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ANALYSIS OF THE DYNAMICS OF CORONAVIRUS INFECTION IN AZERBAIJAN BY THE METHOD OF SYNERGETIC INFORMATION THEORY

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Abstract. This paper has two main objectives: the study of the dynamics of coronavirus infection in Azerbaijan from March 14 to July 11, 2020; to propose a methodology for predicting the incidence rate for the next month up to August 11, 2020. The description and forecasting problems are proposed to be solved on the basis of the theory of synergetic information using entropy.

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1 Introduction

The method of the synergetic theory of information used in recent years is finding an ever-wider scope of application (Haken, 1980). This theory helps to solve new cognitive problems, both theoretical and applied, inaccessible to the traditional theory of information (Likhachev, 1996; Budanov, 1998; Koblyakov, 2000).

As is known, restrictive measures have been taken in large cities of Azerbaijan due to the situation with coronavirus infection. People are forbidden to leave the house, it is recommended, if possible, to be in a separate room. Actually isolation mode has been introduced.

Let us turn to the second law of thermodynamics, according to which entropy cannot decrease in the isolated system (usually it increases). In other words, if at some point in time the closed-loop system is in the non-equilibrium macroscopic state (minimum entropy, full regularity), then at subsequent times the most likely consequence will be a monotonic increase in its entropy (to maximum entropy, complete chaos) until the equilibrium (heat death) state is reached. In this state of equilibrium, no macroscopic processes in a closed system are possible. Along with the increase in entropy and uncertainty of the system the probability of making the wrong decision also increases (Rebane, 1984; Haken, 1985).

In order to reduce the uncertainty of the system, it is necessary to introduce ordering into it and reduce the entropy. To do this, the system must get an external influence. If the isolated systems do not receive additional energy, they cannot be in the non-equilibrium state for a long time Prigogine & Stengers (1985).

Last year we meet a number of published papers have been devoted to the mathematical modeling of the different aspects of infection dynamics (Chen et al., 2020; Yang & Wang, 2020; Naghiyev, 2006).

By the method of combining a mathematical model of severe SARS-CoV-2 transmission with four datasets from within and outside Wuhan, in Kucharski et al. (2020) estimated how

transmission in Wuhan varied between December 2019, and February 2020. Used these estimates to assess the potential for sustained human-to-human transmission to occur in locations outside Wuhan if cases were introduced.

In Liang (2020) is to reveal the spread rules of the three pneumonia: COVID-19, SARS, and MERS. The new spread characteristics of COVID-19 with those of SARS and MERS are compared. By considering the growth rate and inhibition constant of infectious diseases, their propagation growth model is established. The parameters of the three coronavirus transmission growth models are obtained by the nonlinear fitting.

In contrast to Kucharski et al. (2020); Liang (2020), in this article it is preferred to use a system method for analyzing the spread of the virus.

People quarantined in their apartments (both infected with the virus and healthy) are an isolated system. Of course, not all citizens comply with the quarantine regime. Leaving their home people leads to the violation of the self-isolation procedure and, as a result, the spread of diseases caused by a coronavirus. This entails a change in the entropy (organization) of the system. In this case, entropy can be a measure of the disorganization of the system from complete chaos (maximum entropy) to full regularity (minimum entropy) and vice versa.

Entropy for independent random events ϕ_i with Npossible states distributed with probabilities p_i $(i = 1, 2, 3..., N)$ is calculated by the Shannon formula: $I = -\sum_{i=1}^{N_{gr}} p_i \log_2 p_i$bits.

Obviously, absolute chaos in the systems does not exist. All existing real systems have a less or more noticeable order in the structure.

The more the system has orderliness in its structure, the more it moves away from the equilibrium state. On the other hand, non-equilibrium systems tend to move toward the thermodynamic equilibrium, i.e. increase their entropy. If they do not receive additional energy, then they cannot be in the nonequilibrium state for a long time.

The non-equilibrium of the systems plays a significant role in their information exchange. The greater the non-equilibrium, the greater their sensitivity and ability to receive information and the greater the possibility of self-development of the system (Nikolis & Prigogine, 1979).

In Nagiyev (2005); Mirzadjanzadeh et al. (2006a,b), the system analysis method was applied to the problems of petroleum mechanics. In Naghiyev (2006), this technique was applied to study the tendency toward global warming. Here we consider the use of this technique in the analysis and prediction of the incidence of coronavirus in Azerbaijan.

The table below contains daily data on the number of infected people for periods of time from March 14 to April 12, April 13 to May 12, May 13 to June 11 and June 12 to July 11.

Fig. 1 below shows a graph of the number of daily coronaviruses infected in Azerbaijan over the period from March 14 to July 16.

We made the necessary calculations and the entropy values were found to be equal respectively for the time intervals March 14 - April 12 as 2.227877968; April 13 - May 12 as 1.9114078; May 13 - June 11 as 2,33112297, June 12- July 11 as 2.1423674 (see Fig.1).

The dynamics of the entropy of the number of coronaviruses infected in Azerbaijan over the period from March 14 to July 11 was analyzed by the method of synergetic information theory.

2 Main results

The reasons for the fall and then the increase in entropy can be explained if the chronology of the distribution of COVID-19 in Azerbaijan is analyzed.

From March 14 to April 12, the average of 37 cases of diseases were recorded per day in Azerbaijan. Entropy was found to be 2.227877968. During this period, on March 13, Azerbaijan and Georgia closed the common border for all modes of transport for 10 days. On the same day, a decision was made prohibiting the holding of weddings and other public events, a ban on visiting patients by relatives in all medical institutions, a ban on the activities of cultural facilities,

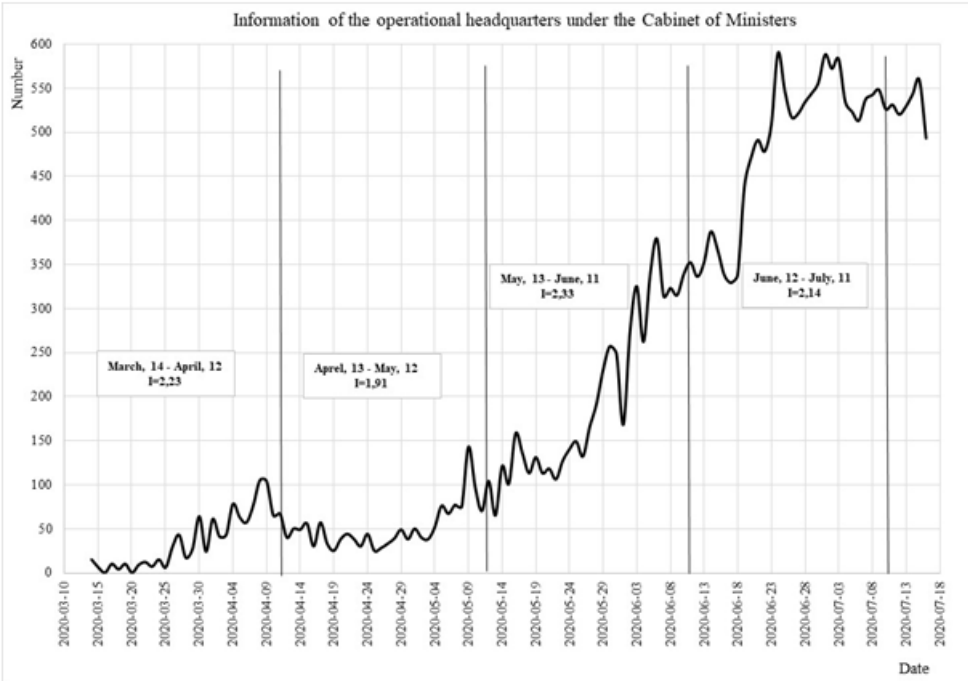

Figure 1: Dynamics of the number of coronaviruses infected in Azerbaijan.

theaters, museums, cinemas, entertainment, sports facilities, as well as special instructions for cafes, restaurants, shops, shopping centers, public transport, etc.

On March 15, a decision was made to temporarily suspend the mutual travel of citizens of Turkey and Azerbaijan by air and land, and the common border was closed to prevent the spread of coronavirus. The ASAN centers and some tourist attractions were also closed for visiting. Flights to some cities in Central Asia, Europe, and the Middle East were also discontinued.

March 17 was forbidden to visit mosques and places of worship. The next day, mass worship in the Orthodox churches of Azerbaijan was also suspended.

Since March 18, transport links between Azerbaijan and Russia were suspended.

From March 19 to 29, the decision of the Operational Headquarters restricted entry to Baku, Sumgayit, and the Absheron region of cars and their passengers.

Since March 23, all major shopping centers have been closed in the country. On the same day, a decision was made to introduce a special quarantine regime, under the terms of which persons over 65 are prohibited from leaving home. In addition, long-distance passenger traffic was suspended throughout Azerbaijan. Also prohibited are meetings of more than ten people.

The validity of the decision on the temporary closure of the state border between the Republic of Azerbaijan and the Islamic Republic of Iran was extended until April 20.

From April 5, people should have received SMS permissions to go out to provide vital services (emergency medical care, the purchase of food and other goods or medicines).

Despite a number of the listed limitations, the system during this period remains almost uninsulated.

From April 13 to May 12, the average number of cases per day increased to 53. On April 29, restrictions on entry and exit through the state border and quarantine in the capital of the Republic of Azerbaijan were extended until May 31, 2020.

There was a decrease in entropy to 1.9114078. A decrease in entropy indicates that the system is still “fueled by energy” and is in a nonequilibrium macroscopic state. But the decision to extend quarantine will subsequently affect the transition of the system to a state of isolation.

The fact that on average during the day from May 13 to June 11 the number of cases of diseases increased to 206 and entropy again increased up to 2,33112297 (higher than in the first

month of observations) indicates that the system is not "fueled by energy". But since May 18, a special quarantine regime has been relaxed in Azerbaijan. On May 16, the Cabinet of Ministers of Azerbaijan adopted an appropriate decision authorizing the restoration of the activities of many facilities. The system of obtaining permission to leave the house via SMS was canceled, the restriction on entry to boulevards, to parks and places of rest provided that no more than 10 people gathered in one place, customer service was resumed in restaurants, cafes, tea houses, and at all catering facilities.

Table 1: Statistical data on the number of coronavirus infections in Azerbaijan

March, 14 - April, 12		April, 13 - May, 12		May, 13 - June 11		June 12- July 11	
Date	Number	Date	Number	Date	Number	Date	Number
2020-03-14	4	2020-04-13	50	2020-05-13	65	2020-06-12	336
2020-03-15	6	2020-04-14	49	2020-05-14	121	2020-06-13	352
2020-03-16	0	2020-04-15	56	2020-05-15	101	2020-06-14	387
2020-03-17	9	2020-04-16	30	2020-05-16	158	2020-06-15	367
2020-03-18	4	2020-04-17	57	2020-05-17	136	2020-06-16	338
2020-03-19	10	2020-04-18	33	2020-05-18	113	2020-06-17	329
2020-03-20	0	2020-04-19	25	2020-05-19	131	2020-06-18	338
2020-03-21	9	2020-04-20	38	2020-05-20	113	2020-06-19	438
2020-03-22	12	2020-04-21	44	2020-05-21	118	2020-06-20	471
2020-03-23	7	2020-04-22	38	2020-05-22	106	2020-06-21	491
2020-03-24	15	2020-04-23	30	2020-05-23	127	2020-06-22	478
2020-03-25	6	2020-04-24	44	2020-05-24	140	2020-06-23	508
2020-03-26	29	2020-04-25	25	2020-05-25	149	2020-06-24	590
2020-03-27	43	2020-04-26	28	2020-05-26	132	2020-06-25	547
2020-03-28	17	2020-04-27	33	2020-05-27	165	2020-06-26	517
2020-03-29	27	2020-04-28	39	2020-05-28	191	2020-06-27	521
2020-03-30	64	2020-04-29	49	2020-05-29	230	2020-06-28	534
2020-03-31	24	2020-04-30	38	2020-05-30	257	2020-06-29	544
2020-04-01	61	2020-05-01	50	2020-05-31	248	2020-06-30	556
2020-04-02	41	2020-05-02	40	2020-06-01	168	2020-07-01	588
2020-04-03	43	2020-05-03	38	2020-06-02	273	2020-07-02	572
2020-04-04	78	2020-05-04	52	2020-06-03	325	2020-07-03	583
2020-04-05	63	2020-05-05	76	2020-06-04	262	2020-07-04	534
2020-04-06	57	2020-05-06	67	2020-06-05	338	2020-07-05	523
2020-04-07	76	2020-05-07	77	2020-06-06	379	2020-07-06	513
2020-04-08	105	2020-05-08	75	2020-06-07	314	2020-07-07	537
2020-04-09	104	2020-05-09	143	2020-06-08	323	2020-07-08	542
2020-04-10	65	2020-05-10	97	2020-06-09	315	2020-07-09	548
2020-04-11	67	2020-05-11	70	2020-06-10	339	2020-07-10	526
2020-04-12	40	2020-05-12	104	2020-06-11	352	2020-07-11	531

Source: Information of the Operational Headquarters under the Cabinet of Ministers.

The restrictions on entry and exit through the state border of the Azerbaijan Republic were extended until May 31, 2020, and a special quarantine regime was extended until June 15. At the same time, it was decided to remove some of the restrictions under the special quarantine regime from May 31. The restriction on the number of employees of state institutions has been abolished; the resumption of the activity of large shopping centers (with the exception of the activities of children's and other entertainment centers, cinemas, and public catering establishments with them); organization of outdoor sports competitions without the participation of spectators is allowed; on-site customer service in restaurants, cafes, tea houses, as well as in all catering establishments with the participation of more than 10 people.

The increase in entropy during this period can be explained, apparently, by the inconsistency

of the introduction and abolition of the regime of isolation of people. The system remains either isolated or open, while the measures taken do not "fueled by energy" the system and entropy continue to grow.

From June 12 to July 11 the average number of cases per day increased to 488 and entropy again decrease to 2.1423674. A decrease in entropy gives reason to make a prediction about the possibility of reducing the intensity of the incidence in the coming days.

Entropy is a quantity that is an inverse to the energy. Every system is designed so that the ordering in it is continuously destroyed if this system is not energized. Orderliness is maintained by a certain level of energy. In such conditions, chaos is not observed due to the favorable conditions for the functioning of the system. Chaos is possible only at small time intervals due to changes in the external conditions of influence on the system. The system is designed so that energy runs out if it is not renewed. Therefore, energy leaves the order - and the order is destroyed.

3 Conclusions

It should be noted that the conclusions below are based only on statistics from the Operational Headquarters under the Cabinet of Ministers on the incidence of coronavirus in Azerbaijan. Moreover, the medical aspects of the problem of coronavirus infection are not considered.

The proposed approach allows not only to explain but to predict the onset of critical states of the system. With high entropy and the preservation of existing conditions, the forecast for the next weeks can only consist in an increase in the incidence. This is evidenced by real data for June 28 to July 16 in Fig.1.

Prediction for the next time periods can be given as data are accumulated and processed statistically using the above methodology.

As for recommendations, I offer to soften the quarantine conditions by reducing the degree of isolation of people in their apartments, by rebuilding a closed system into the open one. Energize the system by:

1. Introducing tight control over measures to reduce the risk of coronavirus incidence and prevent the spread of infection;

2. Timely and high-quality medical care for patients; strengthening of sanitary control at the state border using thermal imaging equipment;

3. The abolition of mass sports, cultural events, the closure of schools and universities;

4. Carrying out anti-epidemic measures by enterprises and organizations, including the disinfection of premises and ensuring an appropriate working regime for workers.

It will contribute to the transition from complete isolation - to control, prevention in all possible ways. At least, the spread of infection can be slowed down due to the measures listed above, which will help solve the problems of the lack of hospital beds, the lack of medical personnel.

The most severe measures cannot be held for long. Very harsh measures such as multi-month quarantine can only lead to the fact that people cease to voluntarily submit to it.

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