RESEARCH ARTICLE

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Model Formulation and Comparative Analysis of Daily Confirmed Cases due to Novel Coronavirus (COVID-19) pandemic 2020

M. R. Phate[1]*, Vikas R. Phate[2], Shraddha B. Toney[3]

[1]Department of Mechanical Engineering, All India Shri Shivaji Memorial Society's College of Engineering, Pune, Maharashtra, India, 411001

[2]Department of Electronics, and Telecommunication Engineering, Government Polytechnic, Amravati, Maharashtra, India, 444603.

[3]Department of Computer Engineering, Sinhgad Institute of Technology and Science, Narhe, Pune, Maharashtra, India, 411048

Abstract

The world health organization (WHO) situation report dated January 21, 2020, highlighted the spread of unknown causes detected in Wuhan city, Hubei Province, China, which was subsequently notified as COVID-19. In 2 months, this virus has shown its atrocious destructive nature worldwide like a pandemic. The infection rate and the death rate have increased tremendously day by day. WHO reported the number of confirmed cases as of May 3, 2020, was around three million three hundred forty-nine thousand seven hundred and eighty-sixed while the total deaths all over the world were two hundred thirty-eight thousand six hundred and twenty-eight. In the present work, the mathematical modeling of the daily reported COVID-19 cases in the country viz. Italy, Spain, the United States of America (USA), China, and India have been presented. Using different statistical techniques, the models have been formulated based on data reported in the WHO situation report 1-103 from January 21 to May 3. Three types of models, viz. polynomial, Gaussian, and Fourier, have been developed, and the best-fitted model can be used to predict the future trends of the new COVID-19 cases based on the current situation. The comparative analysis has been done, and the nature of the COVID-19 pandemic has been presented in the form mathematical model. The future prediction of new affected cases can be made with the help of these models. This paper also presented how different countries are fighting against this pandemic with the great challenge of protecting a huge population.

Keywords: COVID-19, MERS, SARS, WHO.

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Introduction

COVID-19, severe acute respiratory syndrome (SARS) and the Middle East respiratory syndrome (MERS), is caused by a beta coronavirus named SARS-CoV-2 that influences the lower respiratory tract and manifests as pneumonia in humans. China started the development of COVID-19 diagnostic kits in their country on January 12, 2020. The Republic of Korea detected the first imported case on January 20, 2020. Italy identified the first imported case on January 31, 2020. Similarly, the United States of America (USA) detected the first COVID-19 case on January 24, 2020. Spain and France joined the SARS-CoV-2 pandemic-affected countries on February 13, 2020. According to the WHO report dated January 30, 2020, India has reported first (travel history to Wuhan city) confirmed case of COVID-19 along with Finland and the Philippines.

As of January 21, 2020, WHO Situation report 1, 282 confirmed cases had been detected globally, which consists of China-Hubei province (258), China-Guangdong (14), China-Beijing Municipality (05), China-Shanghai Municipality (01); Four confirmed cases were detected outside the china, i.e., Japan (01), Republic of Korea(02) and Thailand (02). The spread of the COVID-19 has drastically affected the entire world.[1] On April 30 2020, WHO reported the number of COVID-19 confirmed cases globally was 3,090,445, with a number of deaths 217,769. European region (1,434,649 confirmed and

Corresponding Author: M. R. Phate, Mechanical Engg. Dept, All India Shri Shivaji Memorial Society's College of Engineering, Pune, Maharashtra, India, 411001, e-mail: mangeshphate03@gmail.com

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135,961 deaths), Region of the Americas (1,246,190 confirmed and 65,228 deaths), Eastern Mediterranean region. (182,417 confirmed and 7,447 deaths), Western Pacific region (147,743 confirmed and 6.094 deaths), South- East Asia region (54,021 confirmed and 2,088 deaths) and African region (24,713 confirmed and 938 deaths).[2] On 03 may 2020, WHO reported the number of COVID-19 confirmed cases globally were 3,349,786 with a number of deaths 238,628. European region (1,518,895 confirmed and 142,667 deaths), Region of the Americas (1,384,641 confirmed and 78,409 deaths), Eastern Mediterranean region. (200,609 confirmed and 7,871 deaths), Western Pacific region (151,444 confirmed and 6.229 deaths), South- East Asia region (64,047 confirmed and 2,375 deaths) and African region (29,438 confirmed and 1064 deaths).[3]

Samuel A. S. and Phebe A. O. have investigated the spread and impact of COVID-19 in the various states of China. A linear model to correlate the number of deaths and the confirmed cases have been developed. The model will help predict the future trend of COVID -19 human-to-human transmission.[4] An outbreak of COVID-19 starts and hits most of China's cities and then spreads worldwide. The researchers estimated the impact from January 10, 2020, to January 24, 2020, on basic reproduction numbers (Ro).[5] The transmission mechanism between human-to-human and the spread of COVID-19 has been examined along with the various symptoms of COVID-19. The impact of quarantine on the spread of this disease also has been discussed in detail at the early stage in China.[6] Researchers compared the mortality per million of the population and the causes of the SARS-CoV-2 spread in the human-to-human transmission.[7] The researcher made a hypothesis that COVID-19, the disease, has been caused by the novel SARS-CoV-2. The hypothesis has been evaluated based on some analysis.[8] Some researchers carried out the genetic analysis and revealed many deaths to provide evidence of the genetic diversity in the infections.[9] The researcher used the data set available through world meter, and statistical analysis was carried out to know the impact of COVID-19 up to April 15, 2020, on the entire population in the world.[10]

Material and Method

Data Source

In December 2019, WHO declared COVID-19 as a novel coronavirus, a respiratory disease similar to respiratory syndrome coronavirus SARA-CoV. The virus rapidly spreads all over the world. The presented work aims to compare and analyze the daily reported new cases of some majorly affected countries viz. Spain, Italy, India, China, and the USA. The mathematical models using polynomial, Fourier, and gaussian techniques were developed, and the best fit model was considered for the future prediction of daily confirmed cases for the respective countries. The data collected between January 21 to May 3, 2020, from Worldometer (https://www.worldometers.info/coronavirus/) and the WHO COVID-19 daily situation reports (https://www.who.int/docs/default-source/coronaviruse/situation-reports) was used for the model formulation

Model Formulation

In the current pandemic situation, policymakers need to implement them effectively to minimize the infection rate and death rate. In line with this, the work presents mathematical models to know the trend of new daily affected cases for studying the effective tenure of this pandemic. Three mathematical models were developed for each country mentioned above using polynomial, Fourier, and gaussian techniques using Matlab2019b curve fitting toolbox. The best fit model amongst these was recommended for predicting the future trend of the new affected cases of COVID-19.

Results and Discussion

The country-wise models studied and the best-fitted model with a high correlation coefficient (R^2) and less root mean square error (RMSE) has been shown in Table 1.

Fourier, polynomial, and Gaussian models have been developed for each country. The India Fourier model shows the best performance in forecasting the possibility of new affected cases with less RMSE and high R^2 value. The best-fitted curve and its 95% confidence interval are shown in Figure 1. Only two points out of sixty-four days from March 1 to May 3, 2020, have been observed out of bound. The best-fitted mathematical model is shown in Eq. 1.

$$Covid19_{Cases} = 2827 - 2727 \times \cos(0.02539 \times Day) - 883.9 \times \sin(0.02539 \times Day) \quad ...(1)$$

Similarly, the Fourier model shows the best forecasting ability to predict new affected instances in Italy. The best-fitted curve and its 95% confidence interval is shown in Figure 2. Only five points out of seventy-two days from February 22 to May 3, 2020, have been observed out of bound. The best-fitted mathematical model is shown in Eq. 2.

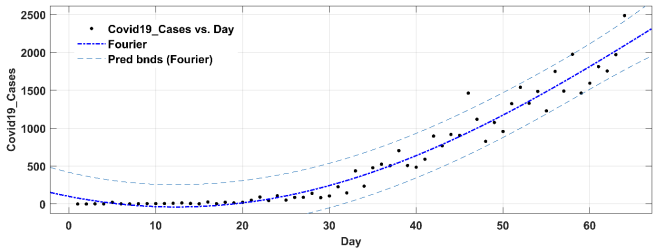

Figure 1: Fourier curve for daily COVID-19 cases in India

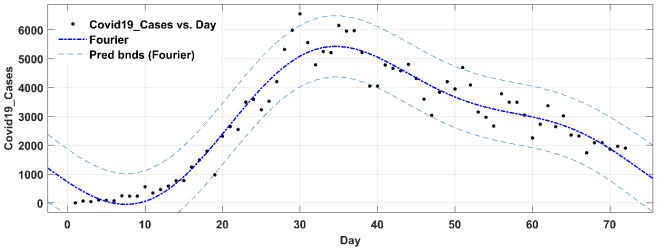

Figure 2: Fourier curve for daily COVID-19 cases in Italy

Table 1: Model formulated for COVID-19 death in various countries

Country	*Model*	*SSE*	*R^2*	*Adjusted R^2*	*RMSE*	*D*
	Fourier	1243000	0.9572	0.9551	143.9	60
India	Polynomial	1227000	0.9578	0.9549	144.2	59
	Gaussian	1316000	0.9547	0.9532	146.9	61
	Fourier	17490000	0.9256	0.92	514.8	66
Italy	Polynomial	28370000	0.8794	0.8721	650.7	67
	Gaussian	20590000	0.9124	0.9058	558.6	66
	Fourier	1007000000	0.9246	0.9212	3849	68
USA	Polynomial	1122000000	0.916	0.911	4092	67
	Gaussian	602000000	0.9549	0.9515	3020	66
	Fourier	7700000	0.921	0.9165	294.1	89
China	Polynomial	10090000	0.8964	0.8918	334.8	90
	Gaussian	3173000	0.9674	0.9656	188.8	89
	Fourier	108000000	0.7888	0.7787	1309	63
Spain	Polynomial	100700000	0.8031	0.7904	1274	62
	Gaussian	56090000	0.8903	0.8813	958.9	61

$$Covid19_{Cases} = 2803 - 2262 \times \cos(0.08242 \times Day) - 521.1 \times \sin(0.08242 \times Day) + 190.8 \times \cos(2 \times 0.08242 \times Day) - 811.3 \times \sin(2 \times 0.08242 \times Day)$$

...(2)

After that for country viz. USA, China, and Spain's gaussian models show a high predicting ability compared with rest two types of models. The best-fitted curve and its 95% confidence interval are shown in Figure 3-5, respectively.

Only four points out of the last seventy-two days in the USA from February 22 to May 3, 2020, have been observed out of bound. The best-fitted mathematical model is shown in Eq. 3.

$$Covid19_{Cases} = 27950 \times e^{-\left(\frac{(Day-68.42)}{14.39}\right)^2} + 28330 \times e^{-\left(\frac{(Day-46.13)}{12.54}\right)^2}$$

...(3)

Similarly, out of the last ninety-three days in China from February 1 to May 3, 2020, only five points were observed out of bounds. The best-fitted mathematical model is shown in Eq. 4.

$$Covid19_{Cases} = 1608 \times e^{-\left(\frac{(Day-5.488)}{4.348}\right)^2} + 2117 \times e^{-\left(\frac{(Day-8.6)}{13.92}\right)^2}$$

...(4)

Lastly, only three points have been observed out of bound for the last sixty-seven days in Spain from February 27 to May 3, 2020. The best-fitted mathematical model is shown in Eq. 5.

$$Covid19_{Cases} = -15800 \times e^{-\left(\frac{(Day-43.28)}{10.51}\right)^2} + 20980 \times e^{-\left(\frac{(Day-41.85)}{14.12}\right)^2}$$

...(5)

The statistical data per one million population and the test conducted by these affected countries is shown in Table 2.

Table 2 shows the overall COVID-19 pandemics statistics to know the severity of its impact on the entire world. The deaths per million of the population is very seriously increased in Spain, Italy, France followed by the USA compared with India and China. As of May 03, 2020, deaths per million are only 1 per million in India and 3 per million in China. At the same time, it has been noted as 553 in Spain,

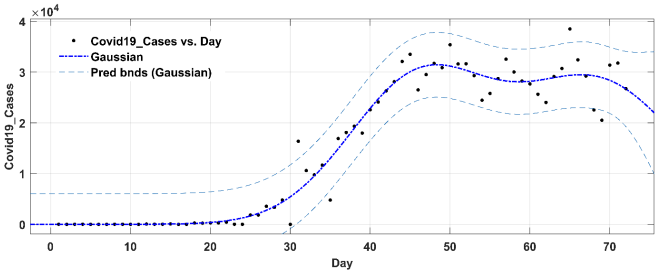

Figure 3: Gaussian curve for daily COVID-19 cases in USA

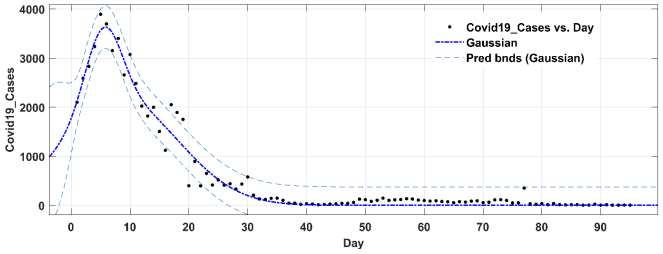

Figure 4: Gaussian curve for daily COVID-19 cases in China

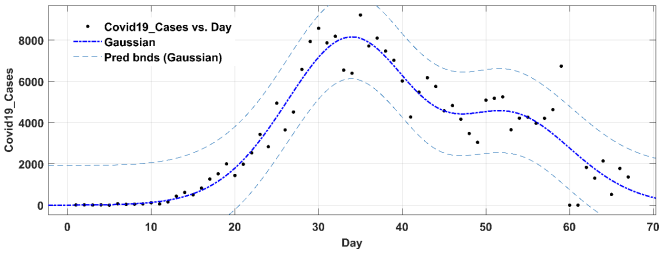

Figure 5: Gaussian curve for daily COVID-19 cases in Spain

Table 2: Country-wise statistics of a fight against COVID-19

Country	*Total recovered*	*Total Cases per one Million population*	*Death per one million population*	*Total Test*	*Test per one million population*
Spain	159359	5426	553	1932455	41332
Italy	85231	3523	485	2246666	37158
France	52736	2613	391	1100228	16856
India	14183	36	1	1276781	925
USA	201011	3742	218	7728605	23349
China	77911	58	3	-	-

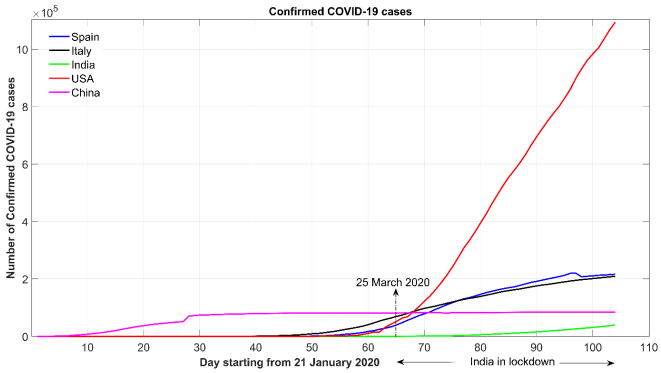

Figure 6: Comparative trend of confirmed cases in COVID-19 pandemic 2020

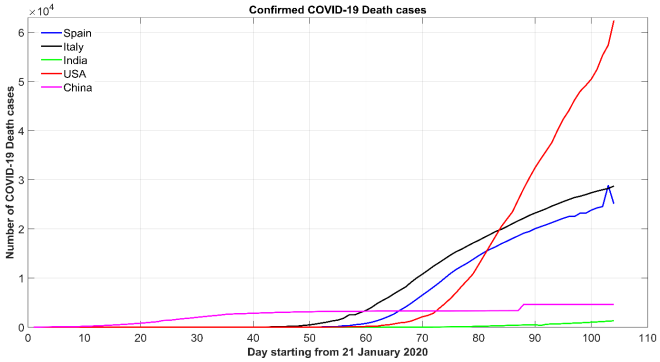

Figure 7: Comparative trend of deaths in COVID-19 pandemic 2020

485 in Italy, 391 in France 218 in UAS. While test per million has been noted more in Spain followed by Italy, USA and France compared with India.

From Figure 6, it is clear that the number of cases in Spain, Italy, USA, and Iran is very large compared with India and China. Figures 6 and 7 show the spread of COVID-19 positive cases and the number of deaths detected from January 21, 2020, to May 3, 2020. The outbreak spread of COVID-19 shows that the number of confirmed cases and deaths is very high in the USA, followed by Spain, Italy, France, China, and India. There has been an initial rise in confirmed cases in China for the first 34 days (February 24, 2020, Starting from January 21, 2020). A stability has been observed, which shows the control over the growth rate COVID-19 confirmed cases. On March 25, 2020 (65th day) number of confirmed cases and death in Spain was 39,673 and 2,696 (Death percentage 6.79%). Italy noted 69,176 new cases and death 6,820 (death percentage 9.85%). France noted 22,025 and 1100 death (Death percentage 4.99%), USA noted 51,914 new cases and 673 death (Death percentage 1.29%), India noted 562 new cases and death of 9 (Death percentage 1.60 %) while China noted 81,848 new cases with the death of 3,287 (Death percentage 4.01%).

The rate of confirmed cases and the death rate on April 15, 2020 (86th day) has an increasing trend. The number of confirmed cases and deaths in Spain was 172,541 and 18,056 (10.46%). Italy noted 162,488 new cases and death 21,069 (death percentage 12.96%). France noted 102,533 and 15708 death (Death percentage 15.31%), USA noted 578,268 new cases and 23,476 death (Death percentage 4.05%), India noted 11,439 new cases and death of 377 (Death percentage 3.29 %) while China noted 83,745 new cases with the death of 3,352 (Death percentage 4.21%).

The rate of confirmed cases and the rate of death rate on April 30, 2020 (101st day) drastically increased. The number of confirmed cases and deaths in Spain was 212,947 and 24,272 (11.39%). Italy noted 203,591 new cases and death 27,682 (death percentage 13.59%). France noted 127,066 and 24,054 death (Death percentage 18.93%), USA 1,003,974 new cases and 52,438 death (Death percentage 5.22%), India noted 33,050 new cases and death of 1074 (Death percentage 3.24 %) while China noted 84,373 new cases with the death of 4,643 (Death percentage 5.50%).

Conclusion

The presented work is based on the available statistical data and basic mathematics and science. We have developed some mathematical models for the available realistic data. The models have demonstrated the growth of confirmed COVID-19 affected cases in various countries which follows a nonlinear nature. The outcome of the work is based on the past available data, but the estimated trends from the formulated models may vary in the future from the realistic data. Keeping because of this reality, we tried to provide the best results to predict the trends of confirmed cases which will be helpful to the policymaker to change the future strategy and strengthen the fight against the COVID-19 pandemic. The outbreak of COVID-19 was worst and worst in the USA, Italy, Spain, and France compared to China and India.

The experimental finding will be helpful in taking corrective actions and implementation of the strategies such as social distancing, travel restrictions, zone and ward identification, restriction on social programs, etc. The most important is to create awareness among the people's responsibilities through the continuous dialogues between the authorities and the country's people. With this work, we have tried to contribute little in the fight against this outbreak of COVID-19.

Declarations

All Authors have contributed to this paper in data collection, models formulation, interpretation of results, and writing the entire paper.

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