CHAPTER 6
MEASURE OF UNCERTAINTY USING S VALUE FOR FUZZY ASSESSMENT METHODOLOGY

6.1 Introduction

Fuzzy Logic is an efficient to deal with vagueness and uncertainties. Fuzzy Expert System is the collection of facts and rules. These facts and rules help to solve problem concerning a particular domain. For much problem final answer are unknown because of uncertainty. In many situations the expert’s rules are vague and users are unsure to answer the question. In Expert System the representation of rule is important. The fuzzy rules are framed with database. The data are managed in the form of table. In this part queries can be used in the place of reasoning to improve the efficiency of Expert System [YTX02]. The knowledge is uncertain and incomplete. To build the FES knowledge it is very important. Knowledge has lot of information. Uncertainty of knowledge and information are by ambiguity which is introduced in rules. So the concept of imprecision is very much important in research of FES. Fuzzy rules are captured with the fuzzy variables and it is a collection of fuzzy relationship. The knowledge is captured and the rules are framed for Fuzzy rule based architecture [WF01]. This type of problem is seen in diagnosis system, where expert couldn’t define about the symptoms and disease.

6.2 Importance of Uncertainty in Fuzzy Expert System

Harvey J. Gold et al. [HGY01] derived a methodology for uncertainty, combining diverse sources of information within the framework of Expert System for soybeans. In the soybeans data the uncertainty is managed to get an accurate conclusion. Norman D. Clarke et al. [NMT01] used Certainty Factor to represent uncertainty in Expert System. The rule based Expert System was used to test the uncertainty for tillage selection alternatives for corn and soyabean production. Savita Kolhe et al. [SRH01] used a rule promotion based on Fuzzy Logic to draw an intelligent inference for management of crop disease using Microsoft .Net framework. The rule promotion uses confidence factor to manage uncertainty in rules. Ioannis Hatzilygeroudis et al. [IAP01] designed a PASS(Predicting Ability of Students to Succeed) a rule based system which uses Certainty Factor. This is used in prediction to support the students towards national exam. Baldwin J. F. [Bal01] used Bayesian decision theory for incomplete, inconsistent knowledge representation to manage uncertainty in Expert
Jyotirmoy Ghosh and S. Mukhopadhyay [JM01] generated an intelligent system with fuzzy rule generation algorithm with Certainty Factor. In Certainty Factor of each rule is calculated by membership value. Baraldi P. et al. [BLZ01] characterized qualitative uncertainty to model the Fuzzy Expert System. Uncertainty analysis is a useful tool to analysis source of uncertain data in the fuzzy input and output mapping. Alauddin Alomary and Mohammad Jamil [AJ01] projected an Expert System to handle uncertainty in attractive domains of applications to deal with imprecise information. Andrew L.S. Gordon et al. [AIS01] developed a hybrid approach given for uncertainty, unexpectedness and complexity. Expert System was developed using Fuzzy Logic for IT security risk assessment. Uncertainty is a very important problem to deal with this a new hesitant fuzzy set has been presented. The concepts of hesitant Fuzzy linguistic terms are instructed. These terms gives a powerful decision model [RLF01].

**Dempster Shafer theory**

The method to handle uncertainty is Dempster Shafer theory designed in 1960s and 1979s. This theory was designed as mathematical theory of evidence. The theory says that probability theory is not suitable to manage uncertainty. Dempster theory constructs function for computation of evidence. Function is known as Dempster’s rule of combination [SL01]. Fact Values are used to manage uncertainty with Measure Credulity and Measure of Incredulity. In this study we present a modified framework by introducing S Value for each rule by considering both T and F Value. All the traditional method follows mathematical theory. They are tough to calculate and mathematically oriented. Uncertainty can be managed using Fuzzy Logic. Even Fact Values and Certainty Factor all follows probability value. To overcome all these pitfalls S Value is designed based on fuzzy rule to manage uncertainty in FES.

Knowledge is extracted from the data with the help of fuzzy rule and membership function. Fuzzy Rule is used to derive S Value. S Value (SV) helps to represent the fact from the data. There are many methods to represent uncertainty in fuzzy inference process. S Value helps to fine tune the system performance.

S Fuzzy Assessment Methodology (SFAM) measures the similarity between fuzzy set, fuzzy number and fuzzy rule. SFAM uses S Value to manage uncertainty in the system. In this method three fuzzy sets are taken at a time and the sets are reduced. With the reduced set the similarity between the fuzzy rules are derived to improve the Accuracy of FES.
6.3 Design of Fuzzy Expert System using S Fuzzy Assessment Methodology

FES is very important to diagnosis the patient suffering from diabetes with the algorithm S Fuzzy Assessment Methodology (SFAM). Fuzzy Expert System consists of the following elements such as Fuzzification Interface, S Fuzzy Assessment Methodology and defuzzification. S Fuzzy Assessment Methodology uses the K ratio to find overlapping between membership function, to measure the similarity between fuzzy set, fuzzy number and fuzzy rule T Fuzzy similarity is used and S Value to manage uncertainty in rules. T Value and F Value compute S Value. Fuzzy Expert System to diagnosis diabetes represented is Figure 6.1.

Pima Indian Diabetes Dataset

The Pima Indian Diabetes Dataset is used to test the proposed algorithm S Fuzzy Assessment Methodology.

Fuzzification Interface

The transformation of crisp inputs into fuzzy values is achieved through Fuzzification Interface. The fuzzy values are taken as the input for the S Fuzzy Assessment Methodology. Membership function adopted is triangular function with the parameter set \([a,b,c]\).

Figure 6.1: Diagram of the Fuzzy Expert System for diabetes using the algorithm SFAM

6.4 S Fuzzy Assessment Methodology

S Fuzzy Assessment Methodology (SFAM) three triangular membership functions (MFs) are used for each input variable \((D_1, D_2, D_3, D_4, D_5)\) and four triangular MFs for the output variable \((O)\).

K ratio

For the input variable the membership functions are designed. K ratio measures overlap between membership functions.
T Fuzzy Similarity Measure between fuzzy set and fuzzy numbers

Fuzzy set similarity always considers the two fuzzy set, the proposed T Fuzzy Similarity Measure considered three fuzzy set A, B, and C. The similar fuzzy set are reduced and applied in fuzzy rule.

T Fuzzy Similarity Measure between fuzzy rules

The rules are reduced by using the similarity measure. With the similar fuzzy set and fuzzy numbers, the fuzzy rules are reduced in S Fuzzy Assessment Methodology.

6.4.1 Measure of Uncertainty using S Value from fuzzy rules

Data are inconsistent, incomplete or even missing. Uncertainties in the data are maintained by using S Value (SV) represented in Figure 6.2. Using T Value (TV) and F Value (FV), SV is calculated. OR operator is used to evaluate the antecedent part of the rule.

The antecedent of the rules are \(d_{11}, d_{12}, d_{13}, d_{21}, d_{22}, d_{23}, d_{31}, d_{32}, d_{33}, d_{41}, d_{42}, d_{43}, d_{51}, d_{52}, d_{53}\).

Fuzzy Logic rule approach can be explained as follows

6.4.2 S Value

Human knowledge is inexact, incomplete and imperfect. So the reasoning with the uncertainty in Fuzzy Expert System is constructed by using S Value. S Value is an alternative to Certainty Factor. S Value is explored by using fuzzy rules with antecedent and consequent. S Value is a method for representation and manipulation of uncertainty. The basic idea behind this method is to extract the knowledge from fuzzy rules. S Value is a numerical
measure between \(-1\) to \(1\). To manipulate the S Value we need the antecedent and consequent part in each rule.

In Fuzzy Expert System, the knowledge base consists of a set of rules with S Value that have the following syntax:

IF \(<\) antecedent >

THEN \(<\) consequent > \{S Value\}

where S Value is the measure of uncertainty.

In the construction of the FES we generate rules; S Value is defined as the maximum value of T Value and F Value. S Value represents the relationship between the symptoms and disease. S Value can be calculated using the eqn.(6.1). S Value is based on the two functions: measure of T Value and measure of F Value. The maximum value of T Value and F Value forms the S Value. The strength of T Value and F Value depends on the antecedent and consequent part of fuzzy rule.

\[
S \text{ Value} = \text{Max}(T \text{ Value}, F \text{ Value})
\]

\[\text{---------eqn.}(6.1)\]

### Table 6.1: Uncertain Terms

<table>
<thead>
<tr>
<th>Terms</th>
<th>S Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Very High or High</td>
<td>-1.0</td>
</tr>
<tr>
<td>Not Medium</td>
<td>-0.8</td>
</tr>
<tr>
<td>Not Very Low or Low</td>
<td>-0.4 to -0.6</td>
</tr>
<tr>
<td>Disease not known</td>
<td>-0.2 to 0.2</td>
</tr>
<tr>
<td>Very Low or Low</td>
<td>0.4 to 0.6</td>
</tr>
<tr>
<td>Medium</td>
<td>0.8</td>
</tr>
<tr>
<td>Very High or High</td>
<td>1.0</td>
</tr>
</tbody>
</table>

### T Value

To calculate the S Value, calculate T Value from the fuzzy rules. First calculate the number of antecedent part in each rule. Next part is to calculate the number of consequent part that match with the antecedent part. T Value lies between 0 to 1 and calculated using eqn. (6.2).
Number of Consequent part match with antecedent part

\[ T \text{ Value} = \frac{\text{Number of Consequent part match with antecedent part}}{\text{Number of antecedent part of rule}} \]  \quad \text{eqn.}(6.2)

**F Value**

To calculate the S Value, calculate F Value from the fuzzy rules. First calculate the number of antecedent part in each rule. Next part is to calculate the number of consequent part that doesn’t match with the antecedent part. F Value lies between 0 and 1 and calculated using eqn.\(6.3\).

Number of Consequent part doesn’t match with antecedent part

\[ F \text{ Value} = \frac{\text{Number of Consequent part doesn’t match with antecedent part}}{\text{Number of antecedent part of rule}} \]  \quad \text{eqn.}(6.3)

Consider the following rule to calculate the S Value

If \((D_1 \text{ is } d_{12}) \text{ or } (D_2 \text{ is } d_{21} \text{ or } d_{23}) \text{ or } (D_3 \text{ is } d_{33}) \text{ or } (D_4 \text{ id } d_{42}) \text{ or } (D_5 \text{ is } d_{51} \text{ or } d_{52})\) then 

\((O \text{ is } O_3)\) using eqn.\(6.4\)

\[ S \text{ Value} = \max(T \text{ Value, F Value}) \]

In this equation

Number of Consequent part match with antecedent part

\[ T \text{ Value} = \frac{\text{Number of Consequent part match with antecedent part}}{\text{Number of antecedent part of rule}} \]

With the above rule the denominator is calculated by number of antecedent part in the rule. The number of antecedent part are \((D_1 \text{ is } d_{12}) \text{ or } (D_2 \text{ is } d_{21} \text{ or } d_{23}) \text{ or } (D_3 \text{ is } d_{33}) \text{ or } (D_4 \text{ id } d_{42}) \text{ or } (D_5 \text{ is } d_{51} \text{ or } d_{52})\)

Number of antecedent part of rule = 5

With the above rule the numerator is calculated by Number of Consequent part match with antecedent part. The consequent part of the rule is \(O \text{ is } O_3\).

Number of Consequent part match with antecedent part are \((D_2 \text{ is } d_{21} \text{ or } d_{23})\) and \((D_3 \text{ is } d_{33})\) = 2

\[ T \text{ Value} = \frac{2}{5} = 0.4 \]

So calculated T Value is 0.4.

Number of Consequent part doesn’t match with antecedent part

\[ F \text{ Value} = \frac{\text{Number of Consequent part doesn’t match with antecedent part}}{\text{Number of antecedent part of rule}} \]
With the above rule the denominator is calculated by number of antecedent part in the rule. The number of antecedent part are \((D_1 \text{ is } d_{12})\) or \((D_2 \text{ is } d_{21}\text{ or } d_{23})\) or \((D_3 \text{ is } d_{33})\) or \((D_4 \text{ id } d_{42})\) or \((D_5 \text{ is } d_{51} \text{ or } d_{52})\)

Number of antecedent part of rule \(= 5\)

With the above rule the numerator is calculated by Number of Consequent part doesn’t match with antecedent part. The consequent part of the rule is \(O \text{ is } O_3\).

Number of Consequent part that doesn’t match with antecedent part are \((D_1 \text{ is } d_{12})\), \((D_4 \text{ id } d_{42})\) and \((D_5 \text{ is } d_{51} \text{ or } d_{52}) = 3\)

\[
\frac{3}{5} = 0.6
\]

So calculated F Value is 0.6.

\[
S \text{ Value} = \text{Max}(T \text{ Value, F Value}) = \text{Max}(0.4, 0.6) = 0.6
\]

The maximum value of T Value and F Value is 0.6. So S Value is 0.6.

For the set of rules S Value are calculated using the eqn. (6.1). The set of rules are given below

7. If \((D_1 \text{ is } d_{11})\) or \((D_2 \text{ is } d_{21}\text{ord}_{22})\) or \((D_3 \text{ is } d_{31})\) or \((D_4 \text{ is } d_{41})\) or \((D_5 \text{ is } d_{51}\text{or } d_{52})\)
then \((O \text{ is } O_1\text{or}O_2)\).

8. If \((D_1 \text{ is } d_{11})\) or \((D_2 \text{ is } d_{21}\text{ord}_{22})\) or \((D_3 \text{ is } d_{33})\) or \((D_4 \text{ is } d_{41})\) or \((D_5 \text{ is } d_{51}\text{or } d_{52})\)
then \((O \text{ is } O_1\text{or}O_2)\).

9. If \((D_1 \text{ is } d_{12})\) or \((D_2 \text{ is } d_{23})\) or \((D_3 \text{ is } d_{33})\) or \((D_4 \text{ is } d_{42})\) or \((D_5 \text{ is } d_{51}\text{or } d_{52})\)
then \((O \text{ is } O_3)\).

10. If \((D_1 \text{ is } d_{13})\) or \((D_2 \text{ is } d_{21}\text{ord}_{22})\) or \((D_3 \text{ is } d_{33})\) or \((D_4 \text{ is } d_{43})\) or \((D_5 \text{ is } d_{51}\text{or } d_{52})\)
then \((O \text{ is } O_4\text{or}O_5)\).

11. If \((D_1 \text{ is } d_{13})\) or \((D_2 \text{ is } d_{21}\text{ord}_{23})\) or \((D_3 \text{ is } d_{31})\) or \((D_4 \text{ is } d_{41})\) or \((D_5 \text{ is } d_{53})\)
then \((O \text{ is } O_4\text{or}O_5)\).

12. If \((D_1 \text{ is } d_{11})\) or \((D_2 \text{ is } d_{21}\text{ord}_{22})\) or \((D_3 \text{ is } d_{31})\) or \((D_4 \text{ is } d_{41})\) or \((D_5 \text{ is } d_{53})\)
then \((O \text{ is } O_1\text{or}O_2)\).

For Rule1 S Value = 1

Rule2 S Value = 0.8

Rule3 S Value = 0.6

Rule4 S Value = 0.6
Rule 5 S Value = 0.6

Rule 6 S Value = 0.8

The first rule is

If (D1 is d11) or (D2 is d21 or d22) or (D3 is d31) or (D4 is d41) or (D5 is d51 or d52) then (O is O1 or O2).

S Value for the first rule is 1. Uncertain term for 1 is Very High or High. The rule is given as

If (D1 is d11) or (D2 is d21 or d22) or (D3 is d31) or (D4 is d41) or (D5 is d51 or d52) then (O is O4 or O5) by using the uncertainty term in Table 6.1.

The second rule is

If (D1 is d11) or (D2 is d21 or d22) or (D3 is d33) or (D4 is d41) or (D5 is d51 or d52) then (O is O1 or O2).

S Value for the second rule is 0.8. Uncertain term for 0.8 is Medium. The rule is given as

If (D1 is d11) or (D2 is d21 or d22) or (D3 is d33) or (D4 is d41) or (D5 is d51 or d52) then (O is O3) by using the uncertainty term in Table 6.1.

The third rule is

If (D1 is d12) or (D2 is d23) or (D3 is d33) or (D4 is d42) or (D5 is d51 or d52) then (O is O1 or O2).

S Value for the third rule is 0.6. Uncertain term for 0.6 is Very Low or Low. The rule is given as

If (D1 is d12) or (D2 is d23) or (D3 is d33) or (D4 is d42) or (D5 is d51 or d52) then (O is O1 or O2) by using the uncertainty term in Table 6.1.

The fourth rule is

If (D1 is d13) or (D2 is d21 or d22) or (D3 is d33) or (D4 is d43) or (D5 is d51 or d52) then (O is O4 or O5).

S Value for the fourth rule is 0.6. Uncertain term for 0.6 is Very Low or Low. The rule is given as

If (D1 is d13) or (D2 is d21 or d22) or (D3 is d33) or (D4 is d43) or (D5 is d51 or d52) then (O is O4 or O5) by using the uncertainty term in Table 6.1.

The fifth rule is

If (D1 is d13) or (D2 is d21 or d23) or (D3 is d31) or (D4 is d41) or (D5 is d53) then (O is O4 or O5).
S Value for the fifth rule is 0.6. Uncertain term for 0.6 is Very Low or Low. The rule is given as

**If (D1 is d13) or (D2 is d21ord23) or (D3 is d31) or (D4 is d41) or (D5 is d53) then (O is O4orO5)** by using the uncertainty term in Table 6.1.

The sixth rule is

If (D1 is d11) or (D2 is d21ord22) or (D3 is d31) or (D4 is d41) or (D5 is d53) then (O is O1orO2).

S Value for the sixth rule is 0.8. Uncertain term for 0.8 is Medium. The rule is given as

**If (D1 is d11) or (D2 is d21ord22) or (D3 is d31) or (D4 is d41) or (D5 is d53) then (O is O3)**

by using the uncertainty term in Table 6.1.

With the T Value and F Value, S Value is calculated for all the six fuzzy rule and results are displayed in Figure 6.3.

<table>
<thead>
<tr>
<th>Rule</th>
<th>Antecedent part of the rule</th>
<th>Consequent part of the rule</th>
<th>T Value</th>
<th>F Value</th>
<th>S Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>If (D1 is d11) or (D2 is d21ord22) or (D3 is d31) or (D4 is d41) or (D5 is d51ord52) then (O is O4orO5)</td>
<td>(O is O4orO5)</td>
<td>0.60</td>
<td>0.60</td>
<td>0.60</td>
</tr>
<tr>
<td>2.</td>
<td>If (D1 is d11) or (D2 is d21ord22) or (D3 is d33) or (D4 is d41) or (D5 is d51ord52) then (O is O3)</td>
<td>(O is O3)</td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
</tr>
<tr>
<td>3.</td>
<td>If (D1 is d12) or (D2 is d23) or (D3 is d33) or (D4 is d42) or (D5 is d51ord52) then (O is O1orO2)</td>
<td>(O is O1orO2)</td>
<td>0.60</td>
<td>0.60</td>
<td>0.60</td>
</tr>
<tr>
<td>4.</td>
<td>If (D1 is d13) or (D2 is d21ord22) or (D3 is d33) or (D4 is d43) or (D5 is d51ord52) then (O is O4orO5)</td>
<td>(O is O4orO5)</td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
</tr>
<tr>
<td>5.</td>
<td>If (D1 is d13) or (D2 is d23) or (D3 is d31) or (D4 is d41) or (D5 is d53) then (O is O4orO5)</td>
<td>(O is O4orO5)</td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
</tr>
<tr>
<td>6.</td>
<td>If (D1 is d11) or (D2 is d21ord22) or (D3 is d31) or (D4 is d41) or (D5 is d51ord52) then (O is O3)</td>
<td>(O is O3)</td>
<td>0.80</td>
<td>0.80</td>
<td>0.80</td>
</tr>
</tbody>
</table>

**Figure 6.3:** Rules for Fuzzy Expert System in MATLAB -SFAM

**MIN and SUM operator**

Antecedent part of the rule gives a single number for implication process. To fire more than one fuzzy rule at same time, MIN operation is used by the system. The output of each rule is combined into single fuzzy set by aggregation process using SUM operator.

**Defuzzification Interface**

The result obtained from the aggregation is fuzzy value. To convert the fuzzy value obtained from SFAM into crisp value defuzzification process using centroid method is used.

S Fuzzy Assessment Methodology analyzes the personal physical data, converts the results into knowledge and the patterns of statement for output descriptions. The pattern of the statement helps the medical practitioner to diagnosis the patient from diabetes.
6.5 Proposed Algorithm: S Fuzzy Assessment Methodology (SFAM)

Begin

13. Input: Fuzzy input variables are $D_1, D_2, D_3, D_4, D_5$.
15. Set PIDD with N values
16. Initialize $i = 1$

Method

Step 1: Input fuzzy set are

\[ D_1(d_{11}, d_{12}, d_{13}) \]
\[ D_2(d_{21}, d_{22}, d_{23}) \]
\[ D_3(d_{31}, d_{32}, d_{33}) \]
\[ D_4(d_{41}, d_{42}, d_{43}) \]
\[ D_5(d_{51}, d_{52}, d_{53}) \] and

Output fuzzy set is

\[ O(O_1, O_2, O_3, O_4, O_5) \]

Step 2: Calculate Mean, Minimum, Maximum and Standard Deviation Values with N cases using MMMSDV.

Step 3: Calculate K ratio with $P_1, P_2, LM$ and $UM$

If ($K \geq 1$) then

(Calculate $LMK$ and $UMK$)

Else

(No change in the membership function)

End If

Step 4: Call (S Value).

Step 5: Rules

- If ($D_1i$ is $d_{11}$) or ($D_2i$ is $d_{21}$) or ($D_3i$ is $d_{31}$) or ($D_4i$ is $d_{41}$) or ($D_5i$ is $d_{51}$)

then $O_i$ is $O_3$ (S Value).

Step 6: Call Procedure (T Fuzzy Similarity Measure).

Step 7: Use MIN operator to fire more than one rule.

Step 8: Output of each rule is correlated to form single fuzzy set by SUM operator.

End
**Procedure S Value (SV)**

Begin

Step 1: Calculate S Value (SV), True Value (TV) and False Value (FV) for all Rules

\[
S\text{ Value} = \text{Max}(T\text{ Value}, F\text{ Value})
\]

\[
T\text{ value} = \frac{\text{Number of Consequent part match with antecedent part}}{\text{Number of antecedent part of rule}}
\]

\[
F\text{ value} = \frac{\text{Number of Consequent part doesn’t match with antecedent part}}{\text{Number of antecedent part of rule}}
\]

Step 2: Compute SV for each Rules

For all rules (Rule_i to Rule_6) i=1 to 6

Rule_i (S Value) = Max(T Value, F Value)

End

**Procedure for T Fuzzy Similarity Measure for fuzzy set, fuzzy numbers and rules**

Begin

Step 1: Generate initial fuzzy set, fuzzy numbers and rules for diabetes data.

Step 2: Find the similarity measure between three sets A, B and C. We conclude that set A, B and C are similar if they have both the values equal otherwise not equal. If the two values are equal then merge into two sets A1 ad B1.

Step 3: Apply the merged set in rules.

Step 4: Compute the Degree of Similarity between all rules in the order.

Step 5: Constant Degree of Similarity (CDS) is set to 50%

   If (DS > CDS) Then
      (Goto Step 6)
   Else
      (Stop the algorithm)
   End If

Step 6

Calculate cvalue of dissimilar input parameters (C1 and C2), output parameter(D1 and D2), Kcalvalue and Kbase
If (Kcalvalue > Kbase)

   (Two fuzzy number ie, C1 and C2 are reduced. Minimum value C1 is deleted,
    Maximum value C2 is considered in rule)

Else

   (Not reduced)

End If

Similarly cvalue, Kcalvalue, Kbase values of D1 and D2 are calculated and two rules are merged into one rule.

6.6 Results

S Fuzzy Assessment Methodology uses Pima Indian diabetes Dataset to evaluate the performance. Figure 6.4 indicate the result obtained from SFAM. Table 6.2 indicates the result obtained from SFAM. The acquired result from Table 6.2 transferred into knowledge and presented in the human understandable form. Results obtained by using the algorithm SFAM from MATLAB Fuzzy Logic Toolbox for all Age: Fuzzy Association is shown in Table 6.3.

6.7 Assessment of System Performance

Performance Assessment Statement can be assessed based on the Accuracy level. Accuracy is the proportion of the total number of predictions that were correct. The eqn. (6.4) show the formula for Accuracy. The Accuracy parameter for TP, TN, FP and FN for various Age level are represented in Figure 6.5 and 6.6.

\[
\text{Accuracy} = \frac{TN + TP}{TN + FP + FN + TP} \times 100\% \quad \text{eqn.(6.4)}
\]
**Table 6.2:** Final Result for Medical practitioner from SFAM

<table>
<thead>
<tr>
<th>Data</th>
<th>Glucose (mg/dl)</th>
<th>INS (mu U/ml)</th>
<th>BMI (Kg/m²)</th>
<th>DPF</th>
<th>Age</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>177</td>
<td>478</td>
<td>34.6</td>
<td>1.072</td>
<td>21</td>
</tr>
</tbody>
</table>

**Statement Study**

If(Glucose is Gh) or(INS is INSm) or (BMI is BMIh) or (DPF is DPFh) or(Age is Agey) then (DM is DMh)

**Assessment Statement**

The Assessment Statement justifies that the possibility of suffering from diabetes for this patient is high(possibility:0.62)

**Justification by Medical Practitioner**

Medical practitioner justification is the person is diabetes

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**Table 6.3:** Results obtained by using the algorithm S Fuzzy Assessment Methodology from MATLAB Fuzzy Logic Toolbox

<table>
<thead>
<tr>
<th>Age: Fuzzy Association</th>
<th>Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slightly Old(41-45)</td>
<td>93.42</td>
</tr>
<tr>
<td>Slightly Young(36-40)</td>
<td>92.10</td>
</tr>
<tr>
<td>More or Less Young(31-35)</td>
<td>88.89</td>
</tr>
<tr>
<td>Very Young(26-30)</td>
<td>93.27</td>
</tr>
<tr>
<td>Very Very Young(0-25)</td>
<td>83.52</td>
</tr>
</tbody>
</table>
Figure 6.4: Result obtained from MATLAB using SFAM

The final experiment compares the Accuracy of the proposed method with results of studies involving the Pima Indian Diabetes Dataset [CM01, KS01, XJ01, HN01]. The proposed method achieves the highest Accuracy value for all Age: Fuzzy Association than earlier methods which are indicated in the Table 6.4 and Figure 6.7.

Figure 6.5: Accuracy parameter for the Age: Very Young(26-30) using SFAM
**Figure 6.6:** Accuracy parameter for the Age: More or Less Young(31-35) using SFAM

**Figure 6.7:** Graphical represent of Accuracy using SFAM
### Table 6.4: Comparison of Accuracy of SFAM with Earlier Methods

<table>
<thead>
<tr>
<th>Methods</th>
<th>Accuracy (%)</th>
<th>Authors</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Our study for Slightly Old (41-45)</em></td>
<td>93.42</td>
<td><em>M. Kalpana and Dr. A. V. Senthil Kumar</em></td>
</tr>
<tr>
<td><em>Our study for Very Young</em></td>
<td>93.27</td>
<td><em>M. Kalpana and Dr. A. V. Senthil Kumar</em></td>
</tr>
<tr>
<td><em>Our study for Slightly Young (36-40)</em></td>
<td>92.1</td>
<td><em>M. Kalpana and Dr. A. V. Senthil Kumar</em></td>
</tr>
<tr>
<td>A FES for Diabetes Decision Slightly Old</td>
<td>91.2</td>
<td>Lee and Wang</td>
</tr>
<tr>
<td>A FES for Diabetes Decision Slightly Young</td>
<td>90.3</td>
<td>Lee and Wang</td>
</tr>
<tr>
<td><em>Our study for More or Less Young (31-35)</em></td>
<td>88.89</td>
<td><em>M. Kalpana and Dr. A. V. Senthil Kumar</em></td>
</tr>
<tr>
<td><em>Our study for Very Very Young (0-25)</em></td>
<td>83.52</td>
<td><em>M. Kalpana and Dr. A. V. Senthil Kumar</em></td>
</tr>
<tr>
<td>A FES for Diabetes Decision more or less young</td>
<td>85.9</td>
<td>Lee and Wang</td>
</tr>
<tr>
<td>A FES for Diabetes Decision very young</td>
<td>81.7</td>
<td>Lee and Wang</td>
</tr>
<tr>
<td>HNFB$^{-1}$</td>
<td>78.26</td>
<td>Goncalves <em>et al.</em></td>
</tr>
<tr>
<td>Logdisc</td>
<td>77.7</td>
<td>Statlog</td>
</tr>
<tr>
<td>IncNet</td>
<td>77.6</td>
<td>Norbert Jankowski</td>
</tr>
<tr>
<td>DIPOL 92</td>
<td>77.6</td>
<td>Statlog</td>
</tr>
<tr>
<td>Linear Discriminant Analysis</td>
<td>77.5</td>
<td>Statlog, ster and Dobnikar</td>
</tr>
<tr>
<td>A FES for Diabetes Decision Very Very young</td>
<td>77.3</td>
<td>Lee and Wang</td>
</tr>
<tr>
<td>VISIT</td>
<td>77</td>
<td>Chang and Lilly</td>
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<tr>
<td>SMART</td>
<td>76.8</td>
<td>Statlog</td>
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<tr>
<td>GTO DT(5 X CV)</td>
<td>76.8</td>
<td>Bennet and Blue</td>
</tr>
<tr>
<td>ASI</td>
<td>76.6</td>
<td>Ster and Dobnikar</td>
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<tr>
<td>Fisher Discriminant Analysis</td>
<td>76.5</td>
<td>Ster and Dobnikar</td>
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<td>MLP+BP</td>
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<td>LVQ(20)</td>
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<td>Ster and Dobnikar</td>
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<tr>
<td>LFC</td>
<td>75.8</td>
<td>Ster and Dobnikar</td>
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6.8 Summary

This chapter presents the application of Fuzzy Expert System for diagnosis of diabetes using S Fuzzy Assessment Methodology. S Fuzzy Assessment Methodology uses K ratio to find the overlapping between the membership function, T Similarity Measure is used to find the similarity between fuzzy set, fuzzy numbers and fuzzy rules and S Value to manage uncertainty in Fuzzy Expert System. Finally defuzzification is adopted to convert the fuzzy output set to a crisp output. Accuracy values are calculated for all the Age groups.