make the most informed first treatment decisions, preventing further difficulties. Moreira et al. [21] proposed a Particle Swarm Optimization (PSO) as a way to lower the multilayer perceptron's (MLP) computational cost without sacrificing precision rate. The findings demonstrated that the PSO algorithm can enhance computational model performance, exhibiting validation error rates that are lower than those of the traditional method. The research can help choose the optimal parameters and offer a productive way to train the MLP algorithm. The results indicated that the suggested strategy reduced the false positive ratio (FPR) by 35.4% and outperformed other approaches by 14.9% and 26.4%, respectively, in terms of precision and true positive ratio (TPR). Additionally, when applied to the delivery outcome for pregnant women, the results demonstrated that the suggested technique outperformed the MLP algorithm by 2.3 and 10.2%, respectively, in terms of precision and area under the receiver operating characteristic curve. Using an Improved Adaptive Genetic Algorithm (IAGA) and an Extreme Learning Machine (ELM), Ravindran et al. [22] proposed a unique clinical decision support system for the assessment of fetal well-being from the cardiotocogram (CTG) dataset. In order to prevent premature convergence, the IAGA uses a new scaling technique. Adaptive crossover and mutation procedures with masking principles are also applied to improve population variety. Additionally, the performance of this search algorithm is evaluated using three distinct fitness factors. The classification results demonstrated that utilizing IAGA to select an ideal feature subset yields a promising 94% classification accuracy. Also, to support its thorough search for the global optimum, the classification results are contrasted with those of alternative feature reduction methods. Additionally, five additional benchmark datasets were utilized to assess the effectiveness of the suggested IAGA algorithm. Based on cardiotocography data, Nagendra et al. [23] proposed a real-time fetal monitoring system using random forest classifiers and support vector machines (SVM). The findings demonstrated that support vector machines and random forests were both over 96% accurate in predicting the outcomes of fetuses, with SVM outperforming random forests in cases that were questionable.

The rest of this study is designed as follows: Materials and methods are presented in Section 2. The results and discussion are presented in Section 3. Section 4 concludes the work.

2. Materials and method

This study proposes the use of an expert system approach based on a forward-chain inference engine. Finding an inference rule where the antecedent (if clause) is known to be true is the goal of the forward chaining inference. The engine can draw conclusions or infer the consequent (Then clause) when one of these rules is discovered, which adds new data to its collection. Forward-chaining has an advantage over backward-chaining in that new data can lead to new conclusions. This means that the engine is more suited to dynamic circumstances where conditions are expected to change, such as prenatal care or other health-related issues. The expert system takes in responses from users to some vital health questions relating to prenatal care and sends them to its inference engine based on forward chaining to determine the right condition of a prospective pregnant woman and the right advice to offer at a particular instance based on its predefined rules in its knowledge base. The expert system generates intelligent prenatal care advice and recommendations, and it also serves as a better way to get more pregnant women to participate in prenatal care programs as opposed to the medical expert's approach. The overall architecture of the expert system will be shown in Figure 1.

2.1 Design architecture

2.1.1 Patient Database

The patient database works as the expert system's working memory, storing the information provided by the patient in response to questions the system poses about their health. These responses were utilized by the expert system to determine the best course of action for the pregnant patient and to update its rules in the knowledge base. A relational database system can be likened to the patient database. It includes data that the final user has provided. The knowledge base's antecedents are assessed using this information. The working memory updates its old values when there is a change in the knowledge base, which generates new values.

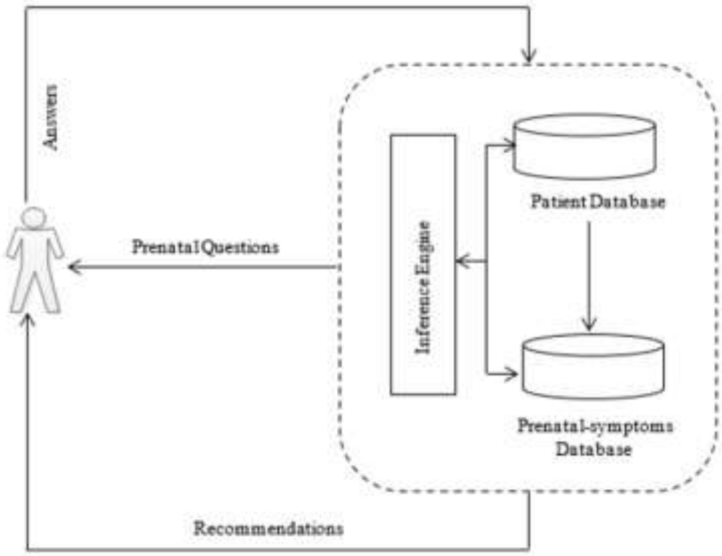

Figure 1. Architecture of the Expert System for Prenatal Care Advice

2.1.2 Prenatal- symptoms Database

The knowledge base of the suggested prenatal expert system is represented by the prenatal-symptoms database. The patient's symptoms, which comprise a set of facts and rules that encompass all known information about the problem domain, form the core of the expert system that has been created. As a result, the expert system uses it to store all pertinent data, rules, cases, and relationships. The probable symptoms that a pregnant woman may have been represented in the if section of the rules, and the recommendation that is related to the if- part of the rules is represented in the then- part. The facts for the rule formation are derived from relevant sources, related kinds of literature, and medical experts' knowledge [24, 25, 26, 27]. A total of 81 rules were derived at the time of this documentation. Here are a few instances of the rules that comprised the database for patient symptoms:

If habit is smoking AND weight is obese THEN Blood pressure is above 140/90mm Hg.

If the urine color is dark AND the headache is persistent THEN drink a lot of water and rest properly.

If the urine color is light-yellow AND the Baby's heart rate is above 140 beats per minute THEN the patient's urine is ok and the baby is a girl.

If the urine color is dark AND the Baby's heart rate is lower than 140 beats per minute THEN the patient is dehydrated and the Baby is a boy.

2.1.3 Inference Engine

The artificial intelligence reasoning process is implemented by the prenatal care expert system's inference engine, which is comparable to human reasoning. Its job is to use the user's input and the facts and rules from the knowledge base to come up with a solution to the problem. An inference engine's job is to search the knowledge base for relationships and facts, and then use those relationships to generate answers, forecasts, and recommendations in a manner similar to that of a medical expert. The forward chaining inference engine utilized by the prenatal care expert system's design allows it to gather data before using it to determine the solution. Since forward chaining is data-driven, it is employed in situations when the precise solution is unknown. The inference engine follows a structured sequence of processing steps as follows:

(1) **Input variables**

The input variables x_3 to x_{13} for the inference engine are those represented in Table 2. The input variables denote prenatal symptoms (see Equation 1) and are derived from related kinds of literature and experts' knowledge.

Input variables = $\{x_3, x_4, x_5, x_6, x_7, x_8, x_9, x_{10}, x_{11,} x_{12}, x_{13}\}$ (1)

(2) Distance measurement

The inference engine first computes the similarity distance between input variables presently entered by the user and its corresponding past cases. This distance measurement is based on the Euclidean distance between present user input, past cases, and a time factor. The time factor is applied to past cases to place priority on the recent solutions rather than the older solutions. The distance measurement is calculated as follows:

$$d(X, X^*) = \frac{\sqrt{\sum_{i=1}^{n} t_i (x_i - x^*_i)^2}}{\sum_{i=1}^{n} t_i} \quad (2)$$

where $d(X, X^*)$ is the distance measurement between the variable from the present user input X and the past case X^*, and n is the number of past cases that are time-related, and t_i represents time-decreasing factor of past case at time i.

(3) Variable Similarity (VS)

The variable similarity is computed based on the distance measurement in (2). A minimum threshold d_{min} and a maximum threshold d_{max} are values determined by medical experts. The present case is said to be similar to the past case if the distance between them is less than d_{min}, and dissimilar if the distance between the present input and past case is greater than d_{max}. Therefore, the variable similarity varies proportionately between d_{min} and d_{max}. Therefore, the inference system will recommend the solution to the past case for the present case if the variable similarity value is 1, and no solution is recommended if the value is 0, as shown in (3).

$$VS = \begin{cases} 1, & d(X, X^*) \le d_{min} \\ \frac{d_{max} - d(X, X^*)}{d_{max} - d_{min}}, & d_{min} < d(X, X^*) < d_{max} \\ 0, & d_{max} \le d(X, X^*) \end{cases} \quad (3)$$

(4) Inference rules

Lastly, if there are no past case solutions for the inference engine to compute its recommendations, the inference engine will obtain recommendations by using the if-then rules in the prenatal- symptoms database of the developed system. The knowledge representation for prenatal care advice was formulated in the form of if-then rules for expert recommendations based on the facts in the prenatal- symptoms database as in section 2.1.2.

Figure 2 shows the flow diagram for the designed expert system for prenatal care advice that represents a flow or set of dynamic relationships (movement of people or things) in a system.

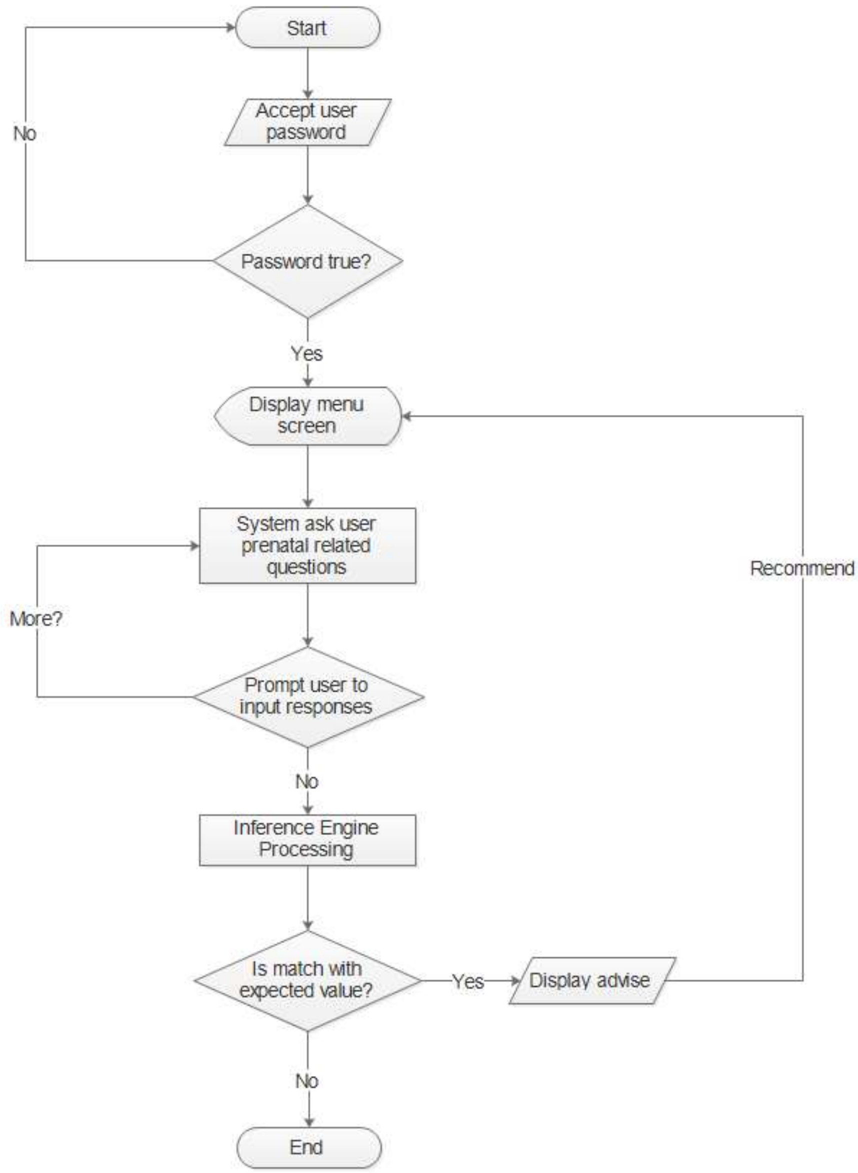

Figure 2. Flow Diagram for Expert System Prenatal Care Advice

2.1.4 User interface

The conversation between the user and the system is managed by the user interface. It is how the end-user responds to some yes-or-no questions about pregnancy, allowing the expert system to reason and offer pertinent replies. It serves as a communication channel between the user and the expert system. The user interface's goal is to make it easier for developers, users, and administrators to utilize the expert system.

2.1.5 Recommendation

The end user receives the outcome of the prenatal care expert system's recommendation module's processing and reasoning based on the data and guidelines in its knowledge base. The advice for the end user to make the right choice can take the shape of a recommendation, forecast, or solution.

2.2 Algorithm

The forward chaining method, which is based on the conflict resolution technique, is employed by the expert system providing prenatal care guidance. When determining the sequence in which to evaluate the criteria for matching (in the for-loop), the forward chaining may employ a conflict resolution technique. Until there is no change in working memory or STOP signal, the algorithm selects one triggered rule instance, fires it (throws away other instances), and applies the conflict resolution approach if necessary. The stated rules in the knowledge base of the expert system that was created are predetermined and depend on the end user's yes/no responses. Algorithm 1 displays the pseudocodes for the expert system that was built.

Algorithm 1. ForwardChaining prenatal care

```
Input: set of rules in knowledge base: KB; set of facts in working memory: WM
Output: solution; d
Begin
    WM ← {q_1, q_2, q_3, ..., q_n}
    KB ← {r_1, r_2, r_3, ..., r_n}
    repeat
      for every rule r_1 ∈ KB do
        for every fact q_1 ∈ WM do
          if antecedents match assertions in the working memory and consequents would
             change the working memory then
             Create triggered rule instance
          end if
        end for
      end for
      d ← Pick one triggered rule instance, using conflict resolution strategy if needed, and fire it
          (throw away other instances)
      until no change in working memory WM, or no STOP signal
      returns d
End
```

3. Results and Discussion

The implementation process of the suggested expert system for prenatal care advice in the medical field is covered in this session. The prenatal care recommendation expert system was implemented with the help of MySQL and the Java programming language. The suggested system's front end was created using the Java programming language, and its back end, which contained user authentication information for both new and existing users as well as the ability to store and produce reports for specific recommendation decisions, was created using MySQL. Because of its versatility, support for pure object-oriented design, and sophisticated graphical user interface, the Java Application Programming Interface was chosen.

3.1 Database design

Mysql was utilized in this study as the back-end database application to store all of the login credentials for the expert system that provides prenatal care guidance in the medical field, as well as to store any suggestion decisions made at any given time. The schema for the key relationships required for the database application concerning the expert system created for this study will be displayed in the following subsections.

3.1.1 Login relation

All of the system users' personal information should be contained in the user login relation that was established inside the prenatal expert database. The two fields that are necessary for all users to authenticate themselves in the system are their name and password. This relation also stores the information of recently registered users. The prenatal_expert database's user login table's design is displayed in Table 1. For each user in the system, their password and name must be distinct.

Table 1: user_login Table

Field Name	Data Type	Width	Constraint
Username	Varchar	50	Not Null
Password	Varchar	50	Not Null

3.1.2 Prenatal_form relation

The input data from the user based on their answers to a few health-related pregnancy questions should be included in the prenatal_form relation. The primary key for the table was automatically incremented using the prenatal_form relation serial number. The prenatal_form connection and all of the definitions are displayed in Table 2.

Table 2: prenatal_form Table

Variable	Field Name	Data Type	Width	Constraint
X1	S/N	INT	5	Not Null
X2	Patient_id	Varchar	5	Not Null
X3	Age	Varchar	20	Not Null
X4	Height	Varchar	20	Not Null
X5	Weight	Varchar	20	Not Null
X6	Blood_pressure	Varchar	20	Not Null
X7	Abdomen_measure	Varchar	20	Not Null
X8	Baby_heart_rate	Varchar	20	Not Null
X9	Urine_color	Varchar	20	Not Null
X10	First_time_pregnancy	Varchar	20	Not Null
X11	Family_disease_history	Varchar	20	Not Null
X12	Drink_alcohol	Varchar	20	Not Null
X13	Smoking	Varchar	20	Not Null

3.2 Login pane

A screenshot of the Expert System for prenatal care recommendations is displayed in the login window. Users of the system are granted authentication on this pane or page. In order to authenticate, it requests the password in addition to the username (Figure 3). By selecting the "SIGNUP" button, new users can register on the same page. Similarly, Figure 4 shows an error notice indicating that the password and username fields are not allowed to be empty.

3.3 Registration pane

A new user must first register using the SIGNUP button in the login window in order to be authenticated as the user. It is required of the new user to provide certain personal information, such as their username and password (see Figure 4). As shown in Figure 5, the signup data is entered into the database using the Mysql server. The login pane will search the database (see Figure 6) for the registered user's presence whenever they attempt to log in to the system.

Figure 3. Login pane

Figure 4. Error message pane

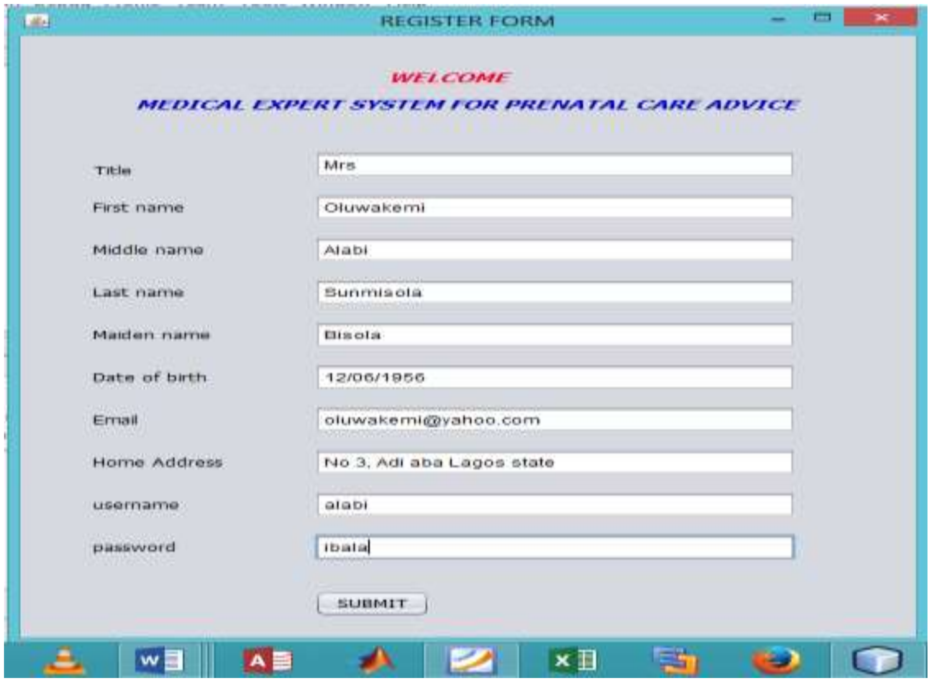

Figure 5. Registration pane

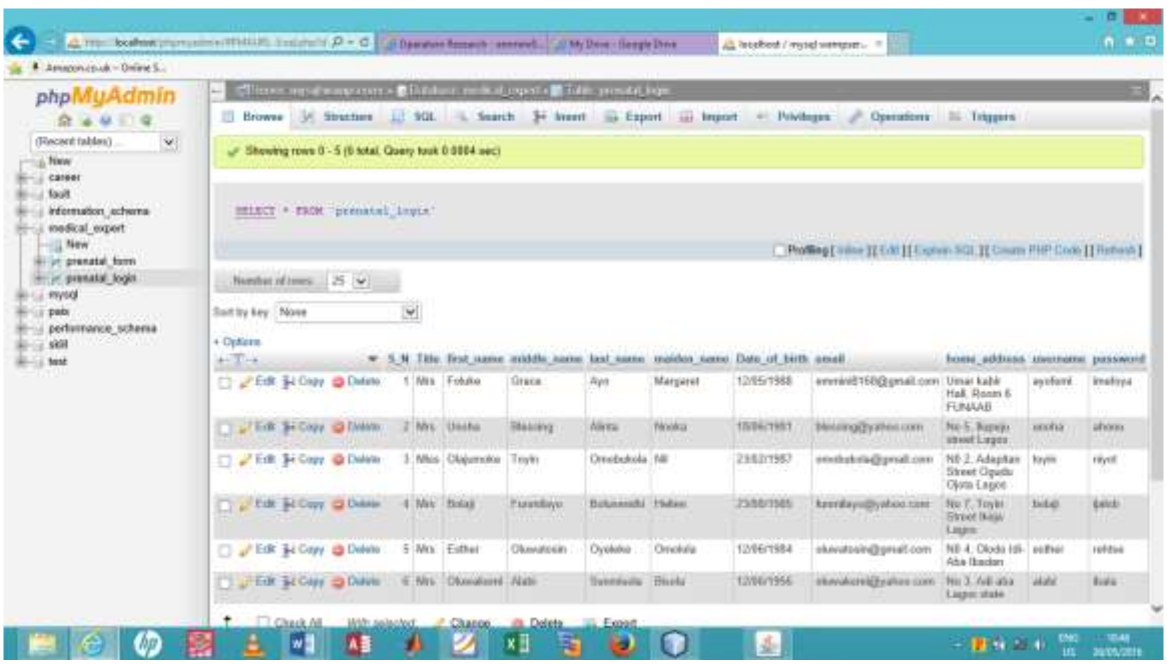

Figure 6. login database

3.4 Patient specific data pane

Most of the work is concentrated on this panel. This panel uses the forward chain inference technique to carry out all diagnoses. As seen in Figure 7, the forward chain inference system refers to obtaining a conclusion based on the known facts in the form of rules inside the knowledge base (such as symptoms and physiological data). The "Height" option includes Tall or medium, where medium also covers those that are relatively short. Similarly, the "Weight" option includes Normal or Obese, whereas normal also covers those who are underweight. Figure 8 also shows the memberships in brackets for each of the inputs. This guides the user on the expected responses on the variety of inputs and their degree of memberships.

3.5 Result and Advice pane

By clicking the diagnostic button in the patient-specific data pane, the user submits information, and this pane essentially provides an answer based on that data. In addition to providing suggestions to the user based on the compiled data, it responds according to the information gathered from the diagnosis button. The advice could come in the form of pregnancy-friendly diets and physical activities (See Figure 8). The result is considered reliable and acceptable since the diagnosis rules are provided and verified by medical experts.

3.6 Patient specific Data Database

The information submitted by users is recorded in the patient-specific database, which may be utilized to enhance the prenatal care advising expert system's knowledge base (see Figure 9). It functions as the working memory, holding the data necessary to update the knowledge base.

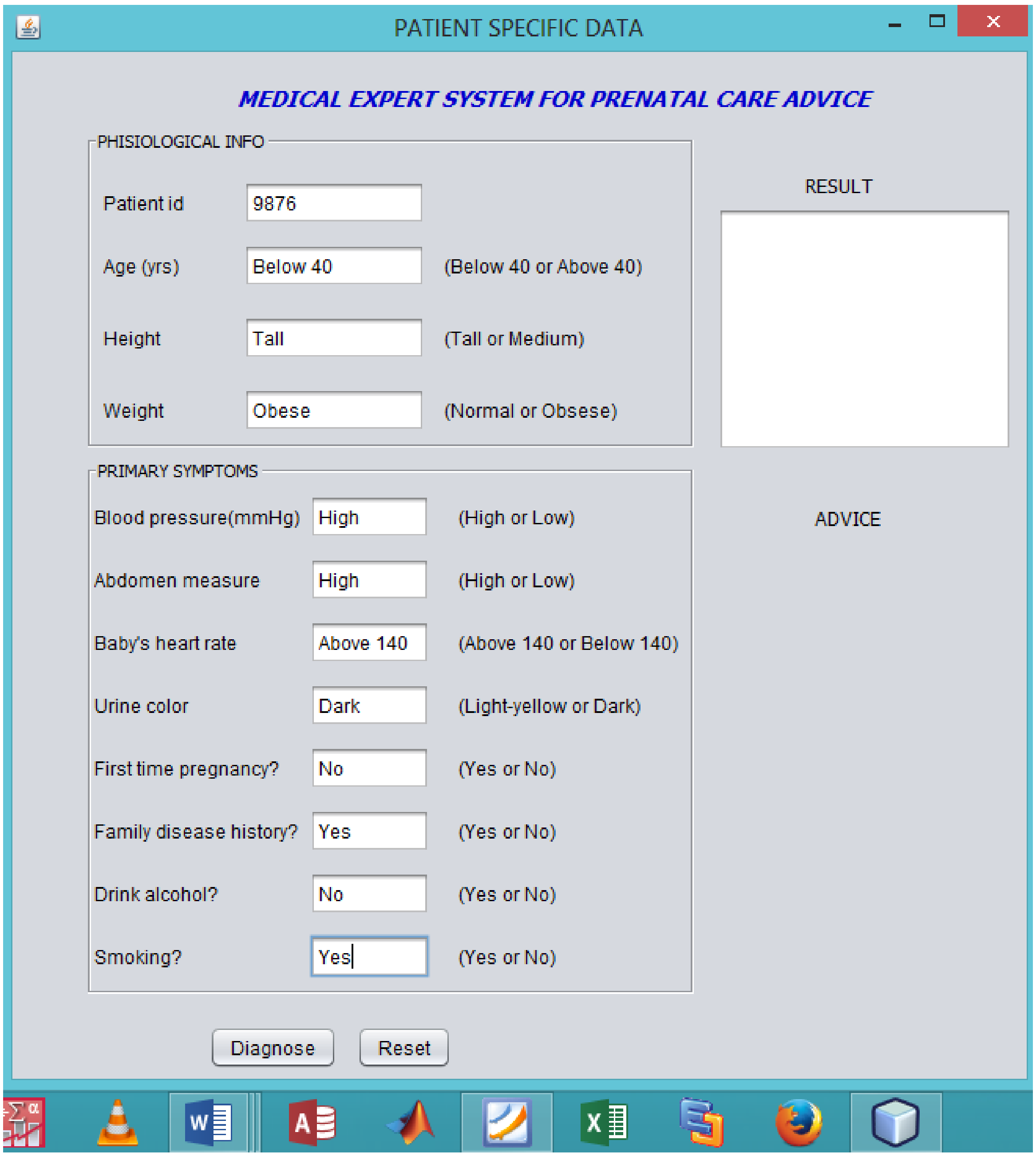

Figure 7. Patient specific data pane

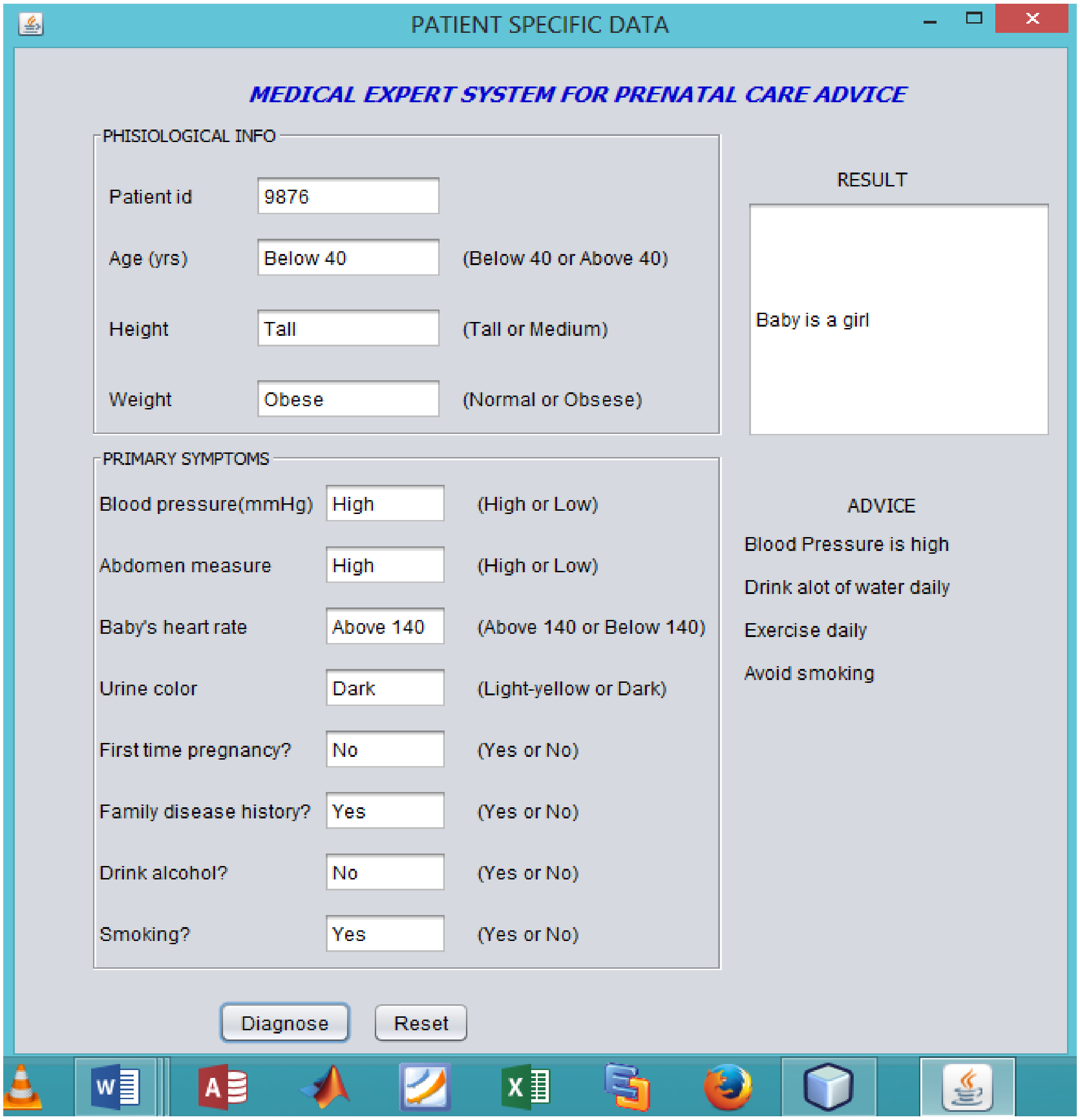

Figure 8. Result and Advice pane

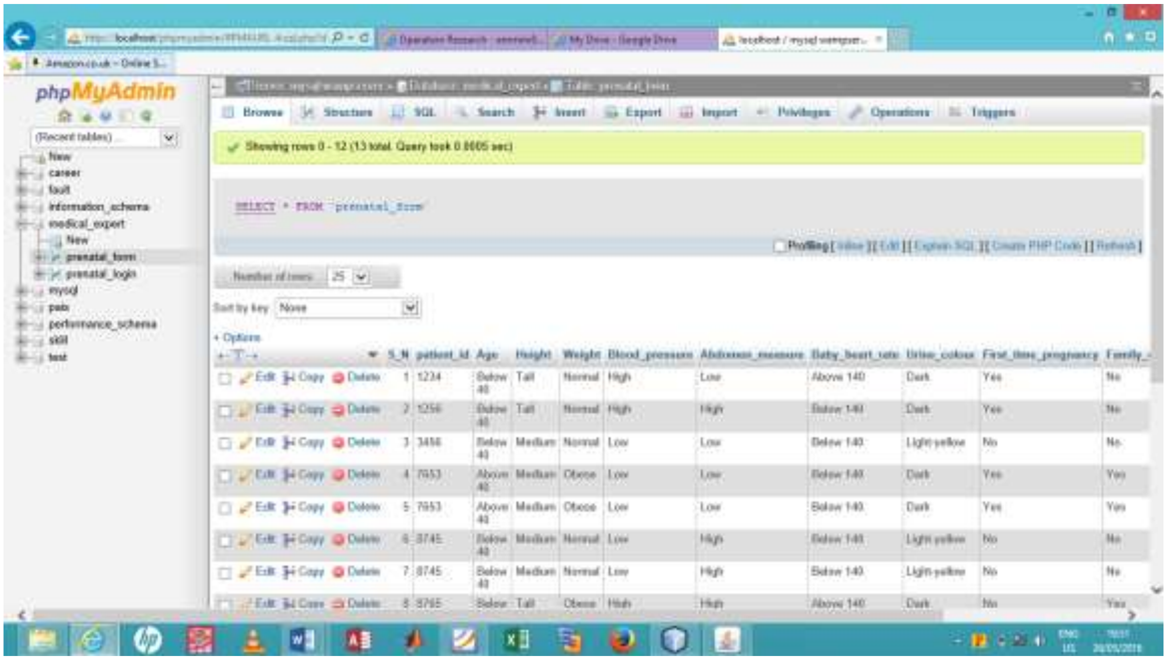

Figure 9. Patient specific Data Database

3.7 Result evaluation

This work employed the direct technique of expert system validation, as described by [28], to validate the prediction accuracy of the built expert system. To determine the degree of user satisfaction with the planned expert system, the validation concept calls for medical experts to do a usability evaluation of the sample program installed on their system. To verify the prenatal guidance provided by the system against that of medical experts in the field, a brief survey was carried out utilizing the direct technique. Participants in the poll were asked to be a select group of medical experts in the prenatal care health area of a few chosen hospitals. Every medical expert's individual received an identical set of surveys and had an installed version of the expert system that was intended for them. In order to determine how true or incorrect the prenatal care recommendations are, the medical experts were asked to rate the responses provided by the built expert system on a Likert scale ranging from 0 to 5. Below is a quick summary of each evaluator's direct expert system evaluation methodology:

(i) A sample copy of the software system to be examined is provided to the evaluator.

(ii) The assessor uses our specially created expert system to process a benchmark problem that he has chosen based on his experience.

(iii) Following the completion of the benchmark problem, the assessor answers a series of 14 questions from the questionnaire, estimating a quantitative response for each on a scale of 0 to 5, where 5 represents a very truthful response and 0 represents a very false one.

(iv) A weighting factor, as indicated in the weight column, is multiplied by each numerical result.

(v) To obtain a result in the numerical range of 0 to 5, the weighted values are added together and subsequently divided by the total of the weights (19).

A computation of the evaluation experiment carried out by one of the assessors is shown in Table 3. Table 4 displays a portion of the summary findings used to determine the evaluators' experimental evaluation. As seen in Table 4, the mean satisfaction for the five evaluators is determined by adding up all of their computed satisfaction levels and dividing by the total number of evaluators.

Table 3: Evaluator's questionnaire

	Question	Assessment Value	Weight	Value × Weight
	Correctness of Answer			
1	Is there enough information to evaluate the software?	4	(2)	8
2	Does the software give the same answer that a medical expert would give?	4	(2)	8
3	Does the software provide the right answer for the right reasons?	5	(2)	10

	Accuracy of Answer			
4	Is the software accurate in its answer(s)?	4	(2)	8
5	Is the answer complete? Does the user need to do additional work to get a usable result?	5	(2)	10
6	Does the answer change if new but irrelevant details are entered into the software?	5	(1)	5
7	Does the system require a lot of irrelevant questions to reach its answer?	0	(1)	0
	Sensitivity			
8	Does the answer change if irrelevant changes are made to the system rules?	5	(1)	5
	Reliability			
9	Does the software crash or hang ups in its host computer	3	(1)	3
10	Does the system give warnings for cases involving incomplete data or rules?	4	(1)	4
	Cost Effectiveness			
11	Does the software still provide answers with incomplete knowledge?	1	(1)	1
12	Is the cost of the system justified by its performance?	5	(1)	5
	Limitation			
13	Can limitations of the system be detected at this point in time?	5	(1)	5
14	Can the system learn from increased data or experience?	4	(1)	4
	Result = $\sum(\boldsymbol{weight} \times \boldsymbol{value})/\sum(\boldsymbol{weight})$		19	76
			4.00	

Table 4: Result of Evaluation Survey

Evaluator	Computed Satisfaction Level
1	4.00
2	4.10
3	3.91
4	3.58
5	3.78
Mean Satisfaction Level	3.87

4. Conclusion

Upon interpreting the assessments provided by Table 4 of the medical experts who participated in the survey, it was evident that the prenatal care advice expert system had a mean satisfaction level score of 3.87 out of 5.0, indicating a 77.5% user satisfaction rate. This indicates that, after the experts considered important metric parameters such as response correctness, accuracy, reasoning process quality, sensitivity, reliability, cost effectiveness, and observed limitations of the system, the system obtained a mean rating of 77.5%. This indicates that the designed expert system has received a considerable good grade and that it is feasible for it to assist in the duty of giving prenatal care guidance inside the healthcare system. As a future work, the designed expert system can be further enhanced by including more rules in the knowledge base of the expert system in order to improve its reasoning capabilities. Also, the rule adaptation capability of the designed prenatal care advice expert system can be improved because it was observed that some instances presented erroneous results. In such cases, it was hard for the current implementation of the expert system to find an accurate adaptation to produce a good result and prenatal care advice. The room for improvement in the designed expert system is left for future work, even though a medical expert can sometimes be prone to mistakes too.

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نظام خبير ضبابي لتقديم المشورة بشأن رعاية ما قبل الولادة

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المستخلص

تشير رعاية ما قبل الولادة إلى الرعاية الطبية التي تتلقاها المرأة للحفاظ على صحتها وصحة طفلها الذي لم يولد بعد. قد تكون الأساليب التقليدية التي يستخدمها الخبراء في المجال الطبي في تقديم المشورة بشأن رعاية ما قبل الولادة غير كافية في بعض الأحيان وأقل كفاءة بسبب عدد من العوامل. إحدى القضايا الرئيسية هي نقص المعرفة في مجال رعاية ما قبل الولادة لدى معظم الخبراء في مجال الطب، مما يعيق تقديم المشورة الجيدة للنساء الحوامل. ومن أجل التغلب على بعض هذه التحديات، تم اقتراح أساليب تعتمد على الكمبيوتر لأي مشكلة صحية، والتي أثبتت أنها أكثر فعالية ويتم استخدامها بشكل متكرر لرفع مستوى الرعاية الطبية. يقترح هذا العمل البحثي استخدام منهج النظام الخبير استنادًا إلى محرك الاستدلال للسلسلة الأمامية. تم استخدام لغة البرمجة جافا في تنفيذ النظام الخبير المقترح. حصل نظام الخبراء لتوصيات الرعاية السابقة للولادة على متوسط مستوى رضا قدره 3.87 من أصل 5.0، وفقًا لنتائج التقييم المستندة إلى آراء الاستطلاع. ويشير هذا إلى مستوى 77.5% من رضا المستخدمين. ويشير مستوى أداء النظام الخبير في تقديم المشورة الجيدة للنساء الحوامل إلى أنه أسرع وأكثر حساسية وأكثر موثوقية من الطريقة التقليدية المتمثلة في الاستعانة بالخبراء في مجال الطب لتقديم المشورة بشأن رعاية ما قبل الولادة.