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Fuzzy Analysis of Vaccine Efficacy against Covid-19

Bouharati Khaoula[1,2]*, Bouharati Imene[3,4], Guenifi Wahiba[5], Gasmi Abdelkader[5], Boucenna Nassim[5], and Laouamri Slimane[5]

[1]*Department of Epidemiology, Faculty of Medicine, Constantine University, Algeria*
[2]*Laboratory of Health and Environment, UFAS Setif1 University, Setif, Algeria*
[3]*Faculty of Medicine, Paris Sorbonne University, France*
[4]*Laboratory of Intelligent Systems, UFAS Setif1 University, Setif, Algeria*
[5]*Faculty of Medicine, Setif University Hospital, UFAS Setif1 University, Setif, Algeria*.

Abstract: The spread of variants of the COVID-19, the ability of vaccines to resist the evolution of the original strain is a major issue in pandemic study. Hypotheses report that the efficiency drops after six months. Other studies report that these vaccines are six times less effective against the Delta variant than Alpha variant. The type of vaccine (Pfizer Biontech, Moderna, AstraZeneca, Jonson & Jonson, SputnikV or Sinopharm and even the mixing of vaccines) and the type of variant (Alpha, Beta, Gamma, Delta and recently Omicron. others are less influential such as Lambda or Mu) and the duration efficiency. *Methods*: It seems clear that the system is very complex to analyze. Several uncertain factors are involved in the process. This study proposes the analysis of these parameters by fuzzy reasoning. One of the techniques of artificial intelligence is analysis by the principles of fuzzy inference. *Conclusion*: When the base of the rules contains all the possible combinations starting from the real cases, it becomes possible to assign random values to the input variables to instantly read the result at the output in numerical and symbolic terms. This helps predict the impact of each input parameter on the vaccine efficacy.

Keywords: COVID-19, Variants, Vaccines, Fuzzy logic.

INTRODUCTION

In order to cope with the spread of variants of the COVID-19, the study of the ability of vaccines to resist its evolution from its original strain is a major challenge in the face of the pandemic. If the studies are still few, the assumptions of the United States report that the effectiveness drops after six months (Sara, Y. T, 2021). A study by the Pasteur Institute reports that these vaccines are six times less effective against the Delta variant than against the Alpha variant (Rebecca, G. *et al*., 2021). In May 2021, a study by Public Health England presented the Pfizer vaccine as 33% effective against the Delta variant after one dose (against 51% against the Alpha variant) and at 88% after two doses (against 93% against the Alpha variant).

The Pfizer laboratory tried to reassure on December 8, 2021 explaining that the vaccine is still effective against Covid-19, also against the Omicron variant, if it has been administered three times. A study published in the journal "Science" (November, 2021) conducted among nearly 800,000 Americans from February 1, 2021 to October 1, 2021. They show that the effectiveness of vaccines against contamination with SARS-CoV-2 has halved in eight months. Precisely 780,225 individuals, of whom 498,148 were fully vaccinated. It has been observed that the efficacy of all three vaccines decreases after only a few months, even after adjustment for age, gender or co-morbidities. Between March 2021 and October 2021, the effectiveness of vaccines against contamination decreased:

From 86.4% to 13.1% for the Janssen vaccine;
From 89.2% to 58% for the Moderna vaccine;
From 86.9% to 43.3% for the Pfizer-BioNTech vaccine.

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The tendency is to look for a vaccine rich in epitopes Who could change the course of the pandemic (Petric, D. 2021).

In conclusion, to date, the debate continues to rage and including the type of vaccine (Pfizer-BioNtech, Moderna, AstraZeneca, Jonson & Jonson, Sputnik V or Sinopharm and even the mixing of vaccines) and the type of variants (Alpha, Beta, Gamma, Delta and recently Omicron. Others are less influential such as Lambda or Mu) and the duration efficiency of vaccines (Lopez Bernal, J, 2021).

All this all these factors have their influence without mentioning the associated factors such as age, gender, co morbidity, seasons or

***Corresponding Author:** Bouharati Khaoula

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environmental factors (Ngambut, K. *et al*., 2013); (Parry, H. *et al*., 2021).

It seems clear that the system is very complex to analyze. Several uncertain factors are involved in the process. This study proposes the analysis of these parameters by fuzzy reasoning. One of the techniques of artificial intelligence is analysis by the principles of fuzzy inference. Like human reasoning, this technique compensates the uncertainties and inaccuracies for extracting a clear decision (Bouharati, K. *et al*., 2021).

Factor Characteristics

These factors are characterized by their uncertainty and complexity. Patient age, Seasons, Co morbidity, environmental factors, Vaccine type, Vaccine times are far from being necessary as discrete values. Often used analysis tools are limited to statistical analyzes. Given the nature of this data, imprecise and complex, in this study we propose an artificial intelligence tool, in particular the principles of fuzzy logic in data processing.

A fuzzy system is built with fuzzy variables at the input of the system and their impact on the vaccine efficacy as a fuzzy variable at the output. A rule base is built connecting the inputs to the output. Considering them uncertain variables, it then becomes possible to introduce variables at the inputs to predict the impact on a specific case.

General form is:

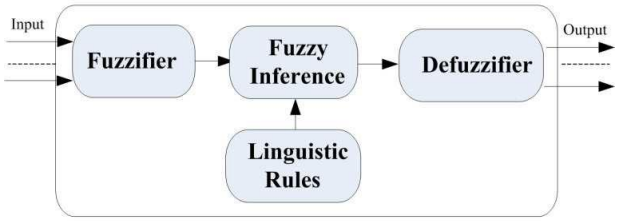
Fuzzy Modeling

Like human reasoning which compensates for uncertainties and inaccuracies in deciding an exact result, a fuzzy inference system is an imitation of it. When the system to be analyzed is characterized by complexity, uncertainty and imprecision, its application becomes adequate. The constructed system includes an input space which groups together the variables that influence the output, and an output space. An established database allows input to output to be linked while encompassing all possible combinations (Khaoula, B, 2021).

METHOD

A fuzzy system is constructed with five fuzzy input variables (Patient age, Co morbidity, Vaccine type, Vaccine times and COVID.19 variant) and an output variable which expresses the corresponding vaccine efficacy in terms of disease with its incidence.

All these variables are considered fuzzy and therefore uncertain. By this, it is necessary to fuzzyfy them (conversion to linguistic terms). A database is built from the actual recorded data. This database links the input variables to the output variable. It must contain all possible combinations. Mathematically, it is the function that links the input linguistic values to the input of the system.



Fuzzy Logic Controller

In our case, the inputs variables linked to output variable is represented in (Figure 1).

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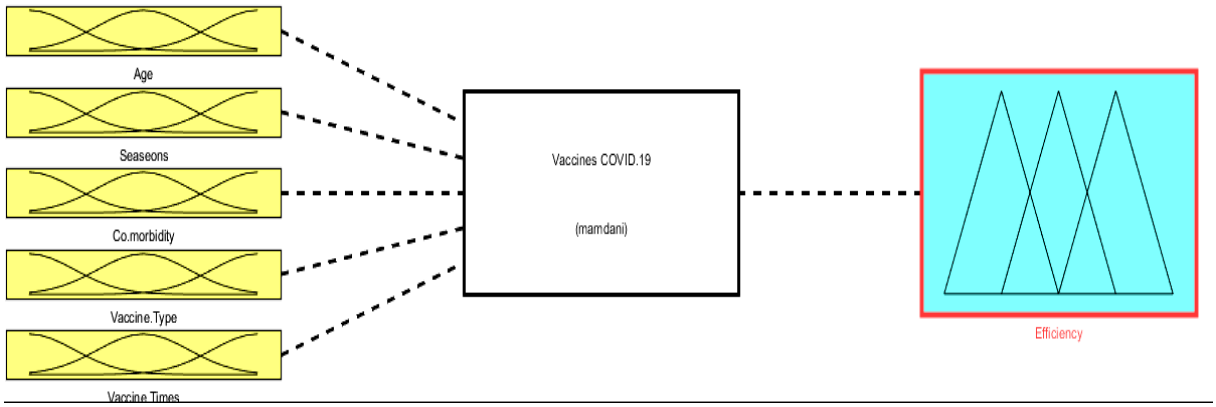

Figure 1: Schematic system

Fuzzyfication of Variables

Each input or output variable must be fuzzyfied. ie its conversion into the linguistic term of human language.

Fuzzyfication of Input Variables

The input or output variables are fuzzyfied.

This is to convert them from numeric to symbolic values. Like human reasoning, variables are treated in linguistic terms.

Variable 'Age' is fuzzyfied into three fuzzy intervals. 'Young, Adult, and Old' (Figure 2)

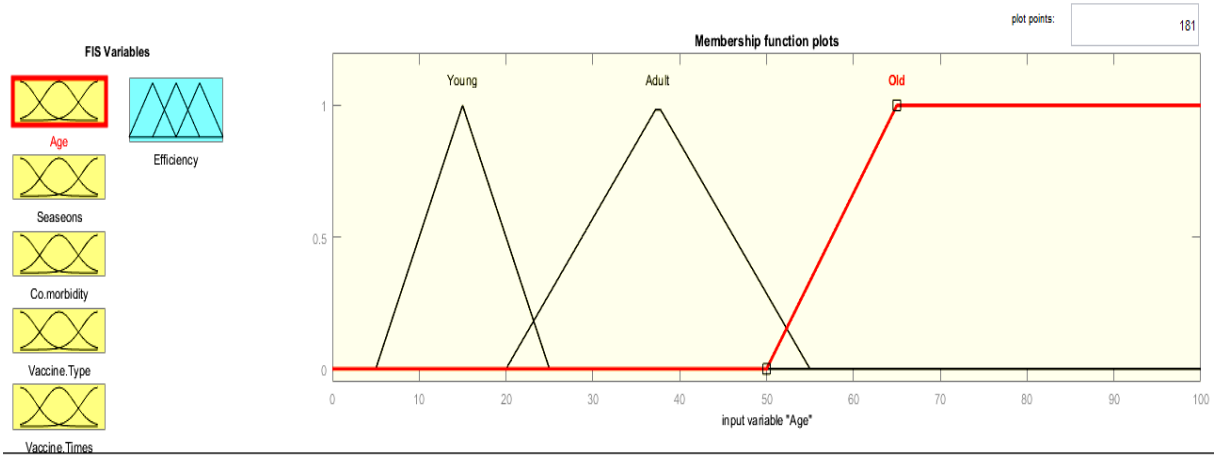

Figure 2: Fuzzyfication of "Age" variable

The variable 'Co morbidity' is fuzzyfied into three fuzzy intervals. 'Severe, medium, and weak' (Figure 4).

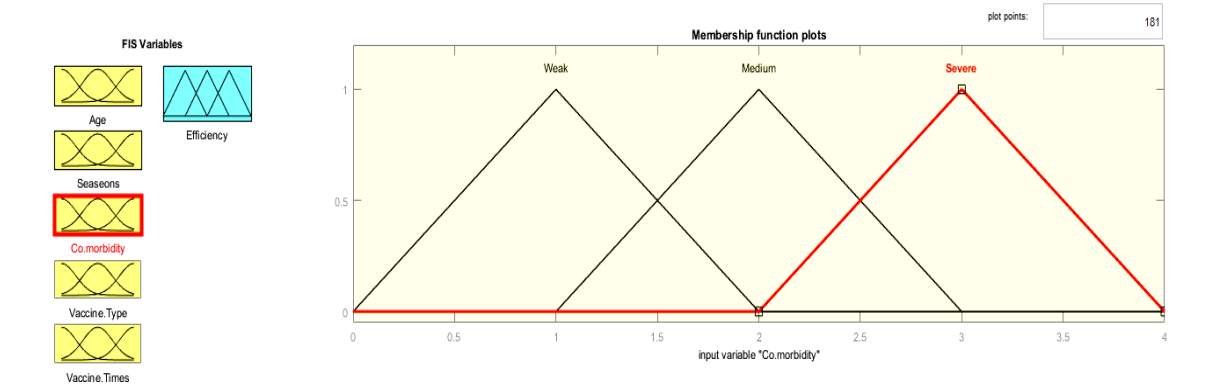

Figure 4: Fuzzyfication of Co morbidity variable

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The variable 'Vaccine Type' is not fuzzyfie. It just expressed into numbers (Figure 5). The variable 'Vaccine Type' is not fuzzyfie. It just expressed into numbers (Figure 5).

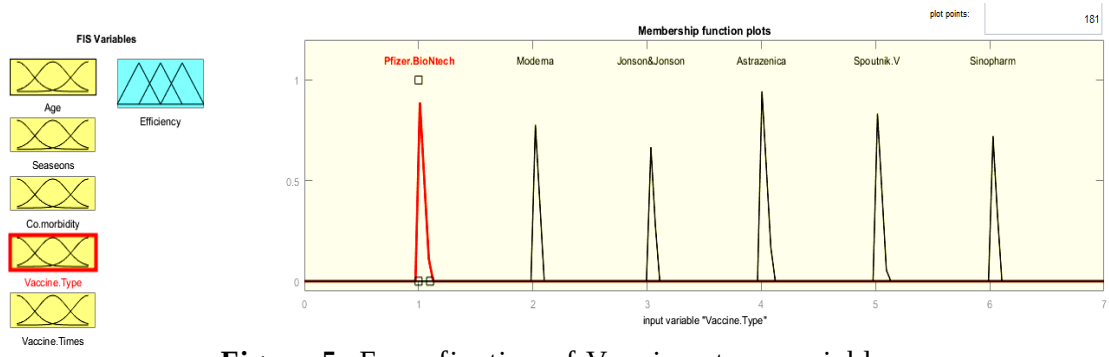

Figure 5: Fuzzyfication of Vaccines type variable

The variable 'Vaccine Times' is not fuzzyfie. It just expressed into numbers of vaccination (Figure 6).

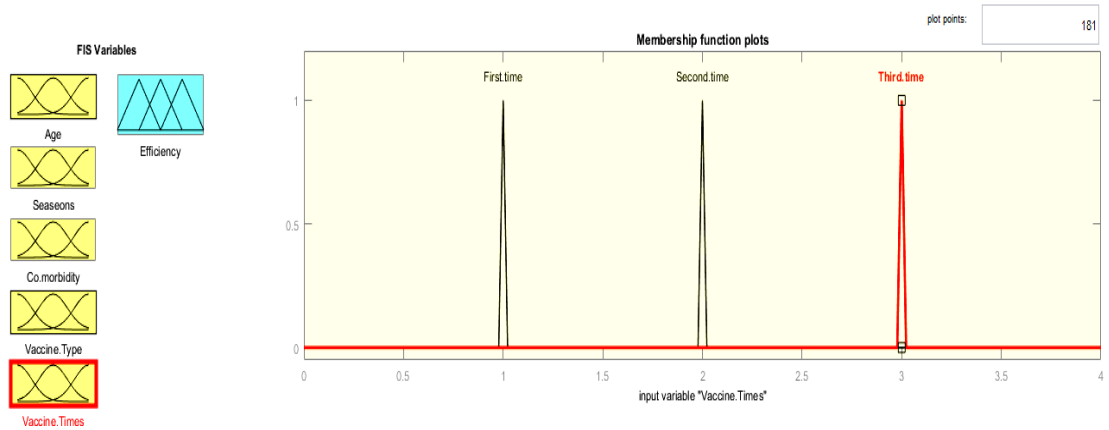

Figure 6: Fuzzyfication of Vaccines times variable

Output Variable

The output variable of the system expressed by the vaccine efficacy is also fuzzyfied in three fuzzy intervals 'Low efficacy, average efficacy and high efficacy' (Figure 7).

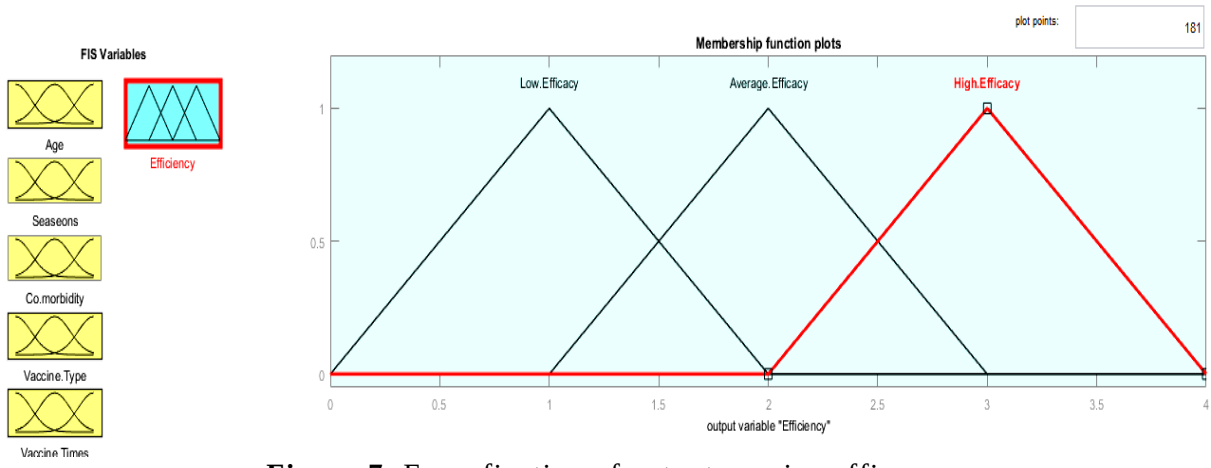

Figure 7: Fuzzyfication of output vaccine efficacy

Base of Rules

After the fuzzyfication of the inputs and output variables, a base rules is established. This base of rules connects the inputs to the output and it is inspired by real cases (What are the starting conditions to operate a result at the output). This base must encompass all possible combinations.

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The general form of a rule is:

IF (X_1 is X_{11} AND X_2 is X_{22} AND X_3 is X_{33}) THEN (Y is Y_1)

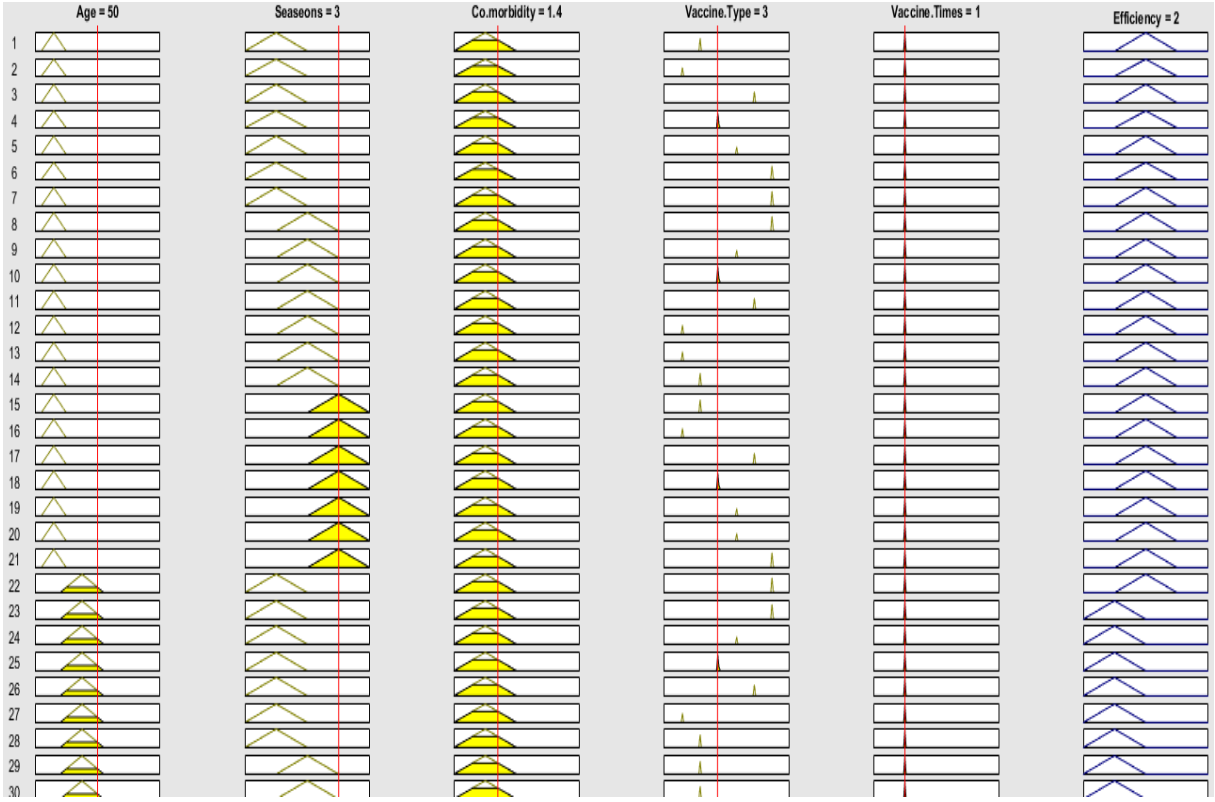

Figure 8: Example of application

CONCLUSION

The system to be analyzed is very complex. There are different factors involved in the process. The analysis of these factors by fuzzy inference takes these imprecision's into account.

By creating fuzzy intervals between two neighboring membership functions, the uncertainties are compensated for. When the base of the rules contains all the possible combinations starting from the real cases, it becomes possible to assign random values to the input variables to instantly read the result at the output in numerical and symbolic terms. This helps predict the impact of each input parameter on the vaccine efficacy. The figure 8 illustrates an example of an application.

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