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WATER FLOW MANAGEMENT AT CANAL SIDE USING FUZZY LOGIC

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ABSTRACT

The main aim of this study paper is to research the answer to two main questions in water flow modeling in canal catchment; (I) how to develop the fuzzy membership functions and rule base to obtain the results, and (II) how to satisfy the demand with minimum losses. The first question is answered in order to develop a decision making model and reduced the error by performance. The second question is answered in order to reduce the canal operation loss i.e. escape loss. The simple membership function and fuzzy rule generation technique (SMRGT) is to develop this model. Fuzzy model is basically operates on "If….Then" kind of statement so it is intuitive and has transparency. This model consists of upstream flow control i.e. inflow in order to satisfy the demand up to its peak level. The obtain results through this model is the new inflow regarding the actual demand so it is compared with the actual inflow for error check and losses are compared with the field data for reliability.

Keywords: *SMRGT, water flow management, irrigation canals, decision making, fuzzy logic, membership function, rule base, inflow, demand, escape loss.*

INTRODUCTION

Agriculture is the main source of revenue in the Indian economy as 70% of income earned from crop production. Crop production is act as scale to know the agricultural status so it is necessary to maintain it. Several elements play role for it like weather conditions, soil conditions, water for irrigation, etc. One of the important elements is water which is obtained from river and rain by nature and artificially by canals. Winter, summer and monsoon are the three seasons of the India among which in only monsoon natural water is available as rain so in rest of the two seasons it is necessary to provide water by means of canal conveyance network or other manner artificially. [3] Canal plays an important role for water conveyance network so it is necessary to operate it in efficient manner as water is also need to be saved. All the above points lead to concentrate on the proper water flow management. There are several losses in the canal catchment like evaporation loss, seepage loss, escape loss, etc. among all the described escape loss can be controlled by proper operation of canal. In order to operate canal with

efficient manner and reliably, first thing strikes in mind canal automation. [9] Logic used for canal automation is very important as local operator deals with this daily. In many classical study articles it is seen that PLC-ladder logic is developed for this automation process. This logic deals with particular values if we talk about binary so only 0 and 1, no in between stages are considered. Fuzzy logic is the one which deals with the range of values rather than particular value so it consists of all the values between 0 and 1. In fuzzy logic it is considered SMRGT technique so it is easy to develop and understand. It is made up of "If….Then" kind of statement as rules so transparent and ease for the local canal operators. To observe this model Kundhela Branch Canal (KBC), a part of Narmada Main Canal (NMC) is chosen as study area. It lies in Vadodara district, Gujarat. In this paper only demand based inflow control is discussed, according to this inflow the gate operation will discussed later on.

FUZZY BASED WATER FLOW MODEL

Fuzzy logic is easy to understand so better enough for modeling and flexible for operations. It is also tolerant of imprecise data and help to model nonlinear function of operation with arbitrary complexity. [8] It deals with the linguistic variables like small, medium, large, etc. The field data available from canal catchment is in terms of ranges and numerical value so those are to be converted into linguistic values. From the classical study survey it is seen that that demand control done by main canal control or reservoir operation. This paper is focused on the model of the branch canal and minors. Escape is made on the side of branch canal or minors, for this reason study area is chosen KBC, Vadodara in Gujarat. In order to develop this model the expert knowledge is required so for it site engineers and canal operating policy is considered. A steady state policy is built from the model developed by the SMRGT method. To evolve this model several steps need to be done [5].

A. Fuzzification of the variables
B. Rule base of the fuzzy set
C. Implication of the fuzzy set
D. Aggregation of the fuzzy output
E. Defuzzification of the fuzzy output

A. FUZZIFICATION OF THE VARIABLES

Data available to us is always numerical value related to fall in universe of discourse. By choosing the membership function the input fuzzy set is applied to obtain the membership degree grade. According to the operations to be done the membership function is developed using the linguistic terms. This may vary according to the problem and its classes. The membership function is developed using the knowledge domain from various sources like literatures, classical studies, expert knowledge, theoretical models, etc. There are two methods to make membership function, direct method and indirect method. Indeed, both the methods

require expert knowledge but in direct method expert need to answer the questions accurately and clearly relevant to the membership function and in indirect method expert need to answer the questions less effective to the biases of the subjective opinion which leads to evolve the membership function. Fig. 1 shows the fuzzification of the demand variable.

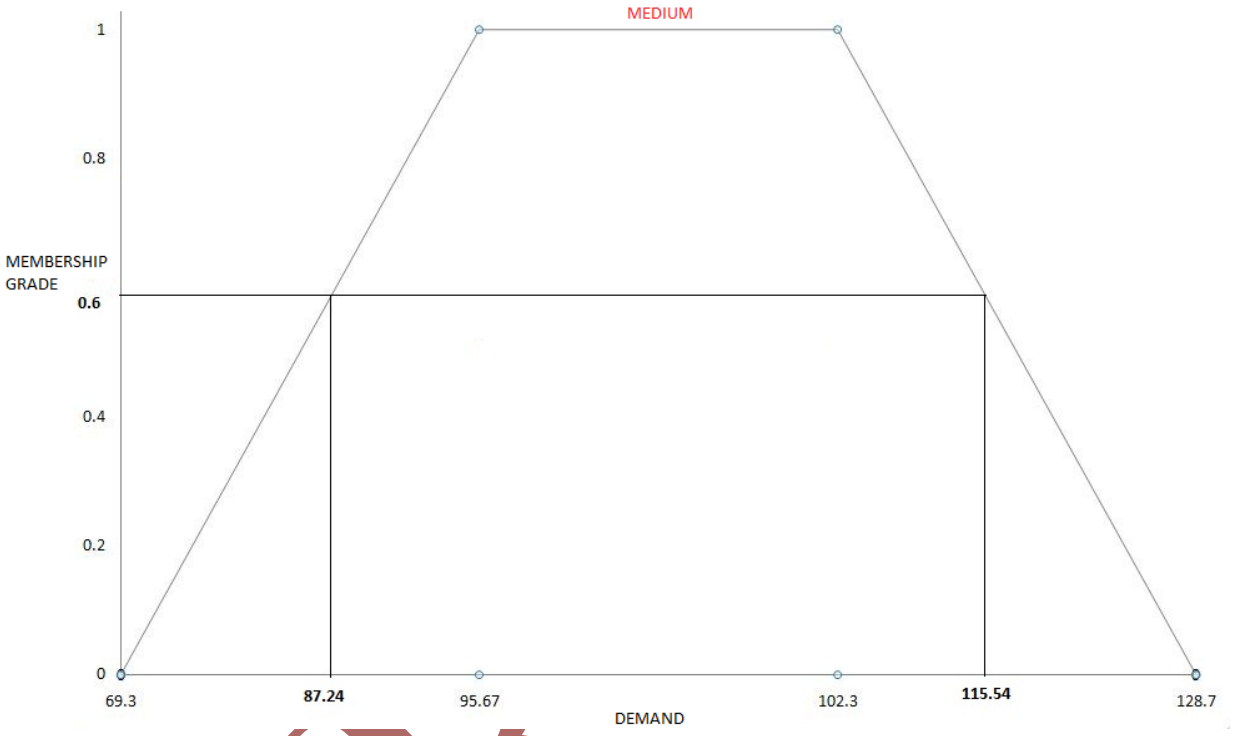


Figure 1. Fuzzification of demand variable

B. RULE BASE OF THE FUZZY SET

Rule base is the heart of the fuzzy model. This rule base is developed very carefully and with proper guidance. So to develop it some expert engineer or researcher is required. This rule merely consists of several rules correlating the input and output variables. This describes how the output should be according to the given input for the value. This rule base is written in conventional logical language which consists of "If….Then" statement with logical operators 'AND' and 'OR'. 'AND' (min) operators gives the value minimum and 'OR' (max) operator gives the value maximum of the provided value. When probabilistic method is used; it will result like as (1).

$$Probor(x,y) = x + y - xy \quad \ldots\ldots (1)$$

For example, "**If** input x is m **and/or** input y is n **then** output z is o"

C. IMPLICATION OF THE FUZZY SET

There are two methods to make operations on the fuzzy output, 'AND' and 'OR'. With the help of these operators it gives the specific fuzzy set. Here the output is obtained from the fuzzy operators is related to the input premises. This premise given as the input for the implication and it returns the fuzzy set as the resultant output. Here 'AND' and 'OR' operator performs clipping and scaling respectively of the fuzzy set. Fig. 2 shows the result of the implication and Fig. 3 shows the clipping and scaling of the fuzzy set.

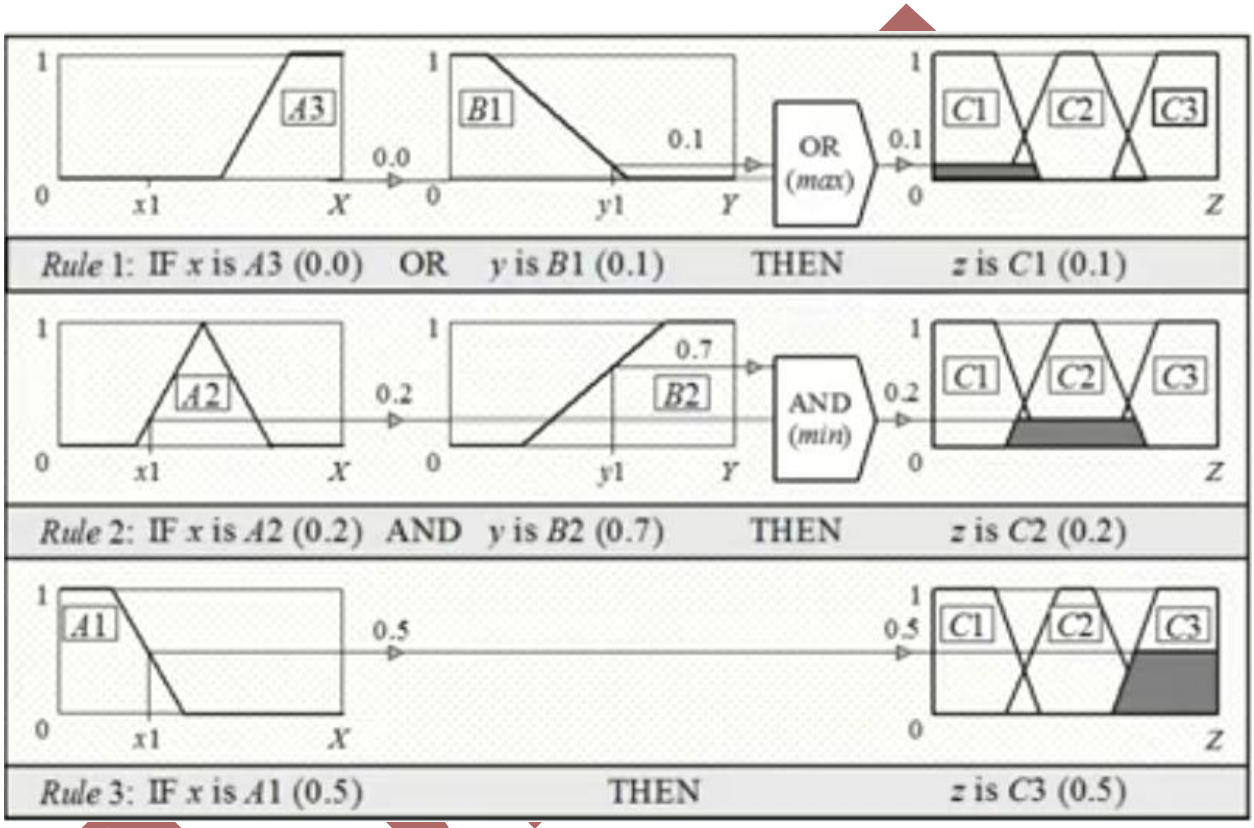


Figure 2. Result of the implication process

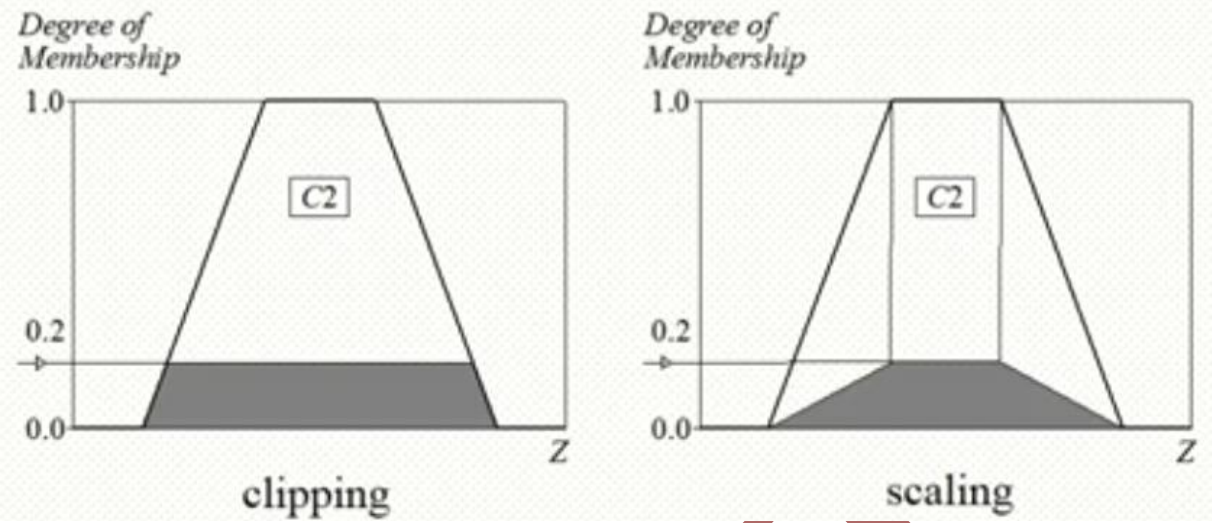


Figure 3. Clippind and scaling of a fuzzy set

D. AGGREGATION OF THE FUZZY OUTPUT

Aggregation word itself interprets its meaning i.e. to gather. It reforms the output by gathering the each output of each rule applied on the input. Aggregation used the output of implication for each fuzzy set as input for a fussy set. This will gives final result as singular fuzzy set from all the given as input. There are different aggregation methods are available like summing (sum), maximizing (max), probabilistic (probor) and custom methods. It is beneficial when one or more membership function overlapped to obtain the corresponding one appropriate output. Aggregated output becomes the input for the defuzzificztion for obtaining the crisp output. Fig. 4 shows the aggregation of the fuzzy output.

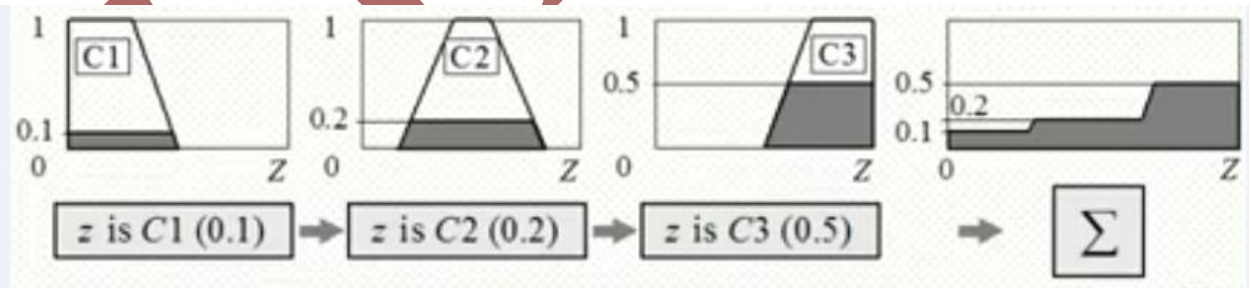


Figure 4. Aggregation of the fuzzy rule set

E. DEFUZZIFICATION OF THE FUZZY OUTPUT

As a main result for a problem, is to obtain the crisp value of output corresponding to the given input. Fuzzy deals with the linguistic variables for the intermediate processes. So it is required

to convert the finalized fuzzy set in to a crisp value. To obtain the crisp value defuzzification of the fuzzy set is required. [7] Several methods are available for the defuzzification techniques like centroid, bisector, middle of maximum (MOM), largest of maximum (LOM), smallest of maximum (SOM), etc. It is observed that centroid method is used widely for this operation, still according to application require any of the described methods can be used. Output of the centroid defuzzification method follows the mathematical expression as in (2).

$$output\ z = \frac{\int \mu_c(z).z\ dz}{\int \mu_c(z)\ dz} \quad \text{..... (2)}$$

Fig. 5 shows the defuzzification of the fuzzy output for the centroid method.

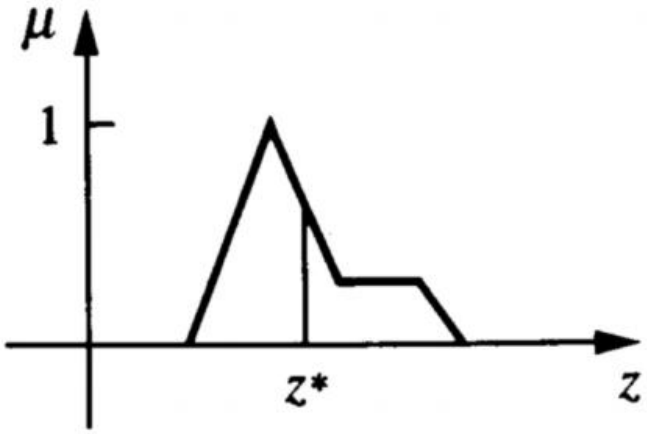


Figure 5. Defuzzification of the fuzzy output (centroid method)

WATER FLOW MODELING USING SMRGT TECHNIQUE

The methodology discussed above is used to evolve the model with the help of SMRGT technique. A said earlier the study area is KBC, a part of NMC, Vadodara. Purpose of considering this as study is command area uses its water for irrigation in agriculture as well as the industrial zone takes water from it. Major crops of the command area are cotton, wheat, maize, castor and sugarcane. Baroda dairy takes water from this canal for the process. Average demand and evaporation-seepage loss is divided into 1 to 40 periods. [1] Evaporation and seepage losses are up to 7 cusecs for the available data of April-2014 to March-2015. The data is separated in several periods according to variations. For the same period the excessive demand is also known so it is divided into several parts as can be known by weekly manner. The fuzzy logic based model presented in this paper is only considered to control inflow according to demand and evaporation-seepage.

Fuzzy logic based model is made using the fuzzy tool available in MATLAB software, version 9.3a (MATLAB, R2009a). [6] Demand and evaporation-seepage are chosen as the inputs of the model and inflow at upstream as output of the model.
Parameters for the fuzzy operations are shown in the Fig. 6.

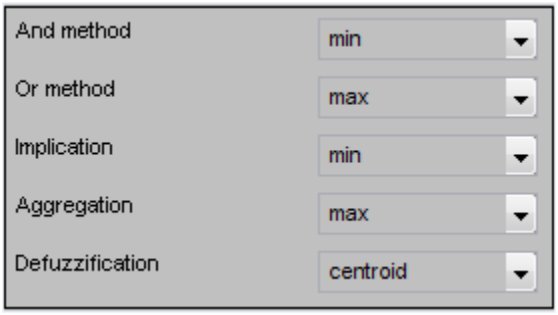


Figure 6. Parameters for the fuzzy operations

'AND' and 'OR' methods operates for minimum and maximum respectively as the classical logical operations. Implication method is taken as minimum so it will give the clipped output with scaling. Aggregation is chosen as maximum to obtain the required inflow fuzzy set. Centroid is used as defuzzification method. [1]

A) FUZZIFICATION OF THE VARIABLES

The degree of measurement related to demand and evaporation-seepage is decided by low, medium or high regarding the available statistical data. It is a way to follow between membership function and number of rules in order to achieve the optimal solution. There are two inputs in this problem, one is demand and another is evaporation-seepage. For the demand trapezoidal membership function is selected from the nature of the data varies and for the evaporation-seepage triangular membership function is selected. The available data helps to make this membership function and plays the role of knowledge base here. Demand is classified into seven several linguistic terms and those are very low, low, medium low, medium, medium high, high and very high. As well as, the inflow is also categorized by same manner as the demand. Evaporation-seepage is classified in three linguistic terms and those are low, medium and high. Demand we need to satisfy precisely so it is divided into more classes whereas evaporation-seepage varies nearly by same manner so it is in fewer classes.

B) FORMATION OF THE FUZZY RULE BASE

As discussed earlier rule base is developed using the knowledge of expert engineer or by the long period studies of the problem. Field engineer and the gate operators are important to decide this part of the model. Field engineer helps to make this rule by his knowledge regarding the functioning of the canal and its decided range of operations whereas the gate operator

provides us the knowledge by his experiences of the canal operation. For the problem stated in this article, using the knowledge of both, rule base is developed. Fig. 7 shows the screenshot of the rule base.

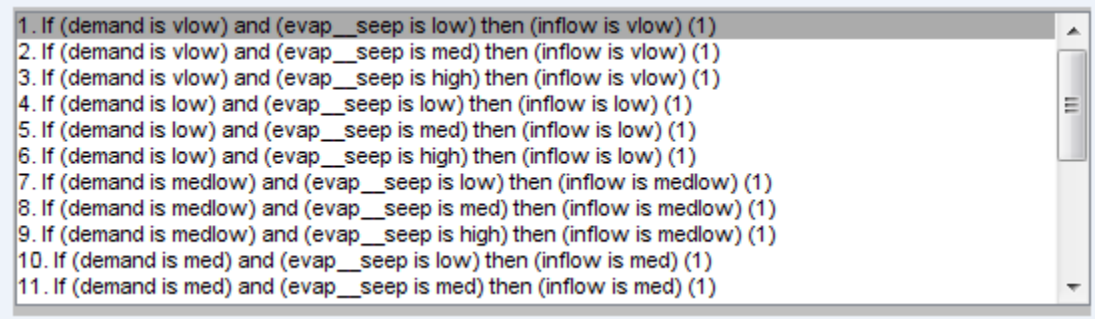


Figure 7. Rule base for the water flow model

C) APPLICATION OF THE FUZZY OPERATOR

Premise of the rule is assigned the membership grade by this operation. Fuzzy operator decides which value is more suitable regarding the rule premises. For example, it is seen from the Fig. 8, in medium membership function of demand 1 is assigned to the numerical value 40 and 95.67 is assigned to numerical value 87.24. If 'AND' operator is used so it returns 0.5 and if 'OR' operator is used so it returns 1 as a result.

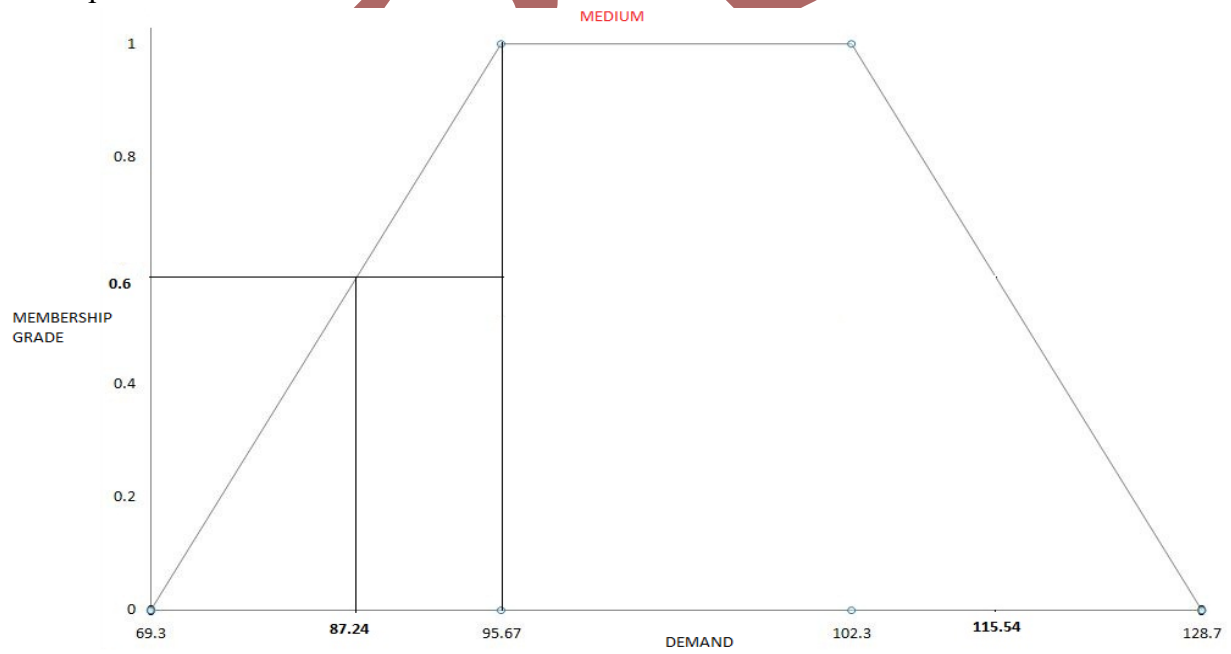


Figure 8. Operator nature on fuzzy set

D) IMPLICATION, AGGREGATION AND DEFUZZIFICATION

The output of the fuzzy operator is applied to the membership function to obtain the consequences regarding the rule base. As discussed earlier, this all processes done one by one. Firstly it clip and scales the output in particular fuzzy set then all the fuzzy set get gathered and converted into one fuzzy set as single fuzzy output. After it finally defuzzification technique is used to obtain the crisp value from the output of the aggregation. Fig. 9 shows the all three processes. Applied membership function is trapezoid and triangular but at the output it has mixture of shape which is shown in image. Also here we can observe the output of each rule. The red line is seen in the figure with a pink circle shows the centroid line which indicated the final crisp value lays on it. The pink square box shows the result of all the above said three processes for the fuzzy set marked with green box. [7]

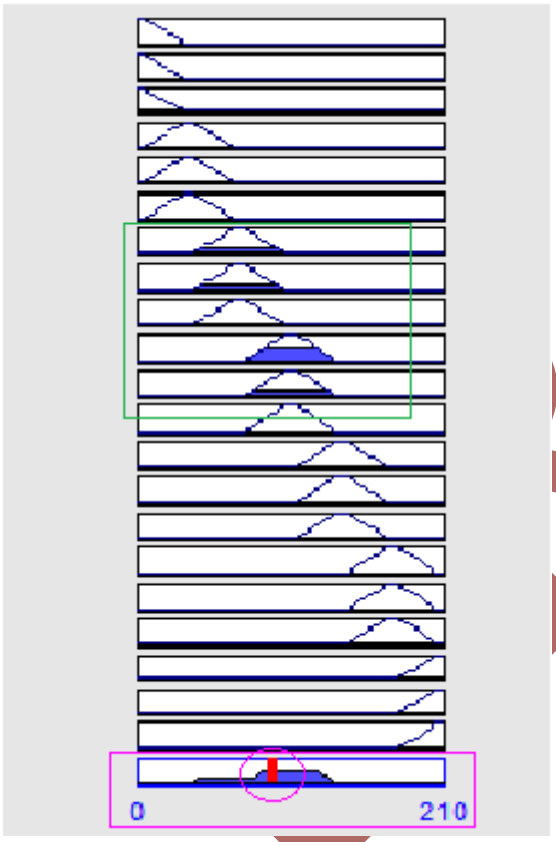


Figure 9. Result of implication, aggregation and defuzzification

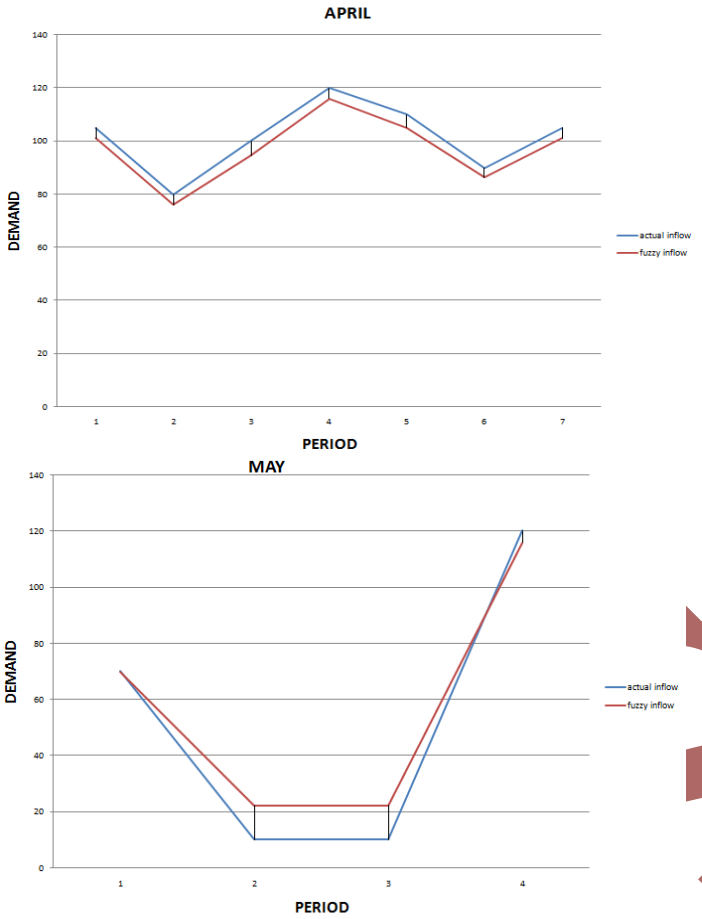
RESULTS

For the considered example data is available from April-2014 to March-2015 i.e. of one year. The range of input and output parameter is decided from as follow. The demand is classified in sever stages as said earlier in the range of [0 198]; the evaporation-seepage is classified in three stages as said earlier in the range of [0 7] and the inflow is classified in the seven stages in the

range of [0 210]. Fig. 10 shows the demand, actual inflow and fuzzy inflow for the four months. Same can be obtained for the yearly data. By comparing the graph it is observed that fuzzy inflow is lower than the actual inflow is available. Also by the calculation it is seen that the overall periodical losses reduces than the actual escape losses. It is shown below in table for four months April, May, June and July i.e. 1 to 18 periods from the total. Graph is drawn for the demand in no of periods of the month. In the graph blue line indicates the actual inflow release and red line indicates fuzzy inflow release. Fig. 11 shows the final output of the inflow release regarding the decided input parameters.

Table 1. Comparison of actual and fuzzy output and loss.

PERIOD	*DEMAND*	*ACTUAL INFLOW*	*ACTUAL LOSS*	*FUZZY INFLOW*	*FUZZY LOSS*
1	94	105	11	101	7
2	72	80	8	76	4
3	90	100	10	94.6	4.59
4	108	120	12	116	8
5	99	110	11	105	5.98
6	81	90	9	86.3	5.29
7	94	105	11	101	6.98
8	63	70	7	70	7
9	9	10	1	22.3	13.3
10	9	10	1	22.3	13.29
11	108	120	12	116	7.69
12	108	120	12	114	6
13	8	10	2	22.5	14.5
14	90	100	10	96.8	6.45
15	90	100	10	96.3	6.32
16	113	125	12	120	7.01
17	45	50	5	47.4	2.4
18	8	10	2	20.8	12.8


APRIL
DEMAND
PERIOD
actual inflow
fuzzy inflow
MAY
DEMAND
PERIOD
actual inflow
fuzzy inflow

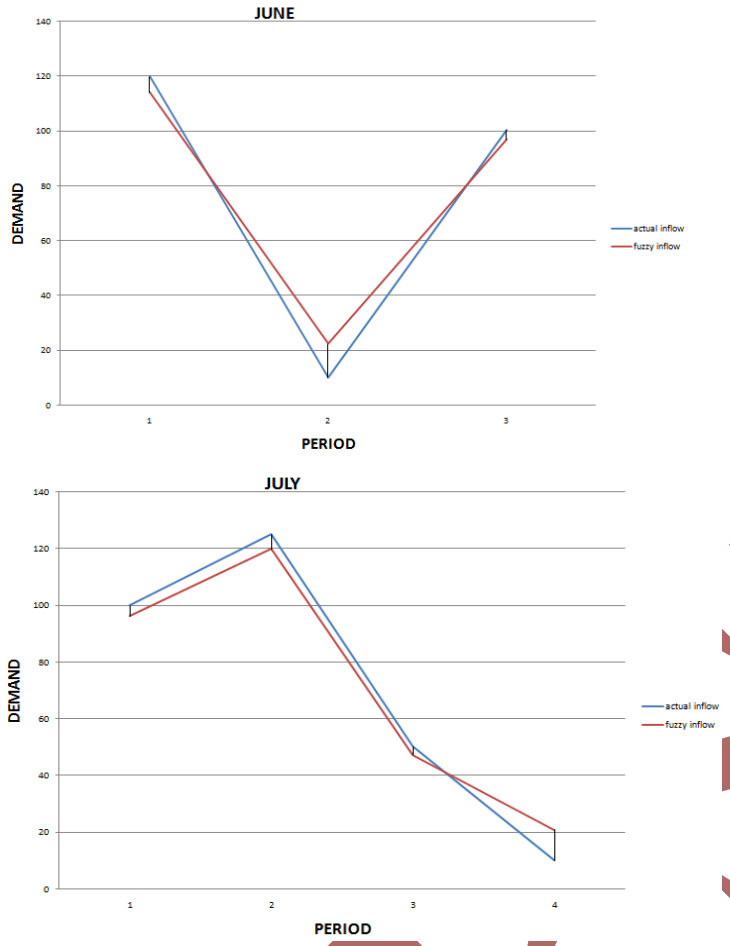


Figure 10. Comparison of actual inflow and fuzzy inflow

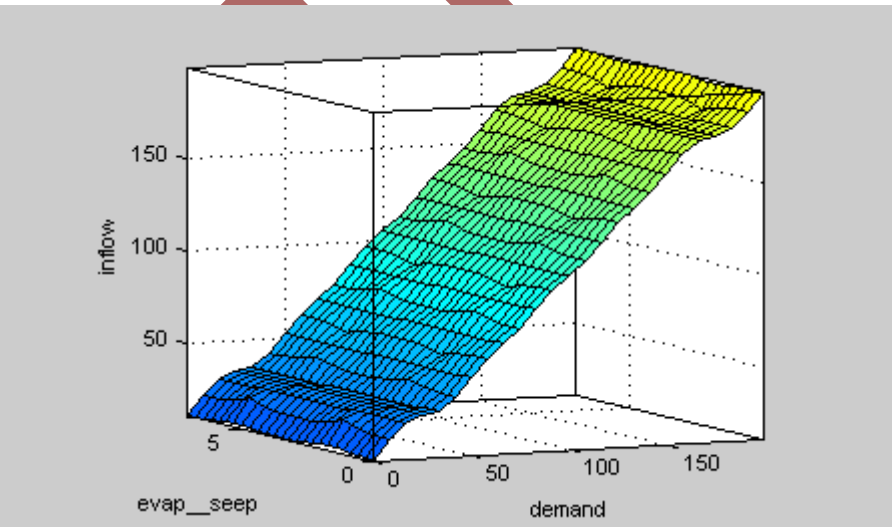


Figure 11. Output of the fuzzy based inflow control model

CONCLUSION

The SMRGT technique is used to develop a water flow management model to control the upstream flow in order to control the downstream demand. It deals with the given parameter and answers the problem without including the complex optimization method. From the results it is observed that the overall loss is reduced than the conventional loss happened up till now. This model is easy to developed and change according to the conditions available at the time of operation. Perhaps, it operates very well but at lower demand, it releases more water than the requirement. This is basically happens as canal should maintain the water level at lower level in order to reduce the water impact on bed of canal. This model is decision making kind only input parameters are to be fed. It is organized by the linguistic variables like 'LOW', 'MEDIUM' and 'HIGH'; so it is very comfortable and reliable to handle and work with it. This can directly used with the gate operation model in order to decide how much gate should be operated.

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