Nebulizer Operational Time Control Based on Drug Volume and Droplet Size Using Fuzzy Sugeno Method

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Abstract — **Nebulizer is one of the electro medic devices that serve to provide therapy for patients who experience abnormalities or disorders of the respiratory tract. Nebulizer system works using piezo electronic device to produces high frequency vibration. With this high frequency vibration the drug liquid molecules breaks down become fumes, thus it can easily to inhale for patient even for children. Unfortunately like other aerosol drug delivery system, the operation of nebulizer is also still manual. The patient doesn't really know when the drug is empty on the canister. The nurses also need to check in regularly to see if the drugs are empty or not. In this paper a fuzzy sugeno methods is used to give prediction of nebulizer time operational. We propose fuzzy sugeno to calculate the time operational nebulizer using two parameters, such as drug droplet size and drug liquid volumes that have been administer by nurses. Using fuzzy sugeno method we can solve the nebulizer manual operational time problem. Our result show that the longest operational time was 26.07 minutes, this achieve when liquid volume was 5 ml and the size of drug droplet was 1 um. Meanwhile for the shortest operational time was 8.07 minutes, this achieve when liquid volume was 10 ml and the size of drug droplet was 4 um. We can conclude that we had successful to control nebulizer operational time using fuzzy sugeno method.**

Keywords — **Nebulizer, Fuzzy Sugeno, time operational, liquid drug, drug droplet, drug volume.**

I. Introduction

The technology development in the health sector is very advancing. a lot of things have been developing to help the patient such as, to administer drugs [1], to help with surgical operation [2], to monitor the vital sign [3], to increase the quality of life for the patient [4], and even to diagnose diseases locally [5] and remotely [6]. One of the medical device that has a function to administer drugs would be nebulizer [7]. Nebulizer is an important device, because it can help breakdown of liquid drug molecules into aerosols, so that it can be inhaled by patient easily [8]. Nebulizer was far superior medical device compare to the dry powder inhalers and slow mist inhalers in treatment where patient has low respiratory rate [9]. This Nebulizer Respiratory device that delivery aerosol drugs is common not just for asthma [10] but for other pulmonary diseases as well [11] such as Lung Cancer [12], Tuberculosis [13], Covid-19 [14], Bronchitis [15] and many others.

Unfortunately like many other aerosol drug delivery system, because user don't know how exactly drug are left in the canister therefore the user need to count manually [16]. The nebulizer operation is also suffering the same problem. The user don't know the time when drugs canister was empty [17]. The nurses also need to check in regularly to see if the drugs are empty or no. a lot of low cost nebulizer has been develop for low power, home, and portable used [18], [19], but not one tackle how to calculate automatically the nebulizer operational time problem.

Based on the problem before, in this paper we propose to use fuzzy sugeno method to solve the nebulizer manual operational time problem. With fuzzy sugeno we can automatically calculate nebulizer operational time. In order to do this, we are using drugs parameter such as volume and droplet (generates by nebulizer) as input for fuzzy sugeno system. For output, sugeno system generates the nebulizer operational time.

II. Method and Design

Fuzzy logic is a system that mimics real world situation which is uncertainty. Fuzzy system firstly introduce by zadeh [20]–[22]. Until now a lot of new fuzzy methods are born to solve real world problem such as monitoring [23], control [24], supplier selection [25], forecasting [26], failure analysis [27], selection admission [28] and many others. One of the time control methods would be fuzzy system, ali and colleagues propose time control using fuzzy sugeno [29]. Figure 1 show diagram block using fuzzy sugeno methods to generates the nebulizer operational time.

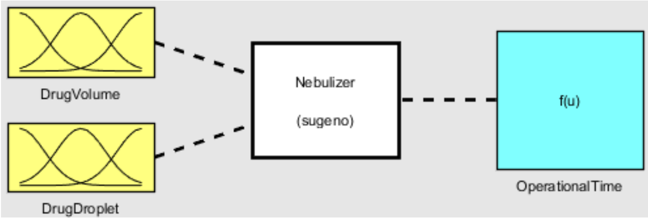

Fig 1. Nebulizer Fuzzy Sugeno block diagram

A. *Design Fuzzy Set Input*

For fuzzy sugeno model, we are using 2 set input memberships which is drug volume and droplet size (please see figure 1). Because fuzzy was meant to solve problem using mimic human behavior [30] and then quantifying it to become machine input [31]. Therefore for fuzzy membership function input such as drug volume and droplet size was based on human experiences. And for membership type we are using triangle. For droplet particle according Zhao and colleagues the maximum was 10 µm [32].

a) The droplet variable (in µm), consists of three fuzzy sets such as :

- If droplet variable was 2.5 - 10 µm THEN High
- If droplet variable was 0.5 - 5 µm THEN Medium
- If droplet variable was 0 - 2.5 µm THEN Low

Figure 2 show membership function of the drugs droplet size.

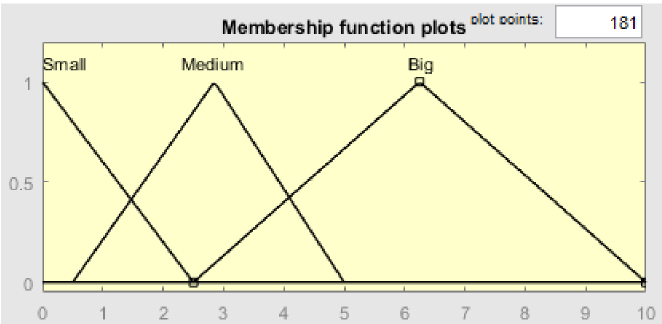

Fig 2. Drug Droplet size membership input

For each membership function from figure 2 was define by each equation below.

Small set:

$$1 \quad , \quad x \leq 0 \quad (1)$$

$$\frac{2.5 - x}{2.5} \quad , \quad 0 \leq x \leq 2.5 \quad (2)$$

$$0 \quad , \quad x \geq 0 \quad (3)$$

Medium set:

$$0 \quad , \quad x \leq 0.5 \quad (4)$$

$$\frac{x - 0.5}{2.85 - 0.5} \quad , \quad 0.5 \leq x \leq 2.85 \quad (5)$$

$$\frac{5 - x}{5 - 2.85} \quad , \quad 2.85 \leq x \leq 5 \quad (6)$$

$$0 \quad , \quad x \geq 5 \quad (7)$$

Big set:

$$0 \quad , \quad x \leq 2.5 \quad (8)$$

$$\frac{x - 2.5}{6.25 - 2.5} \quad , \quad 2.5 \leq x \leq 6.25 \quad (9)$$

$$\frac{6.25 - x}{10 - 6.25} \quad , \quad 6.25 \leq x \leq 10 \quad (10)$$

$$0 \quad , \quad x \geq 10 \quad (11)$$

b) The variable fluid volume of the drug (mL), the amount of volume of the liquid of this drug (in mL), consists of three fuzzy sets:

- If volume variable was 10 - 150 mL THEN Many
- IF volume variable was 5-15 mL THEN Medium
- IF volume variable was 0-10 mL THEN little

Figure 3 show membership function of the drugs droplet size.

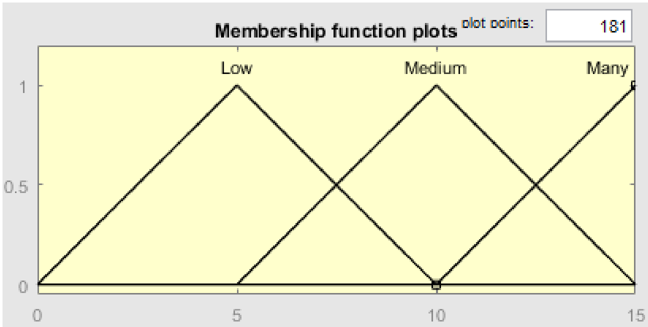

Fig 3. Drug volume membership input

For each membership function from figure 3 was define by each equation below.

Low set:

$$1 \quad , \quad x \leq 0 \quad (12)$$

$$\frac{10 - x}{10} \quad , \quad 0 \leq x \leq 10 \quad (13)$$

$$0 \quad , \quad x \geq 0 \quad (14)$$

Medium set:

$$0 \quad , \quad x \leq 5 \quad (15)$$

$$\frac{x - 5}{10 - 5} \quad , \quad 5 \leq x \leq 10 \quad (16)$$

$$\frac{15 - x}{15 - 10} \quad , \quad 10 \leq x \leq 15 \quad (17)$$

$$0 \quad , \quad x \geq 15 \quad (18)$$

Many set:

$$0 \quad , \quad x \leq 10 \quad (19)$$

$$\frac{x-10}{15-10} \quad , \quad 10 \le x \le 15 \qquad (20)$$

$$1 \quad , \quad x \ge 15 \qquad (21)$$

B. *Design of Fuzzy Output*

Based on Zhao and colleagues the recommended therapy time using nebulizer was 30 minutes [32]. Therefore, for fuzzy sugeno output we have 3 rules, for 0.1 we have briefly, for 0.5 we have Longer and for 1 we have longest, with maximum scale was 30 minutes.

C. *Design of Fuzzy rule*

For fuzzy sugeno rule we have consisted of nine fuzzy sets:

a. If (Drug_Volume is low) and (Drug_Droplet is Small) then (time_operational is Longest)

b. If (Drug_Volume is low) and (Drug_Droplet is medium) then (time_operational is Longer)

c. If (Drug_ Volume is low) and (Drug_Droplet is big) then (time_operational is Briefly)

d. If (Drug_Volume is Medium) and (Drug_Droplet is Small) then (time_operational is Longest)

e. If (Drug_Volume is Medium) and (Drug_Droplet is medium) then (time_operational is Longer)

f. If (Drug_Volume is Medium) and (Drug_Droplet is big) then (time_operational is Briefly)

g. If (Drug_Volume is Many) and (Drug_Droplet is Small) then (time_operational is Longest)

h. If (Drug_ Volume is Many) and (Drug_Droplet is medium) then (time_operational is Longer)

i. If (Drug_Volume is Many) and (Drug_Droplet is big) then (time_operational is Briefly)

j. If (Drug_Volume is low) and (Drug_Droplet is Small) then (time_operational is Longest)

k. If (Drug_Volume is low) and (Drug_Droplet is medium) then (time_operational is Longer)

l. If (Drug_ Volume is low) and (Drug_Droplet is bigger) then (time_operational is Briefly)

m. If (Drug_Volume is Medium) and (Drug_Droplet is Small) then (time_operational is Longest)

n. If (Drug_Volume is Medium) and (Drug_Droplet is medium) then (time_operational is Longer)

o. If (Drug_Volume is Medium) and (Drug_Droplet is bigger) then (time_operational is Briefly)

p. If (Drug_Volume is Many) and (Drug_Droplet is Small) then (time_operational is Longest)

q. If (Drug_Volume is Many) and (Drug_Droplet is medium) then (time_operational is Longer)

r. If (Drug_Volume is Many) and (Drug_Droplet is big) then (time_operational is Briefly)

III. SIMULATION

To validate our hypotheses, we do simulation and measurement. For simulation we are using matlab 2016 software and for measurement we fill the drug canister manually. In this simulation we are planning to use 9 respected conditions. For simulation we change the drug volume and drug droplet respectively and then we see the nebulizer operational time. Figure 4 of simulation results using fuzzy sugeno method for nebulizer operational time.

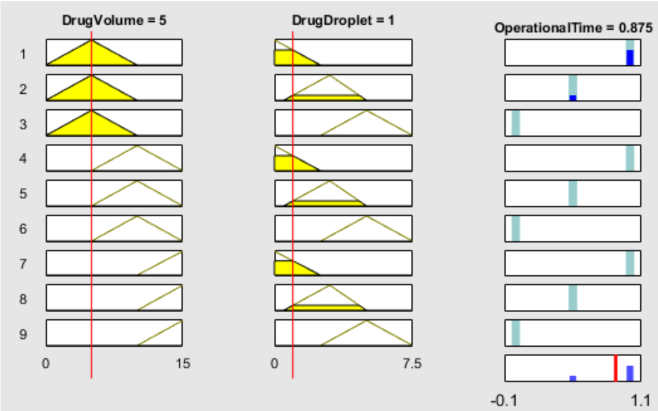

Fig 4. Fuzzy sugeno Simulation using matlab

From figure 4 we can built a list where for each drug and volume configuration resulted in each nebulizer operational time. Table 1 shows list for each drug and volume configuration versus nebulizer operational time.

Table 1. Fuzzy Sugeno Time Operational Simulation using matlab

NO	Liquid Volume (mL)	Droplet Size	Sugeno Ouput	Time Operational (minutes)
1	5	1	0,869	26,07
2	10	2	0,619	18,57
3	15	2	0,619	18,57
4	5	2	0,619	18,57
5	10	4	0,269	8,07
6	15	5	0	0
7	5	5	0	0
8	10	6	0	0
9	15	7	0	0

IV. CONCLUSION

Based on the simulation results indicates in table 1, using fuzzy sugeno methods we manage to generates nebulizer time operational based on drug volume and drug droplets. We can conclude that droplet size has the bigger effect more than drug volume in nebulizer operational time. With fuzzy sugeno we can generate the longest time operational, which is 26.07 minutes that can be achieve when liquid volume was 5 ml and the size of drug droplet was 1 um. Meanwhile for the shortest operational time was 8.07 minutes, this achieve when liquid volume was 10 ml and the size of drug droplet was 4 um

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