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FORECASTING THE SPREAD OF THE COVID-19 EPIDEMIC BASED ON MODELS OF SEASONAL CYCLES AND SYSTEM ANALYSIS

At the heart of effective management of the fight against large-scale viral epidemics, which include the COVID-19 pandemic, there is a whole complex of scientifically based forecasts of various aspects of the development of the epidemic as a systemic phenomenon, differing in the planning horizon, the nature and degree of detail of the forecast object and the tools used.

The most common methods for forecasting the COVID-19 epidemic include the classical system SIR models and their numerous modifications [2], methods for forecasting time series (ARIMA, Holt-Winters method, etc.) [3, 4] and artificial intelligence models [5]. At the same time, models of each type are focused on solving their own range of tasks, within which their use is most productive.

The use of statistical approaches to forecasting time series is most effective for developing short-term forecasts with their subsequent use to identify the presence and nature of shifts in trends in the development of the epidemic. The degree of disagreement between the predicted and actual trajectories of the main indicators of the epidemic makes it possible to judge the effectiveness of the measures used and the need for their timely change.

The starting point of the study was the systemic analysis of the problem of short-term forecasting of COVID-19 and Holt-Winters method [4], operating with three components of the series: a typical value, trend, seasonal component, and using a combination of smoothed components as a forecast value.

Unlike the Holt-Winters method, as well as a number of other similar methods, within the framework of the method developed by the authors of this work, the elimination of the seasonal component is carried out by aggregating the initial time series with a step equal to the duration of the seasonal cycle; the cycle model (seasonal profile) is constructed by the methods of analytical alignment of the dynamics series; forecasting is carried out by extrapolating the trend of the aggregated series with the subsequent unfolding of each of its elements using the cycle model into the corresponding series of the cycle. As a result, the calculated (forecast) time series is the result of concatenation in chronological order of the series of all cycles in the original time scale.

The specified method was developed for short-term forecasting of the development of the COVID-19 epidemic. The object of forecasting is the COVID-19 epidemic in a single country (region), the state of which is characterized by a set of such basic cumulative indicators as the total number of infected (TC), deaths (D), recovered (R) and the number of active cases (AC); incremental indicators such as the daily increase in infected (TC), deaths (D), recovered (R) and active cases (AC), as well as synthetic indicators of the epidemic such as case fatality rates (I_{TC}, I_{CC}) and progress indicator the development of the epidemic (IP).

The information base for constructing predictive models and forecasts of the development of COVID-19 epidemics is the statistical time series of the above indicators with a step per day.

Forecasting the development of the epidemic using the announced method is generally based on the development of models and short-term forecasts of the time series of the reference incremental indicators TC, D, R, the calculation on their basis of the trajectories of the other indicators indicated above, which are derived from them, and assumes for each reference the indicator of the COVID-19 epidemic, the implementation of the following procedures.

1. Analysis of the seasonality of the statistical series $\mathfrak{R}$ of the reference indicator: determination of the presence, duration l and the number n of complete seasonal cycles.

2. Determination of the sum of the levels of the series of each cycle - the main parameter of the cycle - and the formation of the time series $\mathfrak{R}_p$ of the cycle parameters. This is equivalent to aggregating with step l and using the original time series $\mathfrak{R}$ sum operation of the benchmark.

3. Construction on the basis of statistical data of n cycles, taking into account the effect of discounting, the general mathematical model of the cycle $\boldsymbol{M_c}$, which characterizes the averaged contribution of each period of the cycle to the total increase in the indicator during the cycle (seasonal profile of the series).

4. Building a trend model $\boldsymbol{M_p}$ of cycle parameters (trend of the aggregated series $\boldsymbol{R_p}$).

5. Forecasting a time series $\mathfrak{R}$ for a lead period of k cycles:

5.1. Extrapolation of the trend $\mathfrak{R}_p$ of the cycle parameter (trend of the aggregated series p of the reference indicator) by *k* steps forward;

5.2. Calculation based on the cycle model $\boldsymbol{M_c}$ and the value of the cycle parameter of the predicted values of the reference indicator for each of the *k* cycles of the lead period.

After determining the predicted trajectories of all the benchmark indicators of the COVID-19 epidemic, the predicted trajectory of the daily increase in active cases (AC) is calculated, as well as the predicted trajectories of all the above cumulative and synthetic indicators of the epidemic.

The method was tested in the mode of continuous (weekly) rolling (with a week-step) forecasting the development of the COVID-19 epidemic in Ukraine during the second half of 2020 for a lead-time period of 1 + 3 weeks with a step of a day and demonstrated a high level of forecast accuracy in comparison with analogues [1].

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