Averroes European Medical Journal
Open Access Publisher
ISSN: 0772-9200
ISSN (print): 2593-1431

March 2020 • Volume 2 • Number 2

# *Aggravating and progression factors of COVID-19 : Intelligent analysis*

BOUCENNA Nassim[1], BOUHARATI Khaoula[2], BOUHARATI Imene[3, 4], HAMDI-CHERIF Mokhtar [2]

**ABSTRACT**

**Objective**: The COVID-19 is considered to be a highly contagious pathogen. Since December 2019, an orthocoronavirinae virus has caused pneumonia identified as a new type of respiratory infection. This respiratory syndrome has quickly spread to all countries around the world to the point where WHO has declared it pandemic. To date, the source of this virus is not well known, especially since there are no standards for its diagnosis and treatment. Several factors are involved in the spread of the disease. This study tries to make a contribution to the analysis of its spread and the people likely to be affected. Also, the immune response of patients differs from one patient to another, which makes analysis very complex by classical mathematical techniques. As long as the several uncertainties persist to date concerning it, we propose to analyze the relevant factors using fuzzy logic. As this logic takes into account the imprecise and the uncertain, we consider that its application in this area proves to be adequate. **Methods.** Based on the factors reported in different studies concerning this disease established to date as well as the characteristics of the people affected, we have established a fuzzy logic analysis system. The input variables of the system represent the age of the affected patients, their comorbidity (ie sub-adjacent diseases, the confinement degree, the screening policy and the availability of control means) and the output variable expresses the disease rate. **Results.** By doing so, the uncertainties linked to the very nature of the individuals affected, the uncertainties and imprecision inherent in ignorance of the disease and its mechanisms are thus compensated. Once the rule base has been established from actual cases recorded, it becomes possible to predict the degree of certainty of the COVID-19 infringement. **Conclusion**. Several unknowns still persist as to the origin of the virus, its mechanism, its spread and the lack of a vaccine and even less treatment, the WHO declared it pandemic. This study takes up certain factors recorded and reported by previous studies to give a preventive analysis. The application of a fuzzy system overcomes these inaccuracies. The proposed system remains extensible to other factors not supported in this study and which may prove to be relevant over time.

**Keywords:** COVID-19, respiratory syndrome, pandemic, fuzzy logic.

## Introduction

The coronavirus is considered to be a highly contagious pathogen which is often present in certain domestic and companion animals as well as humans. This pathogen is the cause of several acute or chronic diseases[1]. Since December 2019, a virus

1. Faculty of Medicine, Ferhat Abas Setif1 University, Algeria
2. Laboratory of Health and Environment, UFAS, Setifl University, Algeria
3. Radiology department, UFAS, Setifl University, Algeria
4. Laboratory of intelligent systems, UFAS, Setifl University, Algeria
**Corresponding author**
Boucenna Nassim
sbouharati@univ-setif.dz
Tel: +213771816302

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Corresponding author: Boucenna Nassim
Email: sbouharati@univ-setif.dz
Tel: +213771816302

of the genus sarbecorirus of the *orthocoronavirinae* subfamily has caused pneumonia in several patients exposed to the Huanan seafood market in Wuhan city in Hubei province in China. After analysis, this disease is identified as a respiratory infection caused by a new type of coronavirus[2,3]. This respiratory syndrome has quickly spread to all countries around the world[4]. On March 11, 2020, the WHO declared it a pandemic when the threshold reached 110,000 patients with an increasing trend[5]. To date, the source of this virus is not well known, especially since there are no standards for its diagnosis and treatment. This disease is characterized by several indicators, among others the respiratory rate and its insufficiency, which can be considered as an indication of the severity of the patients. Several factors are involved in the spread of the disease. People with a history of smoking are more susceptible. Also, frailty due to physical age can influence its effect on the person affected and on the prognosis[6,7]. This disease is accompanied by manifestations such as fever, fatigue, dry cough as well as other symptoms such as myalgia, chest tightness, dyspnea, nausea and vomiting or diarrhea. The profile of the patients is gradually studied. Until now, the risk factors linked to this syndrome as well as to its progression are old age, neutrophilia as well as organ and coagulation dysfunction[8]. Although high fever is linked to the development of this syndrome, it is not linked to death[9]. However, co morbidity is essential in determining the prognosis especially when it comes to pneumonia[10]. Thus, a link has been reported between nosocomial infections resulting from respiratory diseases and COVID-19 syndrome[11]. This is also observed in other SARS epidemics[12,13].

## Radiological detection

Using the chest CT scan, typical images of bilateral glass consolidation pneumonia with multiple consolidations are seen[14-18]. Some authors suggest the use of CT images as a tool on which the diagnosis is based and this by identifying the changes in these[19,20]. In the general case, the CT scans are important especially in their early use in order to allow the administration of treatment to prevent secondary infections such as viral pneumonia[21].

## Factors spread

The moment this virus is new, it assumes that everyone is susceptible to the infection. Further studies are needed to identify the degree of immunity after infection. However, on board, those at risk are those who have co morbidity. Co morbidity can be considered as a factor favoring this syndrome. This variable was determined from the self-report of patients[22]. The most relevant factors in this case are hypertension, diabetes, cardiovascular disease, respiratory diseases such as asthma and cancer. These factors are much more aggravating in the elderly. This may partly explain why the disease in children is relatively rare and at least mild. From there, age can be considered as factors related to this syndrome. These characteristics have been statistically summarized and age distribution graphs have been drawn up based on patients whose infection is confirmed in Wuhan, China. The age factor does not make a significant distinction[23].

## Used systems

This is to deal with the variables that come into play in the infection of individuals and its spread. In our case, certain factors are known and their effect differs from one person to another. Their impact is not precise, while other factors are completely ignored and which influence the results of analysis. Faced with such a situation, it is impossible to analyze such a system by classical mathematical techniques. The fuzzy inference system proposed allows these uncertainties and inaccuracies to be overcome. Each factor is considered imprecise and therefore fuzzy. If the age factor, for example, is a determining factor in infection and death, it is no less uncertain. In some areas we have seen a high percentage of young patients. Also, the number of deaths high in the category of old people is often attributed to the high co morbidity in them. The co morbidity factor includes several associated diseases, diabetes, obesity, cardiovascular diseases, smoking, etc. The effect of each disease varies from one individual to another and from one age to another. So the system is far from precise. Add to this, the social system of each region which takes into account the way of life of social relationships and the degree of contact between individuals. And to fight the spread of the disease, different approaches are used. Each country has a policy of containment and early detection. In some countries containment is premature, in others late. In some countries, screening is systematic and generalized, in others it is selective. Also, each country is distinguished by its ability to cope with the disease through its hospital equipment and medical staff.

From there, we find that it becomes impossible to analyze such a system and predict its evolution by classical mathematical techniques and on assistance with the collection of statistical data and discuss the application of the curve so as not to overflow the hospitals.

## Fuzzy model

The fuzzy mode imitates human reasoning. Historically, its first foundations were established by Zadeh, 1965[24] on the basis of set theory.

Numerical variables are converted into linguistic variables in human language by the fuzzyfication process. The operations performed on these variables are logical operators (AND, OR, or both)[25].

In our case, the proposed system includes five inputs (age, comorbidity, confinement, screening and availability of control means) and an output variable which expresses the rate of involvement by the disease. Each variable is considered fuzzy and therefore fuzzyfied.

A rule base dependent on inputs to output is established from the actual data in the form (IF ... THEN). Once the system is established, the output result after defuzzyfication expresses the expected number of sick individuals.

The proposed system remains extensible to the other factors not considered here for greater affinity.

$$\text{Outputs } (Dr) = f(A, Cm, Cf, S, Av)$$

*Where :* *A (Age)*
*Cm (Co morbidity)*
*Cf (Confinement)*
*S (Screening)*
*Av (Availability of control means)*
*Dr (Disease rate)*

Using MATLAB R2016a, the system with five inputs and one outputs represented in Figure 1.

The inference between the inputs and the output is of Mamdani type.

The correspondence between the inputs and the output is (IF…THAN).

## Proposed system

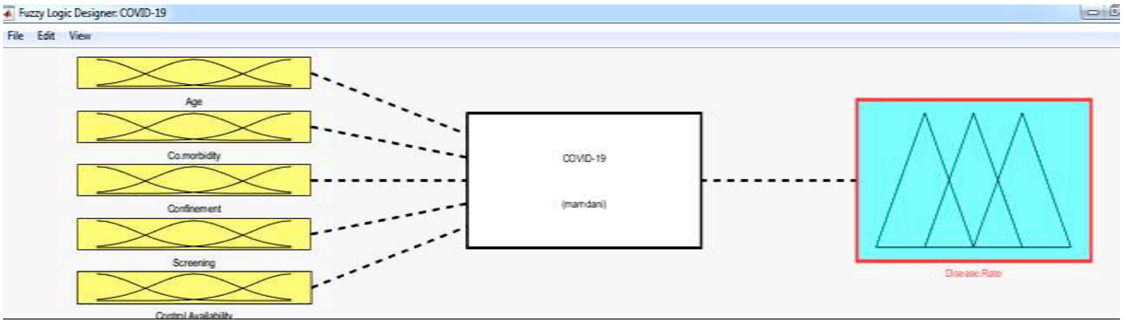


**Figure 1.** Schematic of the proposed system

### *Variables fuzzyfication*

*The input variables are:*

- ***A*** (Age of individuals) is fuzzyfied in three fuzzy intervals (Young, Adult, Old).
- ***Cm*** (Co morbidity, it expresses the effect of each associated disease such as obesity, high blood pressure, diabetes, smoking ... etc.) is fuzzyfied in three fuzzy intervals (Little effect, Medium effect, Large effect).
- ***Cf*** (Confinement, it expresses the effect of confinement on the propagation if it is premature or delayed, if it is total or partial ... etc. is fuzzyfied in three fuzzy intervals (ineffective, medium effective, very effective).
- ***S*** (Screening, this parameter expresses the effect brought about by screening whether it is generalized or selective) is fuzzyfied in three fuzzy intervals (no efficiency, average efficiency, very effective).
- ***Av*** (availability of control means. This expresses the level of availability of these means such as gloves, masks, artificial respirators, the number of beds in the hospital, the availability of medical staff ... etc.) is fuzzyfied in three fuzzy intervals (not available, average availability, very available).

*The output variable is:*

- *Dr* (Disease rate. That expresses the rate of people who can get sick) is fuzzyfied in three fuzzy intervals (little, medium, high).

Each variable is fuzzyfied. This operation consists in converting numerical values into linguistic variables. The variable "Age" for example is fuzzyfied in three fuzzy intervals. (Young, Adult and Old). There we see the creation of overlapping intervals. By this, the uncertainties are offset. Figure 2.

The same reasoning is applied to the other entries.

The output variable is also fuzzyfied into three fuzzy intervals which express the rate of disease involvement. Three intervals are created. Figure 3.

[0-2 "small"]
[1-2 "medium"]
[2-3 "high"]

```
[System]
Name='COVID-19'
Type='mamdani'
Version=2.0
NumInputs=5
NumOutputs=1
NumRules=21
AndMethod='min'
OrMethod='max'
ImpMethod='min'
AggMethod='max'
DefuzzMethod='centroid'

[Input1]
Name='Age'
Range=[0 100]
NumMFs=3
MF1='Young':'trimf',[0 20 40]
MF2='Adult':'trimf',[30 45 60]
MF3='Old':'trimf',[50 70 10000000]

[Input2]
Name='Co.morbidity'
Range=[0 4]
NumMFs=3
MF1='Little.Effect':'trimf',[0 1 2]
MF2='Mediul.Effect':'trimf',[1 2 3]
MF3='Large.Effect':'trimf',[2 3 4]

[Input3]
Name='Confinement'
Range=[0 4]
NumMFs=3
MF1='Medium.Effective':'trimf',[1 2 3]
MF2='Ineffective':'trimf',[0 1 2]
MF3='Very.Effective':'trimf',[2 3 4]

[Input4]
Name='Screening'
Range=[0 4]
NumMFs=3
MF1='No.Efficiency':'trimf',[0 1 2]
MF2='Average.Efficiency':'trimf',[1 2 3]
MF3='Very.Effective':'trimf',[2 3 4]

[Input5]
Name='Control.Availability'
Range=[0 4]
NumMFs=3
MF1='Not.Available':'trimf',[-1.6 0 1.6]
MF2='Average.Availability':'trimf',[1 2 3]
MF3='Very.Available':'trimf',[2 3 4]

[Output1]
Name='Disease.Rate'
Range=[0 4]
NumMFs=3
MF1='Little':'trimf',[0 1 2]
MF2='Medium':'trimf',[1 2 3]
MF3='High)':'trimf',[2 3 4]
```

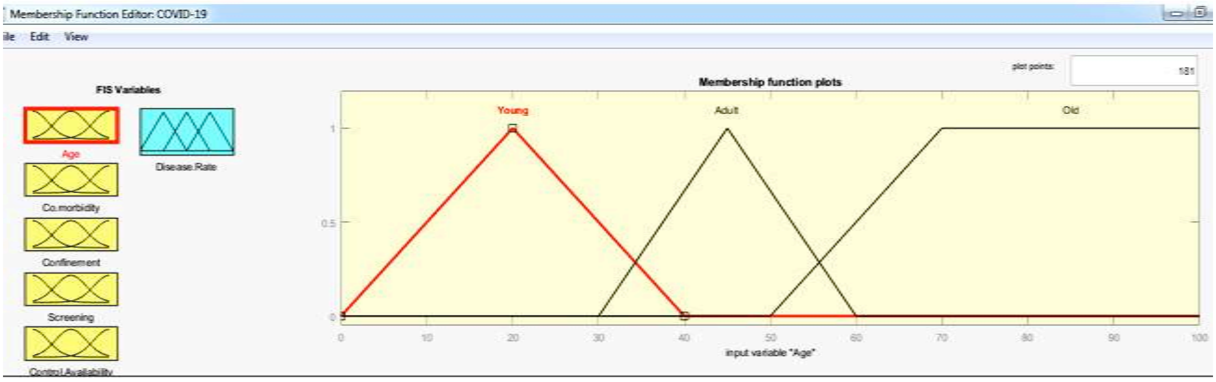


**Figure 2.** Fuzzyfication of the variable "Age"

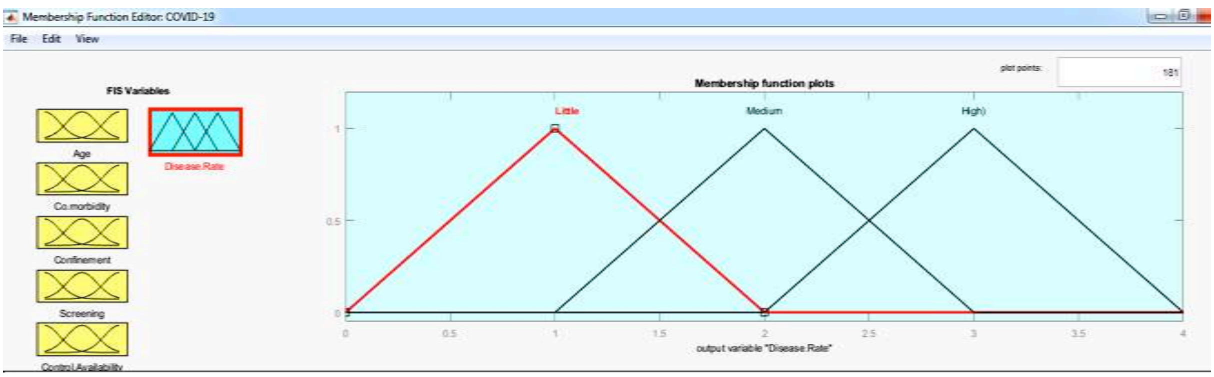


**Figure 3.** Fuzzyfication of the variable "Disease Rates"

## *Base rules*

This is to make the correspondence between the inputs and the output of the system. The rule base must contain all possible combinations. The output result is the aggregation of all the values of the input variables taken in linguistic terms. The establishments of these rules refer to the numbers of COVID-19 patients registered in relation to their risk factors and in which health system are located.

## Conclusion

The analyzed factors in this study are known and relevant factors. However, these factors are characterized by their uncertainty and imprecision. The fuzzyfication of these variables compensates for these inaccuracies. A database from recorded values with their specificities is created. A rule base is created, where a correspondence between the inputs and the output is established. It is noted that if action on certain factors is impossible such as age and comorbidity, action on other factors is possible and even essential. These are factors of screening, containment or availability of the health system and of coping with the pandemic. This study analyzes certain relevant data by considering them vague. This data processing mode achieves the highest possible accuracy.

The established system allows to randomly setting the values at the input to instantly read the value at the output. The numerical value at the output is obtained after defuzzyfication. By referring to the fuzzyfication of this variable, one can make corresponding this numerical value to its equivalent linguistic variable. Figure 4.

This tool can be considered as a tool to help predict the spread of COVID-19 according to the specific data for each region.

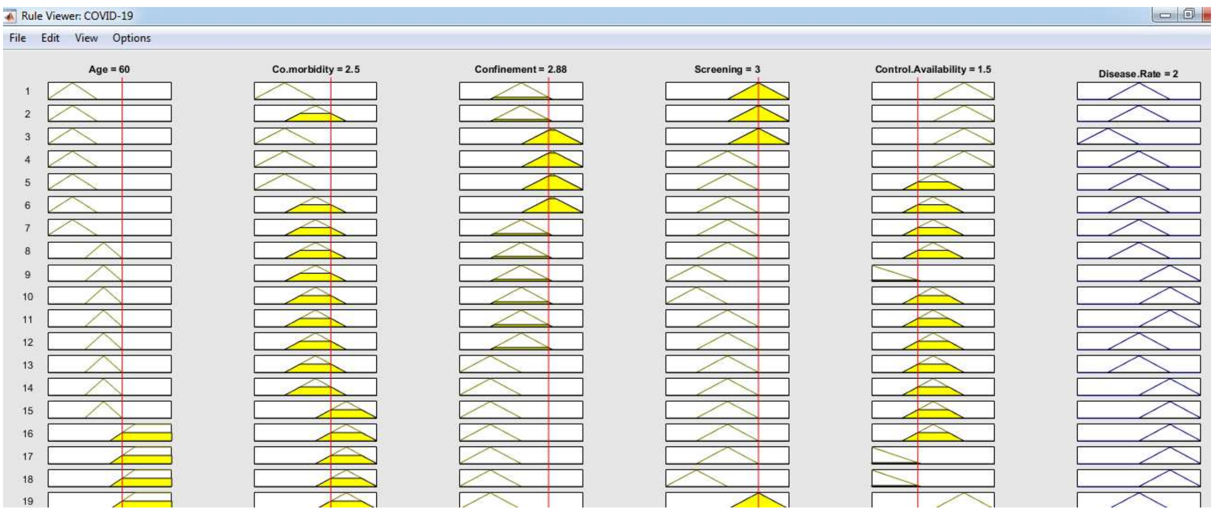


**Figure 4.** Application example

**Conflict of interest**

The authors declare that they have no conflict of interest

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