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Predict recovery risk rate of Covid-19

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Abstract. The outbreak of the 2019 novel coronavirus (2019-nCoV) in Wuhan, China has become expanded globally, the current novel coronavirus (2019-nCoV) or also called COVID-19 pandemic is unprecedented, but the global response draws on the lessons learned from other disease outbreaks over the past several decades. WHO (World Health Organisation) said that Person-to-person transmission may occur through droplet or contact transmission and according to early estimates by China's National Commission (NHC) people with high risk for severe disease and death people is an old age and people with pre-existing health conditios (comorbid) as hyertention, diabetes, cardiovasculer disease, chronic respiratory diseas (asthma, lung etc), heart disease, kidney disease, liver disease, immunodeficiency, cancer and other. The fatality cases about 80% were over the age of 60 and 75% of them had pre-existing health conditios (comorbid). The government prevent further spread of novel coronavirus (2019-nCoV) disease with advice for public on how to keep healthy. In this article we consider a predict recovery risk rate of COVID-19 using fuzzy tsukamoto inference system, representation linguistic variable using linear membership function up and down, use two input, age and comorbid with "IF-THEN" rules, fuzzy logic conjunction connectives. The defuzzification or output mortality rate using centroid triangular fuzzy number.

1. Introduction

Coronavirus COVID-19 has a major impact on 212 countries and regions throughout the world. COVID-19 fatality cases have been estimated at around 2%. However, the WHO press conference held on 29 January 2020 [1] noted that, without knowing how many individuals were actually infected, it was too early to be able to estimate what percentage of the death rate would be. Death rates can change because viruses can mutate with mutation rates, according to epidemiology. In comparison, the fatality rate for SARS cases is 10%, and for MERS 34%. According to WHO, people of all ages can be infected by the COVID-19 coronavirus. The elderly, and people with pre-existing medical conditions/history of previous illnesses (such as asthma, diabetes, heart disease) are more prone to become patients with severe illness. Globally, 10 May 2020, there were 3,925,815 confirmed cases of COVID-19, including 274,488 deaths, reported to WHO, with all the data and uncertainty about the conditions that will occur next, from uncertainty condition about the percentage of recovery rate and fatality risk is required predictions that can be accounted for in data, so as to reduce uncertainty and help medical personnel to know about the risk of recovery and fatal risk of patients, with early predictions about fatality and recovery risk will reduce the burden of medical personnel in classifying patients who need extra treatment in each hospital. Prediction is a process of systematically estimating something in the future

based on information obtained in the past. Some previous research related to predictions using fuzzy tsukamoto inference system (FIS) is Nurul et al. using fuzzy tsukamoto inference system (FIS) on the prediction of lending feasibility with inputs in the form of loan length, collateral price, and condition of goods[2]. Christian Ardianto et al. Implement a fuzzy tsukamoto inference system (FIS) to predict fire insecurity levels with inputs of area, population and rainfall [3]. Ida wahyuni et al predict rainfall using fuzzy tsukamoto inference system (FIS) with inputs in the form of rainfall data per 10 days, 20 days, 170 days, and 340 days [4]. Hilman et al use inputs in the form of responsibility, discipline and reducing factors in the fuzzy tsukamoto inference system (FIS) to predict the assessment of work performance [5]. Mohamad natsir et al, and Zahra Shafia implemented the fuzzy tsukamoto inference system (FIS) in the case of Dengue Hemorrhagic Fever (DHF) [6],[7] the authors proposed to use the Fuzzy Inference System (FIS) with the Tsukamoto method that can be applied to support the completion of predictions about vague variables/ linguistic variables. In the method, the output is obtained in four stages, namely the formation of fuzzy sets, the formation of rules, the application of the functions involved, and defuzzification. This paper discusses Tsukamoto's FIS implementation to predict covid-19 recovery risk.

2. Preliminaries

2.1 Fuzzy logic
Fuzzy logic theory proposed by Zadeh [8], in real life, not all the sets that we encounter in everyday life are clearly defined. In overcoming the problem of the set with indefinite boundaries, Zadeh associates the set with a function that states the degree of conformity of the elements in the universe with the concept, which is a condition of membership of that function. The function is called the membership function, and the value of the function is called the degree of membership of an element in the set. Fuzzy theory is not the same as probability theory. Probability is related to uncertainty and likelihood. Fuzzy logic deals with ambiguity and obscurity.

2.2 The concept of the fuzzy association
According to Sri Kusuma Dewi [9] the fuzzy set has 2 attributes, namely:
1. *Linguistics*, namely the naming of a group that represents a certain state or condition using natural language.
2. *Numeric*, i.e. a value (number) that indicates the size of a variable.

2.3 Fuzzy system
There are 2 linear fuzzy conditions:
1. Fuzzy linear rise
   For Linear ascending: in the form of a straight line, starting from degree 0 moving right to the domain value that has a higher degree of membership, starting from degree 1 on the left side moving right towards the domain value that has a lower membership degree.
2. Fuzzy linear down
   For linear down: in the form of a straight line, starting with the domain value high membership value on the left side, then the right leads to smaller membership values.
3. Fuzzy triangular curve
   Fuzzy triangular curves are a combination of 2 linear fuzzy.

2.4 Fuzzy Tsukamoto
Fuzzy Inference System (FIS) is a computational framework based on fuzzy set theory, IF-THEN fuzzy rules, and fuzzy reasoning. So far, several methods have been famous in FIS; like Tsukamoto, Mamdani and Sugeno. In Tsukamoto's method, every consequence of IF-THEN rules must be represented by a fuzzy set with a monotonous membership function. The inference output from each rule is given explicitly (crispy) based on α-predicate (fire power). The final result uses a weighted average [10]. To determine the sharp output value / yield that is right (X), it is sought by changing the input (in the form

of fuzzy sets obtained from the composition of fuzzy rules) into numbers in the fuzzy set domain. This method is called the defuzzification method [11]. In inferiority, the Tsukamoto method uses the following stages:

1. Fuzzification: fuzzification is the process of changing non-fuzzy variables (numeric variables) into fuzzy variables (linguistic variables). Input values that are still in the form of numerical variables, before processing crips must be changed first into a fuzzy variable. Through the membership function that has been compiled, from input values to fuzzy information that is useful later for the processing fuzzification.

2. The basic formation of fuzzy knowledge (rules in the form of IF ... THEN)
   [R1] IF (x is A1) and (y is B2) THEN (X is C1)
   [R2] IF (x is A2) and (y is B1) THEN (X is C2)

3. Inference Machine:
   Because the Tsukamoto method of set operations used is a conjunction (AND), the antecedent membership value of the fuzzy rule [R1] is the slice of the A1 membership value of Var-1 with the membership value of B1 of Var2. The antecedent membership value of the conjunction operation (And) of the fuzzy rule [R1] is the minimum value between the membership value A1 of Var-1 and the membership value of B2 of Var-2. Likewise, the antecedent membership value of the fuzzy rule [R2] is the minimum value between the A2 membership value of Var-1 and the membership value of B1 of Var-2. Furthermore, the antecedent membership values of the fuzzy rules [R1] and [R2] are each called $\alpha1$ and $\alpha2$.

4. Defuzzification:
   To obtain crisp output values / firm values X, look for by changing the input (in the form of fuzzy sets obtained from the composition of fuzzy rules) into a number in the fuzzy set domain. This method is called the defuzzification method. The defuzzification method used in the Tsukamoto method is the Center Average Defuzzyfier method formulated in the equation

$$X = \frac{\sum_{i=1}^{n} \alpha i X i}{\sum_{i=1}^{n} \alpha i}$$

3. Method and results

### 3.1. Tsukamoto method
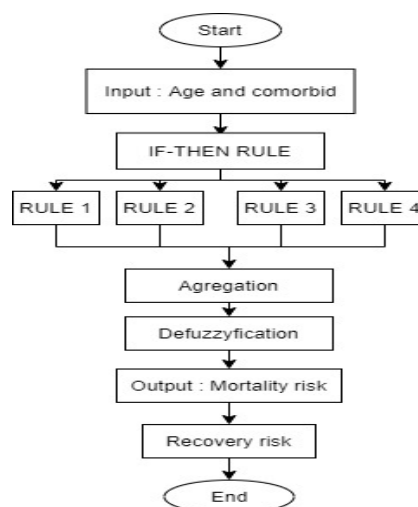
Figure 1. Tsukamoto method

3.2. Result
The final result of fuzzy tsukamoto logic can be used to predict mortality risk, which is then used to calculate recovery risk. The logic of fuzzy tsukamoto is as follows [12] - [15]:
Step 1 Define input and build fuzzy sets on input variables
According to WHO 80% mortality comes from age over 60 years, and 75% mortality is a history of previous disease, then people with 2 categories above are people who enter high risk if infected with corona, input variables are chosen:
1.   Age input (φ)
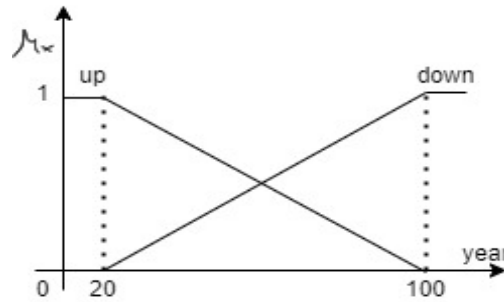
Figure 2. Membership input of age

$$\mu_{ageUP}[\varphi] = \begin{cases} 1 & ,\varphi \leq 20 \\ \dfrac{100 - \varphi}{80} & ,20 \leq \varphi \leq 100 \\ 0 & ,\varphi \geq 100 \end{cases}$$

$$\mu_{ageDOWN}[\varphi] = \begin{cases} 0 & ,\varphi \leq 20 \\ \dfrac{\varphi - 20}{80} & ,20 \leq \varphi \leq 100 \\ 1 & ,\varphi \geq 100 \end{cases}$$

2.   Comorbid or Existing Health Problem (EHP) input (Ψ)
For EHP, according to WHO data that someone with a high death rate is someone with comorbidities such as hypertension, diabetes, cardiovascular disease, chronic respiratory disease (asthma, lung etc), heart disease, kidney disease, liver disease, immunodeficiency, cancer and other . So the authors chose the above disease as an EHP range with a range of 10 range diseases [0,10].
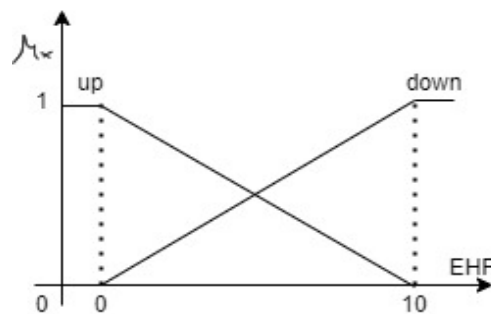
Figure 3. Membership input of comorbid

$$\mu_{ehpDOWN}[\Psi] = \begin{cases} 1 & ,\Psi = 0 \\ \dfrac{10 - \Psi}{10} & ,1 \leq \Psi \leq 10 \\ 0 & ,\Psi \geq 10 \end{cases}$$

$$\mu_{ehpUP}[\Psi] = \begin{cases} 0 & , \Psi = 0 \\ \dfrac{\Psi - 0}{10} & , 1 \leq \Psi \leq 10 \\ 1 & , \Psi \geq 10 \end{cases}$$

3.   Define the Output variable Mortality risk (x)

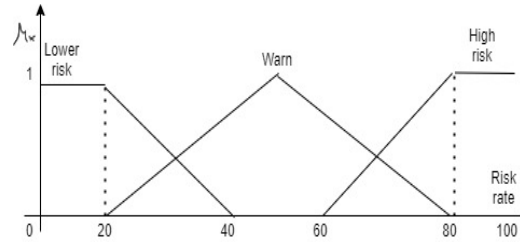For mortality risk, the authors use percentage range from 0 until 100

Figure 4. Membership output of mortality risk

$$\mu_{riskDOWN}[x] = \begin{cases} 0 & , x \leq 0 \\ \dfrac{40 - x}{40} & , 0 \leq x \leq 40 \\ 1 & , x \geq 40 \end{cases}$$

$$\mu_{riskWARNING}[x] = \begin{cases} 0 & , x \leq 20 \ atau \ x \geq 80 \\ \dfrac{x - 20}{30} & , 20 \leq x \leq 50 \\ \dfrac{80 - x}{30} & , 50 \leq x \leq 80 \end{cases}$$

$$\mu_{riskUP}[x] = \begin{cases} 1 & , x \leq 60 \\ \dfrac{x - 60}{40} & , 60 \leq x \leq 100 \\ 0 & , x \geq 100 \end{cases}$$

Step 2 Define the rule

[$R1$]   IF younger age and less EHP THEN low risk mortality
[$R2$]   IF is getting younger and EHP has a lot of THEN mortality alert
[$R3$]   IF age gets older and EHP is slightly THEN mortality alert
[$R4$]   IF age gets older and EHP has a lot of THEN high risk mortality

Step 3 The agregation, define each rule, $\alpha - predikat$
α -predicate and X values for each rule,

RULE 1 $\alpha - \text{predikat} = \mu_{ageDOWN} \cap \mu_{ehpDOWN} = \min [\mu_{ageDOWN}[\varphi] \cap \mu_{ehpDOWN} [\Psi]$

RULE 2 $\alpha - \text{predikat} = \mu_{ageDOWN} \cap \mu_{ehpUP} = \min [\mu_{ageDOWN}[\varphi] \cap \mu_{ehpUP} [\Psi]$

RULE 3 $\alpha - \text{predikat} = \mu_{ageUP} \cap \mu_{ehpDOWN} = \min [\mu_{ageUP}[\varphi] \cap \mu_{ehpDOWN} [\Psi]$

RULE 4 $\alpha - \text{predikat} = \mu_{ageUP} \cap \mu_{ehpUP} = \min [\mu_{ageUP}[\varphi] \cap \mu_{ehpUP} [\Psi]$

Step 4 Defuzzyfication

$$X = \frac{\alpha predikat1 * x1 + \alpha predikat2 * x2 + \alpha predikat3 * x3 + \alpha predikat4 * x4}{\alpha predikat1 + \alpha predikat2 + \alpha predikat3 + \alpha predikat4}$$

4. Simulation and discussion

4.1. Result and simulation

Simulation calculations with examples like the following:

Let the $\varphi = 70$ and $\Psi = 3$ (hypertension, diabetes, cardiovascular disease)

From Figure 2 and $= 70$, we can conclude that

$$\mu_{ageDOWN}[70] = \frac{100-70}{80} = 0.37$$

$$\mu_{ageUP}[70] = \frac{70-20}{80} = 0.62$$

From Figure 3. and $\Psi = 3$ (hypertension, diabetes, cardiovascular disease) , we can conclude that

$$\mu_{ehpDOWN}[3] = \frac{10-3}{10} = 0.7$$

$$\mu_{ehpUP}[3] = \frac{3-0}{10} = 0.3$$

Aggregation, α -predicate and X values for each rule,

RULE 1 $\alpha - predikat = \mu_{ageDOWN} \cap \mu_{ehpDOWN} = \min [\mu_{ageDOWN}[70] \cap \mu_{ehpDOWN}[3]$
$= \min[0.37 ; 0.7] = 0.37$

RULE 2 $\alpha - predikat = \mu_{ageDOWN} \cap \mu_{ehpUP} = \min [\mu_{ageDOWN}[70] \cap \mu_{ehpUP}[3] = \min[0.37 ; 0.3]$
$= 0.3$

RULE 3 $\alpha - predikat = \mu_{ageUP} \cap \mu_{ehpDOWN} = \min [\mu_{ageUP}[70] \cap \mu_{ehpDOWN}[3] = \min [0.62 ; 0.7]$
$= 0.62$

RULE 4 $\alpha - predikat = \mu_{ageUP} \cap \mu_{ehpUP} = \min [\mu_{ageUP}[70] \cap \mu_{ehpUP}[3] = \min[0.62 ; 0.3] = 0.3$

Then look for X of each rule in the set of output membership mortality risk
X value of fuzzy rules [R1]
IF younger age and less EHP THEN low risk mortality RULE 1 $= 0.37$
$\frac{40-x}{40} = 0.37$ then we get $x = 25.2$
X value of fuzzy rules [R2]
IF is getting younger and EHP has a lot of THEN mortality alert RULE 2 $= 0.3$
$\frac{x-20}{30} = 0.3$ then we get $x = 30$
X value of fuzzy rules [R3]
IF age gets older and EHP is slightly THEN mortality alert RULE 3 $= 0.62$
$\frac{80-x}{30} = 0.62$ then we get $x = 61.4$
X value of fuzzy rules [R4]
IF age gets older and EHP has a lot of THEN high risk mortality RULE 4 $= 0.3$
$\frac{x-60}{40} = 0.3$ then we get $x = 48$

Calculate the final X with an average weight:

$$X = \frac{\alpha predikat1 * x1 + \alpha predikat2 * x2 + \alpha predikat3 * x3 + \alpha predikat4 * x4}{\alpha predikat1 + \alpha predikat2 + \alpha predikat3 + \alpha predikat4}$$

$$X = \frac{0.37 * 25.2 + 0.3 * 30 + 0.62 * 61.4 + 0.3 * 48}{0.37 + 0.3 + 0.62 + 0.3}$$

$$X = \frac{9.324 + 10 + 38.068 + 14.4}{0.37 + 0.3 + 0.62 + 0.3} = \frac{71.792}{1.59} = 45.15 \%$$

Based on all process, from crips, fuzzification, rules, inference system, and defuzzification, the result as follows :

Table 4 1 Result of implementation

Age	EHP	up	down	down	up	output RULE 1	RULE 2	RULE 3	RULE 4	fatality risk prediction	recovery risk prediction
77	0	0.713	0.288	1	0	28.5	20	58.63	60	49.964	50.036
77	1	0.713	0.288	1	0	28.5	20	58.63	60	49.964	50.036
40	1	0.25	0.75	0.9	0.1	10	23	72.5	66	28.771	71.229
40	2	0.25	0.75	0.8	0.2	10	26	72.5	72	32.304	67.696
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
16	2	-0.05	1.05	0.8	0.2	8	26	81.5	57	5.194	94.806
17	1	-0.04	1.038	0.9	0.1	4	23	81.13	57.75	0.748	99.252
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

4.2. Discussion

The determination of fuzzy rules in this study is done manually based on covid-19 data in China and expert opinion. Therefore, it takes research on the optimization of fuzzy rules to improve the accuracy of predictions. For further work, we will include other variables that are more relevant or logical and Fuzzy rules are more relevant according to the actual conditions.

5. Conclusion

In this paper, we provide a decision support system with fuzzy logic method tsukamoto inference system is able to predict mortality and recovery risk of covid-19's patients, with 2 input (age and comorbid) and 4 rules we can use the tsukamoto method to the calculation of the implementation of the Fuzzy Inference System (FIS) with the Tsukamoto method that can be applied to support the completion of predictions of the risk of recovery patients with covid-19 shown in table 4.1

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