Prediction of the Type of Delivery using Fuzzy Inference System

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Abstract
In this paper a new fuzzy prediction is designed and developed to predict the type of delivery based on 7 factors. The developed system is highly needed to give a recommendation to the family excepting baby and at the same time provide an advisory system to the physician. The system has been developed using MATLAB and has been tested and verified using real data. The system shows high accuracy 95%. The results has been also checked one by one by a physician. The system shows perfect matching with the decision of the physician.
Keywords
Fuzzy Inference System, Prediction, Delivery, Caesarean, Rules, Medical Factors

1. Introduction

Many families face many fears when it comes to childbirth, especially the first childbirth, so that the thinking is that it is a natural birth or an operation. The process of knowing this facilitates the psychological and financial preparation of the family, as well as the feeling of relief when the day of birth approaches. Sometimes the reasons for a cesarean delivery may be the woman's desire to do so, and these are some of the reasons why some women may choose a cesarean section: Fear and dread of severe pain during vaginal delivery.

The desire to protect the vagina and pelvis from some possible complications, such as: vaginal tears, and urinary incontinence. Shyness, or the desire to make sure that it is precisely the gynecologist who will perform the delivery.
In many cases, childbirth is difficult and the woman did not expect this, despite the presence of several factors, if they had been studied, these results would have been avoided. For example, to know the chance of a natural birth, if the fetus's head is down, it depends on the size of the fetus, and it is preferable that the weight of the fetus does not exceed (4 kg), and there are other factors that interfere with this according to the doctor's assessment of the situation in general, and this depends on the measurements of the mother's pelvis And the height, the size of the previous baby, and whether there is gestational diabetes or not. The predetermined causes of caesarean section do not stop at just the above. Here are some other reasons:

Infection of the mother with some health problems, such as: high blood pressure, kidney disease, heart disease, and diabetes. Infection of a pregnant woman with a sexually transmitted disease, such as AIDS or genital herpes, these diseases may be transmitted to the fetus during the natural delivery process. If a woman undergoes surgery in the womb area in advance, this may increase the chances of uterine rupture during natural childbirth.

Finding a smart system that enables doctors and mothers to know the nature of childbirth is one of the important things he looks forward to. Many studies have shown a set of factors that affect whether a natural birth or a caesarean section, but these factors have not yet been collected and analyzed and a system capable of predicting the nature of birth has not been established. Here, the doctor or midwife explains the overall benefits and risks of a cesarean delivery, which may occur to the woman and her baby compared to a natural vaginal birth. Appropriate advice, and if the pregnant woman is not convinced of a natural birth, then a planned caesarean section can be performed. To make such a system, there are many methods and methodologies in the literature, but the nature of the problem and its factors, the dimensions of which differ from one doctor to another, so the fuzzy logic system was used for this matter in this research.

Fuzzy logic is a science developed by Lotfi Zadeh in his famous fuzzy set paper [1] and this science has begun to spread in many applications [2-15] that include industrial control, medical monitoring, military decisions and communications. Fuzzy logic is one of the sciences that are widely used in medicine because medical factors have a certain extent of correctness and error and differences according to experience and according to the situation and are not as crisp as most other applications And when this science was developed to use it as a better method for data processing, as there are relationships in which the position can be considered partially true or partially wrong at the same time, so the transition between the two positions is gradual. Change, but not a complete change, as it uses the Membership Function, which is a function that determines the degree of belonging of the element to the group.

Manuscript received May 5, 2023
Manuscript revised May 20, 2023
https://doi.org/10.22937/IJCSNS.2023.23.5.7

To decide whether the delivery was natural or by caesarean section, five factors were taken as inputs to the developed medical logic system, which are ... The exit of the system was chosen as the coefficient of risk of childbirth. When the laboratories are greater than a certain limit, the doctor must discuss the matter of caesarean section and prepare for it with the family, as it is safer for the mother and avoids the risks of natural birth that may lead to the loss of the fetus or the mother in some cases.

2. The Developed Fuzzy Delivery Prediction System

To develop a fuzzy logic system to see how dangerous birth is, membership functions have been developed for the factors that are chosen that influence decision-making

Membership functions were also selected for the output, which is the birth risk factor.

To select the membership functions, a cooperation was made with a specialist in obstetrics and gynecology to develop a universal set X for these functions and determine their appropriate periods and the type of functions that correspond to the factor. Mamdani system was used to develop the rules of linking between the input and the output which depend on the if then rules mechanism. These rules have been modified in the training phase by choosing weights for the rules so that the results are highly accurate.

The developed fuzzy logic system works by providing the system with Crisp values as inputs to be fired with the values of the functions, then it produces values to take the highest value from them because the developed system uses the min-max strategy so that the Min has the lowest selective value between the member ship value with the Crisp value and the max The result of meeting the sub-products of the same base. The process is shown in Figure 1. The crisp inputs is applied to the if then rules. The results of all rules are summed to generate the fuzzy output

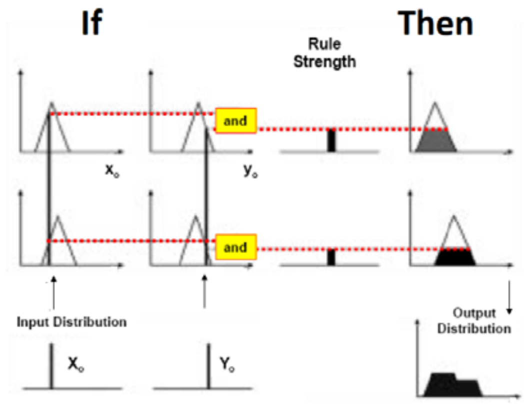

Figure 1: Inference Mechanism

A defuzzification is done by one of the methods used in the literature to convert the result from a function to a point showing the severity of the birth. The fuzzy inference structure is shown in Figure 2.

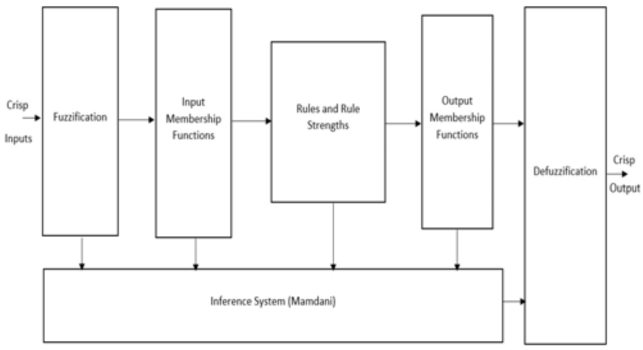

Figure 2: The Architecture of Fuzzy Inference System

The developed Fuzzy Inference system (Figure 3) consists of seven main factors which are age, baby head measure, pelvis size, body mass index, abnormality of blood pressure, health degree risk, and gestational diabetes.

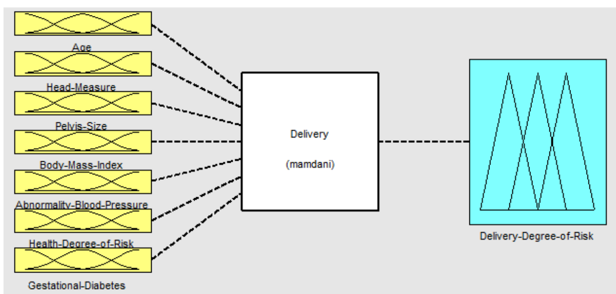

Figure 3: Delivery Type Fuzzy Prediction System

The input and output membership function is selected carefully and tuned in the training stage to achieve acceptable result from physicians. The used membership functions is summarized as equations in Table 1.

Table 1: Definitions of Fuzzy Membership Function

Membership Type	Membership Equation
Trapezoidal	$\mu_{Trap}(x) = \begin{cases} 0, & a < x \\ -\dfrac{1}{b-a}(a-x), & a \leq x \leq \\ \dfrac{1}{d-c}(d-x), & c \leq x \leq d \\ 0, & d < x \end{cases}$
Bell	$\mu_B(x) = \dfrac{1}{1+\left\lvert\dfrac{a-x}{b}\right\rvert^{2c}} \quad , \quad c > 0$
Gaussian	$\mu_G(x) = e^{-\frac{(a-x)^2}{2b^2}}$
Triangular	$\mu_T(x) = \begin{cases} -\dfrac{1}{a-b}(a-x), & a \leq x \leq b \\ \dfrac{1}{c-b}(c-x), & b \leq x \leq c \\ 0, & otherwise \end{cases}$

The Age of the women is very important factor in deciding the type of delivery. The delivery can be complicated in teen age or middle age more than Adult Age. The Age factor has be described by three triangular member ship functions defined as Teen, Adult and Middle-Age as shown in Figure 4.

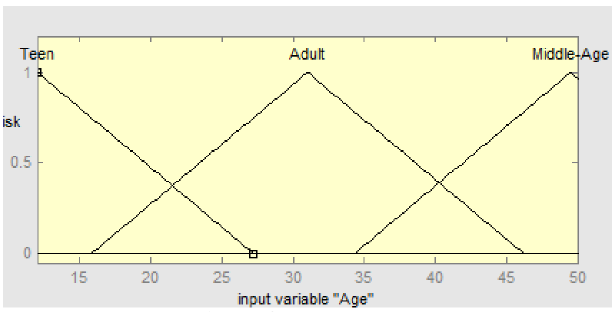

Figure 4: Age Fuzzy Sets

The baby head measure can increase the possibility of having cesarean delivery especially when the head size is grater than 35 cm.

The head measure consists of four triangular membership functions (Figure 5). These membership functions are Very Small, Small, Medium, and Large.

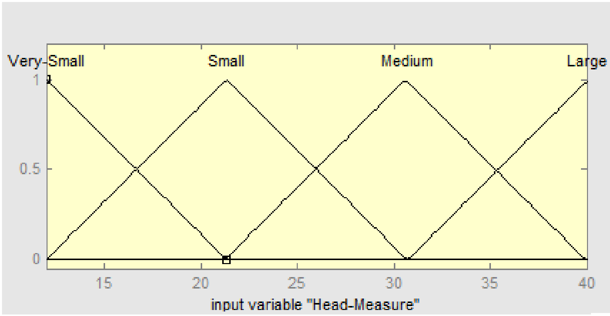

Figure 5: Head Measure Fuzzy Set

The pelvis size is similar to the head measures in term of deciding weather the delivery should be c-cesarean or not.
The pelvis size has been fuzzified by five fuzzy variable which are Very Low, Low, Medium, High and Very-High as in Figure 6.

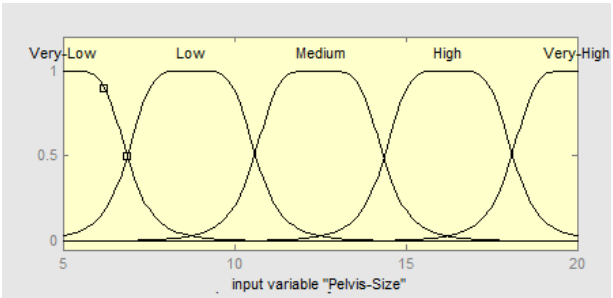

Figure 6: Head Measure Fuzzy Sets

The body mass index is another factors which is selected in this research to perfectly decide the type of delivery. As the Body Mass Index value is small, the chance of having normal delivery is high. The body mass index is described by 5 trapezoidal membership functions as shown in Figure 7.

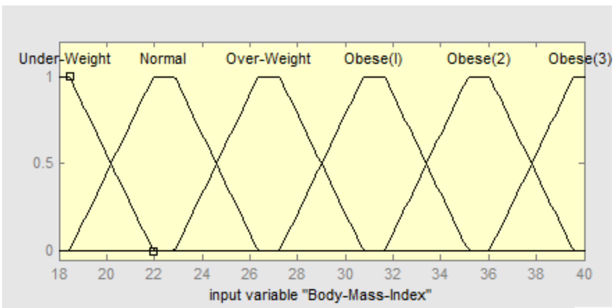

Figure 7: Body Mass Fuzzy Sets

The blood pressure is an important factors in deciding the medical conditions of a patients before performing operations. Similarly, it is continuously checked for the woman before delivery. Having High blood pressure can make normal delivery complicated. To calculate the degree of abnormality of blood pressure, a sub fuzzy inference system is developed with two inputs which are Systolic Blood Pressure (SBP) and Membership function of Diastolic Blood Pressure (DBP). The sub fuzzy system consists of one output which is the abnormality of blood pressure.
The inputs membership functions are shown in Figure 8. and Figure 9. The output variable is described by three membership function which are Low, Medium, and High as in Figure 10.

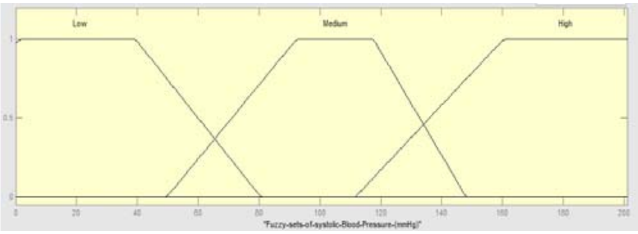

Figure 8: Fuzzy Sets of Systolic Blood Pressure (SBP)

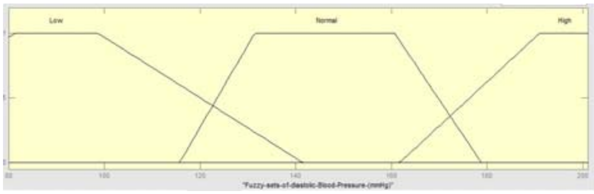

Figure 9: Fuzzy Sets of Diastolic Blood Pressure (DBP)

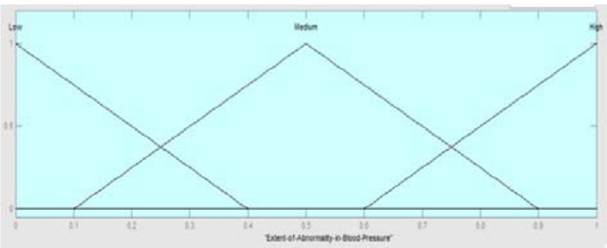

Figure 10: Fuzzy Sets of the Abnormality in Blood Pressure.

The health degree risk is calculated using a previously develop fuzzy inference system in [16]. It depends on many medical conditions and the results of different laboratory results. It consists of 5 triangular membership functions (Figure 11) which are Very- Low, Low, Medium, High, and Very High.

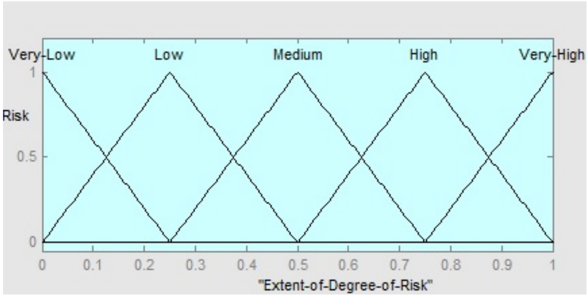

Figure 11: Fuzzy Sets of Health Degree of Risk

The output variable (Figure 12) of the developed system is developed using three trapezoidal fuzzy sets to describe the delivery degree of risk. These membership functions are Low, Medium, and High. As the degree of the risk become high ,i.e., and greater than 0.75 as a value, the delivery is highly preferred to be caesarian.

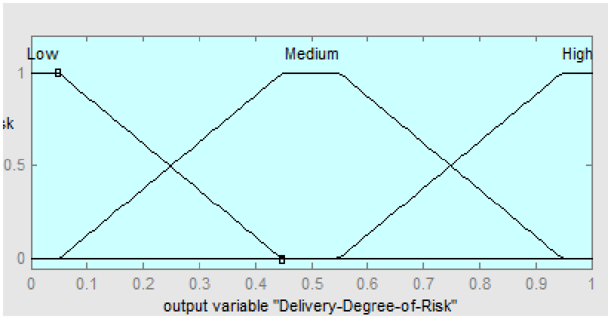

Figure 12: Fuzzy Sets of Delivery Degree of Risk

The develop system consists of 350 if then- rule. The used conjunction operation in the antecedents of the rules are (AND) and (OR). The rule firing strength is calculated to reshape the consequence of the rules. The resulted fuzzy output are combined in to a crisp value to give the delivery risk value. The used defuzzification is center of mass.

3. Experiments and Results

The system has been developed using MATLAB 11 and tested using data from Farah Medical Center in Amman. The data consists of 750 cases. The data has been divided to training data and testing data with percentage 75% and 30% . The achieved accuracy of the testing data which consists of 200 cases is 95%. The confusion matrix is shown in Table 2.

Table 2: Confusion Matrix

	Actually Normal	Actually Cesarean
Predicted Normal	98	6
Predicted Cesarean	4	92

The performance of the developed system is summarized using 6 metrics in Table 3.

Table 3: Developed System Performance

Accuracy	0.95
Precision	0.9423
Recall	0.9608
F1 score	0.9515
True Positive rate (Sensitivity)	0.9608
False Negative rate	0.039216
False positive rate	0.06122
True Negative rate (specificity)	0.9388
False discovery rate	0.05769
Matthews Correlation Coefficient (phi coefficient)	0.9001

The achieved result has been also reviewed by one physician. Kappa statistics is used to compare the result of the system and the physician result. The kappa value id considered high when it is grater than 0.75. The confusion matrix between the physician and the model is shown in Table 4

Table 4: The Confusion Matrix Between the Physician and Model

		Model		
		Normal	Cesarian	Total
Physician	Normal	95	8	103
	Cesarian	9	88	97
	Total	104	96	200

The Kappa Results is shown in Table 5. One way to interpret kappa is with this scale [17]:

- Kappa < 0: No agreement
- Kappa between 0.00 and 0.20: Slight agreement
- Kappa between 0.21 and 0.40: Fair agreement
- Kappa between 0.41 and 0.60: Moderate agreement
- Kappa between 0.61 and 0.80: Substantial agreement
- Kappa between 0.81 and 1.00: Almost perfect agreement."

The result shows perfect agreement.

Table 5: Kappa Results

Number of observed agreements	183 (91.50% of the observations)
Number of agreements expected by chance	100.1 (50.06% of the observations)
Kappa	0.830
SE of kappa	0.039
95% confidence interval:	From 0.752 to 0.907

4. Conclusion

Having a system to predict the type of delivery in advance is highly needed and required by physician. In this paper, a fuzzy inference system is developed to predict the type of delivery as normal or cesarean, The decision is based on seven main factors which are age, baby head measure, pelvis size, body mass index, abnormality of blood pressure, health degree risk, and gestational diabetes. These factors has been carefully selected by the physician in the team. The developed system was tested using real data and the results were reviewed one by one by a physician. The system accuracy was 95% and it has perfect agreement with physician decision.

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