Forecasting the Fund of Time for Performance of Works in Hybrid Projects Using Machine Training Technologies

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Abstract

The aim of the work is to substantiate the approach to forecasting the time fund for work in hybrid projects, taking into account the changing nature and climatic components of the design environment based on the use of neural networks. The neural network architecture involves the use of a multilayer perceptron, teacher training, and the method of backpropagation. It is based on an algorithm that minimizes the prediction error by propagating error signals from the network outputs (predicted duration of naturally allowed forecasting the working time fund) to its inputs (values of the duration of naturally allowed forecasting the working time fund in previous days), in the direction opposite to the direct propagation of signals. Based on the prepared initial data, the training of an artificial neural network was performed, which ensured the creation of an artificial neural network that is able to predict the duration of naturally allowed time to perform work in a software environment written in Python. Studies based on neural network training show that when the number of epochs increases to more than 25,000, the error does not exceed 4.8%. To study the neural network, we used the statistical data of the summer months of 2020 on the naturally allowed forecasting the working time fund during certain days (Fig. 7), which are typical for the conditions of the Volodymyr-Volynskyi district of the Volyn region. The obtained results indicate that the use of the proposed architecture of the artificial neural network gives a fairly accurate forecast and this is the basis for making quality management decisions on planning the content and timing of work in hybrid projects.

Keywords 1

Forecasting, artificial neural networks, time fund, hybrid projects

1. Introduction

Forecasting the working time fund (FWP) is a very relevant management process in various types of projects. The peculiarities of this process largely depend on the types of projects and the characteristics of their project environment. Special attention should be paid to hybrid projects that arise in the operational activities of enterprises and organizations [1, 2, 3, 4]. In agricultural production, there are a number of such hybrid projects that have different life cycle lengths and a special subject component. Among them, the greatest attention of scientists is focused on hybrid projects of crop production, animal husbandry, and transport [5, 6, 7, 8], as the content and time of work in them largely

MoMLeT+DS 2021: 3rd International Workshop on Modern Machine Learning Technologies and Data Science, June 5, 2021, Lviv-Shatsk, Ukraine
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depends on the natural allowable time for work during their life cycle and the scale and features of the subject component of the project environment.

Regarding the naturally allowed FWP during the life cycle of hybrid projects, it is variable and is determined by a number of factors of the natural-climatic component of the design environment (precipitation, dew, moisture deficit, etc.) [9, 10, 11]. At the same time, a changing design environment is very important for coordinating the content and time of work performed in hybrid projects. To take into account the impact of the natural and climatic components of the design environment on the FWP of hybrid projects, accurate tools should be used. Today, the use of neural networks to solve forecasting problems in various applications is becoming more common. However, there are no publications on the use of neural networks to solve FWP forecasting management problems in hybrid projects.

2. Analysis of published data and problem setting

Today, scientists in all fields of activity pay considerable attention to artificial neural networks to perform forecasting processes [12, 13, 14, 15]. At the same time, the development of tools for forecasting involves the implementation of processes of accumulation of information about the state of the system, analysis, and identification of patterns and trends in the forecast indicators [16]. In hybrid projects, based on FWP forecasting, the content and timing of these projects are planned. The FWP forecast provides identification of patterns and trends in the duration of naturally allowed FWP depending on the time of occurrence of a number of agrometeorological events (precipitation, dew, humidity deficit, etc.) [17, 18]. To verify the accuracy of the forecast of naturally allowed FWP in hybrid projects, it is advisable to use a retrospective method. This method involves the implementation of the forecast from the previous similar years and the comparison of the results with actual data. In most cases, the comparison of predicted and real data is performed on the quantitative value of the root mean square error or the mean approximation error [19, 20]. If the obtained results of the comparison satisfy the selected accuracy criterion, then this approach can be used to predict.

One of the methods that can be used to predict FWP in hybrid projects is time series prediction [21, 22]. This method provides a sequence of quantitative values of the process over time, which are displayed as sequential moments of time, preferably at regular intervals. For our conditions, this is the data of the deficit of humidity, which determines the feasibility of work in hybrid projects. Among the methods of forecasting time series, which is mostly used in practice, is the method of autoregression. It reflects the dependence of a given indicator on the set of factors that reflect the linear model:

$$X_t = k + \sum_{i=1}^{j} a_i \cdot X_{t-i} + \delta_t , \quad (1)$$

where k – a constant that reflects the appearance of the model in the case when the influencing factors are zero;

a_i – coefficients of parameter dependence X_t from the factors that characterize the state of the specified parameter on the previous step of the regression;

δ_t – model error, which characterizes the difference between the calculated and known values of the model for certain periods.

The autoregression method reflects the dependence of the parameter X_t on its quantitative value in the previous period of time (day, week, month, etc.). Therefore, the current value of the parameter depends on its quantitative value in the previous period of time. The main advantage of this method is the ability to obtain a quality model with an adequate forecast, which can be performed with minimal time, provided the known initial data. At the same time, the disadvantages of this method include the fact that accurately predict the known data is possible only for one period ahead. For each subsequent period, it is necessary to take the results of the executed forecast that reduces the accuracy of forecasting.

In most cases, the method of autoregression is used to predict the naturally allowed time for work [23, 24]. However, this method makes it possible to obtain adequate forecast results in the absence of events (precipitation, dew, etc.) that cause a change in the content of work in hybrid projects. The presence of a number of variables in the design environment requires the use of other methods for predicting FWP in hybrid projects.

To solve the problems of classification and forecasting in various applied areas use the method of decision trees [25, 26]. If the dependent, i.e. the target variable, acquires discrete values, then the method of the decision tree solves the problem of classification. In this case, provided that the indicator that depends on many factors becomes continuous, the decision tree makes it possible to establish the dependence of this indicator on independent indicators. The decision tree provides the representation of individual rules in a given hierarchical and consistent structure. However, it provides the logical decisions rather than the quantitative value required to predict FWP in hybrid projects, taking into account the changing natural and climatic components of the design environment.

Today, more and more attention is being paid by scientists to artificial neural networks [27, 28, 29]. In particular, they can be used to predict FWP in hybrid projects. The main advantage of artificial neural networks compared to other forecasting methods is that they provide FWP forecasting taking into account many variables of the natural and climatic component of the design environment (precipitation, dew, moisture deficit, etc.). At the same time, the function of the influence of the input characteristics of the design environment on the initial result (the fund of naturally determined FWP in projects) can be of any complexity (nonlinear, non-stationary, etc.) [30, 31, 32, 33, 34]. The advantage of artificial neural networks is that they are nonlinear systems that provide the better classification of data compared to other linear methods. In such systems, problems can be formulated with insufficient accuracy. At the same time, it is artificial neural networks that have the ability to self-learn, which ensures that hidden implicit knowledge (patterns, dependencies, etc.) is found in the given data.

The most important advantage of artificial neural networks is the lack of need for system programming because the neural network is self-learning on the basis of a training sample of data, which significantly distinguishes it from expert systems [15, 35]. The system on the basis of the specified approach is capable to receive the predicted result which is based on the hidden laws. In addition, artificial neural networks provide a change in the predicted indicator for changes in the environment, which is very important for predicting FWP in hybrid projects, taking into account the changing nature and climatic components of the project environment. At the same time, there are no publications on FWP forecasting in hybrid projects using artificial neural networks.

All the above indicates the feasibility of substantiating the approach to FWP forecasting in hybrid projects, taking into account the changing nature and climatic components of the design environment based on the use of neural networks.

3. Goal and tasks of the research

The aim of the work is to substantiate the approach to forecasting the time fund for work in hybrid projects, taking into account the changing nature and climatic components of the design environment based on the use of neural networks.

To achieve this goal should solve the following tasks:

– substantiate the structure and architecture of the neural network to predict the natural allowable time for work during the life cycle of hybrid projects;

– to carry out preparation of initial data, training of an artificial neural network, and estimation of accuracy of the model of forecasting of naturally allowed time of performance of works during certain days.

4. The structure and architecture of the neural network for predicting the natural allowable time of work during the life cycle of hybrid projects

For planning hybrid projects, the main process is to predict the naturally allowed FWP over the life cycle of these projects [36, 37, 38, 39]. The basis of such forecasting for hybrid crop projects is the lack of humidity, which significantly affects the productivity of technical equipment, and hence the time of the relevant work. This should be taken into account when planning FWP in hybrid crop projects. With an increase in the deficit of humidity, there is a decrease in the humidity of the grain mass, which is the basis for increasing the productivity of technical equipment. At the same time, reducing the deficit of humidity provides an increase in the humidity of the grain mass and, accordingly, the value of the productivity of technical equipment [9, 40].

An important property of artificial neural networks is that they are able to learn from the use of known data. The database for training artificial neural networks is the statistical data of meteorological stations [41]. In particular, to predict FWP during the life cycle of hybrid crop projects, air humidity deficit data are used, which are recorded every 3 hours in the period from July 1 to August 15. Only those data of humidity deficit that exceed values of more than 4 hPa are taken into account (Fig. 1). This is due to the fact that the implementation of works in the projects of harvesting early crops is possible only in such natural and climatic conditions. Failure to comply with this condition leads to a significant increase in moisture of the grain stem, as well as to the loss of the crop. It is known [9] that the transition time of the humidity deficit over 4 hPa mostly coincides with the time of appearance and disappearance of dew.

In order to train the artificial neural network, an interactive process of adjusting synaptic weights and thresholds is performed. The artificial neural network learns the relationships that are present in the training data on each of the iterations of the learning process.

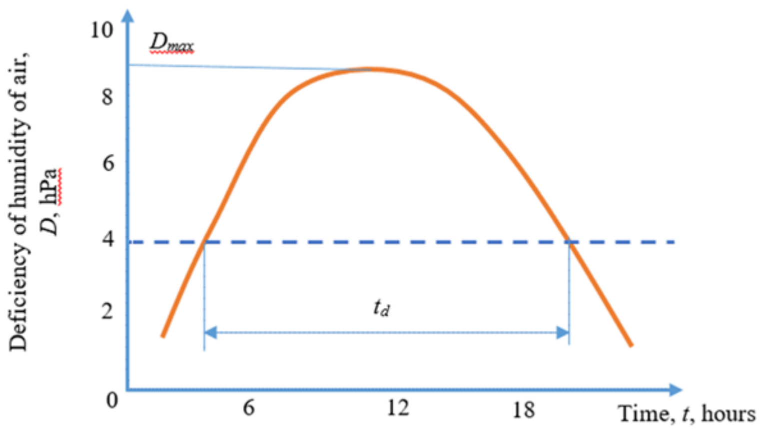

Figure 1: Graphical interpretation of determining the natural allowable time of work during certain days of the life cycle of hybrid projects

To build a system using neural networks, first of all, the choice of its architecture is performed. The architecture of the neural network is selected experimentally on the basis of the technical task. An artificial neural network of direct propagation was chosen for our proposed system (Fig. 2).

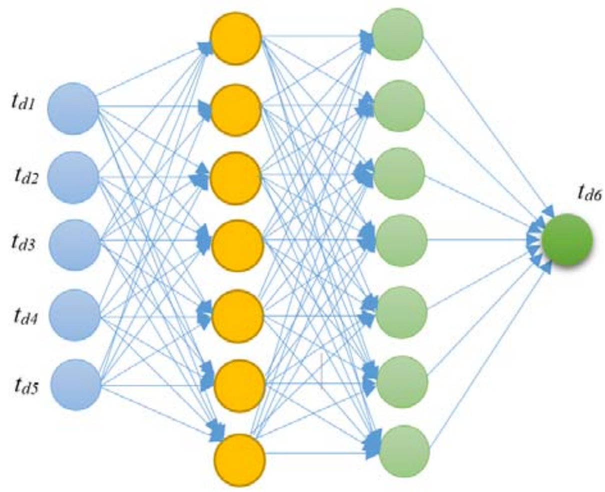

Figure 2: Fully connected direct propagation neural network for FWP prediction during individual days of the life cycle of hybrid projects: t_{d1}, t_{d2},…, t_{d6} – respectively, nature allowable time of work during the first, second, and sixth days

The main task of the proposed neural network is to predict the naturally allowed FWP during certain days of the life cycle of hybrid projects. At the input of the artificial neural network, the quantitative value of the naturally allowed FWP during the previous days is given. The output is the predicted quantitative value of the naturally allowed FWP for the next day. The architecture of the proposed neural network is fully connected. In this case, the number of hidden layers should be selected experimentally, taking into account the condition that the greater their number, the more accurate will be the prediction of naturally allowed FWP in a single day. However, this increases the duration of training of the artificial neural network. The predicted quantitative value of the naturally allowed FWP for the next day is compared with the real one. It is recorded in the database, after which the proposed system undergoes the next iteration of training with a shift by days (Fig. 3).

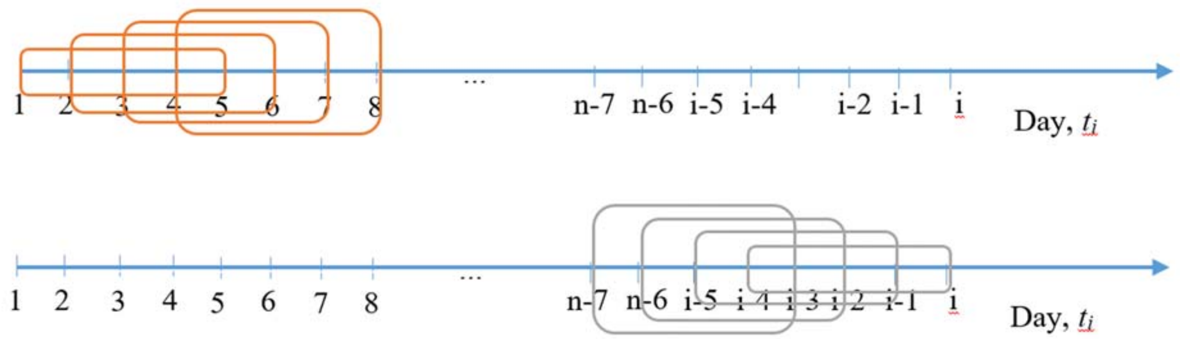

Figure 3: Graphical interpretation of the shift of values of naturally allowed FWP during certain days of the life cycle of hybrid projects

The solution of the FWP prediction problem in hybrid projects is carried out using two measurements during neural network training - space and time. Thus the space-time approach to training a neural network gives the chance to adapt the behaviour to the time structure of events in space. Provided that the artificial neural network reflects a system with a stationary environment, it can be taught the statistical characteristics of the design environment with the help of a teacher. In this case, to obtain and use the experience gained from previous periods, the system should provide for the use of a certain form of memory.

Given the fact that in hybrid projects there is a changing natural and climatic component of the design environment, which is non-stationary, the statistical characteristics of the input signals (duration of naturally allowed FWP) change over time. Therefore, for such a system, teaching methods with a teacher cannot be used, as an artificial neural network will not detect changes in the changing design environment. All the above gives grounds to claim that a given system should provide for the adaptation of network parameters to the variable durations of naturally allowed FWP in reality. The learning process of the artificial neural network in the presented adaptive system is not completed until the data for processing, ie it characterizes the continuous learning (Fig. 4).

One of the essential components of building a neural network for FWP prediction is data normalization. This is done before training and significantly speeds up the learning process of the specified neural network. To normalize the data use the method of minimax within [0, 1], which provides the best results for agricultural production [25]:

$$t_{d_i}' = \frac{t_{di} - t_{dmin}}{t_{dmax} - t_{dmin}}, \tag{2}$$

where t_{di}' – normalized value of FWP during a single day, hours;

t_{di} – current FWP value for a single day, hours;

t_{dmin}, t_{dmax} – respectively, the minimum and maximum value of FWP in a given sample, hours.

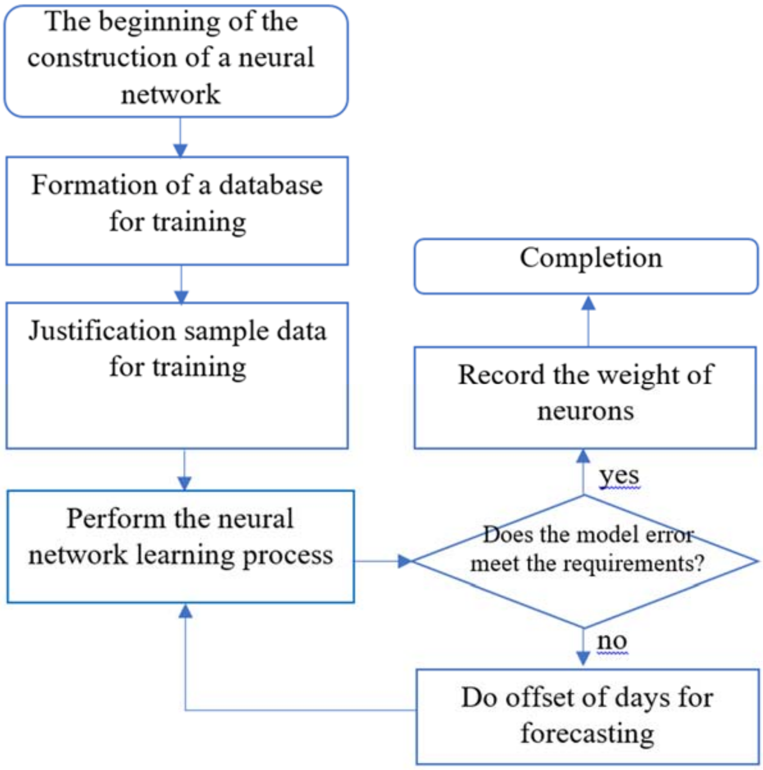

Figure 4: The enlarged neural network learning algorithm for predicting naturally-allowed FWP in hybrid projects

The results of determining the normalized values of naturally-allowed FWP during a single day are given in the table 1.

Table 1
The results of determining the normalized values of naturally allowed FWP during a particular day

Number of the day of the study period	Hour of the day in which the deficit of air humidity D> 4 hPa	Duration of natural-permitted FWP, t_{di}, hours	Normalized duration value of FWP
1	8,0	15,6	0,650
2	7,7	15,8	0,658
3	7,6	16,1	0,671
4	9,0	6,2	0,258
5	8,7	7,8	0,325

Given that the proposed system has quantitative normalized values of naturally allowed FWP during a single day in the range from 0 to 1, we have chosen a sigmoidal function to activate neural networks (Fig. 5):

$$\phi\left(t_{di}'\right) = \frac{1}{1+\exp(-\alpha \cdot t_{di})}. \qquad (3)$$

where α – tilt parameter.

After that, a dictionary is formed with data that provides for the storage of neuron weight. In this case, simultaneously with the weights of the neurons, the value of the number of the hidden layer is fixed and stored, as well as the assigned number of the neuron index. This will make it much easier to read data from the dictionary without searching the required data in the arrays, which will speed up the process of accessing the database.

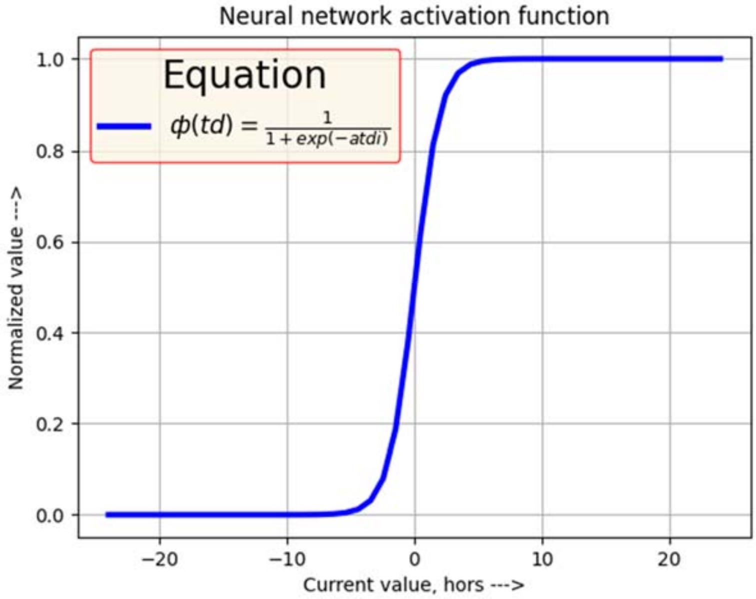

Figure 5: Classical sigmoidal function for neural network activation

The proposed structure of the neuron is such that will provide a single static input, which will be 1, and reflect the threshold value of the neuron (Fig. 6).

It is suggested that the weight of the neuron (w_{tdi}) be stored in RAM during the training of the artificial neural network. This will increase the speed and reduce the duration of the learning process. The obtained weights of neurons (w_{tdi}) are recorded in a database, which allows them to be used as needed. The proposed neural network learning algorithm allows predicting FWP with a given accuracy. In this case, the number of individual hidden layers of the proposed neural network affects the accuracy of the FWP prediction. At the same time, as the number of hidden layers increases, the duration of training of an artificial neural network will increase. The rational number of hidden layers of the artificial neural network should be selected experimentally, depending on the need for accurate forecasting.

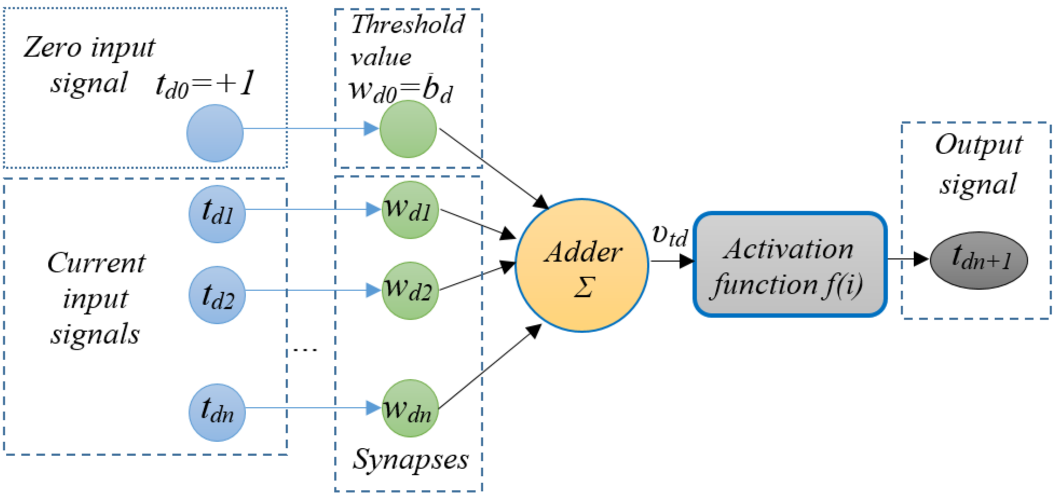

Figure 6: The proposed neuron model for predicting FWP hybrid projects

The proposed neural network architecture involves the use of a multilayer perceptron, which makes it possible to solve the problem of predicting naturally allowed FWP in hybrid projects. At the same time, training with a teacher is envisaged, as we have available statistics from previous periods on the change in the humidity deficit, which determines the start time and duration of the naturally allowed FWP. Based on the comparative analysis of machine learning methods with the teacher, we chose the method of inverse error propagation. It is based on an algorithm that minimizes the forecast error by propagating error signals from the network outputs (estimated duration of natural allowable time for work) to its inputs (values of the duration of natural allowable time for work in previous days), in the direction that is the inverse of direct signal propagation.

5. The results of preparation of initial data, training of the artificial neural network, and evaluation of the accuracy of the model for predicting the natural allowable time of work during certain days

In order to solve the scientific-applied problem of predicting naturally allowed FWP during certain days of the life cycle of hybrid projects, software in Python language has been developed, which is based on the proposed neural network architecture. Given the need for short-term FWP forecasting, it is proposed to use a direct error propagation network with five inputs that reflect the values of FWP duration in previous days. The weights of network neurons are stored in the MS SQL database.

To predict FWP, based on the experiments, the rational structure of the neural network was determined: 5 inputs, which will be the value of the duration of natural time allowed to perform work in 5 previous days, and 2 hidden layers with 5 neurons. To train the neural network, statistical data of the summer months of 2020 on the natural allowable time of work during certain days (Fig. 7), which are typical for the conditions of the Volodymyr-Volynskyi district of the Volyn region, were used.

On the basis of the received data, the histogram of change of FWP duration which underlies training of a neural network is constructed. On certain days, where the duration of the naturally permitted FWP was $t_{di} < 12$hours , precipitation was observed.

Studies conducted based on neural network training show that when the number of epochs increases to more than 25,000, the prediction error does not exceed 4.8%. On the basis of the performed research of the adjusted artificial neural network, the tendencies of change of the naturally allowed FWP during certain days of a life cycle of hybrid projects (real and forecasted value) for conditions of the Volodymyr-Volynskyi area of the Volyn area are established (Fig. 7).

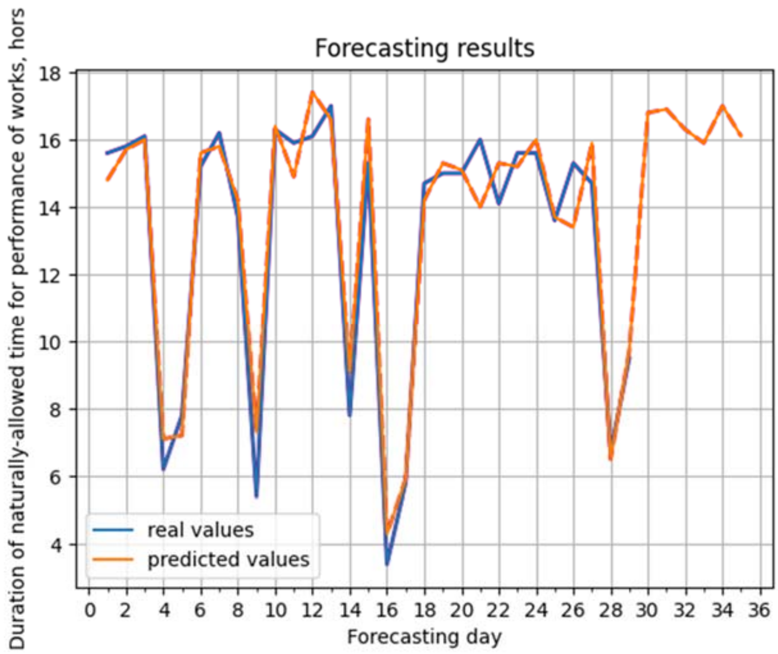

Figure 7: The results of forecasting trends in the change of naturally allowed FWP during certain days of the life cycle of hybrid projects

The presented trends of change of naturally allowed FWP in hybrid projects (real and predicted values) show that the use of the proposed artificial neural network architecture gives a fairly accurate forecast and this is the basis for making quality management decisions on planning the content and timing of work in hybrid projects.

6. Conclusions

1. Substantiated structure of the neural network for predicting natural-allowed FWP during the life cycle of hybrid projects provides 5 inputs that display the value of the duration of natural-allowed time to perform work in the previous 5 days, and 2 hidden layers with 5 neurons. The neural network architecture involves the use of a multilayer perceptron, teacher training, and the method of backpropagation. It is based on an algorithm that minimizes the prediction error by propagating error signals from the network outputs (predicted duration of naturally allowed FWP) to its inputs (values of the duration of naturally allowed FWP in previous days), in the direction opposite to the direct propagation of signals.

2. Based on the prepared initial data, the training of an artificial neural network was performed, which ensured the creation of an artificial neural network that is able to predict the duration of naturally allowed time to perform work in a software environment written in Python. Studies based on neural network training show that when the number of epochs increases to more than 25,000, the error does not exceed 4.8%. To study the neural network, we used the statistical data of the summer months of 2020 on the naturally allowed FWP during certain days (Fig. 7), which are typical for the conditions of the Volodymyr-Volynskyi district of the Volyn region. The obtained results indicate that the use of the proposed architecture of the artificial neural network gives a fairly accurate forecast and this is the basis for making quality management decisions on planning the content and timing of work in hybrid projects.

7. Acknowledgements

The work was performed according to the research theme of "Development of project-led innovative systems, resource-saving technologies and technical means in agroindustrial production and its security" (government registration number of 0116U003179) funded by Ministry of Education and Science of Ukraine.

8. References

[1] M. Salehi, S. Farhadi, A. Moieni, N. Safaie, M. Hesami, A hybrid model based on general regression neural network and fruit fly optimization algorithm for forecasting and optimizing paclitaxel biosynthesis in Corylus avellana cell culture, in: Plant Methods 17(1), 13 (2021)

[2] A. Tryhuba, I. Tryhuba, O. Bashynsky, et al., Conceptual model of management of technologically integrated industry development projects, in: 15th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT), 2, pp. 155-158, September 2020.

[3] R. Ratushny, O. Bashynsky and O. Shcherbachenko, Identification of firefighting system configuration of rural settlements, in: Fire and Enviromnental Safety Engineering. MATEC Web Conf. Volume 247 (FESE 2018).

[4] P. Lub, A. Sharybura, L. Sydorchuk, et al., Information-analytical system of plants harvesting project management, in: CEUR Workshop Proceedings, 2020, 2565, pp. 244-253.

[5] A. Tryhuba, I. Tryhuba, O. Ftoma, O. Boyarchuk, Method of quantitative evaluation of the risk of benefits for investors of fodder-producing cooperatives, in: 14th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT), 3, pp. 55- 58, September 2019.

[6] A. Tryhuba, V. Boyarchuk, I. Tryhuba, O. Boyarchuk, O. Ftoma, Evaluation of Risk Value of Investors of Projects for the Creation of Crop Protection of Family Daily Farms. Acta universitatis agriculturae et silviculturae mendelianae brunensis, 67(5), (2019) 1357-1367.

[7] A. Tryhuba, M. Rudynets, N. Pavlikha, I. Tryhuba, I. Kytsyuk, O. Komeliuk, V. Fedorchuk-Moroz, I. Androshchuk, I. Skorokhod, D.Seleznov, Establishing patterns of change in the indicators of using milk processing shops at a community territory. Eastern-European Journal of Enterprise Technologies: Control processes. 3/6 (102), 57-65 (2019).

[8] A. Tryhuba, V. Boyarchuk, I. Tryhuba, O. Boiarchuk, N. Pavlikha, N. Kovalchuk, Study of the impact of the volume of investments in agrarian projects on the risk of their value (ITPM-2021) In: CEUR Workshop Proceedings vol. 2851 (2021)

[9] P. Lub, A. Sharybura and V. Pukas, Modelling of the technological systems projects of harvesting agricultural crops, in: 14th International Conference on Computer Sciences and Information Technologies (CSIT), 3, pp. 19-22.

[10] A. Tryhuba, V. Boyarchuk, I. Tryhuba, et al., Method and Software of Planning of the Substantial Risks in the Projects of Production of raw Material for Biofuel, in: CEUR Workshop Proceedings. Published in ITPM, 2020.

[11] A. Tryhuba, V. Boyarchuk, I. Tryhuba, et al., Model of assessment of the risk of investing in the projects of production of biofuel raw materials, in: 15th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT), 2, pp. 151-154, September 2020.

[12] T. Neskorodieva, E. Fedorov, Method for Automatic Analysis of Compliance of Expenses Data and the Enterprise Income by Neural Network Model of Forecast (MoMLeT&DS-2020) In: CEUR Workshop Proceedings vol. 2631 (2020)

[13] G. P. Zhang, Time series forecasting using a hybrid ARIMA and neural network model, in: Neurocomputing, 50, 2003, pp. 159-175.

[14] H. S. Hippert, C. E. Pedreira, R. C. Souza, Neural networks for short-term load forecasting: A review and evaluationI, in: EEE Transactions on Power Systems 16(1), 2001, pp. 44-55.

[15] A. Tryhuba, V. Boyarchuk, I. Tryhuba, O. Ftoma, R. Padyuka, M. Rudynets, Forecasting the risk of the resource demand for dairy farms basing on machine learning (MoMLeT&DS-2020) In: CEUR Workshop Proceedings vol. 2631 (2020)

[16] H. R. Maier, G. C. Dandy, Neural networks for the prediction and forecasting of water resources variables: A review of modelling issues and applications, in: Environmental Modelling and Software 15(1), 2000, pp. 101-124.

[17] R. Ratushnyi, O. Bashynsky, V. Ptashnyk, Development and Usage of a Computer Model of Evaluating the Scenarios of Projects for the Creation of Fire Fighting Systems of Rural Communities, Xlth International Scientific and Practical Conference on Electronics and Information Technologies (ELIT), pp. 34-39, September 2019.

[18] A. Tryhuba, V. Boyarchuk, I. Tryhuba, et al., Forecasting of a Lifecycle of the Projects of Production of Biofuel Raw Materials With Consideration of Risks, in: International Conference on Advanced Trends in Information Theory (ATIT), pp. 420-425 (2019).

[19] G. Zhang, B. Eddy Patuwo, M. Y. Hu, Forecasting with artificial neural networks: The state of the art, in: International Journal of Forecasting, 14(1), 1998, pp. 35-62.

[20] A. Saiyad, A. Patel, Y. Fulpagare, A. Bhargav, Predictive modeling of thermal parameters inside the raised floor plenum data center using Artificial Neural Networks, in: Journal of Building Engineering 42,102397 (2021)

[21] A. Tryhuba, R. Ratushny, I. Tryhuba, N. Koval and I. Androshchuk, The Model of Projects Creation of the Fire Extinguishing Systems in Community Territories, in: Acta universitatis agriculturae et silviculturae mendelianae brunensis. 68, 2, 2020, pp. 419-431.

[22] L.I. Quemada-Villagómez, R. Miranda-López, M. Calderón-Ramírez, et al., A simple and accurate mathematical model for estimating maximum and minimum daily environmental temperatures in a year, in: Building and Environment 197,107822 (2021)

[23] I. Bodnar, M. Bublyk, O. Veres, O. Lozynska, I. Karpov, Y. Burov, P. Kravets, I. Peleshchak, O. Vovk, O. Maslak, Forecasting the Risk of Cervical Cancer in Women in the Human Capital Development Context Using Machine Learnin (MoMLeT&DS-2020) In: CEUR Workshop Proceedings vol. 2631 (2020)

[24] Y. Vyklyuk, N. Kunanets, V. Pasichnyk, O. Husak, O. Kunanets, Y. Kryvenchuk, An Information System Prototype for Monitoring and Modeling the Spread of Viral Infections (MoMLeT&DS-2020) In: CEUR Workshop Proceedings vol. 2631 (2020)

[25] G.-B. Huang, Q.-Y. Zhu, C.-K. Siew, Extreme learning machine: Theory and applications, in: Neurocomputing, 70(1-3), 2006, pp. 489-501.
[26] M. Zhai, W. Li, P. Tie, et al., Research on the predictive effect of a combined model of ARIMA and neural networks on human brucellosis in Shanxi Province, China: a time series predictive analysis, in: BMC Infectious Diseases 21(1), 280 (2021)
[27] V.-A. Oliinyk, V. Vysotska, Y. Burov, K. Mykich, V. Basto-Fernandes, Propaganda Detection in Text Data Based on NLP and Machine Learning (MoMLeT&DS-2020) In: CEUR Workshop Proceedings vol. 2631 (2020)
[28] K. Melnyk, The Technology of Short-Term Planning for Resolving the Problems with High Level of Uncertainty on an Enterprise (MoMLeT&DS-2020) In: CEUR Workshop Proceedings vol. 2631 (2020)
[29] R.K. Samala, H.-P.Chan, L. M. Hadjiiski, M. A.Helvie, C.D. Richter, Generalization error analysis for deep convolutional neural network with transfer learning in breast cancer diagnosis, in: Physics in Medicine and Biology, 65 (10), 105002 (2020)
[30] V. Pasichnyk, N. Kunanets, N. Veretennikova, A. Rzheuskyi and M. Nazaruk, Simulation of the Social Communication System in Projects of Smart Cities, in: 14th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT), 3, pp. 94–98, September 2019.
[31] O. Veres, N. Kunanets, V. Pasichnyk, N. Veretennikova, R. Korz and A. Leheza, Development and Operations - The Modern Paradigm of the Work of IT Project Teams, in: 14th International Scientific and Technical Conference on Computer Sciences and Information Technologies (CSIT), 3, pp. 103-106, September 2019.
[32] D. Kobylkin, O. Zachko, R. Ratushny, A. Ivanusa, C. Wolff, Models of content management of infrastructure projects mono-templates under the influence of project changes (ITPM-2021), in: CEUR Workshop Proceedings, 2851, pp. 106-115.
[33] E. McConnell, Project Management Methodology: Definition, Types, Examples. URL: http://www.mymanagementguide.com/basics/project-methodology-definition/.
[34] Y.-D. Zhang, S. C. Satapathy, D. S. Guttery, J. M. Górriz, S.-H. Wang, Improved Breast Cancer Classification Through Combining Graph Convolutional Network and Convolutional Neural Network, in: Information Processing and Management, 58(2), 102439 (2021)
[35] K. Kolesnikova, O. Mezentseva and O. Savielieva, Modeling of Decision Making Strategies In Management of Steelmaking Processes, in: International Conference on Advanced Trends in Information Theory (ATIT), 2019, pp. 455-460.
[36] R. Ratushny, O. Bashynsky, V. Ptashnyk, Planning of Territorial Location of Fire-Rescue Formations in Administrative Territory Development Projects, in: CEUR Workshop Proceedings. Published in ITPM, 2020.
[37] O. Bashynsky, T. Hutsol, A. Rozkosz, O. Prokopova, Justification of Parameters of the Energy Supply System of Agricultural Enterprises with Using Wind Power Installations, in: E3S Web of Conferences 154, 2020.
[38] R. Ratushny, I. Horodetskyy, Y. Molchak, V. Grabovets, The configurations coordination of the projects products of development of the community fire extinguishing systems with the project environment (ITPM-2021) In: CEUR Workshop Proceedings vol. 2851 (2021)
[39] B. Batyuk and M. Dyndyn, Coordination of Configurations of Complex Organizational and Technical Systems for Development of Agricultural Sector Branches, in: Journal of Automation and Information Sciences 52(2), pp. 63-76. January 2020.
[40] O. Bashynsky, I. Garasymchuk, O. Gorbovy, et al., Research of the variable natural potential of the wind and energy energy in the northern strip of the ukrainian carpathians, in: 6th International Conference : Renewable Energy Sources (ICoRES 2019). E3S Web of Conferences 154, 06002, 2020.
[41] O. Prydatko, Y. Borzov, I. Solotvinskyi, O. Smotr and O. Didyk, Informational System of Project Management in the Areas of Regional Security Systems' Development, in: 2th International Conference on Data Stream Mining and Processing, DSMP 2018, 2018, pp. 187–192.