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Improving Resilience Models of Health Systems before COVID-19 Pandemic in Côte d'Ivoire

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Abstract

The resilience of health systems is a major issue and challenge in patients' safety. This security refers to the ability to adapt, approach, anticipate or change after a shock. These shocks generally concern large-scale situations such as the COVID-19 pandemic. To cope with these shocks, certain risk management tools have appeared in healthcare centres. Among these new tools are those called "resilience engineering". However, failure to master some of them sometimes generates erroneous results that lead to even more serious consequences in decision-making. This article proposes an Ivorian resilience model for managing the coronavirus pandemic. The model is the combination of Bayesian and neural techniques with multilayer perceptron in order to best assist Ivorian specialists in their decision-making.

Keywords

Resilience, Corona Virus, Bayesian Network, Neural Network

1. Introduction

The corona virus is a respiratory disease that threatens the world's population's lives and more particularly that of Côte d'Ivoire, which should in turn face the negative effects of the disease. Declared a pandemic by the WHO in the course of 2020 after its speed of spread, the corona virus changed priorities and exposed the shortcomings of the Ivorian development model in all activity areas, in particular that of health system [1] [2] [3]. Thus, the health system review or improvement remains at the core of any thinking. So, a proposal of resilience models of that system is necessary in order to build the future of Côte d'Ivoire. Indeed, as MP Kieny states, if health systems are not sufficiently equipped to face this type of situation [4].

The current study aims to propose solutions in the implementation of resilience models for the Ivorian health system. That solution is based on a formal method to facilitate decision-making since it uses an artificial intelligence method. It is therefore time to present first a literature review of extant models in the management of COVID-19 pandemic in order to identify their specific characteristics. Then, the specific characteristic of a resilience model of the health system will be presented. In the end, the approach adopted in the current study will be described.

2. State of the Art

Neural networks, artificial cellular structures, constitute a strategy permitting to approach from various angles, the issue of perception, memory, learning and reasoning. Thanks to their parallel processing of information and their mechanisms inspired by human neuronal cells, they have properties that allow to solve complex problems. The approach has been the subject of several studies.

Indeed, Caillault *et al.* proposed a hybrid neuro-Markovian architecture comprising on the one hand, a convolutional neural network (TDNN and/or SDNN), and on the other hand hidden-state Markov models (MNC) [5]. The architecture based on the neural network, has a global vision and works at the character level. Similarly khan *et al.* proposed a novel approach to COVID-19 hotspot prediction using hybridization of neural networks and deep learning [6]. As for Kumar *et al.* use the Dark Covid Net architecture to detect symptoms of COVID-19 [7]. The architecture is based on the technique of machine learning (convolutional neural network) to detect symptoms of COVID-19 from CT images of patients. As for the authors Roubehie *et al.*, they have developed in their work mathematical models on the molecular structures of compounds [8]. These models allowed them to predict some physico-chemical parameters of pure hydrocarbons, based on an Artificial Neuron-Perceptron Multi-Layer Network (RNA-PMC).

In addition, the authors Jamilloux *et al*, using a Bayesian network, developed an algorithm to predict the etiology of uveitis for a given patient in the field of medicine [9]. The Bayesian network method permitted to construct a probabilistic graphical model and to calculate the various conditional probabilities and the clinical form of uveitis. The prediction error rate, sensitivity and specificity for each etiology were also calculated. Chaieb *et al.* proposed an information base revision algorithm that leverages the Bayesian network to identify outdated and conflicting information with new information [10].

Another approach consists in carrying out a hybridization of the methods presented above. It suits ATOUI *et al.* whose work relates to the algorithm proposal to merge the interpretation score of the ECG carried out by the neural networks with that obtained by the Bayesian networks from risk factors [11]. All the studies presented are based on scoring methods that use experts' opinions based on qualitative data.

All the models presented in the literature are not adapted to Ivorian realities because of the qualitative and quantitative nature of data from Ivorian health systems. It would therefore be interesting to use a different approach modeled on Ivorian realities. Hence, the interest of the hybrid use of neural and Bayesian models. This model will, not only, take into account the uncertainty problem, but also reduce the error rate in the management systems of COVID-9 pandemic.

3. Methodological Approach and Modeling

The neural networks constitute an approach making it possible to approach under new angles, the problems of perception, memory, training and reasoning.

It sometimes happens that the results obtained by the use of neural networks are marred by uncertainties. To remove all the ambiguities of uncertainty on the data, the Bayesian method is used. Thereby, let us consider *S*, a COVID-19 learning base composed of (*x*, *y*) pairs. Let us assume $x \in \{x_1, \cdots, x_N\}$, a vector associated with the learning base *S* and *y* the corresponding associated output.

Since COVID-19 databases are generated daily with multiple information on the number of sick people/cases recoveries, deaths, it creates an approximation problem of values, classification and prediction. Let us consider the multilayer perceptron (PMC) method of the neural network, which allows to determine the contribution of each weight to the overall error of the network.

Let us assume a neuron *j* in the output layer y_j, when the input x_i is presented to it, it produces the output $y_j(x_i)$ while that is the expected value $d_j(x_i)$. The overall network error on the input x_i is given by:

$$\varepsilon(x_i) = \frac{1}{n}\sum_{j=1}^{m}\left(d_j(x_i) - y_j(x_i)\right)^2 .$$

where, *n*, is the number of the network hidden layers; *m*, the number of neurons in the output layer y_j.

Let us consider, the average network error ε_{moy}. Defined as follows:

$$\varepsilon_{moy} = \frac{1}{N}\sum_{i=1}^{N}\varepsilon(x_i)$$

Substituting $\varepsilon(x_i)$ by its value, we get:

$$\varepsilon_{moy} = \frac{1}{N}\sum_{i=1}^{N}\frac{1}{n}\sum_{j=1}^{m}\left(d_j(x_i) - y_j(x_i)\right)^2$$

$$\varepsilon_{moy} = \frac{1}{Nn}\sum_{i=1}^{N}\sum_{j=1}^{m}\left(d_j(x_i) - y_j(x_i)\right)^2$$

The goal of learning is to minimize the average error corresponding to *N* learning inputs x_i. That error allows us to set the threshold for accepting items from the test base.

After the test base obtained, we use the methods of Bayesian formalism for a complex analysis of uncertainties and data probabilities.

Consider D, the set of new observed data constituting the test base include

$$D = \left\{\left(x^{(1)}, y^{(1)}\right), \left(x^{(2)}, y^{(2)}\right), \cdots, \left(x^{(n)}, y^{(n)}\right)\right\}.$$

Applying Bayes' theorem we get the following posterior distribution:

$$P(D) = \frac{p(\theta)P(\theta)}{P(D)} \alpha L(D) P(\theta)$$

where $L(D)$ the likelihood function is with θ, the element sought with certainty. The aforementioned function gives us the probability that the observed data work on the basis of parameters unknown to the model. Under the circumstances where the data scores are independent and exchangeable, we get: $L(D)\theta$

$L(D) = \pi_{i=1}^{n} P\left(x^{(i)}, \theta\right)$, with n the number of data.

Model algorithm
Randomly initialize the coefficients w_{ij}
Let $x(n) = \{x_1(n), \cdots, x_p(n)\}$, the entrance
Let $d(n) = \{d_1(n), \cdots, d_m(n)\}$, the exit
μ is a positive constant
a_i is the activation value of the neuron N_i
beginning
Repeat:
Take a couple (x, d) in S
Output Error Calculation
Error back-propagation to inputs
Calculate network output for input x y^*
If $d \neq y^*$
Weight update: w_{ij}
$w_{ij} = w_{ij} + \mu * (a_i * a_j)$
End if
end repeat
Let D be the test basis
Application of Bayes' Theorem
End

4. Simulation and Results

As part of the simulation, we used a database of COVID-19 from our country Côte d'Ivoire. The database contains 439 data/elements as represented below (**Figure 1**):

	Jour N°	Date	New Cases	New Recovered	New Deaths	New Analysed	Total Cases
0	439	2021-05-29	38	51	2	2109	47233
1	438	2021-05-28	49	47	0	2064	47195
2	437	2021-05-27	61	40	0	2217	47146
3	436	2021-05-26	338	516	0	8096	47085
4	435	2021-05-25	3	34	0	1312	46747
...	...	...	...	...	...	...	...
434	5	2020-03-20	5	0	0	0	14
435	4	2020-03-18	3	0	0	0	9
436	3	2020-03-16	2	1	0	0	6
437	2	2020-03-14	3	0	0	0	4
438	1	2020-03-11	1	0	0	0	1

439 rows × 7 columns

Figure 1. Evolution of the Covid-19 pandemic in Côte d'Ivoire. https://data.gouv.ci/datasets/covid-civ.

We split the database into two (2) parts, the first part for the training data where we trained our different data and the second part for the test data. As part of the test, we set the number of hidden layers to six (6) taking into account the data mass and to avoid convergence problems.

307 observations for the test data and 132 data for the training data. At that phase end, we obtained a new base; Figure 2 which will serve as a test for our Bayesian model. The said database consists of the following variables:

- New_case: new infections;
- Nouv_Gue: new cures;
- Nouv Mort: new deaths;
- Nouv Anal: new analyses;
- Cumul_cas: the total of the cases.

	Nouv_Cas	Nouv_Gue	Nouv_Mort	Nouv_Anal	Cumul_cas
0	0.465480	0.053468	0.133523	0.642369	0.055482
1	0.366608	0.302023	0.117342	0.359909	0.080581
2	0.044863	0.052023	0.037673	0.143508	0.013210
3	0.348210	0.423410	0.148221	0.325740	0.129458
4	0.440518	0.015896	0.063859	0.535308	0.015852
...	...	...	...	...	...
150	0.697203	0.222543	0.278039	0.799544	0.182299
151	0.408083	0.098266	0.208622	0.425968	0.091149
152	0.248767	0.261561	0.173542	0.261959	0.324967
153	0.429382	0.079480	0.120183	0.487472	0.023778
154	0.075308	0.210983	0.093379	0.186788	0.166446

Figure 2. Bayesian model test basis.

After obtaining this new base, we evaluated our neural model. It gave an accuracy of 90% and an error rate that keeps decreasing as represented in the Figure 3 below:

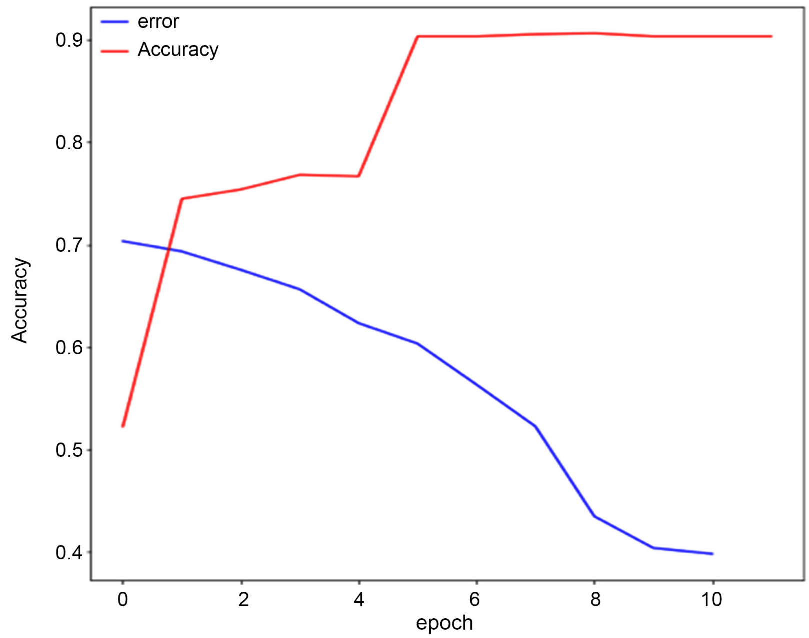

Figure 3. The assessment results.

The Bayesian model applied to the database obtained allows to get **Figure 4** below.

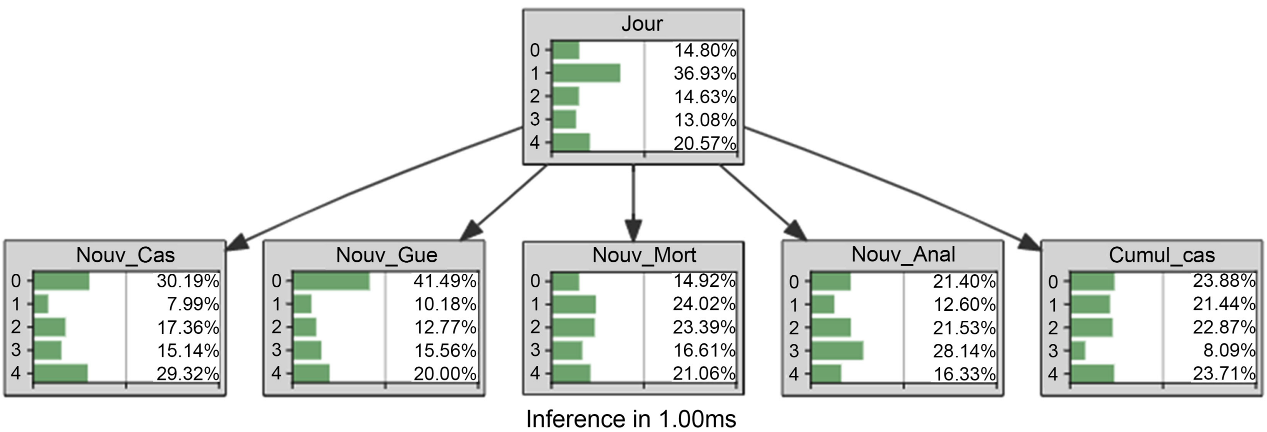

Figure 4. Result of the Bayesian network.

We present here the results obtained on index day 1. The results of the other indices will be based on the same principle. Thus, the interpretation given to this graph is that if we consider five (05) observations (day), the probability that the recorded values reflect reality in view of the observations is presented with an accuracy of 36.93%.

5. Conclusion

The work has permitted to propose an approach for the management of coronavirus disease. The approach consisted of matching the neural network method with Baye's theorem for prediction. Convincing results with an average recognition rate of over 90%. In addition, Bayesian networks allowed the consideration of incomplete data. This correspondence permits us to determine with certainty the moment when an individual can actually be affected by corona virus disease. Although the method used gives satisfactory results, many problems still remain to be solved with regard to the improvement of the precision index. So, a model based on Markov hidden model would allow not only to improve the index precision, but also to analyze the approach results so as to anticipate field managers' decisions that are still going on.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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