Fuzzy System for Treatment of Kidney Stone

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Abstract- **Medical data is very vague and imprecise in nature that makes disease diagnosis a complex and fuzzy process [1]. Fuzzy logic is widely used for diagnosis and treatment of diseases. In this paper we have developed fuzzy system for treatment planning for kidney stone. Also we have tuned the results to check the effect of number of fuzzy sets on accuracy. The paper concludes with findings and further scope to extend the work.**

***Index Terms*- Kidney Stone, Treatment, Vagueness, Fuzzy logic**

I. INTRODUCTION

Kidney Stone is very common disease seen in all the age groups and race. They are more common in men [2]. A kidney stone, also known as a renal calculus, is a solid concretion or crystal aggregation formed in the kidneys when substances in the urine become highly concentrated. Urinary stones are typically classified by their location, in the kidney (nephrolithiasis), ureter (ureterolithiasis), bladder (cystolithiasis) or by their chemical composition (calcium , struvite, uric acid, or other compounds).

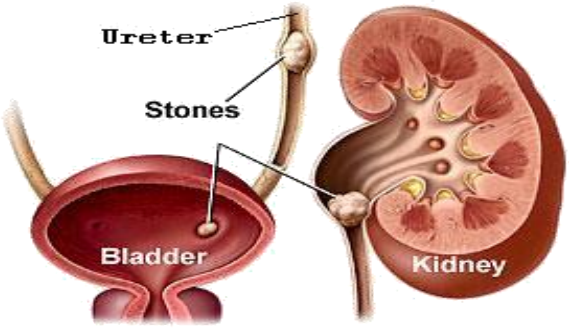

Fig. 1: Kidney Stones

The patient carrying stone often experiences the symptoms like blood in urine, back/flank pain, fever, chills and vomiting [3]. The diagnosis of kidney stones is made from information obtained from the history, physical examination, urinalysis, and radiographic studies. Ultrasound examination and blood tests may also aid in the diagnosis. They are treated by pain control medications such as nonsteroidal anti-inflammatory drugs or opioids. Some stones pass on their own. More severe cases require surgical intervention such as extracorporeal shock wave lithotripsy, laser lithotripsy or percutaneous nephrolithotomy. Treatment differs according to the type and size of the stone and severity of pain.

II. FUZZY SYSTEM FOR TREATMENT OF KIDNEY STONE

The signs and symptoms of kidney stone are vague in nature. Back pain is assessed by physician from observation and physical examination of the patient. Patient may not be able to explain it correctly and doctor's decision may vary. Also there is variation in the criteria about the largeness of the stone size. The size of the stone is interpreted differently by different physicians. Thus, there is variation and ambiguity in the decision which leads to errors in diagnosis and treatment planning. To reduce this ambiguity and decision errors, we have developed fuzzy system for treatment of kidney stone. The system is developed in Matlab using Mamdani approach. Figure 2 shows Fuzzy Inference System for Kidney Stone Treatment. It accepts three input parameters Stone Type, back pain and stone size. The output variable is Treatment.

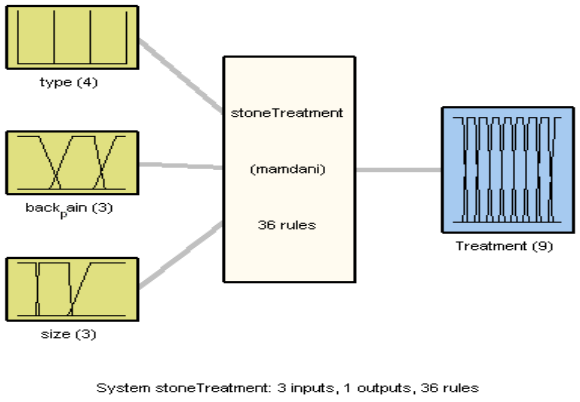

Fig. 2: Fuzzy Inference System for Kidney Stone Treatment

Input and Output Variables

1. **Stone_type:** It is discrete variable that indicates the type of kidney stone. There are four types of stones and treatment differs according to the type of the stone. Four sets are defined for it namely calcium, uric acid, struvite and cystine as given in Table 1. Singleton fuzzy sets are created for Stone Type. Figure 3 shows the membership functions for variable 'Stone Type'.

Table 1: Fuzzy Sets for Stone Type

Sr. No.	Type	Fuzzy set
1	$\mu_{calcium}$	[1, 1, 1]
2	$\mu_{uricacid}$	[2, 2, 2]
3	$\mu_{struvite}$	[3, 3, 3]
4	$\mu_{cystine}$	[4, 4, 4]

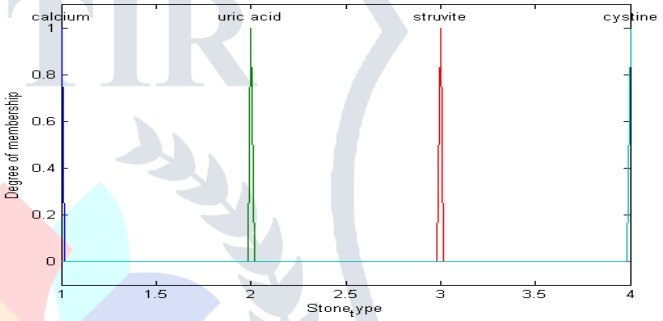

Fig. 3: Membership Functions for Stone Type

2. **Back_pain:** It is a continuous variable. To decide the severity of the back_pain we have used scale from 0-10. This is decided by discussing with doctors and patients. Three fuzzy sets are created for it namely mild, moderate and severe as given in Table 2. Trapezoidal membership functions are used for back_pain. Figure 4 shows the membership functions for variable back_pain.

Table 2 Fuzzy Sets for Back Pain

Sr. No.	Back_pain	Fuzzy set
1	μ_{mild}	[0, 0, 2, 4]
2	$\mu_{moderate}$	[3, 5, 7, 8]
3	μ_{severe}	[7, 9, 10, 10]

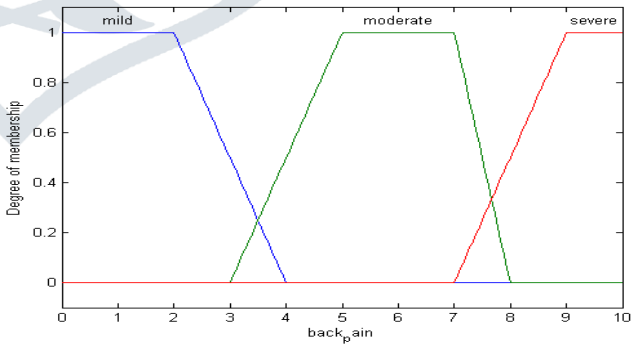

Fig. 4: Membership Functions for Back Pain

3. **Size:** Size indicates the size of kidney stone. It is measured in millimeter (mm). It is continuous variable that has values from 0 to 30. Three fuzzy sets are created for it namely small, medium and large as shown in Table 3. Trapezoidal membership functions are used for size. Figure 5 shows the membership functions for variable size.

Table 3 Fuzzy Sets for Stone Size

Sr. No.	size	Fuzzy set
1	μ_{small}	[0, 0, 5, 6]
2	μ_{medium}	[5, 6, 14, 15]
3	μ_{large}	[14, 20, 30, 30]

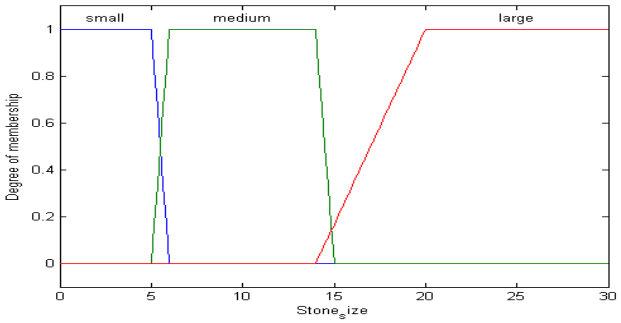

Fig. 5: Membership Functions for Stone Size

4. **Treatment:** The output variable Treatment has values between 0 - 9 which indicate the treatment plan number. Nine fuzzy sets are created for it as given in Table 4. Trapezoidal membership functions are used for Treatment. Figure 6 shows the membership functions for variable Treatment Plan.

Table 4 Fuzzy Sets for Stone Treatment

Sr. No.	Treatment	Fuzzy set	Sr. No.	Treatment	Fuzzy set
1	μ_{T1}	[0, 0, 0.8, 1.1]	6	μ_{T6}	[4.8, 5.2, 5.8, 6.2]
2	μ_{T2}	[0.8, 1.2, 1.8, 2.2]	7	μ_{T7}	[5.8, 6.2, 6.8, 7.2]
3	μ_{T3}	[1.8, 2.2, 2.8, 3.2]	8	μ_{T8}	[6.8, 7.2, 7.8, 8.2]
4	μ_{T4}	[2.8, 3.2, 3.8, 4.2]	9	μ_{T9}	[7.8, 8.4, 9, 9]
5	μ_{T5}	[3.8, 4.2, 4.8, 5.2]			

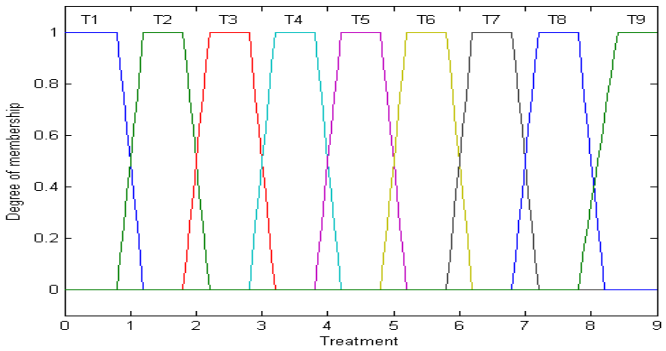

Fig. 6: Membership Functions for Stone Treatment

Fuzzy Rulebase

Fuzzy rule base is developed that consists of thirty six rules as given in Table 5.

Table 5 Fuzzy Rulebase for Kidney Stone

Rule No.	Rule
1	If Stone_Type is 1 And back_pain is mild And Stone_Size is small Then Treatment is T1
2	If Stone_Type is 1 And back_pain is mild And Stone_Size is medium Then Treatment is T8
3	If Stone_Type is 1 And back_pain is mild And Stone_Size is large Then Treatment is T9
4	If Stone_Type is 1 And back_pain is moderate And Stone_Size is small Then Treatment is T2
5	If Stone_Type is 1 And back_pain is moderate And Stone_Size is medium Then Treatment is T8
6	If Stone_Type is 1 And back_pain is moderate And Stone_Size is large Then Treatment is T9
7	If Stone_Type is 1 And back_pain is severe And Stone_Size is small Then Treatment is T2
8	If Stone_Type is 1 And back_pain is severe And Stone_Size is medium Then Treatment is T8
9	If Stone_Type is 1 And back_pain is severe And Stone_Size is large Then Treatment is T9
10	If Stone_Type is 2 And back_pain is mild And Stone_Size is small Then Treatment is T3
11	If Stone_Type is 2 And back_pain is mild And Stone_Size is medium Then Treatment is T8
12	If Stone_Type is 2 And back_pain is mild And Stone_Size is large Then Treatment is T9
13	If Stone_Type is 2 And back_pain is moderate And Stone_Size is small Then Treatment is T4

14	If Stone_Type is 2 And back_pain is moderate And Stone_Size is medium Then Treatment is T8
15	If Stone_Type is 2 And back_pain is moderate And Stone_Size is large Then Treatment is T9
16	If Stone_Type is 2 And back_pain is severe And Stone_Size is small Then Treatment is T4
17	If Stone_Type is 2 And back_pain is severe And Stone_Size is medium Then Treatment is T8
18	If Stone_Type is 2 And back_pain is severe And Stone_Size is large Then Treatment is T9
19	If Stone_Type is 3 And back_pain is mild And Stone_Size is small Then Treatment is T5
20	If Stone_Type is 3 And back_pain is mild And Stone_Size is medium Then Treatment is T8
21	If Stone_Type is 3 And back_pain is mild And Stone_Size is large Then Treatment is T9
22	If Stone_Type is 3 And back_pain is moderate And Stone_Size is small Then Treatment is T6
23	If Stone_Type is 3 And back_pain is moderate And Stone_Size is medium Then Treatment is T8
24	If Stone_Type is 3 And back_pain is moderate And Stone_Size is large Then Treatment is T9
25	If Stone_Type is 3 And back_pain is severe And Stone_Size is small Then Treatment is T6
26	If Stone_Type is 3 And back_pain is severe And Stone_Size is medium Then Treatment is T8
27	If Stone_Type is 3 And back_pain is severe And Stone_Size is large Then Treatment is T9
28	If Stone_Type is 4 And back_pain is mild And Stone_Size is small Then Treatment is T5
29	If Stone_Type is 4 And back_pain is mild And Stone_Size is medium Then Treatment is T8
30	If Stone_Type is 4 And back_pain is mild And Stone_Size is large Then Treatment is T9
31	If Stone_Type is 4 And back_pain is moderate And Stone_Size is small Then Treatment is T7
32	If Stone_Type is 4 And back_pain is moderate And Stone_Size is medium Then Treatment is T8
33	If Stone_Type is 4 And back_pain is moderate And Stone_Size is large Then Treatment is T9
34	If Stone_Type is 4 And back_pain is severe And Stone_Size is small Then Treatment is T7
35	If Stone_Type is 4 And back_pain is severe And Stone_Size is medium Then Treatment is T8
36	If Stone_Type is 4 And back_pain is severe And Stone_Size is large Then Treatment is T9

Defuzzification

MOM defuzzification, Min inference and Max aggregation methods have been used.

III. EXPERIMENTAL RESULTS AND DISCUSSION

The algorithm is tested on the data set of 26 patients and the results are shown in Table 6.

Table 6 Experimental Results of Fuzzy Algorithm for Kidney Stone

Sr. No.	Input			Output	Sr. No.	Input			Output
	Type	Pain	Size	(Treatment Plan)		Type	Pain	Size	(Treatment Plan)
1	1	4	4	2	14	1	6	5.3	2
2	1	1	5.5	**4**	15	2	9	15.1	**9**
3	2	9	14	8	16	3	8	4.8	6
4	4	4	3.2	7	17	3	8	2	6
5	1	3	4	1	18	4	8	4.8	7
6	2	9	7.5	8	19	4	4	3	7
7	1	9	5.1	2	20	1	4	5	2
8	3	7	9	8	21	3	2	5.2	5
9	3	1	17.5	9	22	3	1	5.2	5
10	4	1	19	9	23	1	0	5.2	1
11	1	1	5.2	1	24	1	0	5.1	1
12	1	1	4	1	25	2	8	14.9	**9**
13	2	8	4.3	4	26	1	1	14.7	8
No. of Results Matching with Expected Results									23

Out of 26 patient cases we obtained correct results for 23 cases. The accuracy is 88.46%.

IV. FUZZY TUNING

We checked the effect of number of fuzzy sets on the accuracy of algorithm. The number of fuzzy sets for both back_pain and stone_ size are increased from three to five. The fuzzy sets for stone type are kept constant. The number of fuzzy rules is increased from thirty six to one hundred. Figure 8 and 9 show new membership functions for back_pain and stone_size.

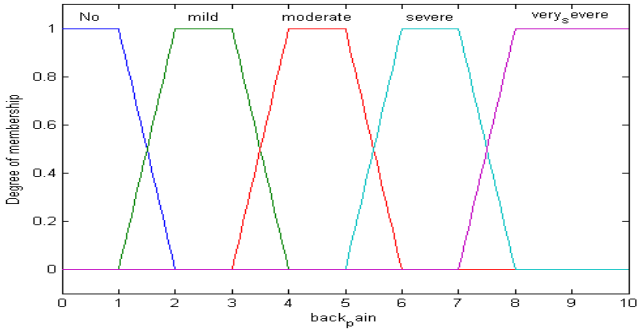

Fig. 8: Membership Functions for Back Pain

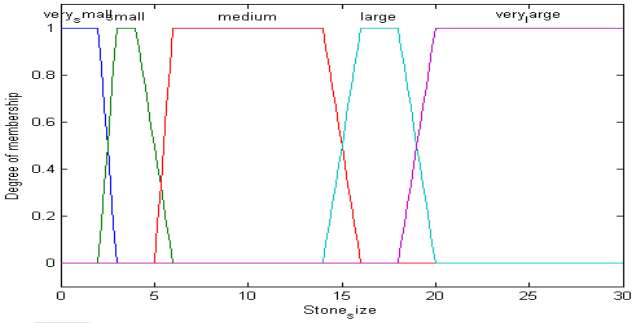

Fig. 9: Membership Functions for Stone Size

Table 7 shows comparison of results before and after tuning. It is found that the accuracy increases as the number of fuzzy sets increase.

Table 7 Result Comparison of Fuzzy Algorithm Before and After Tuning

	No. Of Fuzzy sets Back_pain	No. Of Fuzzy sets Stone Size	No. of Rule	No. Of Accurate Results obtained	Total No. of Patient Record	% increase in Accuracy 100*(24-23)/23
Original	3	3	36	23	26	4.35%
Increased	5	5	100	24		

V. CONCLUSION

Fuzzy system has satisfactory accuracy and is well suited for the given problem. Also it is seen that accuracy increases if more number of fuzzy sets and fuzzy rules are used. The factors like location of stone or obesity of the patient can be included in the algorithm to improve the accuracy of outcome.

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