Technoarete Transactions on Advances in Computer Applications
Vol-1, Issue-1, March 2022
e-ISSN: 2583-3472

A Study of Control Theory Application in Controlling Covid-19

Rudra Bhanu Satpathy[1], J. Sunil Gavaskar[2]

[1] M. Tech, Electrical, Electronics and Communications Engineering, St. Peter's University Chennai.
[2] Assistant Professor, Lord Jegannath College of Engineering & Technology, Ramanathichenputhur
*Corresponding Author Email: [1]rudra@gmail.com

Abstract

The researcher has discussed the application of control theory that has contributed to control the pandemic situation of COVID-19. The researcher has shown the importance of applying the theory to control any situation such as a pandemic. The control theory application is used to give feedback for any issues which have been highly affected in global context. The researcher has shown the impact of the control theory application for controlling the COVID-19 pandemic situation.

Keywords

Control theory application, COVID-19, Infection.

INTRODUCTION

The research article will focus on the control theory for controlling the pandemic COVID-19. The control theory is useful for feedback and also it has many applications in ***computer engineering, operation research, sociology*** and also ***life science***. The theory gives an essential feature to relationships between society and individuals. This is an important theory that has capability to control spread of the virus. The control theory will be discussed at length to understand its effective application within the study.

Rationale

In the whole world, COVID-19 has spread quickly and spread in all the countries day-by-day. Now-a-days, the number of COVID cases are increasing and spreading and there is no prevention to control the disease. All over the world, scientists, epidemiologists, and others have thought about the prevention method of the disease. The situation is vulnerable and deployment of different types of vaccine has been far-sighted.

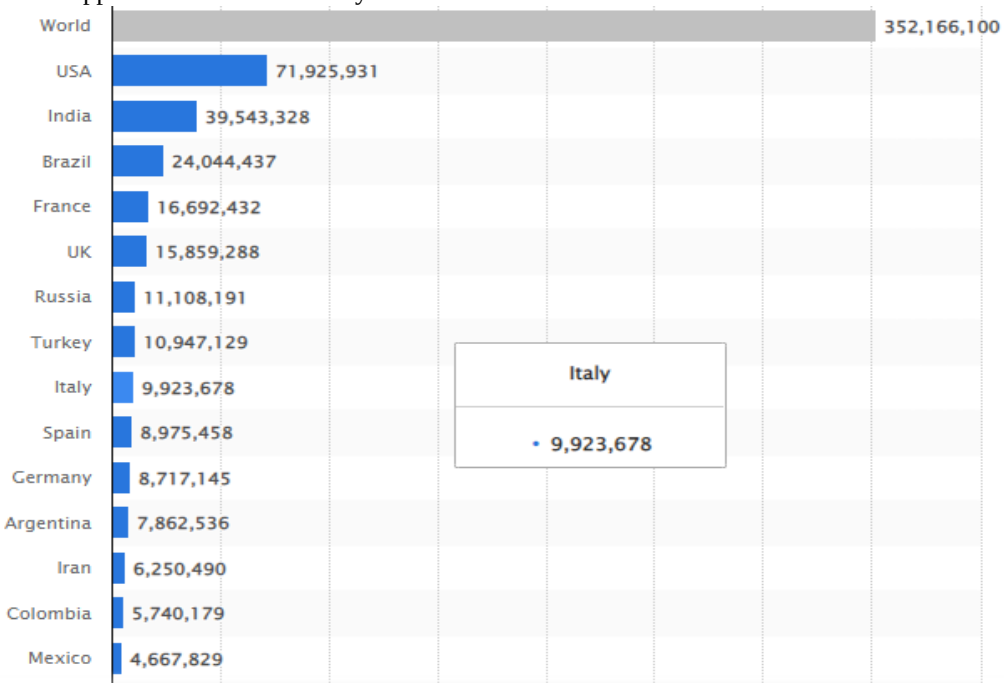

Figure 1: Worldwide COVID-19 cases, by country [10]

The above image shows that the day-by-day number of COVID-19 cases are increasing. The highest number of COVID cases has happened in USA and the amount of coronavirus cases are increasing and the number of COVID cases are 71,925,931 [10]. In the world, India has placed second position, the number of COVID cases are 39,543,328.

e-ISSN: 2583-3472

In the wake of such rising cases of Covid19, there is a need to apply certain mathematical models.

Aim and objectives

In this research study evaluates the application of control theory in COVID-19. The research objectives will be as follows:

- To understand the concept of control theory application
- To evaluate the impact of the application of control theory for controlling situation of COVID-19
- To analyse the application of the theory on COVID-19

LITERATURE REVIEW

Concept of control theory application

In the present-day context, control theory is playing an important role that gives a systematic approach to creating and equipping responses. As per the view of [11], the theory deals with the ***dynamic systems behaviour***, when a controller ***controls the system input for obtaining the effect on the system's output***. The control theory's main goal is to evaluate and achieve optimality for controlling any issues such as COVID-19 controlling. The important branch of applied mathematics is control theory that is dealing through the feedback to achieve a goal. The theory has dealt with mathematical models such as graphs and equations, but the theory has not dealt with physical reality directly. The principles of the theory are ***values, norms, beliefs, commitments*** and also ***individual's relationship***.

Impact of control theory upon COVID-19 control

During the COVID-19 pandemic situation, control theory has helped individuals to control COVID-19. The pandemic situation has been efficiently and effectively established by applying the control theory's principle. In the global context, during the pandemic time, epidemiologists and others have done important work to overcome the crisis. The individuals have ***investigated how the work's feedback can help diminish and stabilise the propagation rate of this virus*** that now plagues individuals. [8], opined that in the pandemic time, the process of physical distancing is highly needed for the society of the affected countries. The physical distancing has played an important role in the perspective of control theory, that are the most significant criteria during that time.

The main purpose of control theory is to influence the behaviours within people systematically. For example, a regular within a steam engine induces a control mechanism. Similarly, it is through feedback on Covid19, the situation can be controlled. Globally, individuals have contributed importantly to the efforts of the ground internationally to manage the outbreak of the spreaded virus. [9], stated that the disease COVID-19 has spread randomly in the whole world. For the deep knowledge of control theory, individuals have designed many rules and regulations through the help of the viewpoint of ***control-engineering***, however the policymakers, epidemiologists and others have extra knowledge for control theory. The control theory's principles such as feedback, has helped the plot for officials, when the individuals attempt to relate with the damaging COVID-19 pandemic.

Application of control theory over COVID-19

$$N(t) = S(t) + E(t) + Q(t) + I(t) + J(t) + R(t).$$

Figure 2: Analysis through control theory[7]

The deterministic model for COVID-19 is presented in this part of the study. According to [7] the model formulation has been used to extend the COVID-19 control process. The above formula shows that the ***total population*** has been indicated as ***N (t)***, where ***t*** is also divided into two parts, such as ***S(t) or "susceptible*** along with ***E(t) or exposed***. ***Q(t)*** denotes ***quarantined***, ***I(t)*** denote "***infection not hospitalised"***, ***J(t)*** specifies ***isolated infections*** and on the other hand, ***R(t)*** denotes the ***term of recovery***.[7] Through the help of this formula, the researcher has known the total number of COVID affected people in a country or a particular area. [7] It is through this formula, a number of individuals affected by Covid19 can be found to control it through the help of this theory practically.

$$\Psi = \frac{\beta\left(I + \varepsilon_1 E + \varepsilon_2 Q + \varepsilon_3 J\right)}{N},$$

Figure 3: Control theory to determine quarantined and non-quarantined people [7]

The above formula shows the various modification factors for quarantined, isolated individuals and exposure. The above parameters such as ***e2*** and ***e3*** are included with the consciousness of the time of the time of isolated and quarantined individuals. The E(t) signifies the total population by the help of infection which was induced by the highly affected disease COVID-19. The element of ***p*** rate denotes the ignorance of being quarantined. It can be found from the formula how many people are quarantined and how many people are not within a country. The formula's element ***d2*** also denotes the death-induced rate of the mentioned disease. Therefore, people who died of Covid19 can also be found from this particular formula to further control the situation.

MATERIALS AND METHOD

Through the help of control theory application, many countries of the world have controlled the spread of COVID-19. In this research study, the researcher has used various types of open data sources with COVID-19 information. The data sources of COVID-19 have been collected through some methods such as ***proactive testing, confirmed cases, individual data,*** and ***contact-tracing***. ***Pro-active testing*** is a process of controlling the infectious

e-ISSN: 2583-3472

disease based on some approaches such as ***risk, voucher,*** and ***studies of serology (RT-PCR)*** [1]. ***Confirmed cases*** are the important indicator to understand the increase or decrease rate of COVID-19.

	Source	GitHub repositories
Argentina	Ministry of Health	Covid19arData
Australia	Australian Health Department	covid-19-au
China	China National Health Commission	JHU, Midas-China
France	Public France Health System	opencovid19-fr
Germany	Robert Koch Institute	covid-19-germany-gae
Iceland	Government of Iceland	gaui-covid19
Italy	Italian Civil Protection Department	pcm-dpc
Paraguay	Ministry of Public Health and Soc. Welfare	covidpy-rest
South Africa	National Inst. Communicable Diseases	covid19za
South Korea	Centers for Disease Control and Prevention	COVID19-Korea
Spain	Ministry of Health	datadista-Covid-19
United Kingdom	Pubic Health England	covid-19-uk-data
United States	Centers for Disease Control and Prevention	JHU, Nytimes

Figure 4: Data resources of regional COVID-19 [1]

The above image has shown the different countries COVID-19 data resources of open data sets. Some socio-economic indicators such as ***mobility, social networks, internet search*** and online questionnaires play an important role to show various types of data source of COVID-19. ***Mobility*** refers to reports of community dynamics and changes in the type of mobility [4]. In this research article, the researcher has used various types of data sources that collected the individual data of the COVID-19's impact. The best social indicator is internet search through some apps such as ***Facebook*** and also ***Twitter***. In Argentina, the COVID data sources have been collected from the Ministry of Health, where the GitHub repository is Covid19ar Data. On the other hand, various countries such as France, Spain, United Kingdom, France have published their COVID-19 data or other information on "Public France Health System", "Ministry of Health" and others.

FINDINGS AND DISCUSSION

Estimation of pandemic situation

The control of COVID-19 situation has required looking at the important indicators and also the prevalence of the disease in the total population. The decision-making process of COVID-19 is looking or monitoring the situation. The process has provided many fundamental information to decide the restrictions and measurement of strength [5]. The process of estimation is obstructed through the COVID-19 incubation period. The process has introduced a time-delay among the virus infection and its potential detection. The other problem is the infectious asymptomatic population that has played an important role as a transmission vector difficult to detect. All of these motivate the deployment of the estimation methodologies and surveillance capable of using the information to enable the adjustment of different measurements of control COVID-19. In this part, the researcher has covered the important techniques to look out for the COVID situation and also has focused on the approaches such as epidemiology of real-time, pro-active testing, methods of state space estimation and surveillance of the epidemic wave. ***Epidemiology of real-time:*** Real-time epidemiology of COVID-19 can be of different origin and nature such as social-media data, mobile phone data, public health system and information of technology (IOT) data. The mobile phone data has represented a difficult arsenal for supporting the actions of public health of the different phases of the pandemic situation. In the present-day context, Big Data technologies and Geographic Information Systems (GIS) are important tools to access the real-time information of the situation.

Pro-active testing: The most essential technique is proactive testing to control the infectious disease COVID-19. The process is a relevant source of information to identify the immunology response level, risk zones, asymptomatic carrier percentage in the population [3]. The individuals of suspected COVID-19 are tested, and this denotes testing not only the individuals of symptoms but also the other individuals that are exposed. In the process of RT-PCR tests, it also detects past infection inability.

Estimation of state space: The models of epidemiological state-pace have played an important role in understanding the region of spread virus [3]. The methodology is important to the parameters inference and also problem estimation which evaluates the model.

Surveillance of epidemic wave: The system of epidemic wave surveillance enables an immediate response which has reduced the various potential burdens of the disease outbreak.

Difference between application of control theory during epidemic and pandemic-325

Optimal control is the technique of state trajectories and determining control for a dynamic system to minimise a performance index over a time period [3]. The theory has applied to reduce in a way change of an epidemic situation. The control theory has provided various methods for solving the problems in the continuous time. The researcher has presented a formulation of a dynamical optimization problem.

e-ISSN: 2583-3472

$$\begin{aligned}
\min_{x(\cdot),u(\cdot)} \quad & S(x(T),T) + \int_0^T F(x(T),u(t),t)dt \\
s.t. \quad & x(0) = x_0, \\
& \dot{x} = f(x(t),u(t),t), \\
& g(x(t),u(t),t) \geq 0, \\
& h(x(t),t) \geq 0, \\
& a(x(T),T) \geq 0, \\
& b(x(T),T) = 0.
\end{aligned}$$

Figure 5: Calculation for optimal control theory during epidemic [2]

The above calculation shows that x (t) has represented the pandemic's state at the time, u(t) has presented the control action that can be opined in a direct way such as recovery rate, immunologic protection, and infection rate. The other equation x (·) = f (·, ·, ·) has represented the model, constraint has allowed the researcher to incorporate constraints on x (·) and u (·), where the original constraint have been used to impose the limits based on the x (·) [2]. The principle has proved the essential conditions which characterise the optimal solution of inequality constraints presence.

$$\begin{cases}
\frac{dS(t)}{dt} = \Lambda_1 - (\mu + \theta_1)S(t) - \beta_1\frac{S(t)E(t)}{N} - \beta_2\frac{S(t)I(t)}{N} \\
\frac{dE(t)}{dt} = \beta_1\frac{S(t)E(t)}{N} + \beta_2\frac{S(t)I(t)}{N} - (\mu + \alpha_1 + \theta_2)E(t) \\
\frac{dI(t)}{dt} = \alpha_1 E(t) - (\alpha_2 + \theta_3 + \mu + \delta_1)I(t) \\
\frac{dR(t)}{dt} = \alpha_2 I(t) - \mu R(t) \\
\frac{dQ_T(t)}{dt} = \theta_1 S(t) + \theta_2 E(t) + \theta_3 I(t) - \mu Q_T(t)
\end{cases}$$

Figure 6: Calculation for optimal control theory during pandemic [6]

The above calculation has shown the graphical representation of COVID-19 mathematical model. In this calculation, the researcher has shown the different types of values, S (0) ≥ 0, E (0) ≥ 0, I (0) ≥ 0, R (0) ≥ 0 and QT (0) ≥ 0 are the initial states. μ denotes the natural mortality rate, β1 indicates the infected people through the contact infected without symptoms, β2 indicates the infected people by the contact with the infected symptoms. α1 denotes the people's rate who have infected normal symptoms and α2 indicates the recovered rate from the virus [6]. The above model described the spread of COVID-19 pandemic situation by the negative impact of applying quarantine total in the total population of a country.

CONCLUSION

The above article has shown the importance of control theory application for COVID-19 control. In this research study, the researcher has shown the usefulness of various theories such as optimal control theory and others. The researcher has evaluated the control theory application and also the global outlook regards the control of COVID-19.

REFERENCES

[1] Alamo, T., Reina, D.G. and Millán, P., 2020. Data-driven methods to monitor, model, forecast and control covid-19 pandemic: Leveraging data science, epidemiology and control theory. arXiv preprint arXiv:2006.01731.

[2] Alamo, T., Reina, D.G. and Millán, P., 2020. Data-driven methods to monitor, model, forecast and control covid-19 pandemic: Leveraging data science, epidemiology and control theory. arXiv preprint arXiv:2006.01731.

[3] Baker, M.G., Gurney, J., Oliver, J., Moreland, N.J., Williamson, D.A., Pierse, N., Wilson, N., Merriman, T.R., Percival, T., Murray, C. and Jackson, C., 2019. Risk factors for acute rheumatic fever: literature review and protocol for a case-control study in New Zealand. International journal of environmental research and public health, 16(22), p.4515.

[4] Gabelica, V., Shvartsburg, A.A., Afonso, C., Barran, P., Benesch, J.L., Bleiholder, C., Bowers, M.T., Bilbao, A., Bush, M.F., Campbell, J.L. and Campuzano, I.D., 2019. Recommendations for reporting ion mobility Mass Spectrometry measurements. Mass spectrometry reviews, 38(3), pp.291-320.

[5] Garg, H. and Kumar, K., 2018. An advanced study on the similarity measures of intuitionistic fuzzy sets based on the set pair analysis theory and their application in decision making. Soft Computing, 22(15), pp.4959-4970.

[6] Kouidere, A., Youssoufi, L.E., Ferjouchia, H., Balatif, O. and Rachik, M., 2021. Optimal Control of Mathematical modeling of the spread of the COVID-19 pandemic with highlighting the negative impact of quarantine on diabetics people with Cost-effectiveness. Chaos, Solitons & Fractals, 145, p.110777.

[7] Madubueze, C.E., Dachollom, S. and Onwubuya, I.O., 2020. Controlling the spread of COVID-19: optimal control analysis. Computational and Mathematical methods in Medicine, 2020.

[8] Pfattheicher, S., Nockur, L., Böhm, R., Sassenrath, C. and Petersen, M.B., 2020. The emotional path to action: Empathy promotes physical distancing and wearing of face masks during the COVID-19 pandemic. Psychological Science, 31(11), pp.1363-1373.

[9] Pikkarainen, M., Gomes, J.F., Ranta, J., Ylén, P., Iivari, M. and Hurmelinna-Laukkanen, P., 2020. Network Orchestration and System Dynamics Modeling in Developing Innovative Decision Support Systems for Policy Makers. In Managing Digital Open Innovation (pp. 177-198).

[10] Statista.com, 2022. *Number of coronavirus (COVID-19) cases worldwide as of January 24, 2022, by country*. Available at:< https://www.statista.com/statistics/1043366/novel-coronavirus-2019ncov-cases-worldwide-by-country/#statisticContainer>[Accessed on 15th January, 2022]

[11] Zhu, Q., Zhang, W., Zhang, J. and Sun, B., 2019. U-neural network-enhanced control of nonlinear dynamic systems. Neurocomputing, 352, pp.12-21.