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THE WAYS OF INTRODUCING AI/ML-BASED PREDICTION METHODS FOR THE IMPROVEMENT OF THE SYSTEM OF GOVERNMENT SOCIO-ECONOMIC ADMINISTRATION IN UKRAINE

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Abstract. The objective of the article is to develop and test in practice a mechanism for constructing AI/ML-based predictions, adapted for use in the system of government socio-economic administration in Ukraine. Research design is represented by several methods like qualitative analysis in order to identify potential benefits of AI use in different spheres of government administration, synthesis to generate new datasets for the experiment, and abstraction to abstract from the current situation in Ukraine, population displacement, uneven statistics reporting. Among empirical methods are prediction and experimental methods to construct a mechanism for the implementation of AI/ML prediction methods in public administration, develop a high-level architecture of the AI/ML prediction system, and create and train the COVID-19 prediction neuron network. A holistic vision of the AI/ML-based prediction construction mechanism, depending on data taken from state official online platforms, is presented, in addition, the ways of its possible practical application for the improvement of the national system of state socio-economic administration are described. The main condition and guarantee of obtaining accurate results is access to quality data through platforms such as Diia, HELSI, national education platforms, government banks, etc. The findings of the research suggest that wide implementation of AI/ML-based prediction technologies will allow the government in perspective to increase the efficiency of the use of budgetary resources, the effectiveness of the government target programs, improve the quality of public administration and to better satisfy the citizens' demand. Future studies should be done to overcome the limitations of the approach: find a way to protect and extract sensitive information from government platforms, fight neural network bias, and create a more perfect system that is able to make multiparameter predictions and is also self-improving on the basis of the obtained results.

Keywords: public administration, a system of socio-economic regulation, AI/ML-based prediction methods, neural networks, enterprise, business model.

JEL Classification: C45, C53, C55, C61, H5, H68, I22, I38.

Introduction

More and more governments in different countries are beginning to pay attention to the development of new technologies and are actively looking for the spheres, where it is possible to implement them in practice. Not surprisingly, because new technologies, especially artificial intelligence and machine learning (AI/ML), open up a lot of opportunities in front of people and can be used for optimization and efficiency increasing in the functioning of various aspects of human life.

The governments of the world's leading countries began to actively introduce various methods of AI technologies into the system of public administration quite a long time ago. Especially relevant today is the use of modern forecasting methods and predictive analytics which are based on AI/ML technologies.

After all, the main task of the state as a guarantor of the safety of its citizens is to prevent possible negative socio-economic and other consequences that may arise in each state and directly affect the well-being of its citizens. It has been proved that modern predictive technologies are quite effective, that's why many public and private organizations worldwide are already actively using the advantages of their application in practice. For example, some of them have been using big data and predictive analytics to identify tax evaders and improve compliance, others use predictive models to enhance the accuracy of tax audits

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and track down tax avoiders. AI-based technologies are also used to anticipate potential instances of crime before they are committed, to identify individuals at higher risk of long-term unemployment, and to improve food security (Perricos & Kapur, 2020).

ML forecasting is helpful in many business and public cases involving massive amounts of data. ML methods usually have higher accuracy and performance rate, than traditional statistical methods. There are various AI/ML predictive analysis algorithms including Linear Regression, Logistic Regression, Neural Networks, Decision Trees, Naive Bayes, etc., the effectiveness of which depends on the datasets on which the prediction models are trained. An algorithm that is efficient for one set of data and for a particular task may not be efficient for another task using different data. It is critically important to choose the right algorithm for the task because choosing the wrong learning algorithm leads to wasted time, resources, incorrect training and the creation of a model with insufficient efficiency (Sarker, 2021).

The main prerequisite for the use of artificial intelligence technologies in forecasting trends and events is the availability of access to a large volume of data. Those states that managed to ensure the accumulation, processing, and synchronization of such data can actively use predictive modeling to achieve certain goals. Ukraine lagged behind in this issue for a long time, because much data was presented in paper form, if there were single electronic resources, they were localized within the limits of certain organizations or institutions, often the information differed depending on the institution that provided it, there was also no unified data systems, therefore their synchronization and full use for building AI-based prediction models was impossible.

However, the situation changed radically in 2019, when the Ministry of Digital Transformation was formed (https://thedigital.gov.ua/) and the Concept for the Development of Artificial Intelligence in Ukraine was developed (Cabinet of Ministers of Ukraine, 2020). Ukraine began to develop quite rapidly in the direction of the latest technologies and has laid the foundations for the formation of a powerful digital resource that can be used for building high-quality predictions and implementation of effective public administration. Thus, the Diia electronic platform was created, on which it is planned to accumulate up-to-date information about all citizens of Ukraine, their socio-economic status and activities; the unified medical platform Helsi, which contains information about the health status of citizens, medical institutions, and doctors; national banks which can be donors of a huge amount of financial information, are also actively developing, which can be donors of a huge amount of financial information; also a single education platform is being created.

Therefore, considering all of the above and the fact that the construction of accurate prognoses in the modern world is an integral component of effective state social and economic management, our research is very relevant and timely.

The novelty of the research is that for the first time a holistic vision of the AI/ML-based prediction construction mechanism, depending on data taken from state official online platforms, is presented, in addition, the ways of its possible practical application for the improvement of the national system of state socio-economic administration are described.

The main objective of the article is to develop and test in practice a mechanism for constructing AI/ML-based predictions, adapted for use in the system of government socio-economic administration in Ukraine.

The main research questions that must be answered to achieve the defined goal are:

What AI/ML algorithms must be taken and how should they be used to build predictions in Ukrainian realities?

What should the model of a single automated complex for collecting, processing, and training neural networks look like so that it can be applied in practice?

In what specific areas of state socio-economic administration and how can the method of prediction based on artificial intelligence technologies be used?

What will be the positive consequences of the widespread use of these technologies in public administration?

How to show the effectiveness of the functioning of this model in practice?

Does the model have limitations, that affect the accuracy of the conducted experiment?

What additional research may need to be done in order to improve the model?

The article includes several parts in which the analysis of publications on the possibilities and prospects of the application of AI technologies, in particular prediction methods, in the field of public administration is consistently revealed. Next, a set of scientific methods that were used to build analytical and practical models for the implementation of AI/ML-based prediction methods in various areas of the government's socio-economic management is described in detail. After that, the results of the conducted experiment, its assessment, and analysis are presented. In the end, conclusions regarding the conducted research are given and limitations and further promising research directions are discussed.

1. The theoretical analysis of the research

The introduction of AI/ML methods including prediction analytics for the improvement of the system of government administration is of great interest and is widely discussed by modern scholars. During the study, it was possible to collect the main opinions of researchers and assess the relevance and degree of the development of this problem.

Ukrainian scholars agree that the development and active application of AI/ML technologies in the public administration system, in the field of strategic planning and operational management of economic development plays an important role in ensuring the full-scale implementation of the 'digital economy' in the country (Kvitka et al., 2021). The priority for creating a "welfare state" is the use of artificial intelligence technologies to help government decision-makers in analyzing, evaluating, and forecasting indicators of socio-economic development (Karpenko & Karpenko, 2021).

According to the point of view of the majority of modern researches, the implementation of AI/ML technologies can benefit the government in many ways. They can provide more accurate predictions, detect anomalies, fulfill real-time tracking, improve resource allocation, contribute to better decision-making and increased effectiveness, ensure data and information processing benefits, service benefits, benefits for society at large (Zuiderwijk et al., 2021). Among the application fields of ML methods for predictive analysis: medicine, social science, building, botany, education, etc. (Bokonda et al., 2020) AI/ML models could be effective in pre and post-diagnosis risk assessment, policy-making and pharmacy and other industries (van der Schaar et al., 2021). In addition, they can generate much savings for the country (Eggers et al., 2017). This is possible because the use of AI/ML technology helps government administrations better meet the needs of their citizens. AI technologies can provide authorities with an understanding of which interventions are likely to have the greatest overall impact and thus clarify how they can efficiently allocate their limited financial resources (Abillama et al., 2021).

AI technologies are able to help governments to achieve their goals and help within a policy-making process. One of the main AI technics, that can be used for this is predictive analytics, because better predictions enable governments to implement preventive and/or more targeted policies (Tito & Croisier, 2017).

The most widely used predictive models are Decision trees, Regression (linear and logistic), and neural networks (Wakefield, 2023). But depending on the task, engineers use a wide variety of different methods and tools.

Some of them prefer mathematical, statistical methods for example, Seasonal Autoregressive Integrated Moving Average (SARIMA) in forecasting models (malaria prediction in South Africa) (Ebhuoma et al., 2018) or Artificial Neural Networks (ANN) based on online incremental learning technique (Farooq & Bazaz, 2021), CNN or other ML algorithms like K-Nearest Neighbor, Random Forest, Naive Bayes, Support Vector Machine, Adaboost and MLP classifier, VGG16 models (COVID-19 disease prediction) (Siahaan & Sianipar, 2021; Mishra, 2020). Many developers use artificial neural networks in combination with regression analysis by utilizing different input variables and a wider range of learning algorithms and topologies of ANNs for predicting (groundwater levels in public administration) (Kouziokas et al., 2017). Others apply a combination of geospatial technologies and artificial neural networks in order to predict efficiently the most dangerous public transportation stations on a daily basis (Kouziokas, 2017). There are also other hybrids, like integrative Random Forest classifier combined with Genetic Algorithm optimization (RF-GA) used for delay problem prediction (Yaseen et al., 2020). Machine learning approaches, including decision tree methods of Random Forest and XGBoost, and deep learning techniques including deep multi-layer and recurrent neural networks, afford unique capabilities to accurately create predictions from high dimensional, multimodal data. These AI methods are well-suited to predict clinical outcomes (Pettit et al., 2021). Another approach in prediction is Genetic Programming, which is commonly used as a tool to optimize the model and facilitate a match between the optimized- and the actual score function (Castelli et al., 2016). But the ANN, LSTM, or parallel CNN-LSTM with autoregressive model and other extended features is considered to be one of most effective to make accurate predictions in the public sector with minimum loss (Mishra, 2020; Osman et al., 2021).

Thus, today there are many tools at our disposal to build accurate forecasts and increase the efficiency of public administration. But it's crucial to elaborate a systemic framework and guidelines to make innovation an integral part of the administration and enhance the capacity of governments to quickly adapt to changing environments and, ultimately, build more robust and sustainable solutions (Kaur et al., 2022). The public sector institutional culture can be changed and become more predictable and transparent through data and time-conscious evaluative frameworks (Pencheva et al., 2020). This will allow governments to target likely problems before they erupt into crises. Their potential benefits will ensure early intervention and prevention, enable better resource utilization, and increase the efficacy of the mission-critical programs (Perricos & Kapur, 2020).

At the same time, many authors agree, that AI/ML-based prediction systems can be fragile, heavily interdependent, and prone to fail in unexpected ways. In the face of increasing digital threats, the state needs to improve the digital security of its numerous information systems and platforms, as well as its users (Kosorukov, 2019, p. 52). Other main risk factors are lack of adequate skills in government authorities in the development, implementation, and management of such systems, concerns about data privacy, the potential of algorithmic bias, complexity and accessibility of data used (Perricos & Kapur, 2020). Dependence on the availability of good-quality data makes the planning and implementation tasks related to the establishment of the e-government and the digital state fairly complex (Fejes & Futo, 2021). Data governance maturity is further identified as an important component of managing some aspects of AI tensions (Madan & Ashok, 2023).

There should be a strong connection between policymakers, government organizations, and teams that are working on particular product in order to prevent mistakes such as incorrect data training and as a result making false predictions. Changes in roles, data collection methods, or interventions may have an impact on AI systems (Buerkli & Gagliani, 2018). Full digitization of public services and complex implementation of AI technologies in all socio-economic spheres can take many years. That's why to mitigate complexity governments can break implementation down into small steps. In addition, it takes time, resources, and efforts to maintain software, including amending it in response to social change (Daub et al., 2020). AI systems may also be vulnerable to attacks that could compromise their functioning, and efforts should be made to test and secure them as appropriate (Buerkli & Gagliani, 2018).

That's why having a great machine-learning model, by itself, is not enough. Because it often needs to be wrapped in an intuitive user-centric experience and properly embedded into workflows (Dhasarathy et al., 2020).

In order to achieve the goal of successful application of AI/ML technologies into the government administration system three main categories of opportunities and problems should be taken into account. These are technology and data, workforce, and risk management. This means, that governments first should first investigate their theoretical and practical potential in this sphere and then try to overcome restrictions and weaknesses and turn them into capabilities. In addition, should consolidate efforts and develop IT systems and products, that not only function effectively in their particular sphere but also have sufficient communication and can be easily integrated into one another (Desouza, 2018).

These prior empirical results allowed to assume the following research hypotheses:

- The introduction of artificial intelligence technologies into the system of state socio-economic management has many advantages, in particular, there is a consensus that the use of modern AI/ML prediction methods (ANN) will make it possible to build fairly accurate forecasts, which can be positively expressed in the increasing of the efficiency of government administration, the high-quality implementation of state programs, saving the state's material resources, better meeting the public needs. However, it is necessary to take into account the limitations that prevent the full implementation of the prediction methods. Among them: are access to quality data, synchronization, skillful use (training), and protection. The authors emphasize that building high-quality AI/ML prediction systems requires a holistic approach involving the constant interaction and communication of all links involved in the direct development of software to those who will serve and use it in the future.
- The research conducted is aimed to test the hypotheses above and is a logical continuation and addition to previous ones, but it has a more practical application in domestic practice because the focus is on the development of a holistic model of the introduction of AI/ML-based prediction methods into the system of socio-economic public administration in Ukraine and the evaluation of its effectiveness based on the conducted experiment.

2. Investigation methodology

The research methodology that was followed, consists of six stages: identification of spheres in socio-economic administration, where AI/ML can be applied; data sources analyzing and high-level system designing; specific data collection, dataset preparation, and selection of the most appropriate AI/ML algorithm (LSTM); proof of concept implementation and approbation; testing the developed LSTM model on COVID-19 prediction in Ukraine and finally results evaluation, analyzing the future research directions and limitations of the model (see Figure 1).

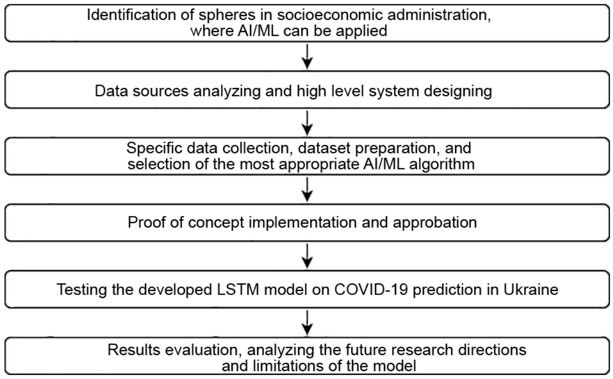

Figure 1. Overview of the research methodology

Several research methods were used during the investigation. These methods can be split into theoretical research methods (quantitative-qualitative analysis, synthesis, and abstraction methods) and empirical methods – prediction (Long short-term memory networks, logistic regression, neuron networks, RSN, etc.) and experimental methods.

Systems, based on artificial intelligence technologies require a lot of data for training and creating a model with a given accuracy. The quality of the data also affects the efficiency of the system. The more data that can be collected, the more accurate system can be built. During this study, the ways of introducing artificial intelligence and machine learning (AI/ML) technologies into the public socio-economic administration system were considered using the ***quantitative-qualitative analysis method***. In Ukraine, many public administration digitalization services have recently been created, such as Diia (https://diia.gov.ua), HELSI (https://helsi.me), platforms for education, etc. All these services accumulate a huge amount of data about citizens with many parameters that allow to successfully apply AI/ML-based prediction methods using this data. According to Ukrainian legislation, information from such government information platforms is confidential and access to it is possible only through a special procedure. Therefore, as an example, it was considered only one area – health care for which the prediction system of the new incidence of COVID-19 based on the open data from the COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (The Center for Systems Science and Engineering, 2023) has been developed.

This approach was an example of an ***abstraction method*** since it was decided to show the effectiveness of AI/ML systems for prediction on the example of one area and extrapolate the results to other areas where similar technologies can be applied for predictions. The abstraction method also suggests that this study was abstracted from some details, such as Russia's armed aggression against Ukraine, refugees and population displacement associated with this, as well as the uneven reporting of COVID-19 incidence data in Ukraine in relation to the war, because of the lack of these data.

The ***synthesis method*** was applied for building an experimental model in order to allow the prediction system to work correctly during the period of the Russian invasion of Ukraine and handle incomplete statistics for this period, the new datasets based on the data from Johns Hopkins University (daily increase in new cases of the disease for each day in the regions of Ukraine, daily increase in new cases for each day for Ukraine, statistics of diseases in European countries) were generated. These datasets included statistics linked to location, date, as well as averaged values for weekly incidence rates in Ukraine.

With the help of the ***modeling method***, a prototype of general approaches to the application of AI/ML-based prediction methods in the spheres of public socio-economic administration was created (see Figure 2).

Using the available government resources, it is possible to apply AI/ML algorithms to public socio-economic areas, such as health care, socio-economic services, budget and finance, education, etc. This will improve the quality and efficiency of socio-economic public administration and the efficient use of budgetary resources.

It is possible to collect from government platforms (Diia, HELSI, etc.) and government financial institutions for example banks (Privat bank, Oschad bank) different personalized data related to the socio-economic activity of citizens and other indicators, and on the basis of this information create AI/ML-based prediction systems that will allow to make predictions in various government sectors. As a result, government administration gets the opportunity for more accurate prediction, planning, and analysis of current needs, as well as feedback on current government programs, which in turn leads to the increasing effectiveness of the financial system as a whole – the effective use of budget resources, active development of the government target programs, provision of the quality public services, better satisfaction of citizens' demand, etc.

Below is an example of the model implementation. For solving the above problems using AI/ML-based prediction methods, a software solution was developed and tested (see Figure 3).

Figure 3 demonstrates a high-level architecture of the prediction system. It contains few main services:

– The main task of "Data collection and transmission service" is to collect data from different sources and generate different datasets to train neuron networks.

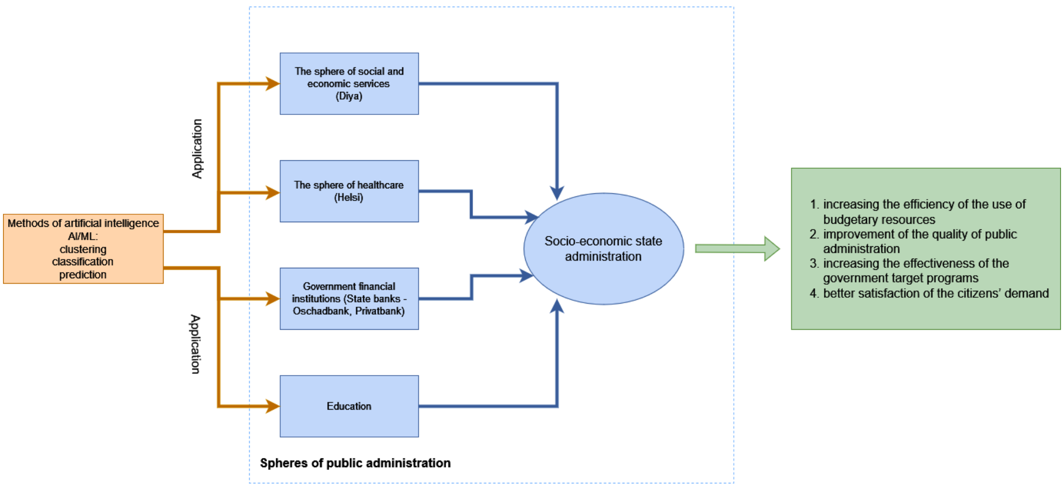

Figure 2. Implementation of AI/ML prediction methods in different spheres of government socio-economic administration

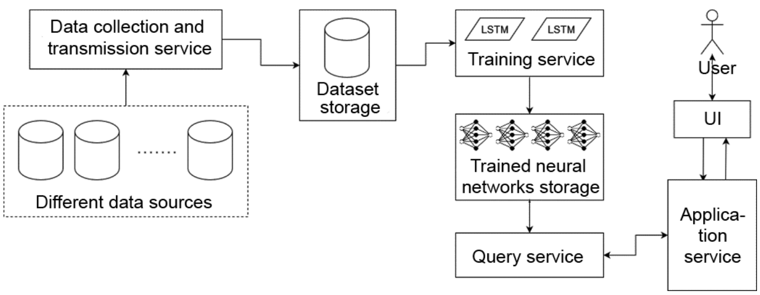

Figure 3. High-level architecture of the AI/ML prediction system

The sources for the Data collection and transmission service can be both open sources and data from Diia, HELSI, or other government platforms.
- "Dataset storage" is a storage for datasets, it can be implemented as a file storage or some NoSQL database. This storage supports dataset versioning, which allows the training of different neuron networks on different datasets.
- "Training service" uses data from Dataset storage to train various neural networks. In this study the Long Short Term Memory Networks (LSTM) algorithms were used for this service. But it can be used other algorithms like ARIMA or Prophet. This service saves neuron networks to the Trained neuron network storage after training.
- "Trained neuron network storage" is a storage for trained neuron networks. Saved neuron networks can be uploaded from it. This service is also responsible for the versioning of these neuron networks.
- "Query service" downloads trained neuron networks from "Trained neuron network storage" and makes different requests to these networks to collect predictions for the request. Query service is triggered by Application service.
- "Application service" is the main service that the user interacts for. It has a user interface and can be used to make predictions for different spheres.

The given mechanism will make it possible to achieve the implementation of a high-precision prediction system based on neural networks, which can be used to build forecasts in almost any area of public administration. The restructuring of forecasting systems with the widespread introduction of AI technologies will make it possible to constructively raise the level of public administration in the most important socio-economic areas, which will bring a lot of benefits to both – the administrative apparatus and the citizens of the country. More specific proposals and prospects for the implementation of the model for each of the four areas under consideration are analyzed below.

In the field of **socio-economic services**, it is possible the use AI/ML-based prediction technologies in the Diia government service. "Diia" has received very wide use and has more than 17 million regular users (Biz Cenzor, 2022). Also "Diia" operates such sensitive information as – biographical data, field of activity, income, taxation, different licensing, etc. This fact allows to apply methods of AI/ML for example prediction, clustering, and parametrization. These technologies can be used for:
- predicting which government programs will be more in demand by the population;
- making different predictions for opening new small businesses, licensing, etc.;
- predicting various social benefits;
- building forecasts on deductions to the budget by small and medium-sized businesses;
- making predictions on changes in the number of vehicle owners and other areas requiring a license, as well as the demand for various state programs for them;
- targeting user groups and purposefully offering government programs (for example, support for small and medium-sized businesses, preferential taxes, programs for farmers) to the group that is potentially interested in these programs;
- making forecasts on bonds and offering them to potential buyers.

All these predictions can be implemented based on the prediction system that was shown in Figure 3.

In **budget and financial sphere**, the use of AI/ML-based predictions is also very actual. Ukrainian state banks such as Oschadbank and Privatbank serve tens of millions of people. The use of data from these banks in combination with data from Diia allows creation of significant datasets, that can be used for applying AI/ML methods for different predictions. For example, it is possible to use the same LSTM algorithms from paragraph "The sphere of healthcare" and make a forecast for future interest rates on deposits and loans; prediction of demand for certain banking products; identify areas where budget investments will bring maximum profit in the future; creation of targeted offers to bank customers, i.e., make specific offers to certain customers of banks in which they are likely to be interested. Also, it would be very useful to use this model for the prediction of budgetary areas that will require the greatest investment; forecasting of the demand for government bonds, government loans, and various government programs. It would also simplify and increase the efficiency of creating new banking products, services and development of new government programs, as well as contribute to more accurate forecasting of macroeconomic indicators, exchange rates, the cost of precious metals, etc. As a result, public money will be used efficiently and the economic situation, performance will be improving.

AI/ML prediction system is also applicable in **Education** sphere. During the COVID-19 pandemic and wartime, the vast majority of schools and higher education institutions in Ukraine began to use online platforms. This allowed the formation of a large number of different datasets that can be used for creating and training different Neural Networks models for various predictions. Of course, for getting more accurate results, these data need to be systematized and additional parameterized, but in combination with data from other government platforms (Diia, HELSI, etc.), it will allow the creation of fairly accurate prediction systems, which could help the government with:
- planning the workload for the next academic years, predicting more popular subjects, and allocating more class hours and specialists to them;
- defining of load on higher education institutions (the number of applicants) and the demand for specialties;
- in combination with other areas, forecasting the state's need for the necessary specialists and the early formation of a state order for the training of such a number of specialists;

– planning of the load on schools and secondary educational institutions;
– evaluating the effectiveness of a particular teaching method.

It was also considered the possibilities of applying AI/ML methods in the sphere of **healthcare**. The HELSI service is very popular in Ukraine, it covers almost the entire population of the country. This fact allows to get statistics on various aspects, such as age, location, medical history, place of work, and so on. Based on these statistics and using AI/ML algorithms, it is possible to build models for predicting diseases, make an estimated calculation of the load on medical institutions of the region, district, city, and even for a specific hospital/clinic. Having accurate forecast results Ukrainian government will be able to efficiently use of budgetary funds because it will be possible to organize in advance the purchase of medicines, equipment, etc., prepare the necessary beds for certain hospitals, and use the available resources (equipment, medicines, specialists) to provide timely and effective assistance for the population.

During this investigation, the ***experimental method*** was applied specifically to the healthcare sphere. The purpose of the experiment was to test the potential of using artificial intelligence and machine learning methods in building predictions for the COVID-19 disease in Ukraine.

Patience data in HELSI platform is sensitive information and access to it is possible only for authorized state organizations, that is why the open data from COVID-19 Data Repository by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (The Center for Systems Science and Engineering, 2023) was used for this experiment. Based on this information it was possible to build a prediction system for Ukraine, but having data from HELSI, it would be possible to build statistics for each region/town/district down to a specific hospital.

Due to the war in Ukraine, COVID-19 disease statistics began to be submitted irregularly. Therefore, both daily data from the Johns Hopkins University and custom-built average datasets for a week and other periods of time were used for the experimental system. Data collection and transmission services were created for these purposes.

To predict new COVID-19 cases in Ukraine the Long Short Term Memory Networks (LSTM) algorithm was selected for Training service (see Figure 3). LSTM is a type of Recurrent Neural Network (RNN). Recurrent Neural Networks are very good at processing sequences of data. They can "recall" patterns in the data that are very far into the past (or future). In other words, this algorithm can process not only a single data point but also the entire sequence of data. It also has feedback connections. LSTM algorithm can make accurate predictions based on the sequential data so it is well suited for COVID-19 infections prediction using historic infection statistics.

In LSTM algorithm for each element in the input sequence, each layer computes the following Equation (1):

$$\begin{aligned} i_t &= \sigma\left(W_{ii}x_t + b_{ii} + W_{hi}h_{t-1} + b_{hi}\right); \\ f_t &= \sigma\left(W_{if}x_t + b_{if} + W_{hf}h_{t-1} + b_{hf}\right); \\ g_t &= \tanh\left(W_{ig}x_t + b_{ig} + W_{hg}h_{t-1} + b_{hg}\right); \\ o_t &= \sigma\left(W_{io}x_t + b_{io} + W_{ho}h_{t-1} + b_{ho}\right); \\ c_t &= f_t \odot c_{t-1} + i_t \odot g_t; \\ h_t &= o_t \odot \tanh\left(c_t\right), \end{aligned} \tag{1}$$

where h_t is the hidden state at time t, c_t is the cell state at time t, x_t is the input at time t, h_{t-1} is the hidden state of the layer at time t–1 or the initial hidden state at time o, and i_t, f_t, g_t, o_t are the input, forget, cell, and output gates, respectively. σ is the sigmoid function, and ⊙ is the Hadamard product, W is the weight matrix and b is bias vector parameter (PyTorch documentation, 2023).

This algorithm can also be used in other spheres as well, such as socio-economic services, budget and financial sphere, and education sphere where we have similar serial data.

For the training model, was used a well-established approach for splitting all data into 3 datasets: training, validation and test datasets. All data were randomly divided into a training set (70% of all data), a validation set (20% of data), and a test set (10% of data). We formed different lengths of sequential data from the original dataset, started from 5 days to 180 days. This allowed us to create our neural network more resistant to errors in the original data.

The LSTM model contained the constructor for layer initialization, the function for resetting weights, and prediction function.

3. Results and discussion

The COVID-19 prediction neuron network was created and trained in a supervised fashion on a set of training sequences during this investigation. These training sequences were generated from datasets from Johns Hopkins University and official data from the Ministry of Health of Ukraine.

It was used 4 hidden layers and 100 epochs of training for this model. Table 1 describes the training loss and validation loss metrics per epoch.

Table 1. Training loss and validation loss per epoch

Epoch num	Train loss	Validation loss
0	0.0853628649168512	0.0481532185429870
10	0.0347739125397622	0.0371528469212195
20	0.0346094731802965	0.0354684881386526
30	0.0345916781807738	0.0350343552834862
40	0.0345517532650192	0.0344232396328192

End of Table 1

Epoch num	Train loss	Validation loss
50	0.0345117921208285	0.0351110855453864
60	0.0344798654738221	0.0347189423028178
70	0.0343297521854990	0.0346853417939093
80	0.0345676832935291	0.0345743528739799
90	0.0344185529541476	0.0343858308976086

Figure 4 demonstrates a graphic of changing training and validation loss during each epoch and their convergence.

As a result, it has been gotten a system with a loss function of 0.034 and an accuracy of 96.50%.

Based on these results it is possible to make a conclusion that LSTM models are effective for predicting new cases of COVID-19 infection.

Using this model, a prediction of a pandemic in Ukraine was created for the period from April 2020 to January 2023.

Figure 5 shows the COVID-19 incidence graphs for Ukraine: the current one (shown in blue) and the prediction graph based on the build prediction system (shown in orange).

It should be noted that it is more correct to consider the obtained results in a retrospective of two periods. The first period – April 2020 – February 24, 2022 – from the start of the pandemic in Ukraine to the start of Russia's full-scale military aggression against Ukraine, and the second period – from the start of a full-scale war in Ukraine to the current moment. Table 2 demonstrates the maximum discrepancies between the predicted and real statistics of the graph from Figure 4 for both periods.

In the first period, data on the incidence were submitted regularly, and the composition of the population of Ukraine and its regions did not undergo significant changes. The system makes predictions with high accuracy during this period. The largest upward deviation during this period was from November 1 to November 7, 2021. The real statistics were 160859 incidences during this week and the system predicted 173038 incidences (which is 7.57% more than the real data). The largest downward deviation was in the week from 7 to 13 February 2022. The real COVID-19 new incidences in this period were 253340, and the system predicted 238056, which is 6.03% less than the real data.

The most accurate prediction system showed in the periods – from October 26, 2020, to January 3, 2021, and from March 15, 2021, to May 2, 2021. During these periods, the increase in incidence followed the patterns obtained in previous time intervals, so the built neuron

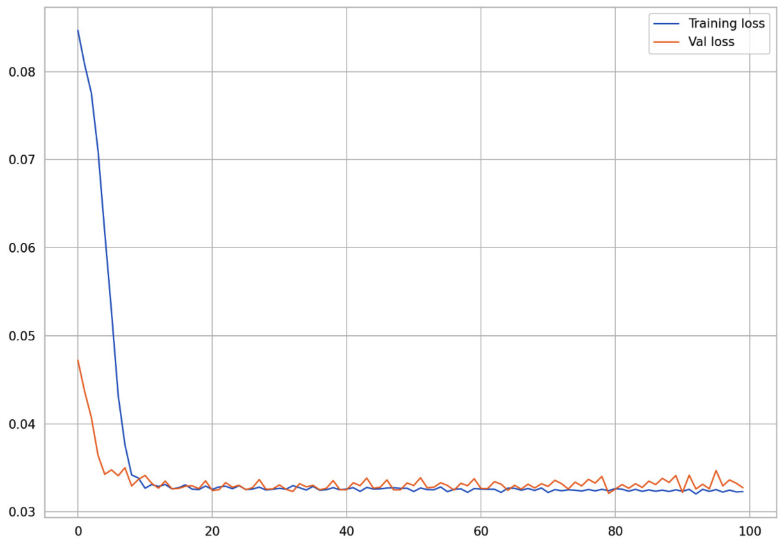

Figure 4. Training and validation loss per epoch

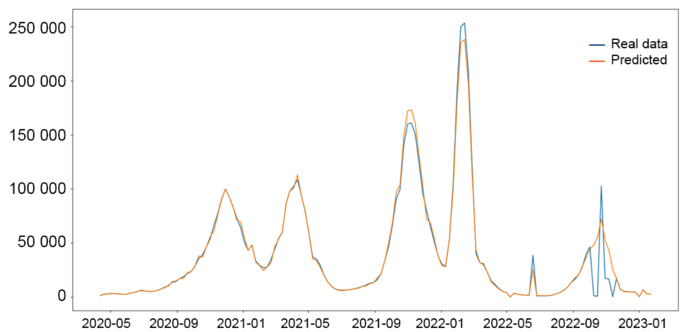

Figure 5. Diagram of real cases and predicted cases of COVID-19 infection in Ukraine (April 2020–January 2023)

Table 2. Maximum discrepancies between the predicted and real statistics

Date	Real new incidences	Predicted new incidences	Difference between predicted and real incidences	Description
1.11.2021–7.11.2021	160 859	173 038	7.57%	The biggest positive deviation from predicted and real statistics
7.02.2022–13.02.2022	253 340	238 056	–6.03%	The biggest negative deviation from predicted and real statistics
17.10.2022–23.10.2022	102740	72446	–29.48%	This spike is associated with irregularity and inaccuracy in reporting information

network predicted the increase in incidence during this period with high accuracy. In the remaining time intervals of the first period, the system made predictions within up to 3% of the error.

The second period (from February 24, 2022, to the present time) – during which, statistics on COVID-19 were submitted irregularly, the statistics did not always correspond to reality. Not all new incidences were collected, because of the war there was an internal displacement of refugees from the areas of hostilities and an outflow of the population abroad (more than 8 million Ukrainian refugees recorded across Europe – Operational Data Portal, 2023). Therefore, the spike in incidence during the week of October, 17 – October 23, 2022, is associated precisely with the irregularity and inaccuracy of reporting information to Johns Hopkins University. The build neuron network gave a prediction at 72446 incidences, while the real statistics was 102740 (while the previous week the real reading was 925 and the week after that the statistic was 17439 new incidences). The prediction graph for this period looks smoother and corresponds to the statistics of the increase in incidence in previous periods.

For training this model it was used only open datasets without additional attributes such as location, age, risk groups, previous cases of illness, etc., and even with these limitations, this model is fairly accurate. Therefore, it can be assumed that having access to data from HELSI, the prediction of diseases in specific regions and hospitals would be possible.

The goal of this study was to design a general system for the implementation of AI/ML forecasting technologies in public administration, because until now, AI technologies have been used in Ukraine by individual companies and enterprises to solve their internal forecasting tasks and there was no vision of how they could be integrated into the state management system. The implemented COVID-19 prediction model was a proof of concept of the elaborated system. It has shown high rates of predicting new cases of the disease. Other authors have also explored the effectiveness of different mathematical and AI/ML methods for predicting the further spread of the pandemic, for example, Pourhomayoun and Shakibi (2020) concluded that neural networks are the most effective COVID-19 prediction, their prediction system had accuracy 93.75%, while the system developed in the current study had an accuracy 96.50%. This is evidence that the LSTM method itself is effective enough for making predictions in public administration.

There are also several suggestions for future research directions.

1. It should be considered that one of the additional ways to improve the model offered is by applying additional algorithms and technics like Gradient boosting and Boruta (Anandhanathan & Gopalan, 2021).
2. In this study LSTM model was widely used to build and train neural networks in the Training service. But there could be also applied to other methods for time series, such as ARIMA (statistical Auto-Regressive Integrated Moving Average) and Prophet for forecasting as well as logistic regression, random forest classification, and Hierarchical Cluster Analysis. It is also possible to use other algorithms or combinations of algorithms for highly specialized areas.
3. The performance of the prediction system can be improved by adding feedback on the basis of how accurately the constructed predictions came true. This would allow to train the neural network and make it more accurate in the future.
4. It is also important in future research to pay attention to elaborating a safe and efficient mechanism for obtaining data from government platforms and expanding this approach to other areas of public administration.

Conclusions

Based on the conducted research, it can be concluded that this work has a scientific and practical value, as it is a logical continuation of the previously conducted researches, it meets modern social challenges and reflects the trends of the current state of scientific, technical, and socio-economic development. The work also contains an example of practical implementation of the given problem, which strengthens the possibility of applying the research results in practice in the field of state socio-economic administration.

The research has shown that neural networks based on the LSTM algorithm can be used with high effectiveness to predict some future trends based on sequential data. This was checked by the experiment on the COVID-19 prediction Neuron network.

This experiment based on the developed software application has shown the effectiveness of the prediction model, because according to the results, it is able to generate fairly accurate forecasts, and therefore can be fully used for its intended purpose. The main condition and guarantee of obtaining accurate results is the availability of access to quality data through existing platforms such as Diia, HELSI, Yedyna Shkola (https://eschool-ua.com/), government banks etc.

In addition, during the conducted research, it was proven that the developed mechanism for introducing AI/ML-based technologies for building predictions in various spheres of state socio-economic management, in case of its application in practice, can be quite effective for Ukraine and may benefit the government in many ways like increasing the efficiency of the use of budgetary resources, improvement of the quality of public administration, increasing the effectiveness of the government target programs and better satisfaction of the citizens' demand.

Along with the positive results obtained during the study, several of its limitations were noticed:

1. Sensitive information requires protection;
2. Neural network bias;
3. The system makes predictions only within the given parameters;
4. The barriers to robust prediction include regulation requirements and limitations in model interpretability, generalizability, and adaptability over time;
5. The system built during the study used data from open sources on the incidence of Covid-19. After Russia's full-scale invasion of ukraine on february 24, 2022, incidence statistics has been submitting irregularly. The statistics were also affected by refugees/migration of the population. Therefore, the constructed system is not as accurate as it could be under the previous conditions.

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