Development of Hardware and Software Complex for Increase of Technical Readiness Transport-Technological Machines in Forestry

S. V. Lyakhov and S. V. Budalin

Abstract The paper studied information technology in relation to the decision-making process in the management of the technical condition of transport and technological machines in forestry. The export of timber and forest products by road has a seasonality, which greatly limits its working time during the year. During this period, the requirements for the technical readiness of the fleet of transport-technological machines of a logging enterprise increase significantly. To reduce the downtime of transport and technological machines, it is planned to develop a software and hardware complex that works on the basis of an advisory information interactive system, which allows optimizing the time for troubleshooting and eliminating it. The implementation of the software and hardware complex in the system of maintenance and repair of transport and technological machines will increase the speed of the quality of technical decisions to ensure their performance. The paper considers the concept of creating an advising system based on deep neural networks.

Keywords Software complex · Hardware complex · Transport machines · Technological machines · Dispatching · Automation diagnostics · Technical service · Information system

1 The Introduction

Operation of transport and technological machines (TTM) in forestry is carried out on considerable distance from production and technical base of services of technical service of the enterprise and in such road conditions which can be overcome only

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by a rolling stock of the raised possibility. The use of modern TTM is accompanied by their maintenance and repair by the manufacturer through a network of dealerships. This allows you to maintain the warranty obligations of the manufacturer, which protects the interests of machine owners. A condition for such protection is the obligation to undergo maintenance and repair only in dealerships.

The intensive development of the TTM fleet is ahead of the development of the production and technical base of enterprises, which has a significant impact on increasing the share of the fleet with high resource mileage [1]. The insufficient perfection of the production and technical base of enterprises, in particular, has an impact on the premature decommissioning of TTMs, whose share reaches from 3 to 8% annually of their total number [2].

In the conditions of considerable dissociation of the operated TTM and remoteness of places of their specialized maintenance and repair, there is a need for providing remote technical impact for the purpose of ensuring their operability. The greatest impact on the efficiency of transport and technological machines has their technical condition. Direct impact on the efficiency of the fleet has four mutually independent indicators of technical operation: $\alpha_в$—factor of technological machines output, β—loaded mileage proportion, γ—cargo load factor, $V_э$—running speed, km/h [3]. All but the second indicator depends on the technical condition of the car. Often carrying out the routine maintenance works defined by manufacturer at technical services does not allow to provide trouble-free operation of cars throughout their resource. The operational management of the above indicators allows us to ensure the required performance of the transport department, taking into account the optimal selection of TTM for the specific energy consumption of removal [4–8]. The scope of maintenance work is formed on the basis of regulations on maintenance and repair of the corresponding machine and carrying out diagnostic works performed without disassembly of components and assemblies or with partial disassembly [9].

2 Object and Methodology

The object of the study is the process of technical impact on TTM in order to restore or ensure their performance. Managing process of maintenance and repair of the TTM involves remote supervision of a specialist technical service (STS) to the dealership with the actions of the mechanic of the enterprise. Mode lack of the ability to provide a reliable remote link with the specialist of STS mechanic has the ability to obtain auxiliary information through the use of special software is an interactive information consulting system (IICS). The system allows you to optimize the process of troubleshooting, accompanied by its comprehensive audio and video information. The target function is to optimize the time spent restoring or maintaining the health of a node or aggregate.

It is proposed to create a hardware and software complex based on information technology, which will provide qualified support of technical impacts on the

machine in the mode of dispatching. Thus, a single technician dispatch service can provide support for maintenance and repair of several machines or their components and assemblies remotely.

If it is impossible to provide control of actions of workers on maintenance and repair of cars or in the absence of such need, it is possible to use the hardware and software complex on the basis of IICS. It allows to carry out under its management a complex of measures directed on clarification of the reason of refusal and also offers technological options of its elimination. The interaction between the mechanic and IICS is carried out by means of voice control. The system contains reference and information support for obtaining the necessary information about the object of influence (unit, mechanism, machine) by mechanic. IICS is used to carry out the process of training of young specialists in the field of maintenance and repair of transport and technological machines, as well as specialists undergoing retraining. IISS provides automation of maintenance and repair of machines by means of search of the reasons of refusal and the offer of technological routes on its elimination, depending on technical equipment of the zone and repair.

Dispatching and automation of maintenance and repair of TTM will significantly reduce the recovery time of their performance, as well as to carry out maintenance without the need to carry out the delivery of machines to the location of the dealer center.

Diagnosis of TTM is planned to be carried out using methods of analysis of vibroacoustic signals and the method of studying sound effects. Analysis of vibration parameters is the only method of non-destructive testing, which allows to determine the actual technical condition of the dynamically operating unit without prolonged downtime [10].

The use of methods based on the study of vibration parameters of individual components and assemblies, both separately and together, gives a more complete picture of the technical condition of the unit or assembly. Study of parameters of vibroacoustic signals is the basis for the formation of databases on which it will be possible to determine the limit for the technical condition of individual components and assemblies of machines and equipment. Also, the need to analyze vibroacoustic signals will require the development of mathematical models for the development of the most common defects and the creation of methods for the use of diagnostic equipment [11, 12].

Each of the methods of vibration control has its own limitations on the scope; there is no single universal method that could be equally effectively used both for express diagnostics with regard to vibration parameters and for periodic monitoring of the technical condition of the object being diagnosed [13]. Only the results of the integrated use of several different diagnostic approaches can provide an opportunity for an effective and accurate assessment of the actual state of the components and assemblies of working mechanisms. The conducted vibroacoustic studies prove that the best results can be achieved using a comprehensive diagnostic approach using several methods of vibroanalysis and non-destructive testing. Usually, the basis of this approach is the results of spectral analysis, in addition to which often use kurtosis, analysis of the envelope and the rotor trajectory/procession, quite often

the shock pulse method can be used [14]. In some cases, it is advisable to add a wavelet transform of the signal and a cepstral analysis to this set [15]. It is this combination of vibroanalysis methods (which depends only on the type of object being diagnosed, its operating modes and measurement features) that is necessary and sufficient to control the vibration parameters of the most different process equipment, allows you to get the maximum useful diagnostic information with minimal time spent on measuring.

To find faults and ways to eliminate them in IICS provides for the use of neural networks, which will significantly reduce the downtime of the machine. The use of neural networks will reduce the duration of training for the diagnosis of various components and mechanisms of transport and technological machines by reducing the requirements for their qualification. Hardware-based neural networks will optimize the collection and accumulation of statistical information for individual machines, allowing to predict their technical condition depending on the complexity of the various production tasks.

The operation of units and mechanisms is accompanied by characteristic sounds that can be classified. The sounds may vary depending on the technical condition of units and mechanisms, as well as to vary among different models, depending on vehicle class. The object of the study is the internal combustion engine of transport and technological machines. The aim of the research is to design an algorithm that allows sound to classify sounds by belonging to the source of excitation.

Recognition of sounds and their classification was carried out on the basis of neural networks that perceive acoustic information in the form of a digital series or vector. This method will allow to solve various problems of classification of sounds.

The vector we can consider as normal in a plane and determine relative to other points of the plane: to the left or to the right of the vector. Neural network is based on the principle of combining individual neurons. Thus, neurons are combined in a network when the outputs of one neuron become inputs of the other. This can be a single-layer network consisting of many neurons, thus increasing the number of inputs and outputs, or they can be Daisy-chained together and organize multi-layered network. Such possibilities allow to make a system of hyperplanes, and which allow to limit rather difficult areas and to solve complex problems of classification when points get to one part, or to other part of area concerning a vector. The neural network indicates the location of this point and thus classifies the input information.

The neural network must be trained to function properly. Training is possible with or without a teacher. For the method with the teacher, a training sample is used, according to which the neural network shows the correct answers to the information submitted for processing.

The problems solved before the 2000s allowed to work with neural networks no more than 5–6 layers thick due to the fact that computing resources were running out. Then, there was a revolution with “cats” and games. At the entrance of the neural network is a photograph, the result is given: if correct, then go to the next set, if not correct, then moving from the end to the beginning of “adjust” the weight of

the neurons so that the answer is correct. This procedure is done as long as the entire training set will not be given the correct answer. This is the process of learning a neural network: each neuron is adjusted weight vector to get the right answer. High results of the neural network are obtained if the network has 5–6 layers or more. Neural network training without a teacher is carried out according to the learning algorithm of Hebb, and this article is not considered. After training a neural network on a training sample, it is given a test sample from the training network and the proportion of correct answers is checked. The degree of accuracy in the area of 90–95% of correct answers is considered acceptable.

The training sample can be manually typed, or you can use specialized databases with handwritten fonts to train the neural network. A neural network can be trained and used in the future for the processing of graphic or audio information. A neural network can be trained to recognize all objects in graphic images. Databases and large productive capacities of personal computers allow to create deep neural networks that allow to create neural networks in 20–30 layers. At the same time, layers can be specialized, for example, so-called convolutional neural networks, where the image is multiplied by the convolution matrix and a reduced image is obtained, which has already lost some of the data, but some features that were not recognizable by the naked eye were highlighted. If you apply this convolution to a photograph several times, you can get a stylized image, in which the characteristic features are separated. This uses such a feature that the used convolutional matrix that processes the image is selected based on the training sample. Thus, the neural network learns to isolate some characteristic features in the photograph. The task is relevant, for example, for processing images from satellites. One layer separates the dashes, the other—the circles, the third—the corners, the next layer collects some objects from them, and the next figure, contour or forms an image.

A new direction for neural networks is to work with sounds. With sounds there is a great difficulty associated with the fact that the sound has both temporal and geometric characteristics. Therefore, it is impossible to apply the same approach as with graphic images. One option, when the amplitude of the sound is depicted, is treated as an image and fed to the input of a neural network trained to work with images and classifies the sound. In this case, the sound should be perceived by the neural network as a whole, that is, the previous neuron in the chain should "remember" information when it is transmitted to the input of the subsequent neuron. As an example, the application "Яндекс. Conversation for Android™" (Yandex Conversation for AndroidTM), which is positioned as an application for deaf people. Speech is recognized by the program and generates text on the smartphone screen. Thus, this text can be read and give the answer. Works almost instantly and pretty quality, taking into account the additional noise and other voices in the dubbing process. Audio processing requires a more complex network architecture than image processing to work with a neural network. The network must have the ability of the network to remember the previous sound States. This means the creation of recurrent neural networks, when connections between neurons are not only in the same direction but also have the ability to move in the opposite direction. The Program

"Яндекс. Conversation for Android™" (Yandex. Conversation for AndroidTM) is based on two recurrent neural networks, one of which divides speech into tokens (syllables), and the other already compares them with text.

3 Research Result

Material and technical support of the hardware and software complex involves the availability of audio and video recording in the area of maintenance and repair of TTM (Fig. 1), GSM/GPS/GPRS communication module and the appropriate software for linking devices with each other and coordinated data exchange between them. Mechanical locksmith is equipped with video recording and devices for wireless audio. Collecting information from the area of maintenance and repair is carried out by storing it on a local server. The above devices are combined into a local network. Through communication via the Internet, you can make the monitoring process in the area of maintenance and repair, and make the control mechanic. This task is assumed by the operator STS, which controls the progress of the maintenance and repair process, providing optimization of this process for the time spent on restoring the health of the node or machine unit.

In the process of using the hardware-software complex, step-by-step collection of information about the repaired objects is carried out. Information from the previously

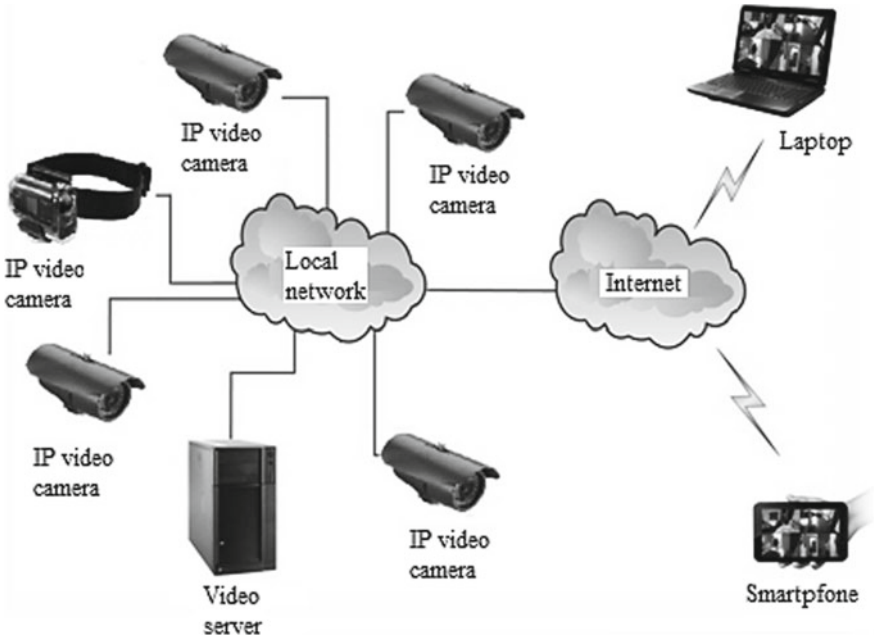

Fig. 1 Structure of IP video recording. Local area network—Internet

identified object is collected by fixing the diagnostic parameters of the objects of each species group using measurement equipment connected to the local server managing the parameter measurement process. Provide possibility of electronic processing of results of diagnostics in two levels: in the local server of species group and in the central computer collecting information from local servers of all species groups.

The possibility of independent evaluation of diagnostic results, and hence the quality of repair work, provide by equipping and local server of each group of objects and computers with autonomous databases. Hardware and software system includes means of identification of the object and the performer. The system for quality control of repair and maintenance is made with the ability to connect to the Internet and allows for a comprehensive, prompt, and timely quality control of repair and maintenance.

Diagnose the object by measuring the parameters of the basic assembly units. Depending on the measurement results, the repair actions include repair or replacement of the base assembly unit with its parts. Parts and assembly units with a change factor above the specified threshold are replaced without diagnosis. Time and material costs are reduced during repair [16–20].

Dispatching of maintenance and repair will allow centralized collection, accumulation of information and its further processing. The updated information on the technical condition of individual units and units of a particular machine will provide the possibility of a more accurate prediction of wear and tear of their elements, as well as advance maintenance of repair production with spare parts and materials. Dispatching will allow to develop the direction of determining the technical condition of the object by processing the sound of their work, in particular, the internal combustion engine [21].

The interactive information consulting system (IICS) is applied in case of absence of possibility of remote technical influence on object. Mechanic-mechanic serving TTM works with the system in voice mode on the principle of question–answer (block diagram design). The system allows:

- to determine the cause of the fault, forming a request or a list of effects on the machine in order to collect the initial data, narrowing the search. This eliminates the error associated with the omission of the probable causes of the fault;
- to create a routing for troubleshooting. The map is formed depending on the technological equipment and qualification of the contractor;
- taking into account the flow chart to form a request to collect the necessary statistics on the technical condition of individual elements, nodes, mechanisms, verification of which in other conditions is unacceptable or undesirable;
- on the basis of probabilistic and statistical information on the object, graphs of optimal moments of technical impacts on the object are formed in order to reduce the cost of ensuring its performance.

Hardware complex, which is a computer (stationary, laptop, touch phone, etc.) with an installed interactive system that helps the user to quickly and accurately determine the fault, as well as to propose measures to eliminate it, depending on a

number of circumstances. In the memory of the central computer introduced pre-prepared digital video containing step-by-step video that shows the relevant component parts of complex technical systems (STS) in the sequence of technological operations and tools. The program of the system is based on block diagrams (question and answer). The peculiarity of working with the system is voice control. Table 1 shows compound classes of IICS and their functions.

The control flow is carried out by the following algorithm:

1. An instance of the Text to Speech class is initialized.
2. An instance of the Recognizer class is created and started.
3. Another question is asked.
4. When the on partial results event (partial information) analyzes the recognized result: if the answer begins with "Yes" or "no", then the following appropriate question is asked.

To create a neural network Python programming language was used, which has a number of advantages:

- built-in data structures;
- a simple and convenient syntax;
- powerful interface;
- portability of code between platforms: (automatic generation of documentation for modules and the ability to write self-documented programs);

At the same time, there are already multi-level libraries that allow you to manually configure each neuron, and there are high-level libraries that allow you to create a neural network, the second—to load a series of data, the third—to process the results of the study. In three lines, it is possible to write the program allowing to process thousands of data by a neural network and to give out result.

For training, the neural network was used for more than ten recorded sounds of engines of cars of different brands. In view of the insignificance of the number of sound for each imposed different effects:

- was cut into pieces of different lengths;
- turned the melody;
- changed the volume and quality of the melody.

The effects applied to the existing audio files have increased the training sample by an order of magnitude.

Table 1 Composite classes of the interactive information consulting system

Program	Function
Main activity	Contains instances of other classes, basic system methods
Recognizer	Convert speech to text
Recognizer listener	Obtaining a control flow in the event the speech recognition
Text to speech	Convert speech to text
Question	Storage of a tree of questions and answers

In the future, a test sample was fed to the input of the neural network, the results of which determined the proportion of correct answers in percentages. The results of the neural network are presented in the form of a matrix, which vertically postponed the expected answers, and horizontally received. Ideally, all answers must match and be placed on the diagonal (Fig. 2). And, the answers do not fall on the diagonal are errors in the processing of information through a neural network.

For processing information, neural network sounds of the engines fed to the input in a different sample. Initially, the neural network processed the whole selection of sounds, which was obtained after applying additional sound effects (Fig. 2). The accuracy of information processing in this case reached 94%. After processing the information by the neural network, the responses are summed up and the library itself allows you to determine the accuracy of the developed neural network.

The second sample consisted of four complete audio files of the engines of all four cars (Fig. 3). The accuracy of the answers decreased to 91%.

In addition, to check the efficiency of the neural network, the previous four sounds were applied to the input but inverted on the contrary. The processing result is shown in Fig. 4. The accuracy of information processing decreased to 90%.

The development of neural networks application in the field of TTM diagnostics will allow creating compact devices and hardware complexes with low cost in the mode of constant time, which control the technical condition of individual units and mechanisms of aggregates according to the level of information quality, not inferior to the work of a qualified diagnostic specialist.

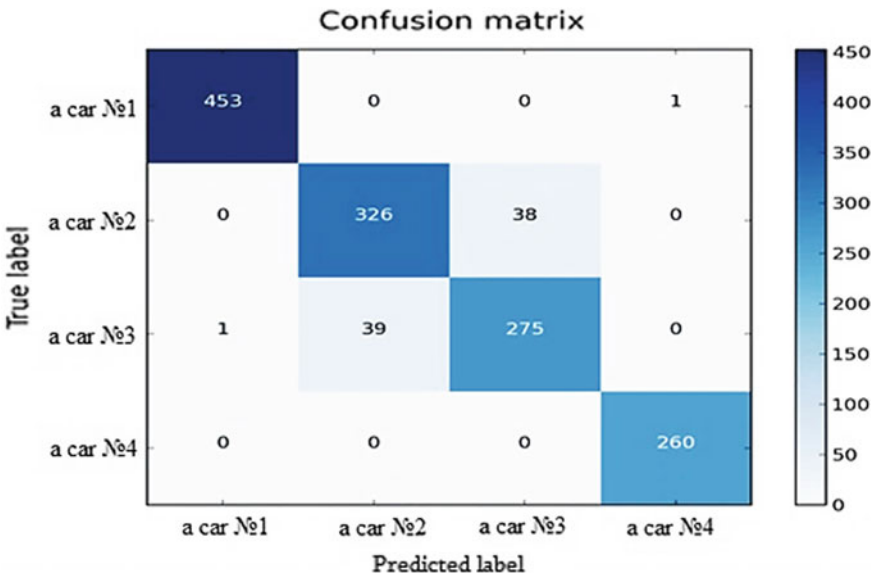

Fig. 2 Error matrix classification of engine sounds of the cars for the whole sample (Quality 0.94)

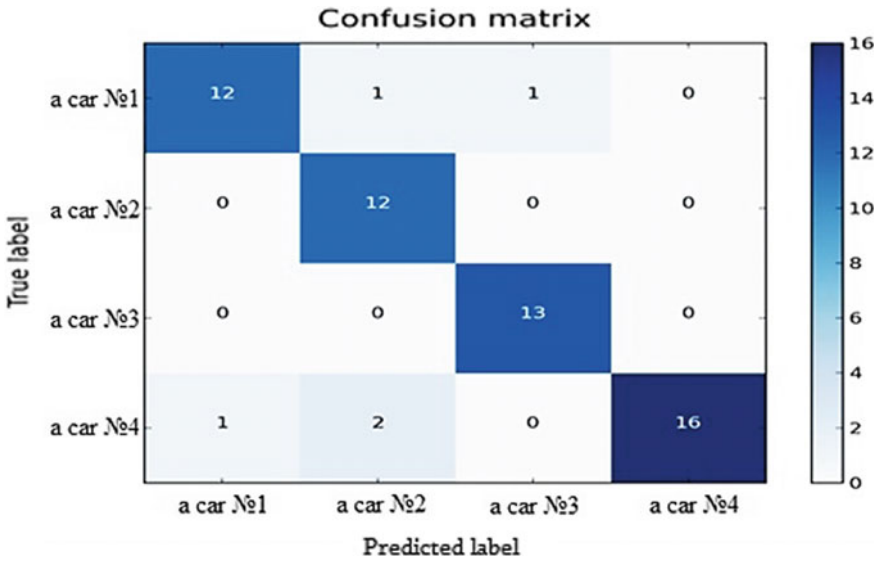

Fig. 3 Error matrix classification of the sounds of the engine car for 4 whole sounds (Quality 0.91)

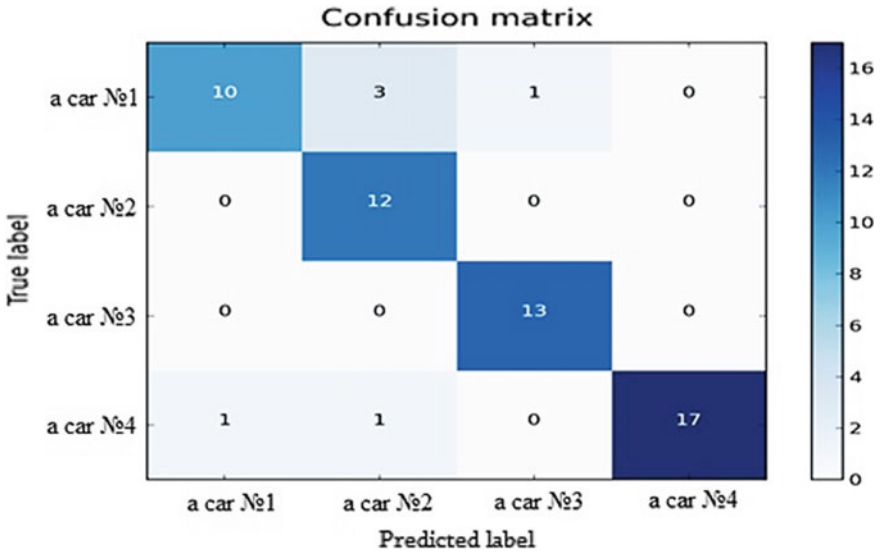

Fig. 4 Error matrix classification of the sounds of the car engine 4 integer reverse sound (Quality 0.90)

4 Conclusion

The use of information technologies to improve the efficiency of TTM use in forestry will ensure:

1. Restoring the health of the host or assembly of TTM in the shortest possible time.
2. The absence of unnecessary empty runs TTM or additional costs for their delivery to the place of service or repair (dealership).
3. Subject to all requirements of the maintenance and repair system, the maintenance of warranty obligations (if any), both the supplier of the machine and the supplier of equipment installed on the machine.
4. The ability to restore the efficiency of the machine outside the production and technical base of the enterprise, in the case of sufficient technical and technological support.
5. Reduce the complexity of the control and increase the accuracy of information about the technical condition of machines and equipment.
6. Reducing the probability of line failure.
7. Reducing the need for disassembly and assembly operations in the diagnosis of individual units of mechanisms and assemblies.
8. Implementation of quality control of the performed maintenance and repair, and also running-in.
9. Accumulation of statistical information on the intensity and development of failures for the formation of laws and mathematical models of changes in the technical condition of components of mechanisms and assemblies.
10. Maintenance of operation of transport and technological machines on their actual technical condition.

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