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NAS RK is pleased to announce that News of NAS RK. Series physico-mathematical journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of chemistry and technologies in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of chemical sciences to our community.

Қазақстан Республикасы Ұлттық ғылым академиясы «ҚР ҰҒА Хабарлары. Физикалық-математикалық сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Webof Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын усынады. ҚР ҰҒА Хабарлары. Химия және технология сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді химиялық ғылымдар бойынша контентке адалдығымызды білдіреді.

НАН РК сообщает, что научный журнал «Известия НАН РК. Серия физико-математическая» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по химическим наукам для нашего сообщества.

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Myrzatay A.A.[1*], Rzayeva L.G.[1], Uskenbayeva G.A.[1], Shukirova A.K.[1]Abitova G.[2]

[1]L.N. Gumilyov Eurasian National University, Nur-Sultan, Kazakhstan;
[2]Astana IT University, Nur-Sultan, Kazakhstan.
E-mail: mirzataitegiali@gmail.com

THE EFFECT OF THE AMOUNT OF DATA ARRAY ON THE RESULTS OF FORECASTING NETWORK EQUIPMENT FAILURES

Abstract. The article discusses three methods for predicting network equipment failures and the impact of the data array of input controllers. The purpose of the article is to reveal the relevance of the approach proposed by the authors to the use of large-amount of data in the chosen method of machine learning and to make a comparative analysis of the final values with the works of other world researchers. In the first section, the authors analyze the work of scientists from the Beijing University of Post and Telecommunications, noting the strengths and weaknesses of their method. In Section 2, the authors analyze the Holt-Winters method for developing algorithms for analyzing network traffic, which was applied by researchers from the Tomsk State University of Control Systems and Radio Electronics. In section 3, the authors applied the method of random trees in the modeling of machine learning methods of Rapid Miner Studio. The authors have carried out work with a large amount of data, and a comparative analysis of the results of modeling the method. The importance of using large amounts of information to train a model of network equipment failure forecasts is proved. In the final section, the authors highlight the need to improve forecasting models for its further implementation in the working environment. Also, the authors emphasize that the two articles considered by international researchers are a special case, as well as their chosen method for predicting failures in the LAN system.

Key words: machine learning methods, modeling of machine learning method, network equipment failure forecasts, LAN.

Introduction. Incessant development of information technology has led to an increase in the number of active equipment and the size of local networks of enterprises, as well as problems associated with its proper organisation and monitoring. In this article, we would like to focus on companies providing services in the field of information technology, in particular services related to the provision of local area networks (LAN) systems. These IT firms provide end users with Internet access services, organisation and maintenance of LANs, and active equipment such as switches, routers, hubs, servers, and so on. Due to the scale of the deployed network, companies providing these kinds of services, face difficulties trying to maintain a high quality of services and technical and economic performance of the system. The existing automated enterprise management systems (ACS) must meet the stated requirement in the context of ever-growing complexity of the problem being solve: the constant growth of the scale of the provided service, the development of the route network, logistics management, the increase in time and event loads.

Often-times, companies providing these kinds of services use real-time monitoring systems. In the operational monitoring and incident management system (OM&M), incidents are recorder – incidents related to equipment breakdowns, delay or loss of traffic, overheating or failure due to external factors, and other important events. Those incidents are registered promptly from the devices (switches) of the company or through the communication channels of the end users of the services. It is a common practice to handle incidents at the levels of dispatch services or monitoring centres. Some categories of incidents require prompt resolution, for example, all kinds of breakdowns (failures) of active equipment. In order to improve the efficiency of the companies operations, the fault tolerance of a number of active LAN equipment can be predicted.

The main expected business effect from the use of forecasting tools is a reduction in financial losses by an increase of the technical availability of equipment. This goal should be achieved by providing a means of predicting the fault tolerance of equipment based on the researched forecasting methods.

Nowadays, knowledge in the data mining is widely represented, there are many IT publications on the topic. However, in most cases, those papers focus on a particular case, or the study has an ample space for further development, through addition of new variables, which in turn can affect the final result of the forecasts. [8]

This article addresses the issues of using data mining in data transmission systems' industry through comparison of the random tree method chosen by the authors with the SVM-DES method chosen by researchers from a Chinese university [2] and the works of Russian researchers [3,4]. In this paper, we conduct a comparative analysis of the need to feed a large amount of data to the input of controllers using machine learning for further study in this direction.

Materials and methods. Review and analysis of the article «Failure prediction using machine learning and time series in optical network». The article «Failure prediction using machine learning and time series in optical network», written by the researchers from the Beijing University of Posts and Telecommunications in collaboration with China Mobile Corporation, proposes a method for predicting optical network equipment failure based on a method combing double exponential smoothing (DES) and specially selected support vector machine learning (SVM). The proposed DES-SVM forecasting method can be applied in a software-defined network. The basic algorithm is not complicated, so the proposed method is easy to install in the network controller. Equipment information from a monitoring records of a network management system in a real wavelength division multiplexed (WDM) network was used to validate the chosen method.

A typical learning algorithm is usually challenged by the enormity of raw data (for example, typically more than 100000 items) required to train a decision model. At this scale, the controller must have a large memory capacity and corresponding powerful computing power. In a real network, determining the availability of a node is performed by many different types of equipment. If the controller monitors and predicts the state of each piece of equipment on this scale, it will be under a heavy load. One needs to choose machine learning algorithm that is able train a highly accurate model with less data. The SVM algorithm has high efficiency and high accuracy with a data volume less than 5000, which is suitable for practical application in the WDM optical network.

The main application scenario for the proposed method is a software-defined metropolitan area network (SDMAN / POGS), as shown in Figure 1.

In the physical plane, WDM nodes form a metropolitan network in a mesh topology. In the control one, the central controller collects operational and maintenance (O&M) data from all WDM nodes and then proceeds to analyse the data before providing the instructions.

The method proposed by Chinese researchers works in controller, using these operations to train a predictive model and predict equipment failure. Upon an identification of a potential hardware failure using the DES-SVM prediction method, the controller initiates protection measures in advance to calculate the best approach to protecting services. The controller then sends control messages to all WDM nodes; these nodes, in turn, switch services to a secure path to prevent data loss. The basic procedure for the DES-SVM forecasting method is listed below:

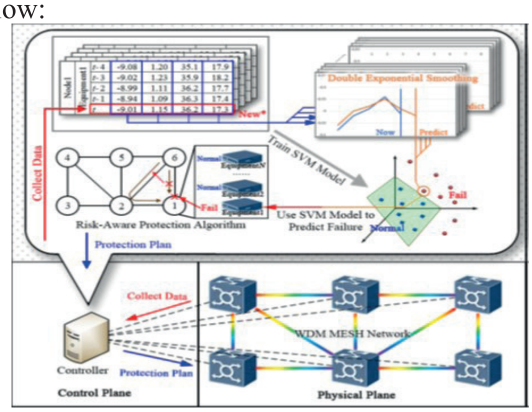

Figure 1. DES-SVM forecasting method is predicting equipment failure, and a risk-based protection algorithm, preventing data loss in SDMAN/POGS.

1. The controller collects data and selects indicators. In the SVM algorithm, we use functions to form a vector x in each data item, these features are values of the indicators. In Figure 2 we illustrate the ability to use the classification accuracy trained on one metric to get the relationship between that metric and equipment failure. If a metric is closely related to equipment failure, a change in that metric will obviously affect the equipment failure state.

2. The next step is to train the best model for diagnosing failures. In the use of the SVM algorithm, tow parameters – the kernel function and penalty factor – were chosen according to the characteristics of the problem data. The choice of the kernel function and penalty factor directly affect the accuracy of the model.

3. The third step of this forecasting procedure is the prediction of the indicator value. At this point, they use DES for each function, thereby setting and adjusting the prediction curve according to the latest monitoring data.

4. Then comes an attempt to predict the hardware failure. Thus, they obtain a model for diagnosing equipment malfunction in stages 1 and 2, and derive the predicted value of each function in stage 3.

According to the experimental data shown in Figure 3, the accuracy of the DES-SVM forecasting method averaged 95.59%, which meant that the failure state of 95% of the boards could be correctly predicted. Moreover, for forecasting, they chose about 10 (ten) boards that tended to fail. Although, their indicators underwent very large fluctuations, the prediction accuracy reached 86,37%. These results indicate that their forecasting method often predicted the state of the equipment correctly.

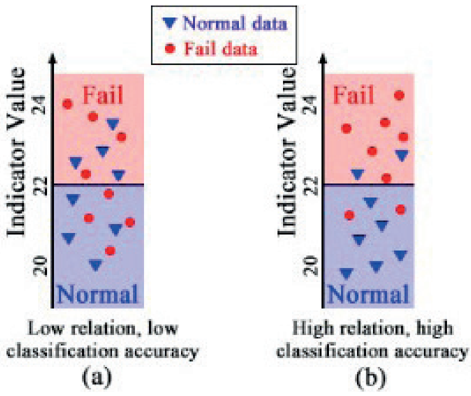

Figure 2. The classification accuracy for one indicator reflects the degree of the relationship between this indicator and equipment failure.

According to the experimental results, the DES-SVM forecasting method offers the following key benefits. It can predict board failure on a WDM network, which means that services can be protected from data loss before the network fails. In addition, it can observed that SVM and DES are not complex algorithms. Thus, the proposed combined method can be easily installed in the controller system.

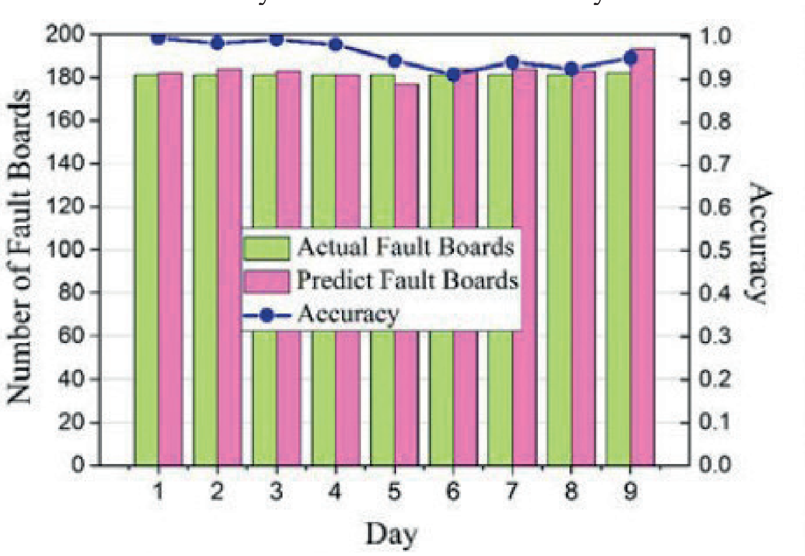

Figure 3. Number of predicted boards faults versus actual boards faults; and the accuracy of the DES-SVM forecasting.

However, due to the poor response of DES during the period when the period when the data trend changed markedly, their method was unable to accurately predict the inflection point. If the data were more accurate (for example, data was recorded hourly rather than per day), better predictors of metric values could had been identified.

2. **Review and analysis of the article by researchers from the Russian Federation.** In contrast to Chinese researchers, the scientific study of researchers from TUSUR was in the plane of short-term forecasting of incidents [3] and forecasting in the LAN monitoring system through analysis of the network traffic [4]. In both works, the authors used the Holt-Winters method to develop algorithms for analysing network traffic. As a result, the researchers obtained a good performance of the chosen technique for their particular case [3] Figure 4.

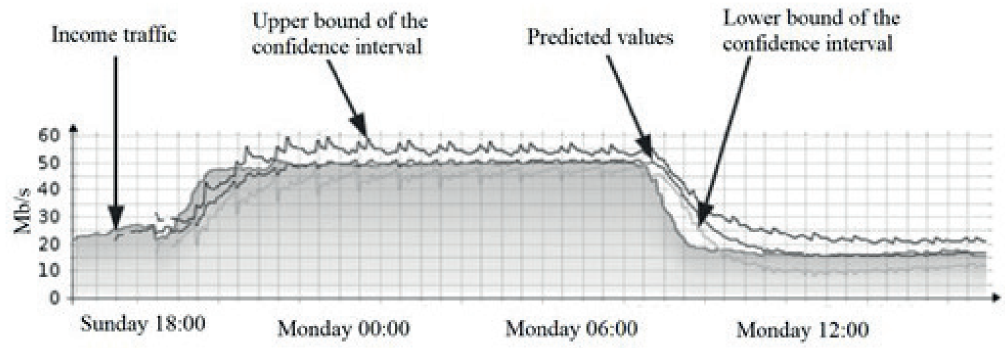

Figure 4. An example of data visualization of using the Holt-Winters method to analyse the load of one of the network interfaces on a router using the mechanism of confidence intervals.

It should be noted that due to the impossibility of the conduction of experiments under equal conditions on identical equipment [5] by researchers, it was not possible to carry out any quantitative assessment of this parameter. However, such comparative studies are likely to be made later in other works of the authors.

Also, it is worth to mention the problems, identified during the processing of large data arrays by the selected ELK stack by the researchers from TUSUR, namely: the criticality of the stack to errors of a certain type [6,7], which provokes interruptions in the operation of the stack and low coefficient of recovery of the stack in case of interruptions.

However, the undoubted advantage of the proposed approach is the regular adjustment of the criteria based on previous observations and the possibility of identifying correlations between, at first glance, unrelated values of the parameters of controlled objects. Besides, it is possible to correct all the coefficients, in the midst of the observation process, which makes it possible to ensure the required level of model accuracy. The limitation in terms of the requirement for accumulation of data prior to the construction of predicted values in solving practical problems is levelled on the basis of the principles of functioning of modern telecommunication networks, as well as the volume and speed of data transmission in them [3].

3. **Review of the fault forecasting model using the method of random trees of machine learning solutions and its comparison with abovementioned method of foreign researchers to this particular case.** The authors of this article analysed a wide range of machine learning forecasting methods for its application in predicting faults of LAN equipment. As an alternative to the methods discussed earlier, we decided to use the random tree method. PRTG Network Monitor software was used to collect metadata from several CISCO network equipment due to the simplicity of collecting from a wide range of sensors. A possible alternative to the chosen software, one can also consider other software, for example, ZABBIX monitoring systems.

Next, a model was built based on machine learning – random tree with cross validation: "Random forest with cross validation".

Prior to construction of the model, the analysis and preparation of the data was carried out, the relationships of the data, the frequency of their update (changes) were determined.

The essence of the model based on the method of random tree for solving machine learning was that the collected sample consisted of 365, more than 1800 and more than 2500 records, that is, from the statistics of operational sensors of the 1st, 5th and 7th network switches. The number of parameters for each record was 8, 14 and14, respectively (Figure 5). The relationships between the parameters and their weights are determined automatically and so-called tree models are created (Figure 6). However, some parameters were either simplified or not taken into account by the model. In this case, when evaluating the model, the available data is divided into k parts. Then the model is trained on k-1 pieces of data, and the rest of the data is used for testing. The procedure is repeated k times; as a results, each of the k pieces of data is used for testing. This results in an assessment of the effectiveness of the chosen model with the most even use of the available data.

The most important point in machine learning is data preparation. This stage entails data cleansing, unification, adding values, fields, etc. In this case, the main data preparation was carried out using the tools of the PRTG Monitor monitoring system and Excel, but, additionally, the data was adjusted. In the future, this process can be brought to automation through various subroutines.

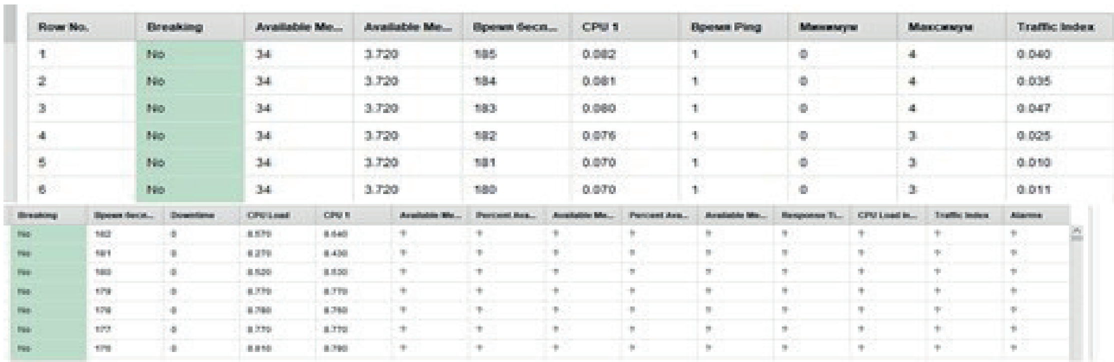

Figure 5. An example of data sampling. The amount of data and their parameters; from 8 to 14 parameters per record.

The data analysis using a predictive model was carried out not on an industrial scale, on clusters, as is usually the case, but on a regular computer device (Inter® Core(TM) i5-7500, 3,40GHz, 16GB RAM). In order to increase performance during the processing of the input data, especially with the large volumes, it is advisable to store all data in one source, if possible, not to abuse the merger of a large number of tables, as well as conditions and subqueries. Also, all calculated fields should be stored in the table, already prepared and not calculated on the fly. For example, the number of breakdowns (faults) and the time interval between the last breakdowns were calculated in advance. There is no need to shift the calculation and processing of complex formulas to a data mining tool.

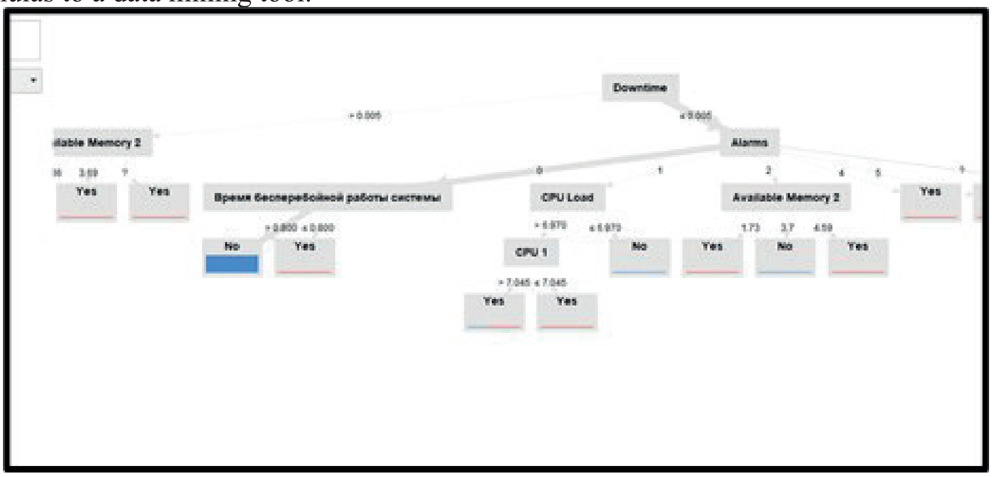

Figure 6. One of the 1000 decision tree in the model.

The model (Figure 7) was built using Rapid Miner Studio version 9.8, an open source solution with powerful development functionality and an intutive graphical interface.

As a **results** of the study, the authors came to the following conclusion:

1. With and increase in the total number of breakdowns (faults), the number of samples, and parameters, the results of the model forecast based on machine learning turned out to be more or less accurate, accuracy rate of more than 72% (Figure 8).

2. After an increase in the total number of samples of about 2500 records with the same number of 14 parameters per record, the forecast accuracy increased to 100%, while the accuracy of breakdown prediction decreased to 96% (Figure 9, 10)

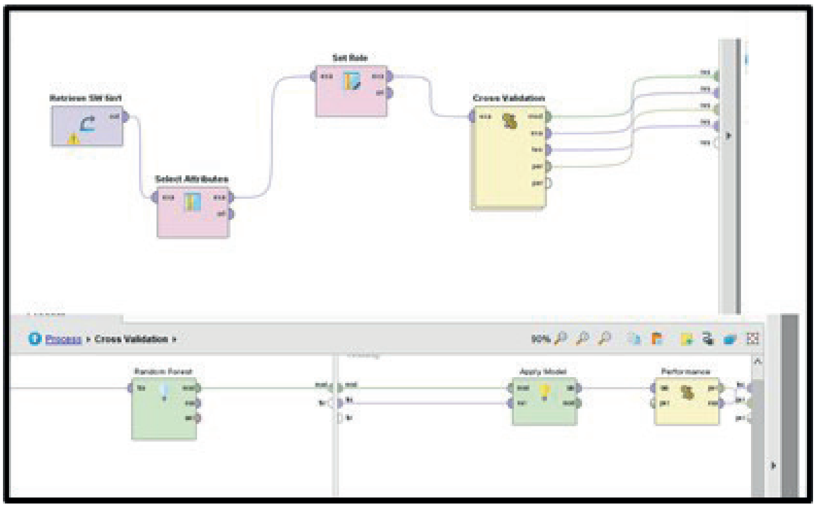

Figure 7. The Random forest model with cross validation

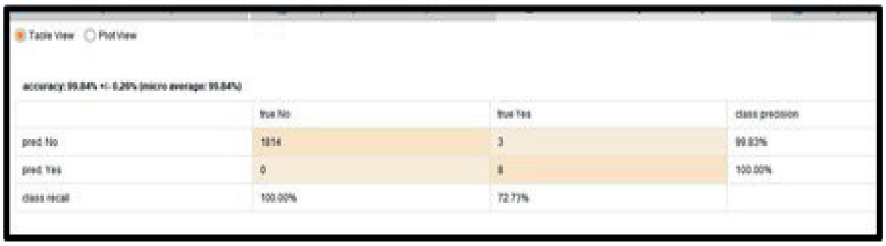

Figure 8. The results of the predictive model based on machine learning with a sample of about 1800 records and 14 parameters.

Figure 9. The results of the forecasting model based on machine learning after an increase in the number of sample to about 2500 records with the same number 0f 14 parameters per record.

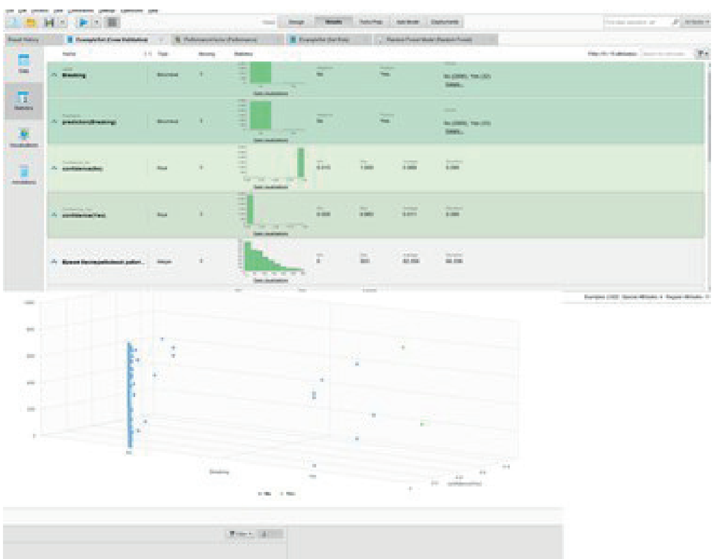

Figure 10. Visualisation of model results in the form of statistics and graphs.

Discussion. First of all, it should be noted that the authors of this article were tasked with investigation of the effect of the volume of the data array on the results of forecasting network equipments faults.

Considering the abovementioned goal, we found that the problems of processing large amount of data per unit of time remain unchanged. So, if were to compare the first method, the DES-SVM method, with the other two, then the disadvantage of this method is the difficulty of processing input data by more than 5000 per unit of time, while our method could allow an increase that number to more than 2500*14= 35000 data units per unit of time. This indicator is extremely important, since the breakdown (fault) prediction will be more accurate if the data at the input of the controllers is more varied and voluminous. In other words, the more data, the less are the chances of a false prediction by the model. In addition, according to the researchers from the Beijing University of Posts and Telecommunications, themselves, their method was unable to accurately predict the inflection point due to the poor response of DES at a time when data trend changed markedly. If the data were more accurate (for example, data was recorded hourly rather than per day), better predictors of metric values could had been identified.

Conclusion. At the same time, the authors of the second method also faced the problem of processing large data. Their method is preferable because of the possibility of adjusting the criteria based on previous observations and the ability to identify correlations between, at first glance, unrelated values of the parameters of controlled objects.

Secondly. It should be emphasised that researchers from the Beijing University of Posts and Telecommunication have proven their theory in practice, and their data on the DES-SVM method of verification is closer to the real conditions and is more reliable; just like the results of researchers from TUSUR; in contrast, to the Random-Forest with Cross Validation method tested by the authors of this article on RapidMiner software, albeit with the live metadata.

The authors hope that further research in this direction will make it possible to use methodological support for solving various problems and obtaining quantitative estimates of future results.

Мырзатай А.А.[1*], Рзаева Л.Г.[1] Ускенбаева Г.А.[1], Шукирова А.К.[1], Абитова Г.[2]

[1]Л.Н. Гумилев атындағы Еуразия Ұлттық Университеті, Нұр-Сұлтан, Қазақстан;
[2]Astana IT University. Нұр-Сұлтан, Қазақстан.
E-mail: mirzataitegiali@gmail.com

ДЕРЕКТЕР МАССИВІ КӨЛЕМІНІҢ ЖЕЛІЛІК ЖАБДЫҚТЫҢ ІСТЕН ШЫҒУЫН БОЛЖАУ НӘТИЖЕЛЕРІНЕ ӘСЕРІ

Аннотация. Мақалада желілік жабдықтың істен шығуын болжаудың үш әдісі және мәліметтер массивінің таңдалған методтарныа әсері қарастырылған. Мақаланың мақсаты - машиналық оқытудың таңдалған әдісінде үлкен көлемдегі деректерді қолдануға авторлар ұсынған тәсілдің өзектілігін ашу және қорытынды мәндерді басқа, әлемдік зерттеушілердің жұмыстарымен салыстырмалы талдау жасау. Бірінші бөлімде авторлар Пекин пошта және телекоммуникация университетінің ғалымдарының жұмысын талдайды, олардың таңдаған әдісінің күшті және әлсіз жақтарын атап өтеді. 2-бөлімде авторлар Томск мемлекеттік басқару жүйелері және радиоэлектроника университетінің зерттеушілері қолданған желілік трафикті талдау алгоритмдерін жасау үшін қолдаңған Хольт-Винтерс әдісін талдайды. 3-бөлімде авторлар RapidMiner студиясының Машиналық оқыту әдістерін модельдеуде «Кездейсоқ ағаш» әдісін қолданды. Авторлар деректердің үлкен көлемімен жұмыс жасады және әдіспен модельдеу нәтижелеріне салыстырмалы талдау жасады. Желілік жабдықтың істен шығуын болжау моделін оқыту үшін үлкен көлемдегі ақпаратты пайдаланудың маңыздылығы дәлелденді. Қорытынды бөлімде авторлар оларды жұмыс ортасына одан әрі енгізу үшін болжау модельдерін жетілдіру қажеттілігін атап өтеді. Сондай-ақ, авторлар халықаралық зерттеушілер қарастырған екі мақалалар - ерекше жағдай екенін, сондай-ақ олар таңдаған жергілікті желі жүйесіндегі сәтсіздіктерді болжау әдісі екенін айтады.

Түйінді сөздер: машиналық оқыту әдістері, Машиналық оқыту әдісін модельдеу, желілік жабдықтың істен шығуын болжау, жергілікті желі.

Мырзатай А.А.[1], Рзаева Л.Г.[1], Ускенбаева Г.А.[1], Шукирова А.К.[1], Абитова Г.[2]

[1]Евразийский Национальный Университет им. Л.Н.Гумилева. Нур-Султан, Казахстан;
[2]Astana IT University. Нур-Султан, Казахстан.
E-mail: mirzataitegiali@gmail.com

ВЛИЯНИЕ ОБЪЕМА МАССИВА ДАННЫХ НА РЕЗУЛЬТАТЫ ПРОГНОЗИРОВАНИЯ ОТКАЗОВ СЕТЕВОГО ОБОРУДОВАНИЯ

Аннотация. В статье рассматриваются три метода прогнозирования отказов сетевого оборудования и влияния массива данных на входных контроллеров. Цель статьи – раскрыть актуальность предложенного авторами подхода к использованию данных большого объёма в выбранном методе машинного обучения и произвести сравнительный анализ итоговых значений с работами других, мировых исследователей. В первом разделе авторы анализируют работу учёных из Пекинского университета почты и телекоммуникаций, отмечая сильные и слабые стороны их метода. В разделе 2 авторы анализируют метод Хольта-Винтерса для разработки алгоритмов анализа сетевого трафика, который был применён исследователями из Томского государственного университета систем управления и радиоэлектроники. В разделе 3 авторы применили метод случайных деревьев при моделировании методов машинного обучения студии Rapid Miner. Авторы провели работу с большим объёмом данных и провели сравнительный анализ результатов моделирования методом. Доказана важность использования больших объёмов информации для обучения модели прогнозирования отказов сетевого оборудования. В заключительном разделе авторы подчёркивают необходимость совершенствования моделей прогнозирования для их дальнейшего внедрения в рабочую среду. Также авторы подчёркивают, что две статьи, рассмотренные международными исследователями, являются частным случаем, как и выбранный ими метод прогнозирования сбоев в системе локальной сети.

Ключевые слова: методы машинного обучения, моделирование метода машинного обучения, прогнозы отказов сетевого оборудования, локальная сеть.

Information about authors:

Myrzatay Ali – PhD student of Eurasian National University, Nur-Sultan, Republic of Kazakhstan; mirzataitegiali@gmail.com; ORCID ID: https://orcid.org/0000-0002-5339-2437;

Rzayeva L.G. – PhD, acting Associate Professor, Department of System Analysis and Management, Faculty of Information Technology, Eurasian National University. L.N. Gumilyov, Nur-Sultan, Republic of Kazakhstan.; leilarza2@gmail.com; ORCID ID:*https://orcid.org/0000-0002-3382-4685*;

Uskenbayeva G.A. – PhD, acting Associate Professor, Department of System Analysis and Management, Faculty of Information Technology, Eurasian National University. L.N. Gumilyov, Nur-Sultan, Republic of Kazakhstan.ORCID ID:*https://orcid.org/0000-0001-6904-8000*;

Shukirova A.K. – PhD, acting Associate Professor, Department of System Analysis and Management, Faculty of Information Technology, Eurasian National University. L.N. Gumilyov, Nur-Sultan, Republic of Kazakhstan.ORCID ID:*https://orcid.org/0000-0002-3032-47822*;

Abitova G. – PhD, acting Associate Professor, Astana IT University. ORCID ID:*https://orcid.org/0000-0003-3830-6905*.

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