Fuzzy rule based models for solving agricultural problem

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Abstract
The point of this paper is to make a brief study on fuzzy rule-based models for solving real life problems. Also we have discussed Mamdani model based on fuzzy if–then rules for solving real life problems.

Keywords
Fuzzy rule model, Mamdani model.

AMS Subject Classification
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1. Introduction

In the fifties, educator Lofti A. Zadeh accepted that all genuine issues could be explained with productive, investigative strategies and additionally quick (and enormous) electronic PCs. Right now, has made huge commitments in the advancement of framework hypothesis and software engineering. In mid 1960s, in any case, he started to feel that conventional framework examination systems were unreasonably exact for some mind boggling certifiable issues. In his paper distributed in 1961, he referenced that an alternate sort of science was required.

Indeed, even through there was solid protection from fluffy rationale; any scientists around the globe turned into Zadeh’s devotees. Significant ideas presented by Zadeh during this period incorporate fuzzy multistage dynamic, fuzzy comparability relations, fuzzy limitations, and phonetic fences.

In the late 1970s a couple of little college explore bunches on fuzzy logic were set up in Japan. A significant achievement throughout the entire existence of fuzzy logic control was set up by Assilian and Mamdani [3] in 1974. They built up the primary fuzzy logic controller, which was for controlling a steam generator.

Fuzzy logic is an innovation for creating canny control and data frameworks. Fuzzy logic is getting progressively significant in cutting edge data frameworks. Notwithstanding its potential for creating keen programming specialists, it has been utilized for putting away and recovering loose data from databases and data sources, just as for extricating fascinating examples from a lot of information.

2. Kind of Fuzzy Rule-Based Models

There are three kind of fuzzy rule-based models for function approximation.

1. The Mamdani Model
2. The Takagi–Sugeno–Kang (TSK) model and
3. Kosko’s Additive Model (SAM)

The surmising plan of SAM is like that of TSK model. Them two utilize a deduction undifferentiated from the weighted total to total the end. In this way, we allude to these standard model as added substance rule models. Conversely, the Mamdani model joins derivation consequence of rules utilizing superimposition not expansion. Henceforth, it is a non-added substance rule model.

Classification of Fuzzy Rule-based Model is as follows: Fuzzy Rule-based Model
The principal rule-based model improvement was the Mamdani model which was named after E.H. Mamdani [2] who built up the primary fuzzy logic controller utilizing the model. Most fuzzy control frameworks advancement during the 80s utilize the Mamdani model. The Takagi-Sugeno-Kang (TSK) model was first presented by T. Takagi and Prof. M. Sugeno around 1985. Another study of Sugeno, K.T. Kang kept on dealing with applications and distinguishing proof of the model. The assignment model has attracted substantially more consideration the 90s both in the exploration network and in industry. One of the principle favorable circumstances of the TSK model is that it can estimated a capacity utilizing less standards.

The Mamdani model and SAM use rules whose consequent part is a fuzzy set:

\[ R_j: \text{If } x_1 \text{ is } A_{1j} \text{ and } x_2 \text{ is } A_{2j} \text{ and } \ldots \text{ and } x_r \text{ is } A_{rj}, \text{ then } y = f_j(x_1, x_2, \ldots, x_r), i = 1, 2, \ldots, M, \]

where \( M \) is the number of fuzzy rules, \( x_j \in U_j (j = 1, 2, \ldots, s) \) are the input variables, \( y \in V \) is the output variable, and \( A_{ij} \) and \( C_i \) are fuzzy sets characterized by membership functions \( \mu_{A_{ij}}(x_j) \) and \( \mu_{C_i}(y) \), respectively.

These two fuzzy rule-based models differ in their inference schemes. The TSK model uses a rule whose then part is a linear model:

\[ R_j: \text{If } x_1 \text{ is } A_{1j} \text{ and } x_2 \text{ is } A_{2j} \text{ and } \ldots \text{ and } x_i \text{ is } A_{ij}, \text{ then } y = f_j(x_1, x_2, \ldots, x_i), i = 1, 2, \ldots, m, \]

where \( f_j \) is a linear function.

3. Mamdani Model

One of the most widely used fuzzy model in practice is the Mamdani model [2] a mapping from \( U_1 \times U_2 \times \cdots \times U_r \) to \( W \).

\[ R_i: \text{If } x_1 \text{ is } A_{1i} \text{ and } \ldots \text{ and } x_r \text{ is } A_{ri}, \text{ then } y = C_i \text{ where } x_j (j = 1, 2, \ldots, r) \text{ are the input variables, } y \text{ is the output variable, and } A_{ij} \text{ and } C_i \text{ are fuzzy sets for } x_j \text{ and } y \text{ respectively.} \]

Given inputs of the form: \( x_1 = A_{1j}, x_2 = A_{2j}, \ldots, x_i = A_{ij} \) where \( A_{1j}, A_{2j}, \ldots, A_{ij}, \ldots, A_{ij} \) are fuzzy subsets of \( U_1, U_2, \ldots, U_r \) (eg. Fuzzy number) the contribution of rule \( R_i \) to a Mamdani model’s output is a fuzzy set whose membership function compute by

\[ \mu_{C_i}(y) = (\alpha_i \wedge \alpha_2 \wedge \cdots \wedge \alpha_m) \wedge \mu_{C_i}(y) \]

where \( \alpha_i \) is the matching degree (that is firing strength) of rule \( R_i \), and where \( \alpha_{ij} \) is the matching degree between \( x_j \) and \( R_i \)’s condition about \( x_j \)

\[ \alpha_{ij} = \sup_{x_j} (\mu_{A_{ij}}(x_j) \wedge \mu_{A_{ij}}(x_j)) \]

and \( \wedge \) denotes the “\( \min \)” operation. This is the “clipping inference method”.

The final output of the model is aggregation of outputs from all rules using the max operator:

\[ \mu_i(y) = \max \{ \mu_{i1}(y), \mu_{i2}(y), \ldots, \mu_{iM}(y) \} \]

Note that the output \( C \) is a fuzzy set. This fuzzy output can be defuzzified in to a crisp output using one of the defuzzification techniques.

4. Agricultural problem

If, we want to cultivate a paddy crop, we have to analyze whether the rainfall, soil fertility and pest control are suitable. To analyze this process we use the Mamdani model.

The following linguistic rule that describes a aping from \( U_1 \times U_2 \times U_3 \) to \( W \):

**Rule 1:** IF (amount of rainfall is High) and (fertility of the soil is high) and (level of pest controlling is Highly intensive) THEN (10 Quintals/acre yield is not possible)

**Rule 2:** IF (amount of rainfall is Below average) and (fertility of the soil is Poor) and (level of pest controlling is Non intensive) THEN (10 Quintals/acre yield is possible)

where amount of rainfall, fertility of the soil, and level of pest controlling are the input variables, yield is a output variable. Highly intensive, Below average, Poor, Non intensive are the fuzzy sets.

**Table 4.1. Membership values**

| Amount of Rainfall in cms | 90 | 95 | 100 | 105 | 110 | 115 | 120 |
|--------------------------|----|----|-----|-----|-----|-----|-----|
| High                     | 0  | 0  | 0   | 0   | 0.2 | 0.8 | 1   |
| Moderate                 | 0  | 0  | 0.3 | 1   | 0   | 0   | 0   |
| Below Average            | 1  | 0.5| 0   | 0   | 0   | 0   | 0   |

| Fertility of the soil (in percentage) |
|---------------------------------------|
| High                                  | 0  | 0  | 0   | 0   | 0.1 | 0.5 | 0.8 | 1   |
| Moderate                              | 0  | 0  | 0.4 | 1   | 1   | 0   | 0   | 0   |
| Poor                                  | 1  | 1  | 0.6 | 0.2 | 0   | 0   | 0   | 0   |

| Level of pest controlling (frequency) |
|--------------------------------------|
| Highly Intensive                     | 0  | 0  | 0.6 | 1   |
| Moderately Intensive                 | 0  | 0.3| 1   | 0   |
| Non Intensive                        | 1  | 0.2| 0   | 0   |

| Yield(y) |
|----------|
| Possible | 0  | 0.2 | 0.6 | 1   |
| Not possible | 1 | 0.5 | 0.1 | 0   |

Given inputs of the form: Amount of rainfall is high, Fertility of the soil is moderate, Level of pest controlling is Moderately intensive.

First, we find the value of \( \alpha_{ij} \), where \( \alpha_{ij} \) is the matching degree between \( x_j \) and \( R_i \)’s condition about \( x_j \)

\[ \alpha_{ij} = \sup_{x_j} (\mu_{A_{ij}}(x_j) \wedge \mu_{A_{ij}}(x_j)) \]

\[ \alpha_{11} = \sup_{x_1} (\mu_{A_{11}}(x_1) \wedge \mu_{A_{11}}(x_1)) = \sup(0.8 \wedge 1) = 0.8 \]
The final output of the model is max operator.

\[
\alpha_{12} = \sup_{x_2} (\mu_{A_2}(x_2) \land \mu_{A_{12}}(x_2)) = \sup_{x_2} (0.4 \land 1) = 0.4
\]

\[
\alpha_{13} = \sup_{x_3} (\mu_{A_{13}'}(x_3) \land \mu_{A_{13}}(x_3)) = \sup_{x_3} (0.3 \land 1) = 0.3
\]

\[
\alpha_{21} = \sup_{x_1} (\mu_{A_{11}'}(x_1) \land \mu_{A_{21}}(x_1)) = \sup_{x_1} (0.2 \land 1) = 0.2
\]

\[
\alpha_{22} = \sup_{x_2} (\mu_{A_{22}'}(x_2) \land \mu_{A_{22}}(x_2)) = \sup_{x_2} (0.4 \land 1) = 0.4
\]

\[
\alpha_{23} = \sup_{x_3} (\mu_{A_{23}'}(x_3) \land \mu_{A_{23}}(x_3)) = \sup_{x_3} (0.3 \land 1) = 0.3
\]

The contribution of rule \( R_i \) to a Mamdani model’s output is a fuzzy set whose membership function is computed by

\[
\mu_{C_i}(y) = (\alpha_{i1} \land \alpha_{i2} \land \cdots \land \alpha_{in}) \land \mu_{C_i}(y)
\]

\[
\mu_{C_i}(y) = (\alpha_{i1} \land \alpha_{i2} \land \alpha_{i3}) \land \mu_{C_i}(y) = (0.8 \land 0.4 \land 0.3) \land 1 = 0.3 \land 1 = 0.3
\]

\[
\mu_{C_2}(y) = (\alpha_{21} \land \alpha_{22} \land \alpha_{23}) \land \mu_{C_2}(y) = (0.2 \land 0.4 \land 0.3) \land 1 = 0.2 \land 1 = 0.2
\]

The final output of the model is max operator.

\[
\mu_c(y) = \max\{\mu_{C_1}(y), \mu_{C_2}(y)\}
\]

\[
= \max\{0.2, 0.3\} = 0.3
\]

By applying the same method of computation, we can get the values for \( \mu_c(y = 15), \mu_c(y = 20), \mu_c(y = 25) \).

Thus we obtain the output \( C \) as a fuzzy set. This fuzzy output can be defuzzified into a crisp output using any of the defuzzification methods.

5. Conclusion

Hence we acquire the yield \( C \) as a fuzzy set. This fuzzy yield can be defuzzified into a fresh yield utilizing any of the defuzzification techniques.

Additionally, we can take care of any genuine issue utilizing Mamdani model. Like Mamdani model we can utilize TSK model or SAM model for tackling any genuine issue.

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