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ORIGINAL ARTICLE / ARTÍCULO ORIGINAL

PREDICTIVE ALGORITHM ANALYSIS FOR OPTIMAL PREVENTIONS IN TIME OF CORONAVIRUS (COVID-19) DURING QUARANTINE

ANÁLISIS PREDICTIVO DEL ALGORITMO PARA UNA PREVENCIÓN ÓPTIMA EN EL TIEMPO DE CORONAVIRUS (COVID-19) DURANTE LA CUARENTENA

J. Alan Calderón Ch[1,2]; Julio Tafur Sotelo[2]; Benjamin Barriga Gamarra[2]; Julio Guevara Guevara[2,3]; John Lozano Jauregui[2,4]; *Juan Lengua Arteaga*[2] *& Gonzalo Solano*[2]

[1]Applied Biophysics, Institute for Physics, Technical University of Ilmeanu , Ilmenau 98693, Germany
[2]Pontificia Universidad Católica del Perú, Mechatronic Master Program and Energy Laboratory, Lima 32, Peru
[3]Department of Protocol and Investigation National Hospital Guillermo Almenara, Perú.
[4]Northern (Artic) Federal University named after MV Lomonosov, Arkhangelsk Russia.
*Corresponding author: alan.calderon.@pucp.edu.pe
https://orcid.org/0000-0002-6486-5105

ABSTRACT

This research explains the applications of the algorithm that was designed to provide statistical support for medical doctors. The support that was achieved from this research looks for an urgent interpretation of parameters such as the rate of infection by COVID-19 and the rate of mortality because of the virus. Furthermore, this research achieves prediction rates that were provided by a mathematical model that observes and adapts real statistical data from other countries, where governments are trying to find solutions for COVID-19 propagation. In order to get accuracy in prediction results, it was necessary to analyse the statistical behaviour from China and other countries that returned to normal activities before virus required confinement of the population inside homes. The viruses problematic growth and some suggestions, on how to avoid deep complications in health and economy of people (for instance, quarantine as the main response to attenuate advance of this virus) are offered.

Keywords: COVID-19 propagation – statistical data – Mathematical modeling

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RESUMEN

En esta investigación se explica las aplicaciones del algoritmo que fue propuesto para proporcionar apoyo estadístico para los médicos. El apoyo que se realizó en esta investigación busca una urgente interpretación de parámetros como la tasa de personas infectadas por COVID-19 y la tasa de personas fallecidas a causa de este virus. Además, esta investigación logra predecir las tasas que fueron proporcionadas por un modelo matemático que observa y adapta datos estadísticos reales de otros países donde están tratando de encontrar soluciones contra la propagación del COVID-19. Esto implica que, con el fin de obtener precisión en los resultados de la predicción, fue necesario analizar cuál fue el comportamiento estadístico de China y otros países que volvieron a la normalidad de sus actividades, tal como era antes de que el virus impusiera a la población a permanecer en sus hogares. Por otro lado, se resume el crecimiento problemático del virus y algunas sugerencias de cómo evitar complicaciones profundas en la salud y la economía de las personas (por ejemplo, los días de cuarentena, como principal respuesta para atenuar el avance de este virus).

Palabras clave: Propagación de COVID–19 – datos estadísticos – modelamiento matemático

INTRODUCTION

In March 6, 2020, the first infected person (Coronavirus en el Perú, 2020), was detected in Peru (Figure 1, letter "A"). Therefore, there was many recommendations given by Peruvian government such as cleaning and keeping rest in home, as it was made by the international community, which is crossing the same task. Nevertheless, it was expected exponential growth of the infected quantity of people curve that was the reason why the government decided to declare days of quarantine from March 16, 2020 (El Peruano, 2020).

For this reason, data (as all statistical data about COVID-19 in Peru obtained from official and public information of Peruvian Health Ministry, MINSA) was processed to show the behaviour of infected quantity growth as the dependence of current days and quarantine days.

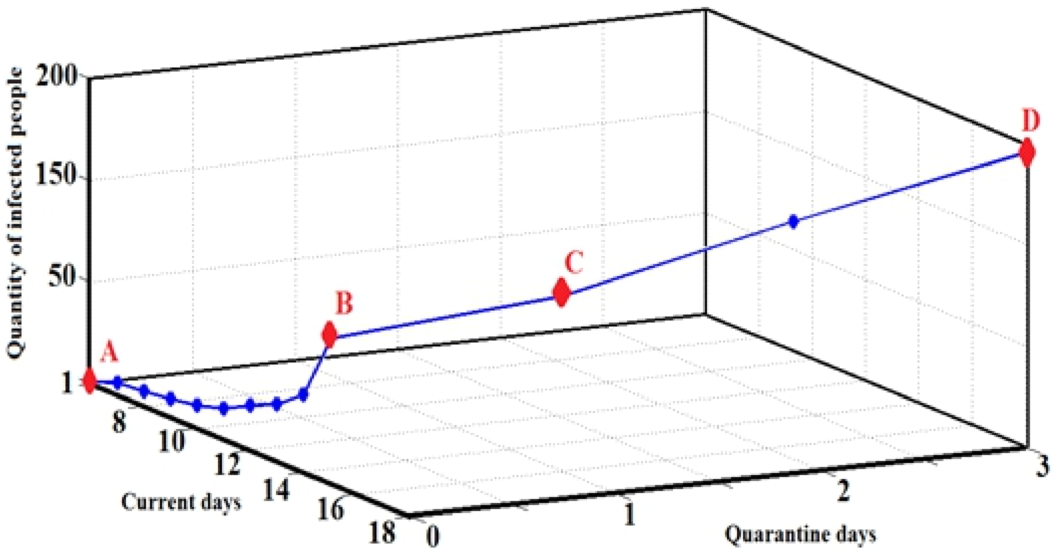

Figure 1. The curve of the quantity of infected people as the dependence on 18 current days and 3 quarantine days.

MATERIALS AND METHODS

Hence, the blue colour curve of Figure 1 shows the increase of people, who were infected by the virus even though after 10 days of finding the first infected person in Peru, the "Quarantine days" started (as it is possible to see from the letter "B" in the same Figure).In order to give a mathematical formalism for the statistical data that was achieved, this research analyse a general polynomial (it is showed in equation 1), which depends on its coefficients *(a, b)* and derivatives $P = d/dt$ (with order n) as the consequence of the response Y, the excitation variables u, internal variables x and error e (all of them depend on time t) (Pearson, 1979; Chowell *et al*., 2016; Chen *et al*., 2020).

This general polynomial model is known as Modulating Functions technique that is very adapted for many changes and its solution is another polynomial model that was adjusted to the desired response. Hence, it is possible to achieve predictions that depend on adaptive coefficients, it means a better accuracy to get estimations in multivariable and non-linear models.

$$P^n y(t) + \sum_{j=0}^{n} a_j p^{n-j} y(t) = \sum_{j=0}^{n} b_j p^{n-j} + e(t) \qquad (1)$$

where solution error analysis *e(t)* is the error described by the following equation, in which, V keeps the Fourier series coefficients, indexes *m, n, k, a*, moreover the parameters matrix θ.

$$e_n(m) = \sum_{k=m}^{n+m} \alpha(k, m, \theta_a) V(k) \qquad (2)$$

In the following equation, α is the frequency parameter function, C is the combination for coefficients, a_j keeps the physical parameters and $(ik\omega_o)^{n-j}$ is a complex number for the corresponding index:

$$\alpha(k, m, \theta_a) = C_{k-m} \sum_{j=0}^{n} a_j (ik\omega_0)^{n-j} \qquad (3)$$

For which, the nonlinear model for error analysis is given by the following equation, in which, g is the given function for parameters θ, E and F are specified functions for the input variables u and responses y, P are the fixed polynomials as dependence on derivatives $p = d/dt$:

$$\sum_{j=0}^{n1} \sum_{k=1}^{n2} g_j(\theta)\, F_{jk}(u, y) P_{jk}(p) E_k(u, y) = 0 \qquad (4)$$

Therefore, the costing function that depends on the function r of the complex conjugations is given by the equation 5:

$$J(\theta) = \sum_{j=0}^{n1} \sum_{k=0}^{n2} r_{jk} g_j(\theta)\, g_k(\theta) \qquad (5)$$

also, in order to get the main model parameters, the derivation of the costing function J was achieved as it is described by the following equation, in which θ is the physical parameters matrix, W_C is the weights matrix, Y_C and Γ are composed on the real and imaginary coefficients from the linear regression model:

$$\frac{\partial J}{\partial \theta} = (Y_C - \Gamma\theta)^T W_C^{-1} (Y_C - \Gamma\theta) \qquad (6)$$

It means, that parameters are shown in equation 7 that depends on the adaptive coefficients:

$$\theta = (\Gamma^T W_C^{-1} \Gamma)^{-1} \Gamma^T W_C^{-1} Y_C \qquad (7)$$

On the other hand, it is obtained the estimated response $\hat{Y}$:

$$\hat{Y} = X\hat{\beta} \qquad (8)$$

In which, due to get the adaptive estimation (it is looking for optimal predictions), it is necessary the weight matrix W_m:

$$\hat{\beta} = (X^T W_m^{-1} X)^{-1} X^T W_m^{-1} Y_C \qquad (9)$$

W_C and W_m depend on adjusted coefficients ρ that is inside the range between -1 and 1 (values were chosen for W_C and $W_m$respectively).

$$W^{-1} = \begin{pmatrix} 1 & -\rho & 0 & \cdots & 0 \\ -\rho & 1+\rho^2 & -\rho & \cdots & 0 \\ 0 & -\rho & 1+\rho^2 & -\rho & 0 \\ \vdots & \vdots & -\rho & 1+\rho^2 & -\rho \\ 0 & 0 & 0 & -\rho & 1 \end{pmatrix} \quad (10)$$

Hence, the expected solution $\hat{Y}$ is adapted to its own dynamic that was observing the dynamic of another countries too, which give solution ranges for W. It means, whether an expected curve P (as it is depicted in the following figure) needs the prediction to continue the trajectory from the point Q, this trajectory can follow 3 possibilities by the indicated arrows (up, down or right side).

Notwithstanding, it is suggested in this research to see this problem as a complex statistic task and this is the reason, why it is analysed as a dynamic system, in which the prediction needs a reference trajectory owing to get this road. Moreover, it is necessary to recognize that every curve has its own dynamic (O, G, B) with own difficulty to be predicted (such as in the context of COVID-19), it is suggested that adaptation factors need to be correlated with adaptation factors of other dynamics (from O, G, B) due to prevent or achieve a better successful prediction of the new trajectory of P. Despite, the road of P could change suddenly (Bouchnita & Jebrane, 2020; De Falco *et al.*, 2020; Fang *et al.*, 2020).

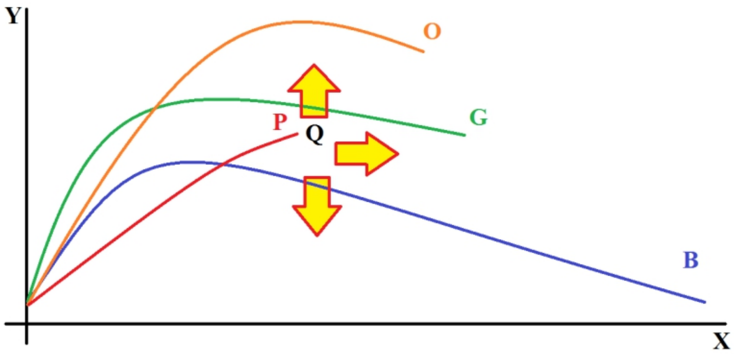

Figure 2. Dynamic curves for the proposed analysis.

The complexity of this proposal is given in changes of the input matrix variables due to these excitation signals take the information of the real response or the expected response. It means for COVID-19 application (quantity of infected and deceased people prediction) cannot achieve the desired prediction, while it is not concentrated in the real dynamic of the system (population changes) and to make comparisons with other dynamics, some curves just crossed the increasing transient and achieved the decreasing response. What does this context mean in the dynamic that was correlated for the other curves? This was explained by the compromise of the adaptation matrix of every dynamic and the expected response as the dependence on the parameters of the curves that got a decreasing response. In this context, this is an advantage of this proposal, because of COVID-19 context. It can be interpreted as every curve represents countries dynamics with their own coefficients and adaptations, which need to be analysed for the dynamic of the system, which is looking for its own prediction. That matrix can be composed by this question: What medicine or procedure support were prepared by the government of countries where confinement only cannot guarantee decreasing of the curve? Furthermore, to get understanding of the behaviour of every dynamic, it means there are countries with more flexible rules to get a collective response, but the flexibilities or other as a collective are not fast. Therefore, there are countries with similar dynamics if to compare with other. Hence, it can be obtained matrixes and coefficients of an expected dynamic.

However, what does it mean as a suggested answer for the collective group? That translation is the complex and it needs much communication between authorities of different countries that analysed countries dynamics, because perhaps these coefficients can be translated as the medical treatment between patients and medical doctors. What support by medicine and what is the psychological answer for the collective group? What is about the economical proposal solutions for the collective? As it is proposed in this research, every variable needs to be studied and correlated and the result of the dynamics curves needs to be interpreted according to get better prediction in stochastic context. It is faster while medicine answer accelerates this process (for example, plasma analysis or increasing immunity of people). To sum up, the data interpretation needs to be analysed as the dynamic, but not to be isolated from others, ever proposal solution needs to be adapted for every reality.

RESULTS

Can quarantine days to achieve decreasing of the quantity of infected people curve?
This question needs to be solved through optimal predictions from the database that was published by MINSA. In this context, it was modelled a polynomial model algorithm, which is depicted in the flowchart of Figure

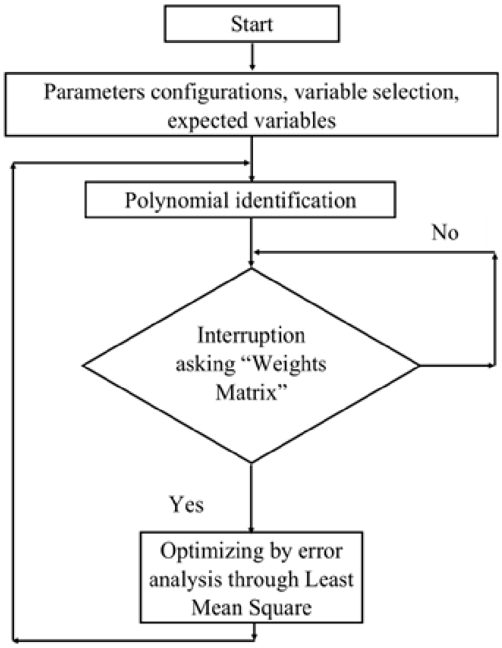

Figure 3. Flowchart to describe the algorithm that was designed to predict the quantity of infected people during quarantine days.

The first step is given by the polynomial identification from the input data. For this task it was organized as input variables the quantity of infected people, current days and quarantine days. After it was necessary to calculate the matrix weight by interruption of the main algorithm, owing to adapt the weight coefficients. Finally, it was analysed the error compromise by optimizing the predicted quantity of infected people with the expected response from its dynamic model that was obtained before (from the polynomial model). Hence, the algorithm *Least Mean Square* as subroutine was the tester of the error of the result.
Executing the algorithm, it was possible to understand the problem: the number of infected people continues to grow as it is shown by the red colour curve of Figure 4.

For this moment, in which it was achieved the last result of the algorithm execution, it is March 19, 2020. It means the letter *E* of Figure 4 depicts the quantity of infected people as 234, which is 89 more than the value in letter *D* (one day ago). Therefore, from the red curve is showed that the growth speed will continue until 440 infected people in the eighth quarantine day with the error of ±3, only whether data published that was registered by MINSA that keeps accuracy during the patients' tests.

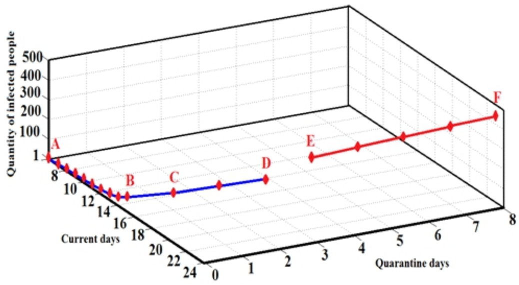

Figure 4. The curve of the quantity of infected people as the dependence on current days and quarantine days that were joined to the expected curve.

The information that is showed in Figure 4 was achieved during the middle of March 2020 (when in Peru there was not registered deceased people because of COVID-19). Figures 4 and 5 were obtained as a consequence of registered data from MINSA and the prediction result from the designed algorithm (until April 6, 2020). In figure 5 is depicted three internal figures due to analysing the real data that was published by MINSA, even though the real quantity of infected people is only from the people, who made the test (whether achieved infection or not). Therefore, to know the real quantity of infected people in the country is not simple, because the virus transmission can be given from people, who are asymptomatic or who did not make the infection test. However, for the analysis to proportionate in this research, it is used official data that was registered for MINSA.

In Figure 5*A*, it is depicted the curve (blue colour) of virus infection evaluated people (quantity) *E* and the curve (yellow colour) of no infected people, both curves are under the dependence of the total current days and quarantine days. It is possible to see that during last days (since the 10-quarantine day or the 25 current days) the quantity of non-infected people started to decrease more and more (more infected people were achieved).

In Figure 5*B*, it is showing the curve (green colour) of the quantity of infected people *I*, the curve (violet colour) - no deceased people quantity *Nd* and the curve (red colour) – the quantity of deceased people. It is possible to see that quantity of deceased people started to increase since the 3rd quarantine day.

In Figure 5*C*, it is showing the curve (red colour) of deceased people (expanded view from Figure 5*B)*.

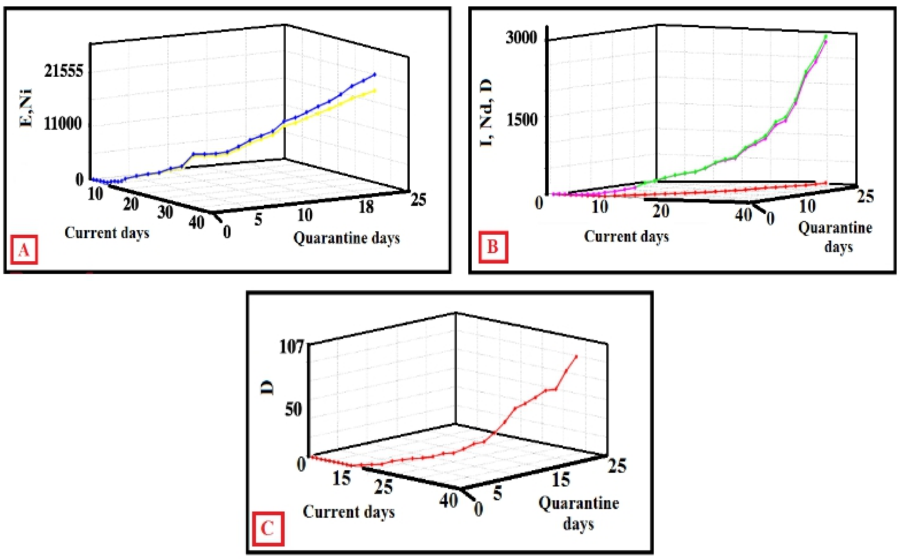

Figure 5. Curves of evaluated people, infected people, and deceased people for Peru, that were based on published data by MINSA.

In context to analyse an optimal prediction of the variables: the quantity of infected people and the quantity of deceased people, it was necessary to give as the reference information of the designed algorithm: the dynamic answer of China, Russia, Spain and Italy to deal with COVID-19 (this information is official and it was published by Health Ministry of these countries). In China it was reduced the number of infected people and the quantity of deceased people before the 100 day after infection started in this country. Therefore, the red colour curve in Figure 6 depicts dynamic of Peru, the blue colour curve depicts dynamic of Russia, the yellow colour curve depicts dynamic of Spain, the green colour curve depicts dynamic of Italy.

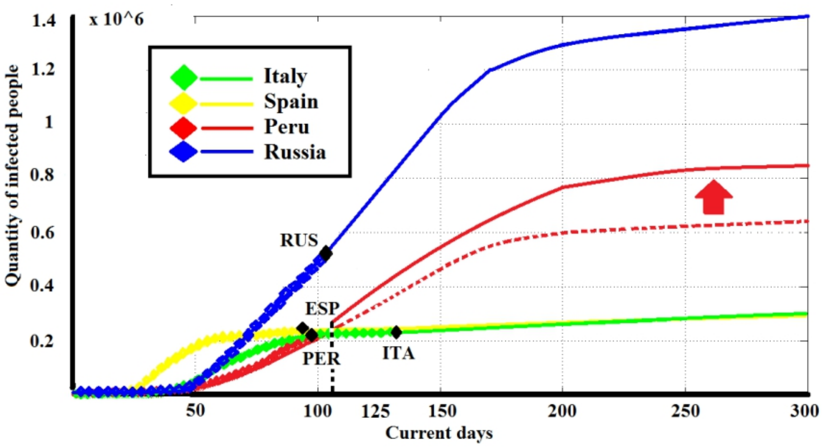

Figure 6. The curve of the quantity of infected people as the dependence on current days and quarantine days that were joined to the expected curve (Total stored amount).

This information was a reference variable to achieve the Dynamic Peruvian model (red colour curve) as it is showed in Figure 6. It was possible to get the prediction of the maximal quantity of infected people for every country from every letter indicated that was indicated in Figure 6 (*R, S, P, I*). It was correlated every curve that gives priority to the coefficient weights that was obtained from the countries data, which crossed the peak of their curves (such as China, Spain, and Italy). Therefore, the correlation of that dynamics in the main model helped to finish the estimation for all of them and to propose an optimal road for Spain, Italy, Russia and Peru.

The blue colour rhombus represents the number of the infected people since infection started in Russia until the infection day number 103, in which was achieved 485253 infected people approximately (the rhombus *R*). After to correlate this curve with the curves of other countries (Peru, Spain and Italy), it was obtained the estimation that was depicted by the blue colour curve (crossing 1400000 infected people until the day number 300). The red colour rhombus represents the number of the infected people since infection started in Peru until the infection day number 98, in which was achieved 203736 infected people approximately (the rhombus *P*). After to correlate this curve with the curves of other countries (Russia, Spain and Italy), it was obtained the estimation that was depicted by the red colour dotted curve (around 700000 infected people until the day number 300, while it is not stopped the quarantine days). The yellow colour rhombus represents the number of the infected people since infection started in Spain until the infection day number 109, in which was achieved 241966 infected people approximately (the rhombus *S*). After to correlate this curve with the curves of other countries (Russia, Peru and Italy), it was obtained the estimation that was depicted by the yellow colour curve (around 295000 infected people until the day number 300). The green colour rhombus represents the number of the infected people since infection started in Italy until the infection day number 133, in which was achieved 235561 infected people approximately (the rhombus *I*). After to correlate this curve with the curves of other countries (Russia, Peru and Spain), it was obtained the estimation that was depicted by the green colour curve (around 300000 infected people until the day number 300).

Notwithstanding, the quarantine time was stopped in Peru after 107 days and this effect caused that red colour dotted curve changed its dynamic to the expected red colour curve (showed in Figure 6). The reason, why the number of infected people increased, could be explained by social phenomena that was correlated with economic problems for the country. Therefore, the designed algorithm predicted this change by the result of the red colour curve.

By another side, there is another high quite important variable to keep in mind that is the quantity of deceased people as it is shown in Figure 7: the red colour is for Peru, the blue colour is for Russia, the green colour is for Italy, the yellow colour is for Spain.

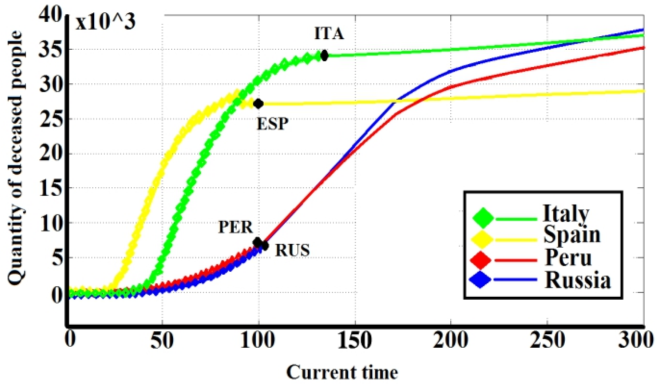

Figure 7. The curve of the quantity of deceased people as the dependence on current days and quarantine days that were joined to the expected curve.

The estimation can give the information to achieve steady-state of the quantity of infected people and deceased people, more or less since the 100 days of the current days. Notwithstanding, it must to be clear that this prediction could get good accuracy only whether Peruvian government takes in control variables as Chinese government did (to deal with the virus). Italy, Spain and Russia are doing this (to deal with the virus) as for example, to store people inside homes in a strict way and medical parameters for patients and population. But the dynamic of Peru is not the same as the dynamic of China due to many variables based in the economy, population, behaviour of people etc. That is the reason, why it is very important to study dynamics from other countries too, in China it was achieved good result and there are countries that cannot get it yet. This is important to model the algorithm that was designed according to be prepared for different possibilities during next days, because to not make mistakes to care life of humans, even though to keep Peruvian population inside homes is dangerous for economic variables that means to correlate them in this research it needs next step.

The designed mathematical model takes as the reference variables the dynamic models from other countries owing to achieve adaptive coefficients matrices, which can reduce the error as the dependence of the main target: reduce virus transmission and quantity of deceased people. The blue colour rhombus represents the number of the deceased people since the infection started in Russia until the day number 103. Until that day, approximately 6142 infected people died (the rhombus *R*) after to correlate this curve with the curves of other countries (Italy, Peru and Spain), it was obtained the estimation that was depicted by the blue colour curve (around 38000 died people until the day number 300).

The red colour rhombus represents the number of the deceased people since the infection started in Peru until the day number 98. Until that day, approximately 5738 infected people died (the rhombus *P*) after to correlate this curve with the curves of other countries (Italy, Russia and Spain), it was obtained the estimation that was depicted by the red colour curve (around 35000 died people until the day number 300).

The yellow colour rhombus represents the number of the deceased people since the infection started in Spain until the day number 109. Until that day, approximately 27136 infected people died (the rhombus *S*) after to correlate this curve with the curves of other countries (Italy, Russia and Peru), it was obtained the estimation that was depicted by the yellow colour curve (around 29000 died people until the day number 300).

The green colour rhombus represents the number of the deceased people since the infection started in Italy until the day number 132. Until that day, approximately 33964 infected people died (the rhombus *S*) after to correlate this curve with the curves of other countries (Spain, Russia and Peru), it was obtained the estimation that as depicted by the green colour curve (around 37000 died people until the day number 300).

It is necessary to analyse that the designed algorithm estimated the effect of the increasing number of infected people as the consequence of the number of deceased people. Nevertheless, it is predicted that it cannot be a significant cause to make changes as it is shown in Figure 7.

DISCUSSION

It is proposed to study the dynamic of COVID-19 in every country as a polynomial model that can be correlated each other according to optimize prediction answers, there is no mathematical model that adapts to the predictions such as the number of infected people and the quantity of deceased people (Kruse & Alkhushayni, 2020; Kucharski *et al*., 2020; Marmarelis, 2020; Ping, 2020; Rustam *et al*., 2020; Trigger & Czerniawski, 2020; Wang *et al*., 2020; Yuankang *et al*., 2020). Hence, every adaptive coefficients of matrix can be translated as interchanging information between every country, regarding to share many details and steps that could deal with this pandemic. A good solution could be to impose radical procedures to the population as the dependence on researching immunity of people. However, humans are not predictive variables due to tests statistical methodologies that is the reason, why in this research it is proposed interchanging solutions between countries owing to this pandemic is a world task now.

It is suggested to increase analysis by many variables, such as the number of infected people by different regions in Peru. Moreover, it is necessary to compare curves with other countries results, which crossed COVID-19 or which are under this task too. The effect of external variables (population parameters) helps to foresee an economical effect in Peru, owing to the correlation among the economy and the health can warrant successful control in this epidemic situation.

It is expected to expand this research according to study the consequences of this pandemic, through correlating dynamics in economy, public health and education from many countries around the world dealing with this virus.

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