Application for the diagnosis of pneumonia based on Pneumonia Severity Index (PSI) values

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***Abstract*—There have been several studies discussing the diagnosis of pneumonia based on symptoms experienced by patients, some using artificial intelligence methods such as monotonous and non-monotonous methods with mixed results. According to the results of previous studies, there have been no results that can be directly implemented by experts, especially lung specialists in Indonesia. The cause is according to the Indonesian pulmonary doctor, the reference used to diagnose pneumonia patients is to use the Pneumonia Severity Index (PSI) which is it can classify pneumonia levels and determine therapeutic solutions appropriate to the level of pneumonia of patients. Level results according to PSI will be qualitative and unambiguous values so that the Sugeno fuzzy logic method is very suitable to overcome these problems. Application results using Sugeno Fuzzy Logic have been successfully applied to diagnose the level of pneumonia and are matched with PSI Score with a value of 75%, based on four clinical data that have tested at Balikpapan Hospital.**

Keywords— Pneumonia, Fuzzy Logic, Sugeno, Pneumonia Severity Index (PSI).

I. INTRODUCTION

Pneumonia is a disease that attacks lung tissue with a cough and hard to breathe symptoms [1]. Based on the Guidelines for Diagnosis and Management of Community Pneumonia Indonesia, pneumonia is defined as an acute inflammation of lungs parenchyma caused by a microorganism (bacteria, virus, fungi, parasite) [2].

Even based on the results of Riskesdas 2007, pneumonia ranked second in the proportion of the cause of death the children aged 1-4 years. It is therefore seen that pneumonia is a major health problem in Indonesia [3].

Other research ever conducted by [4] on URI (Upper Respiratory Tract Infection) diagnosis expert system for under five years old, here it is said that children especially the age of toddler is very susceptible to URI disease including Pneumonia and if the delayed subscription risk that will happen very danger. In addition, it is also explained that the application succeeded to be one way to diagnose 7 URI disease including Pneumonia with Certainty Factor method. It's just that this research is not specifically diagnosed with Pneumonia disease.

Subsequent studies were also for the diagnosis of 6 URI of colds, sinusitis, pharyngitis, laryngitis, bronchitis, and pneumonia. As for the data included symptoms are body temperature, the number of a cough in one minute, pain in the head, pain during swallowing, thick and smelly secretions, stiffness, sneezing, throat feels sputum, nausea, nasal congestion, shortness of breath, and pain on the chest. Then after the input is accepted it will be processed by Fuzzy Mamdani, this research focuses only on the diagnosis of various URI but not specific to Pneumonia [5].

Subsequent research in press [6] focusing on the diagnosis of pneumonia disease level using the Fuzzy Tsukamoto method here focuses on cases of pneumonia that experts say can be classified as "mild" and "severe" which also adjusts cases that often occur. The results of the study using the user accepted test to the expert states that 95% of the results have been accepted by experts so that it can be used as a recommendation for the diagnosis of patients.

From this research try to be developed again for the result obtained really in accordance with the requirement of expert especially Indonesian Lung Specialist. The reference used by Indonesian pulmonary specialist is the value of Pneumonia Severity Index (PSI) which is used to classify Pneumonia level, so to develop previous research this application requires a method that can overcome the qualitative output that is using Fuzzy Sugeno. Fuzzy Sugeno is a method that has tolerance on the data and is very flexible. The advantages of the Sugeno method are intuitive and can provide feedback based on information that is qualitative, inaccurate, and ambiguous. [7].

Expected by developing previous research this application can be useful by lung doctors in diagnosing pneumonia disease accurately and in accordance with the value of Pneumonia Severity Index (PSI).

II. THEORETICAL FRAMEWORK

A. *Fuzzy Logic*

Fuzzy logic was introduced for the first time by Lothfi A. Zadeh, a professor from the University of California. Fuzzy logic has a degree of membership in a range 0 to 1, which is different from digital logic or discrete that only has 2 value, 0 and 1. Fuzzy logic is used to translate a unit which is expressed using linguistic language. For the example, we can express a scale of the speed with slow, rather a quick, fast, and very fast [8].

B. *Membership Function*

The fuzzy membership function is a curve that shows the mapping of data input to the degree of membership which has the value between 0 to 1. Some of them are mentioned under the following lists [9]:

1. Linear Representation

Linear representation is described as a linear line. There are 2 only ways of possibility:

- The ascension of the set starts from 0 degrees of membership and then move to the right, which is the direction that has a higher domain value.

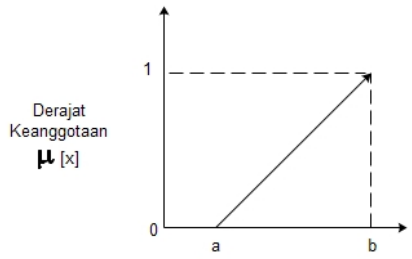

Fig. 1. Representation of uphill curve fuzzy

Membership:

$$\mu[x,a,b] = \begin{cases} 0; & x \le a \\ \frac{x-a}{b-a}; & a \le x \le b \\ 1; & x \ge b \end{cases} \quad (1)$$

- Descension starts from the higher domain, and then move right to the lower domain value.

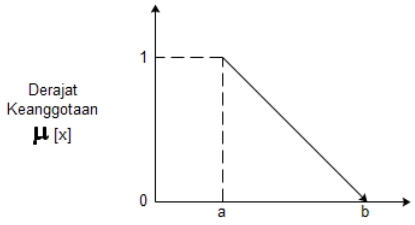

Fig. 2. Representation of downhill curve fuzzy

Membership:

$$\mu[x,a,b] = \begin{cases} \frac{b-x}{b-a}; & a \le x \le b \\ 0; & x \ge b \end{cases} \quad (2)$$

2. Representation of Triangle Curve

Basically, this curve is a merge of two linear curves.

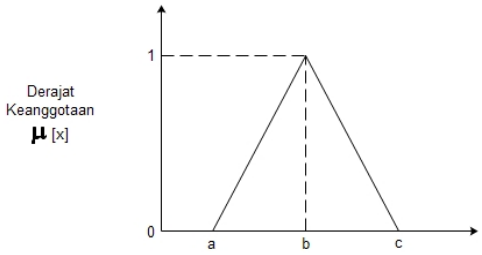

Fig. 3. Representation of Triangle Curve

Membership:

$$\mu[x,a,b] = \begin{cases} 0; & x \le a \text{ atau } x \ge c \\ \frac{x-a}{b-a}; & a \le x \le b \\ \frac{c-x}{c-b}; & b \le x \le c \end{cases} \quad (3)$$

3. Shoulder Curve

The area that is made at the center of the variable that is represented as a triangle curve will increase and decrease at the left and right side of it. But sometimes one of the sides of it doesn't change at all.

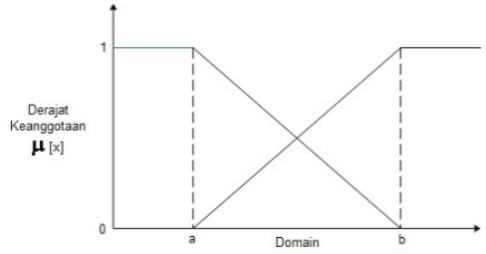

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Fig. 4. Shoulder Curve Representation

Membership:

$$\mu[x,a,b] = \begin{cases} 0; & x \ge b \\ \frac{b-x}{b-a}; & a \le x \le b \\ 1; & x \le a \\ 0; & x \le a \\ \frac{x-a}{b-a}; & a \le x \le b \\ 1; & x \ge b \end{cases} \quad (4)$$

C. Fuzzy Inference System Sugeno Method

The Sugeno method was introduced by Takagi-Sugeno Kang in 1985 [10]. this method is similar to the Mamdani method in many respects. The first two parts of the fuzzy inference process, Fuzzyfication the inputs and applying the fuzzy operator, are the same. The main difference between Mamdani and Sugeno is that the Sugeno output membership functions are either linear or constant.

A typical rule in a Sugeno fuzzy model has the form:

IF Input 1 is X AND Input 2 is Y, THEN output is Z = ax+b+c. (5)

For a zero-order Sugeno model, the output level z is a constant (a = b = c = 0).

Each rule weights its output level, Zi by the firing strength of the rule, Wi. For example, for an AND rule with Input 1 = x and Input 2 = y, the firing strength is:

$$w_i = AndMethod(F_1(x), F_2(y)) \quad (6)$$

where F1,2(.) is the membership functions for Inputs 1 and 2. The final output of the system is the weighted average of all rule outputs, computed as:

$$\text{Final Output} = \frac{\sum_{i=1}^{N} w_i z_i}{\sum_{i=1}^{N} w_i} \quad (7)$$

where N is the number of rules.

D. Pneumonia Severity Index (PSI)

The pneumonia severity index (PSI) or PORT Score is a clinical prediction rule that medical practitioners can use to calculate the probability of morbidity and mortality among patients with community-acquired pneumonia [11].

The PSI score is used to classify the Pneumonia level as well as the appropriate type of treatment for the patient [12]. Following table 1, The degree of PSI risk score based on the Indonesian Lung Doctor Association:

TABLE I. PSI RISK SCORE DEGREE

Total Value	Level of risk	Class of risk	Death rate	Type of Treatment
Not Predictable	Low	I	0.1%	Outpatient
<70	Low	II	0.6%	Outpatient
70-90	Low	III	2.8%	Inpatient/ Outpatient
91-130	Moderately	IV	8.2%	Inpatient
>130	High	V	29.2%	Inpatient

[a] Data were taken from Indonesian Lung Doctor Association guide

III. SYSTEM ANALYSIS

It is known that there are 4 steps to determine the disease that is suffered by the patients. They are anamnesis, physical check-up, laboratory check-up, and another step to know the history of the patient's diseases. Anamnesis is a step used by the doctor by asking the patient in order to get to know the symptoms that are happened to the patient. Next is the physical check. Pulse rate, blood pressure, temperature, respiration, and age. Next is laboratory check-up. This is done so that the doctor knows the value of the Blood Urea Nitrogen, Glucose rate, Ph, PaO2, Hematocrit, and Sodium. And for the last, to identification the other disease that has been experienced by the patient, we can combine the result of all the steps, or based on the patient's documents.

After all examination results obtained, then the next step all the data entered into the system to be calculated by a Sugeno method, then the system will provide output in the form of diagnosis of URI level and the URI value suffered by the patient. So the doctor can make the output system as an alternative solution to diagnose Pneumonia disease with the value of the PSI Abbreviations and Acronyms. Business process flow can be seen in Figure 5:

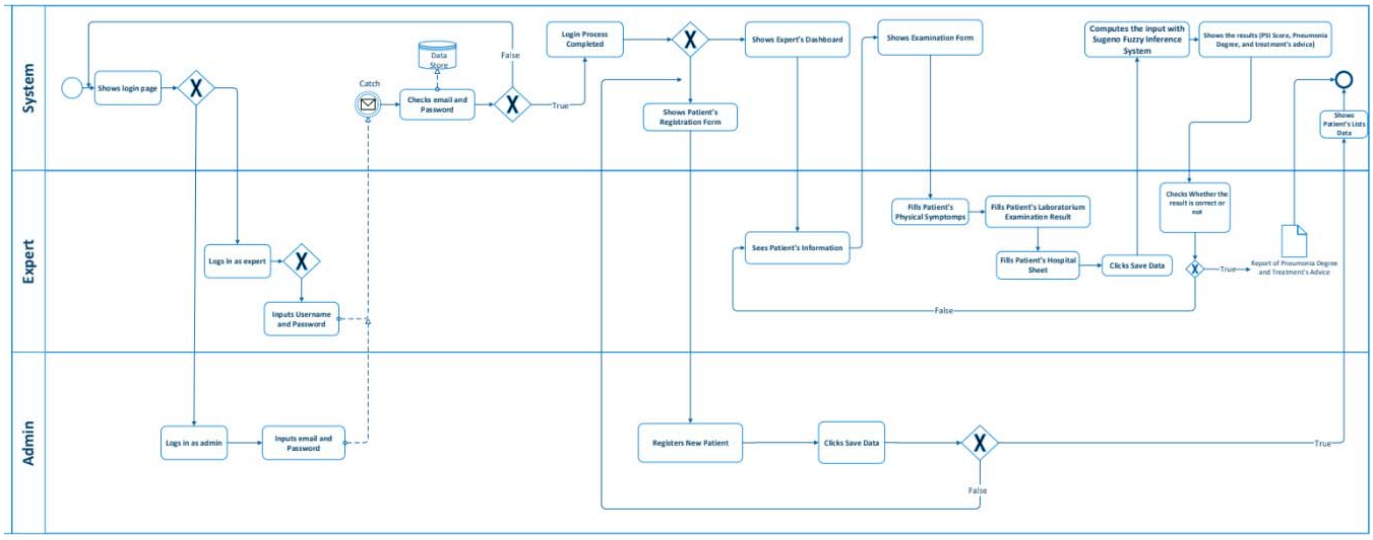

Fig. 5. Business Process Fuzzy Inference System

Based on Figure 5 on the flow of the business process system to diagnose the level of Pneumonia, it can be seen that the system has a very important role to assist experts in providing output in the form of pneumonia levels and their respective therapies. while the benefits that can be obtained by patients are information on the level of pneumonia and the type of therapy can be obtained quickly and accurately.

A. Sistem Testing

There are 11 Fuzzy variables and 7 crisp variables that are classified based on the observation and discussion with the lung doctor at Kanudjoso Djatiwibowo Hospital Balikpapan. Each Fuzzy variable has 3 fuzzy sets except Pao2 and Blood Urea Nitrogen (BUN), from some variables and fuzzy set it can be compiled some Fuzzy rules referenced from lung doctor at RSKD Balikpapan according to Pneumonia Severity Index (PSI)

The following are examples of cases using 21 Fuzzy rules: medical examination results obtained, Name: Patient X Age: 23 year, Temperature: 36 degrees Celsius, pulse 110 x / min, respiration 25 x / min, systolic 90 mmHg, and after that also obtained laboratory results: PaO2 70 mmHg, Ph 7.4, BUN 20 mmol / L, 135 mEq / L sodium, glucose 200 mmol /

L, 40% hematocrit, no pleural effusion, and patient history of disease have impaired consciousness.

The first step calculated by the Sugeno method is Fuzzyfication process that is the calculation contained in the fuzzy set of each variable. The Fuzzification Process of each variable is as follows:

TABLE II. FUZZY MEMBERSHIP VALUE FOR EACH VARIABLE

Variable Name	Low	Moderately	High
Temperature (36)	0.33	0.67	0
Pulse rate (110)	0	0.6	0.4
Respiratory (25)	0	0.5	0.5
Systolic (90)	1	0	0
Age (23)	1	0	0
Blood Urea Nitrogen (20)	0.23	0	
Glucose rate (200)	0	0.38	0.62
PaO2 (70)	0.5	0.5	
Ph (7.4)	0	1	0
Hematocrit (40)	0	1	0
Sodium (135)	0	1	0

The above Fuzzy membership values are obtained from equations of formula 1 through 4, according to the fuzzy set classification each divided into 3, namely: low, moderate and high, except BUN and PaO2 which are only divided into low and high.

The next step is to calculate the Crisp value obtained from the observation of other disease symptoms that may be suffered by the patient, it will be worth 1 if the patient has the symptoms (including the members) and if not then it will be worth 0 (not members), according to the previous patient case example only experience Disturbance of Consciousness so that membership 1 and the other is 0.

TABLE III. CRISP MEMBERSHIP VALUE OF EACH VARIABLE

Variable Name	No	Yes
Pleural Effusion	1	0
Malignancy comorbid	1	0
Liver disease	1	0
Congestive heart	1	0
Cerebrovascular	1	0
Kidney	1	0
Disturbance of Consciousness	0	1

After the Fuzzyfication process of each Fuzzy set gets its own membership value, the next step is to do the composition rule process, that is calculated fire strength (α) because the operator used for the rule is "AND" then look for the minimum value of each rule used. Then after the value of α is obtained, the next step is to find the z value of each rule. There are 21 composition rules, which are adopted from expert knowledge. From the results of the composition of the rules, it is obtained the results of calculating the α value, z value and the value of defuzzification.

The final stage in the Sugeno method is Defuzzyfication referring to the formula 7. This process aims to find the weighted average value of the 21 rules by dividing the total value of z from each rule by the total alpha value of predicate (α) of each rule. Then get the value as follows:

$\sum z = 14.95$

$\sum \alpha = 0.23$

$$\text{Defuzzification} = \frac{14.95}{0.23} = 65;$$

The conclusion of the defuzzification result is the final score of 65 which results are matched with Table 1 of the PSI Risk Score Degree, then the patient X belongs to the level I category with low pneumonia level and is recommended for outpatient treatment.

B. Implementation of system testing

Testing the system is the final stage after getting the calculation of fuzzy Sugeno. This step is performed to test the level of validity and calculation results generated system as well as to test the conformity of results with expert knowledge that refers to the PSI.

The test results of the system by using input data in accordance with the same case example can be seen in figure 6:

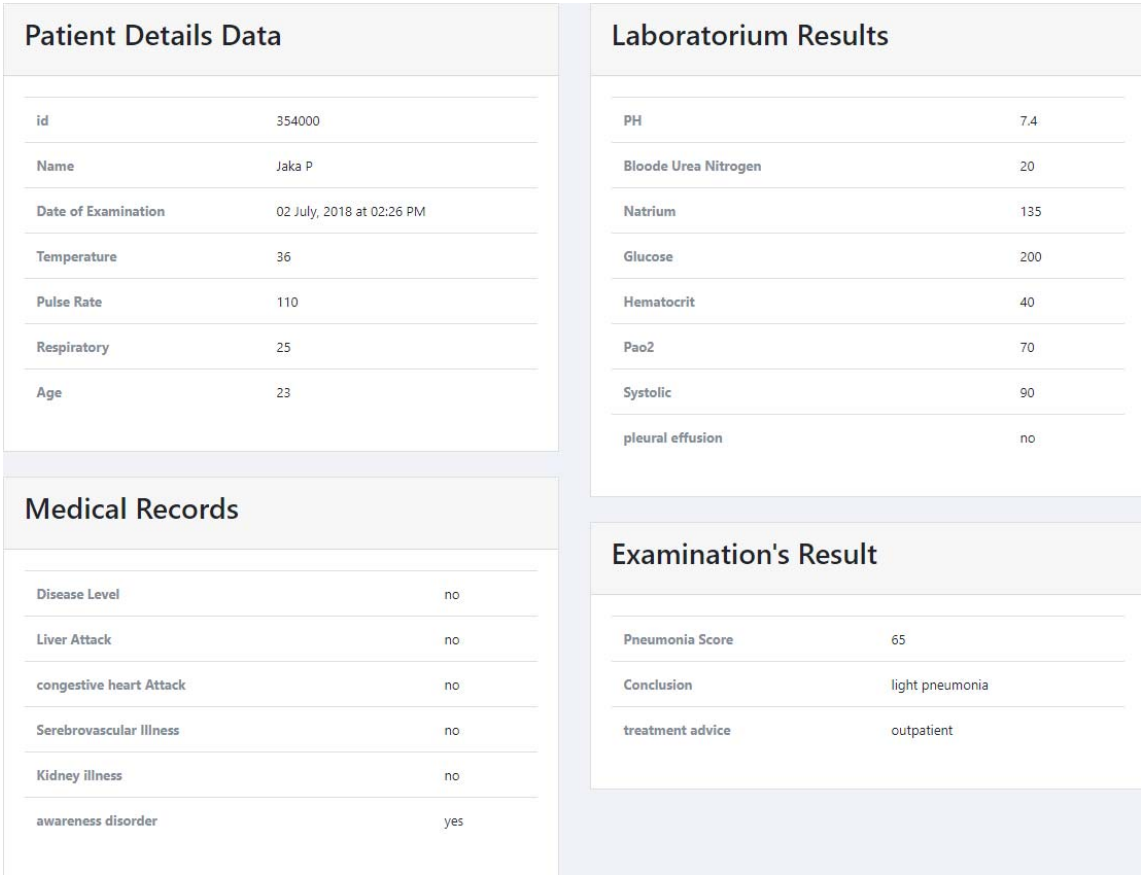

Fig. 6. Sistem Test Result with case Example

The result of the system test in Figure 6 can be concluded that with the input according to the case example get the same output with the manual calculation and the result is also according to the reference value of PSI value used by Indonesian Lung Doctor Association, it can be concluded that the test result of the system is valid.

IV. Experimental Result

A. Testing Effectiveness

This test is done to know the amount of system accurate by comparing the result of the pneumonia severity index and the system's output. Cases were obtained from some patients who experienced Pneumonia in RSKD Balikpapan. The following table is a result of the test.

TABLE IV. Effectiveness Test Results

No	Name	PSI	System	Evaluation
1	Patient 1	100 (Moderately)	100 (Moderately)	Appropriate
2	Patient 2	65 (Low)	65 (Low)	Appropriate
3	Patient 3	195 (High)	195 (High)	Appropriate
4	Patient 4	80 (Low)	85 (Low)	Not Appropriate

After comparing the result, the next step is to do the average calculation:

$$\text{Average} = \frac{3}{4} * 100 = 75\ \%$$

By all of the data that has been tested above, it is concluded that the accuracy of the system is amount to 75%.

V. Conclusions

The conclusions obtained from some test results that are tailored to the expert knowledge of pulmonary specialist are:

1) The system has been successfully applied to help the expert to diagnose the pneumonia

2) Sugeno fuzzy logic has been successfully applied in the decision-making process of pneumonia and is matched with a Severity Pneumonia Index Score of 75% based on test clinical data of patients with pneumonia in Balikpapan Hospital.

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