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Effect of Fuzzification Technique on Accuracy of Fuzzy Algorithm

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ABSTRACT: Fuzzy logic is widely used for medical diagnosis and treatment due to vagueness and fuzzy nature of medical domain. In this paper we have designed fuzzy algorithm to diagnose and treat Hyponatremia disease. Algorithm is designed using Matlab software. The fuzzy system gives satisfactory results. We checked the effect of fuzzification method on the accuracy of algorithm. It is observed that trapezoidal fuzzification has more accuracy than triangular fuzzification.

KEYWORDS: fuzzy logic, hyponatremia, fuzzification, accuracy, diagnosis, treatment

I. INTRODUCTION

Hyponatremia is decrease in Serum Sodium, Na, concentration to a level less than 136 mEq/L caused by an excess of water relative to solute. It can be hypotonic, isotonic or hypertonic [1]. Common causes include Diuretic use, Diarrhea, Heart Failure, and Renal Disease. Clinical manifestations are primarily neurologic (due to an osmotic shift of water into brain cells causing edema), especially in acute hyponatremia, and include headache, confusion, and stupor; seizures and coma may occur. Symptoms can be subtle and consist mainly of changes in Mental Status, including Altered Personality, Lethargy and Confusion. As the serum Na falls to < 115 mEq/L, stupor, neuromuscular hyperexcitability, hyperreflexia, seizures, coma, and death can result [2].Diagnosis is by measuring serum Na. Serum and urine electrolytes and osmolality help determine the cause. Causes of hyponatremia include disorders in which ADH levels are disturbed , hyperglycemia, hyperlipidemia etc. [3].Treatment involves restricting water intake and promoting its loss, replacing any Na deficit, and correcting the underlying cause.

Medical domain is full of vagueness [4]. Symptoms of disease vary significantly as per age, sex and patient specific characteristics. Some patients may not experience any symptom. Thus diagnosis data is inadequate and uncertain. Fuzzy logic may be used to model such uncertainty and find out the severity level and symptom specification set [5]. For laboratory tests and imaging tests different devices and equipment are used. The accuracy of these devices and methods of measurement contribute to vagueness in data. Also different laboratories use different reference ranges. Thus there is vagueness in the interpretation of the test results. This vagueness and inexact boundary can be well modeled using fuzzy logic's flexibility.

In this paper we have designed fuzzy algorithm to diagnose and treat Hyponatremia. Also we checked the effect of fuzzification method on the accuracy of algorithm.

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II. DESIGN OF FUZZY ALGORITHM

Fuzzy algorithm is designed in Matlab usiing Mamdani approach. Algorithm takes two inputs Serum_Na and Volume_status and one output Treatment. Fig. 1 shows FIS for Hyponatremia.

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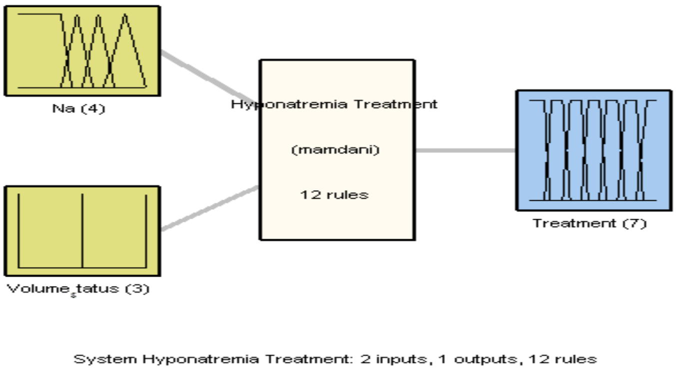

Fig. 1 Fuzzy Inference System for Hyponatremia Treatment

A. Input and Output to Algorithm

1. Serum_Na: Serum Na is low in hyponatremia. It is measured in mEq/L. Its normal range is 135-145. Seven fuzzy sets VL (Very Low), L (Low), JL (Just Low), N (Normal), JH (Just High), H (High) and VH (Very High) are defined for the severity Serum_Na as given in Table I.

TABLE I
FUZZY SETS for SERUM_Na

Sr. No.	Serum_Na	Fuzzy set
1	μ_{VL}	[90, 90, 110, 115]
2	μ_{L}	[110, 117.5, 125]
3	μ_{JL}	[120, 127.5, 135]
4	μ_{N}	[130, 140, 150]
5	μ_{JH}	[140,150,160]
6	μ_{H}	[150,160,170]
7	μ_{VH}	[160,170,200,200]

Triangular membership functions are used for Serum_Na. For extreme values, trapezoidal functions are used as shown in Fig. 2.

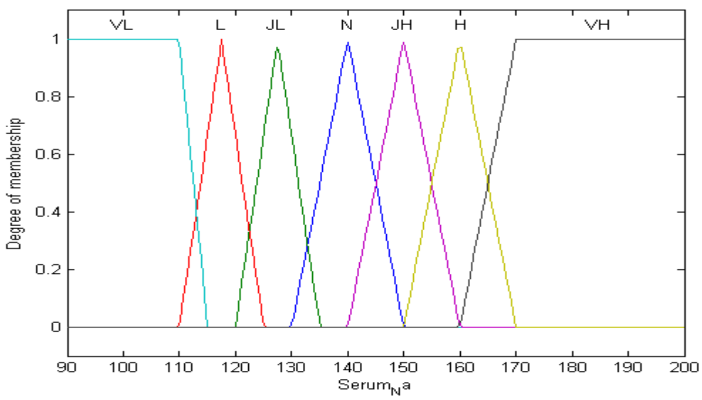

Fig. 2 Membership Functions for Serum_Na

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2. Volume_status: Three singleton fuzzy sets hypovolemic (low blood volume), normovolemic (normal blood volume) and hypervolemic (excess blood volume) are defined for the Volume_status as given in Table II.

TABLE II
FUZZY SETS for VOLUME_STATUS

Sr. No.	Volume_status	Fuzzy set
1	$\mu_{hypovolemic}$	[1, 1, 1]
2	$\mu_{normovolemic}$	[2, 2, 2]
3	$\mu_{hypervolemic}$	[3, 3, 3]

Singleton membership functions are used for Volume_status as shown in Fig. 3.

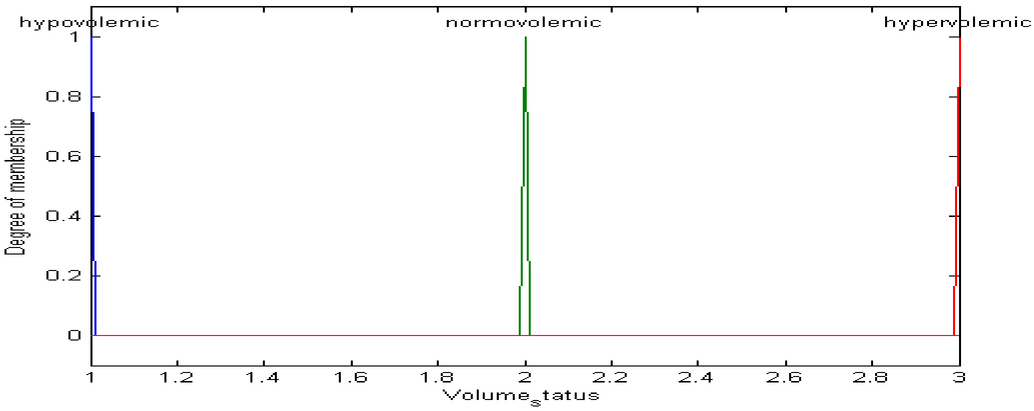

Fig. 3 Membership Functions for Volume_status

3. Treatment: This is the output variable of the algorithm. There are total of seven treatment plans considered by researcher by discussing with experts. Fuzzy sets for each treatment are shown in Table III. Fig. 4 shows trapezoidal membership functions used for Treatment.

TABLE III
FUZZY SETS for HYPONATREMIA TREATMENT

Sr. No.	Treatment	Fuzzy set	Sr. No.	Treatment	Fuzzy set
1	μ_{T1}	[0, 0, 0.8, 1.1]	5	μ_{T5}	[3.8, 4.2, 4.8, 5.2]
2	μ_{T2}	[0.8, 1.2, 1.8, 2.2]	6	μ_{T6}	[4.8, 5.2, 5.8, 6.2]
3	μ_{T3}	[1.8, 2.2, 2.8, 3.2]	7	μ_{T7}	[5.8, 6.4, 7, 7]
4	μ_{T4}	[2.8, 3.2, 3.8, 4.2]			

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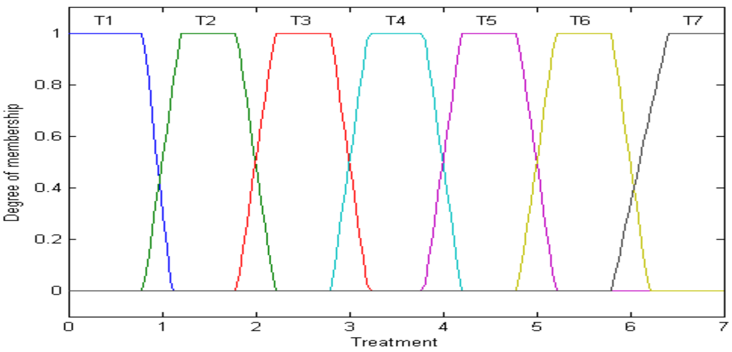

Fig. 4 Membership Functions for Hyponatremia Treatment

B. Fuzzy Rulebase

Fuzzy rule base is developed that consists of 12 fuzzy rules as shown in Table IV.

TABLE IV
FUZZY RULEBASE for HYPONATREMIA

Rule No	Rule
1	If Na is N And Volume_status is Hypovolemic Then Treatment is T1
2	If Na is N And Volume_status is Normovolemic Then Treatment is T1
3	If Na is N And Volume_status is Hypervolemic Then Treatment is T1
4	If Na is JL And Volume_status is Hypovolemic Then Treatment is T2
5	If Na is JL And Volume_status is Normovolemic Then Treatment is T3
6	If Na is JL And Volume_status is Hypervolemic Then Treatment is T4
7	If Na is L And Volume_status is Hypovolemic Then Treatment is T5
8	If Na is L And Volume_status is Normovolemic Then Treatment is T6
9	If Na is L And Volume_status is Hypervolemic Then Treatment is T6
10	If Na is VL And Volume_status is Hypovolemic Then Treatment is T7
11	If Na is VL And Volume_status is Normovolemic Then Treatment is T7
12	If Na is VL And Volume_status is Hypervolemic Then Treatment is T7

C. Defuzzification

MOM method is used for defuzzification. Min inference and Max aggregation methods have been used.

D. Experimental Results and Discussion

Algorithm is tested on the data set of 62 patients and the results are shown in Table V. Mismatching results are shown in bold case.

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TABLE V
EXPERIMENTAL RESULTS of FUZZY ALGORITHM for HYPONATREMIA

Sr. No.	Input		Output	Sr. No.	Input		Output
	Na	Volume_status	Treatment		Na	Volume_status	Treatment
1	110	1	7	32	130.2	3	4
2	124	2	3	33	132	1	2
3	114	1	5	34	122	2	6
4	105	3	7	35	112	2	**7**
5	126	3	4	36	105	1	7
6	134	1	1	37	131	2	3
7	129	2	3	38	112.5	1	**7**
8	115	2	6	39	113	1	**6**
9	124	1	2	40	106.5	3	7
10	133	3	1	41	122	1	5
11	108	1	7	42	111.6	1	**7**
12	117	1	5	43	124.3	2	3
13	112	3	**7**	44	133.6	1	1
14	110	2	7	45	99.7	1	7
15	104	3	7	46	114.2	1	5
16	98	1	7	47	137.5	1	1
17	95	2	7	48	98.7	1	7
18	126	1	2	49	122.5	2	**4**
19	128	1	2	50	110.1	1	7
20	133	2	1	51	118.5	1	5
21	123	1	2	52	129.8	1	2
22	109	2	7	53	115.3	2	6
23	111	3	7	54	107.2	2	7
24	121	1	5	55	114.7	1	5
25	106	1	7	56	126.5 1	1	2
26	128	2	3	57	119.2	2	6
27	122.5	1	**4**	58	134.2	1	1
28*	109	1	7	59	105.5	1	7
29	127.6	1	2	60	140.2	1	1
30	120	1	5	61	123	2	**3**
31	104.5	3	7	62	121.8	2	6
No. of Results Matching with Expected Results						54	

Out of 62 cases 54 cases are correctly diagnosed and treated. Accuracy of algorithm is 87.09%. Fig. 5 shows surface diagram. Asymmetric asymmetric shows non linear relationship between input Serum Na, Volume Status and output Treatment.

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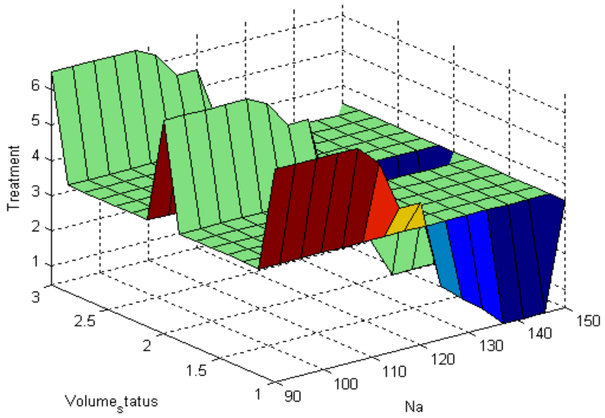

Fig. 5 Surface Diagram

III. FUZZY TUNING

We checked the effect of fuzzification process on the accuracy of algorithm. Fuzzification for Serum_Na is changed from triangular to trapezoidal membership function. New membership functions for Serum_Na are shown in Fig. 6.

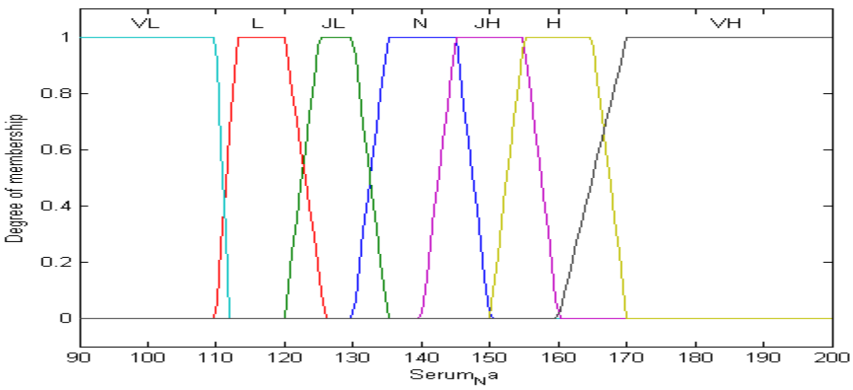

Fig. 6 Trapezoidal Membership Functions for Serum_Na

The result obtained from trapezoidal fuzzification for patient record with Serum_Na value of 112 and Volume_status value of 3 is shown in Fig. 7.

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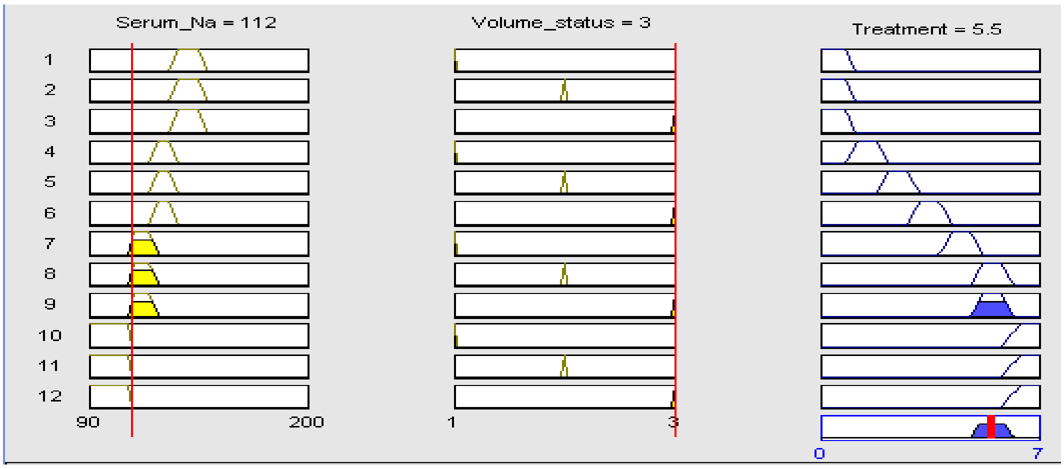

Fig. 7 Defuzzified Output for Serum_Na=112 and Volume_status=3

It is seen that trapezoidal fuzzification has more accuracy than triangular fuzzification. Table VI shows the result comparison for the two fuzzification methods.

TABLE VI

RESULT COMPARISON of FUZZIFICATION METHODS: HYPONATREMIA

Fuzzification Method	No. Of Accurate Results Obtained	Total No. of Patient Records	% increase in Accuracy 100*(59-54)/54
Triangular	54	62	9.26%
Trapezoidal	59		

IV. Conclusions

Fuzzy system is developed for diagnosis and treatment of Hyponatremia disease. The results are satisfactory and prove that fuzzy logic is best suitable for vague medical domain. Present algorithm suggests treatment for only hyponatremia. It does not treat its complications. The work can further be extended to treat the complications by adding more symptoms and rules. Also, the effect of fuzzification technique on accuracy of algorithm is checked. It is observed that trapezoidal fuzzification has more accuracy than triangular fuzzification.

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