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Using Artificial Intelligence to Identify Damaged Goods by the External Appearance of the Package when Performing Logistics Operations

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ABSTRACT

A proposed promising method for recognising damaged goods by external appearance of packaging using a learning neural network considers the predicted long-term growth in the volume of transported goods, the increasing influence of economic and territorial factors on transportation processes, the complexity of logistics services and the increase in requirements for their quality, the spread of information technology and the improvement of artificial intelligence tools.

The objective of the study is to describe the principles of using an artificial neural network to identify damaged goods by their external appearance. The relevance of the problem is confirmed by data on damage to goods during transportation. The methods used in the study help collecting and analysing data, describing and comparing existing and promising technologies, monitoring and modelling the process of cargo handling, and summarising the results. The analysis of common and promising methods of prevention and detection of cargo damage is backed by the results of research on detecting defects on various surfaces and recognising signs and colours in motion using intelligent technologies.

The problems of recognising damages on packaging in complex and unfavourable conditions for machine vision are solved with the help of a convolutional neural network. In accordance with the proposed algorithm, image capture is carried out using standard video surveillance cameras. From the image entered into the neural network, fragments with characteristic features are distinguished, which are further checked for compliance with damage patterns. Following damage contour analysis, the neural network recognises the cargo as damaged. The process of training the neural network and integrating the proposed tool throughout the supply chain ensures the recognition of actually damaged goods and elimination of errors associated with minor permissible damage and packaging features. The proposed concept does not require the installation of additional equipment and does not imply a significant cost of damaged cargo recognition services. The paper offers and describes processes of video recording of the cargo flow, loading an image into a neural network, and a model for recognising damaged cargo by the external appearance of the package.

Keywords: cargo transportation, search for damaged cargo, improvement of logistics processes, convolutional neural networks, cargo flow video recording, supply chain management, tools for intelligent transport systems.

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INTRODUCTION

Cargo handling is a necessary component of any production processes and logistics activities. The volume of cargo transportation grows with an increase in the volume of production and sales of goods. There is a growing need for high-quality logistics services.

The movement of goods and the exchange of information is carried out between companies located in different socio-economic conditions, significantly far from each other, in hard-to-reach areas or megacities and industrial centres, which leads to the complication of transportation processes and to an increased likelihood of cargo damage.

The logistics system is created and operated to provide safe and efficient services to shippers and consignees [1].

At the same time, the reliability of transportation and transport services constitutes one of the main requirements for logistics companies, and that is largely determined by safety of transported and stored goods [2; 3].

The cargo can be considered damaged if its qualitative or quantitative characteristics change during transportation. As a result of cargo damage, negative consequences occur for all persons interested in high-quality transportation.

For consignees, such negative consequences are the damage associated with the loss of the marketable state and useful properties of the cargo, and, as a result, failures in business processes. For persons responsible for transportation, this is the need to compensate cargo owners for losses associated with damage to cargo, a decrease in the level of trust and the likely loss of customers and of competitive positions in the transport services market, etc.

Damage to cargo during transportation is not only an extremely undesirable event itself, but also entails additional difficulties for both transport service providers and consignees.

In accordance with the rules of law in the field of transportation of goods, ensuring the safety of goods with proper packaging and compliance with other requirements on the part of the consignor is the responsibility of the carrier or the person responsible for transportation immediately after acceptance and before the release of goods, and is mandatory stipulated in the contract of transportation [4].

Damage to the cargo is one of the reasons for the claims of cargo owners related to transportation of goods [5].

The carrier may not detect damage to the cargo and hand the damaged cargo to the consignee, and the recipient may find out that the cargo is damaged later in its warehouse or from its customers. Damage to cargo occurred at the beginning of the supply chain can be detected much later at the point of use of the transported goods.

Obtaining information on the total number of goods damaged during transportation and related operations and other statistical data in this area is quite difficult.

Nevertheless, the urgency of the problem of cargo damage is evidenced by the growing demand for insurance of transportation objects, including against damage during transportation and the resulting losses.

The volume of the global logistics insurance market is increasing annually and, according to forecasts, by 2027 it can reach 76 billion US dollars [6].

The number of insured events is also increasing, and when transporting groupage cargoes, large transport companies may by default include cargo insurance in the transportation tariff [7].

Harm to transport companies from damage to cargo for various reasons during transportation can be a significant part of the total loss of cargo.

Modern scientific research in the field of transport operations and cargo transportation steadily tends to improve transportation and warehouse processes using modern technologies, most of them being related to digitalisation of the transportation management system and the transport industry as a whole, as well as to digitalisation of transportation safety [8].

Integration of modern digital technologies into the transport system allows modelling the transportation process and managing traffic flows using intelligent systems.

Intelligent transportation systems (ITS) themselves, together with breakthrough technologies such as the Internet of Things, digital control, cloud services, big data, unmanned vehicles, fully robotic warehouses, etc., are necessary to implement concepts that meet the future-expected requirements for the quality of life and business processes, such as smart cities or completely automated production, 3D industry and industry 4.0.

ITS should ensure delivery of goods of proper quality, without damage, which, in turn, requires creation and use of technologies for timely

detection of damaged goods. The concepts of smart cities or transportation managed by ITS, in themselves, do not imply an increase in problems with damaged cargo, nor significant costs for detecting and preventing cargo damage.

Transport strategy adopted in the Russian Federation provides for pilot project for railways that should ensure reduction in loss and damage to cargo by ten times [9]. This means a significant reduction in damage to cargo, but still a complete elimination of the possibility of damage to cargo is not expected even in the long term.

There are some difficulties with development of ITS. If large transport and manufacturing companies have the resources to introduce new technologies, then carriers that do not have such capacity are in no hurry to use them [10].

Transport and logistics companies have the potential to provide remotely a full range of information services, including those related to transportation of goods. However, the use of existing technologies is not carried out in full [11].

This is due to the need to install additional expensive equipment and develop or purchase software, which requires significant investments and may not provide an immediate economic effect. According to representatives of business, including transportation business, sometimes it is better to wait until the technology becomes available.

Thus, damage to cargo during transportation, storage and related operations is an urgent problem for all participants in the transportation and logistics process and the entire economy. The problem should be solved by all the companies involved in the logistics process together, regardless of the size of an enterprise.

Artificial intelligence and machine learning technologies can be the most effective tools for solving fundamental transport problems, including the task of significantly reducing cargo damage and timely detection of damage within cargo traffic. At the same time, such tools should be available to absolutely all interested parties, which means that they involve the use of cheap, but quite effective technologies without additional equipment.

In the context of increasing global competition embracing the transportation market and the influence of other factors of economic growth, including the expected spread of effective digital technologies, the restructuring of the world economy and the change in the balance between economic centres, there will be worldwide growth in requirements for the quality of local, national, and international cargo transportation and related, including logistics, cargo handling. The transport industry needs technology to cost-effectively identify damaged goods before they are released to the recipient.

The *objective* of the study is to develop a concept that facilitates the creation of such a technology.

The problem of damage to goods can be deemed relevant since the requirements for reliability of logistics system, safe and efficient transportation process are among key requirements addressing cargo carriers and forwarders, and that the data on cargo insurance testify considerable volume of goods damaged during transportation. Digitalisation is among prevailing trends in improvement of transportation processes, and tools based on implementation of artificial neural networks are among most promising ones.

The tasks of the study were focused on revealing visually recognisable damage to packaging, describing process of image capturing, its downloading into the neural network and identifying the damage.

RESEARCH METHODS

The study followed the algorithm described below.

The conducted review of open sources of information (websites of transport companies, government authorities, thematic publications, etc.) was followed by their analysis.

The trends in science and technology, including those related to the development of ITS and the planned transition to an intensive, innovative type of development of the transport industry and the entire economy allowed to draw conclusions on the need to use artificial intelligence and machine learning to solve the revealed problem.

The further analysis referred to some of the technical and technological solutions offered on the market designed to detect damage to the packaged cargo, including without opening the package.

A review of scientific research in the field of application of artificial intelligence technologies in the transport industry helped to focus on specific knowledge from such areas of machine learning as obtaining and recognising images of real-world objects for their visual verification

and measurements (machine vision), creating an artificial neural network and the tools used for this, algorithmizing of neural network learning and the use of neural network tuning methods.

The suggested approach to use artificial intelligence to identify damaged goods analysing the external appearance of the package was based on the transfer of the skills of specialists who have long experience in direct work with various goods and are able, based on their experience by the organoleptic method by the appearance of the package, to determine the degree of safety of the goods and the cause of damage in case, if any, to a set of computer programs.

It was determined what damage is visible on the packaging and how the external appearance of the package changes due to these damages.

The study contains a description and graphical interpretation of the process of video capture of packaged goods, their recognition, identification of signs of damage to the package and the relationship between the state of the package and possible damage to the cargo.

REVIEW OF APPROACHES TO THE PROBLEM

Many studies in the field of damage to goods consider the problems of damage and loss of goods in conjunction with the problems of damage to vehicles and transport units (intermodal containers) in which these goods were transported.

In this case, scientific research is aimed at identifying and eliminating the main causes of road accidents, as well as at reducing the risk of accidents and potential damage by choosing the right rolling stock and transportation route, monitoring the condition of drivers, identifying their abnormal behaviour, etc. Artificial intelligence technologies are used to eliminate factors that lead to damage to vehicles.

In recent years, deep neural network learning has also been used to model road safety [12].

However, damage to cargo may not be associated with damage to the vehicle. A significant part of the damage during transportation is caused by the damage that occurred due to the incorrect location and fastening of the transported cargo. During transportation, the cargo can be damaged due to displacement because of sliding on the surface of the body or swinging and turning over due to vibration.

To exclude such reasons, it is proposed to secure the goods with belts, ropes, chains, etc. during loading and place the goods in the body in such a way that they remain blocked during transport and do not change their position. The stated recommendations for safe securing of loads consider the strength of the materials from which the loads and packaging are made, as well as the tightening force applied in the clamping devices used.

There are international and national rules for securing cargo on vehicles of various modes of transport, which are not always mandatory, but contain enough information and instructions to facilitate the safe loading and transportation of goods.

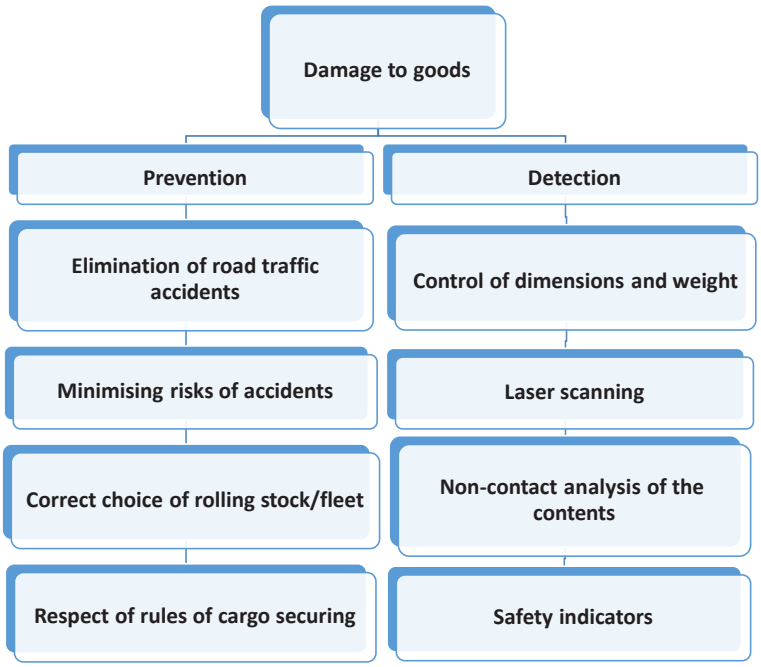
Despite the measures taken, damage to goods does occur, and therefore there is a need for timely detection of damage. Out of technological solutions to the problem of detecting damaged cargo, one can single out the control of dimensions and weight using a scanning system (infrared, laser scanning, etc.). Such control is carried out at the time of measuring the dimensions of the package in three dimensions when the packaged cargo is placed on the weighing device. The discrepancy between the actual parameters of the package dimensions or the weight to specified values indicates possible damage to the cargo (Pic. 1).

This technology requires loading the data about each checked cargo and permissible deviations into the memory of a device, as well as using of special equipment and performing additional operations with each cargo.

A fairly common way to control cargo is a non-contact analysis of the contents of the package, for example, using X-ray television equipment. But this method is used, as a rule, to identify a certain type of goods in the general flow of goods, and not to detect damaged goods.

To detect damage to goods, safety indicators can be used in the form of additional labels sticked to each package. Such labels change colour indicated on them (for example, from white to red) if the package of cargo on which they are placed was subjected to a force due to an impact above the threshold set on the label (5G or 50G overload, etc.) or to high temperatures, or to an extremely humid environment, or has deviated dangerously from an upright position, etc.

Such indicators can signal possible damage to the cargo, but such a solution again requires additional processing of each package (labelling and monitoring the status of the indicator by a specialist).



Pic. 1. Existing methods and technologies of prevention and detection of damage to cargo [compiled by the author].

None of the common methods, even with the utmost improvement, can be applied without adjusting the process of moving cargo, attracting specialists, using special equipment or additional materials, and so does not meet the requirements for the developed concept for identifying damaged cargo, as outlined in this study.

However, in the field of artificial intelligence and machine learning, there are approaches and methods, the combined application of which allows us to develop a technology that meets such requirements.

Solutions using artificial intelligence and machine learning have already proven themselves in the transport industry. Such solutions are more effective than standard ways to improve the efficiency of logistics operations.

It is possible to use machine vision technologies to recognise damaged cargo. However, such technologies have their own nuances. Machine vision may not be effective enough under difficult weather conditions, for example, when there is insufficient lighting, precipitation, glare from the sun or when an object is in the shade, etc., all this making difficult to detect deviations in the appearance of the package from the norm.

So, the performance of damaged cargo detection can be significantly degraded in difficult conditions [13].

This problem is eliminated in the process of neural network training. For example, the automatic (ultrasonic, eddy current, etc.) control of railway rails for damage can be replaced by the method of image processing by a convolutional neural network.

The experimental results confirm that the proposed models can, for example, detect rail surface defects in real time and show high detection accuracy [14].

In this case, damage can be recognised even under conditions that are unfavourable for machine vision.

During practical application of the deep convolutional architecture of neural networks, it was possible to recognise the colour of the sticker located on the windshield of the car and the numbers on it from the video stream received from the road camera with an accuracy of 90 to 98 % [15; 16].

In this case, damage to the controlled object can be detected even if its moves at the speed up to 100 km/h.

In the process of developing a system for detecting damage to the asphalt pavement in real time, the interdependence was revealed between the accuracy of determining damaged sections of the road and the time for processing information.

Image pixelization and segmentation provides the ability to classify damage, but requires large

Table 1

Classification of damage to cartonboard [compiled by the author]

Damage	Possible causes	Possibility of visual detection	Probability of damage to cargo
Impurity	Open body	Yes	Not
Rupture	Force impact	Yes	Yes
Worn spots	Abrasion	Yes	No
Chemical impact	Chemical agents	Yes	Yes
Thermal impact	Overheating	Yes	Yes
Colour inhomogeneity	Wetting	Yes	Yes
Dents	Impact	Yes	No
Violation of geometry	Fall	Yes	Yes
Breakage of the seals	Malicious acts	Yes	Yes
Unreadable marking	Impurities	Yes	No

Pic. 2. Deformed packaging. [Electronic resource]: https://pravodeneg.net/buhuchet/uchet/primery-izderzhek-proizvodstva.html. Last accessed 17.07.2022.

Pic. 3. Ruptures of the packaging. [Electronic resource]: https://www.bansarchina.com/china-quality-control. Last accessed 17.07.2022.

Pic. 4. Packaging with traces of soaking. [Electronic resource]: https://thegioidat.info/will-recycling-take-wet-cardboard.html. Last accessed 17.07.2022.

computational costs, which can lead to suboptimal work in the «real time» mode [17].

The use of a multiscale convolutional neural network makes it possible to achieve high accuracy of results in the automatic detection of cracks on an asphalt pavement regardless a complex background [18].

The upsampling module allows combination of low-level functions and continuous convolution functions to realise pixel-level prediction.

The amount of developments and practical results presented in scientific research suggests that at the moment there are real solutions, software platforms and libraries for machine learning that compile many different algorithms and allow creating a software product that can train an artificial neural network to perform the necessary functions to identify damaged goods within the cargo flow [19].

RESULTS

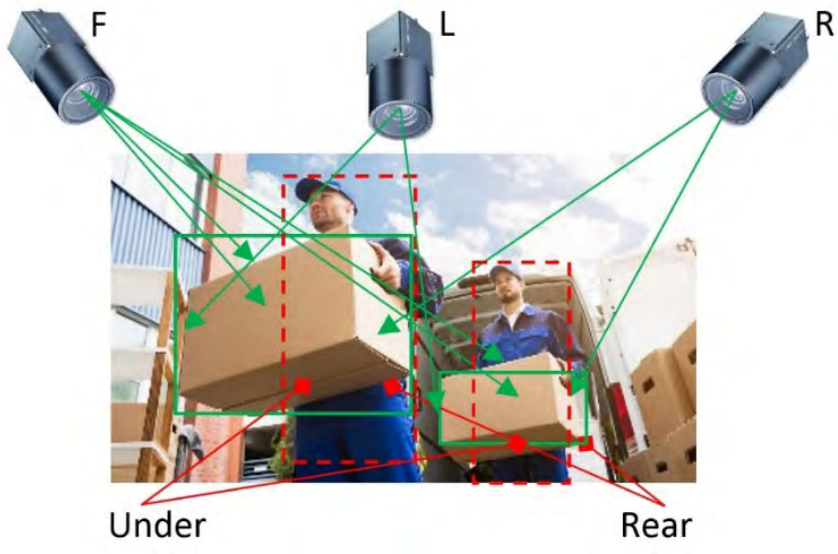
Depending on the cause of the damage, various traces remain on the packaging. Given this feature, we can assume the presence and cause of damage to the cargo basing on the external appearance of the package.

Impacts on the package, including those resulting from a damage to the vehicle, improper fastening of loads, falling out of the body, etc., can lead to its deformation (Pic. 2) or rupture (Pic. 3).

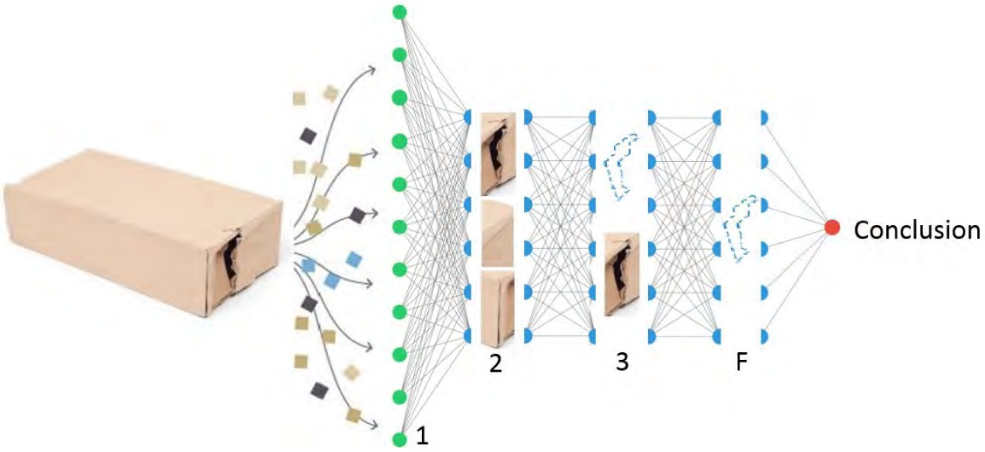
Exposure to moisture, such as rain, snow, or sea water during transportation by water, causes characteristic marks remaining on the packaging even after it has dried (Pic. 4).

Other damages such as those due to insect or rodent attack, mildew, high temperatures, chemicals, etc. also leave special traces on the packaging (Table 1).

As can be seen from Pics. 2–4 and Table 1, all damage to the carton package is quite clearly visible visually. Therefore, using the experience of processing images with a convolutional neural network, it is possible to train the neural



Pic. 5. Video recording of a cargo flow [compiled by the author].



Pic. 6. Loading an image into a neural network and identifying damaged packaging [compiled by the author].

network to recognise the cargo and detect damage to the package.

For computer processing and damage recognition, it is necessary to obtain images of the visual world from 2D video cameras synchronised with the neural network and installed at the places of loading and unloading operations [20].

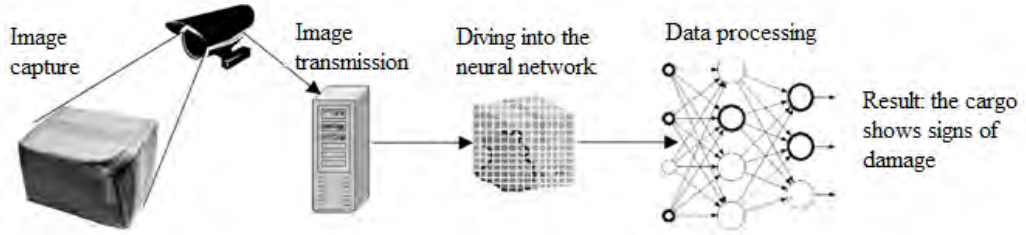
Image resolution is determined by the resolution of the camera. To detail the controlled object and recognise the boundaries of defects on the package, video cameras must shoot video with a sufficiently high resolution and transmit the image without compression. The number of bits per pixel should be sufficient to detail the colour of the image, which will ensure the recognition of the contours of the damage.

It is better to use a high-resolution camera than to develop and apply a super resolution algorithm.

These recommendations assume that it is better to use more memory to store the image and spend more time on its transfer than to increase the time of image processing and damage detection.

In case of a change in external conditions, for example, a deterioration in visibility, the neural network will recognise damage to the cargo in a higher resolution image with greater accuracy. Higher image resolution also helps detect minor, subtle damage.

To identify damaged packaging, it is sufficient to get an image obtained from one or more cameras installed on the path of the cargo



Pic. 7. Model of damaged cargo recognition by an artificial neural network [compiled by the author].

moving during loading and unloading operations (Pic. 5).

If three cameras are installed, as shown in Pic. 5, and the cargo gets into their visibility zone, images of the right and left sides of the package will be obtained from the cameras «R» and «L», of the front side from the camera «F» and of the top side from all cameras («R», «L» and «F») respectively.

The back (rear) and the bottom («under») sides of the package remain hidden for the cameras. In the case of moving stacked or palletised goods, only one side of the package may remain visible to the cameras. In some cases, the packaging may be completely hidden from the cameras. In such a situation, the probability of detecting damaged cargo is reduced. However, damage can be detected during depalletization of loads if they fall into the image capture area.

Using methods and algorithms for searching for an object within a video stream based on global and local features, such as colour or shape, it is possible to recognise the load (to classify an object) by key points (to load an image into the neural network), as shown in Pic. 6. Key points and samples of detected objects are extracted from a set of reference images stored in the data library.

A software platform for modelling a neural network, the number of layers and neurons in each layer, the coefficient of permissible error growth, the maximum system training time and other parameters are determined and selected in the process of its design and development.

The input layer of the neural network «1» receives all the pixels in the image. The features of the desired object are perceived by the neural network as a group of pixels that are of the greatest interest and are analysed for compliance with patterns.

The computational layers of group «2» extract features by filtering. The size and depth of the fragments will be determined by the number and colour of pixels.

The neural network matches the colours of the packaging at different points and the contours of places that differ in colour that are then compared with damage patterns.

Merging layer «3» keeps only the desired images of existing damage.

The final layers analyse the features of the image and classify them according to the given algorithm. These layers are made up of sets of neurons that represent parts of the package image, such as damaged areas. When a sufficient number of neurons signalling damage to the package are activated, the package will be classified as damaged (Pic. 7).

The neural network needs to be trained and has the ability to improve itself in the process of analysing a huge amount of data. In this case, the initial randomly assigned weights of neurons are corrected. The adjustment is carried out until the results become acceptable and allow the neural network to function autonomously. It is possible to control the processes of learning and self-improvement of the neural network by checking the output data.

DISCUSSION

Damage to cargo can occur for various reasons, for example, due to a road traffic accident, improper fastening of cargo in a vehicle, personnel errors during loading and unloading operations, or the influence of other external factors.

The applied technologies for detecting damaged cargo combine the obligatory presence of a specialist, the exercise of control on his part and the performance of additional operations with the cargo.

In the case when damage to the cargo is accompanied by damage to the packaging, the assumption that the cargo is damaged can be made by the external appearance of packaging.

Specialists who directly perform cargo operations, with operational experience gain skills that allow them to determine by the external appearance of the package whether the cargo is damaged or not. However, they are not always interested in the damage being detected since, among other reasons, they themselves can also damage the cargo due to an error.

If the experience accumulated by specialists is transferred to ITS through trained neural networks, then ITS will be able to detect the cargo and signal this to the carrier or other interested participants in the logistics process. Damage to the packaging may be minor, and the cargo in this case may remain intact, for example, as shown in Pic. 2. When training the neural network, it is possible to adjust the weights of the neurons in such a way that the value set in the range from 0 to 1 allows not to identify as probably damaged the goods, the packaging of which is damaged slightly only.

Packaging of goods can perform various functions. One of the main functions is to ensure the safety of goods and the optimisation of transportation processes. Within the framework of this study, packaging can supplement the set of information functions, confirming the safety of the cargo or timely warning of possible damage.

To identify the packaging, the external appearance of which is preferable to identify damaged goods, the packaging can be divided by its purpose into additional outer, transport, and consumer packaging.

Consumer packaging must retain its original appearance, as it plays an important information and aesthetic role and becomes the property of the buyer along with the goods. Sometimes consumer packaging cannot be separated from the product. Some goods, for example, food, are forbidden to sell in case of violation of the tightness of consumer packaging.

A digital intelligent expert system will be able to draw conclusions about the damage to the cargo if the damaged packaging falls into its visibility zone. Consumer packaging during transportation can be hidden by transport packaging, and therefore its recognition becomes difficult.

Additional outer packaging includes large-sized containers, for example, intermodal containers, a skeleton crate made according to the individual dimensions of the transported goods, pallets for moving goods by forklifts and other packaging options that protect cargoes from the effects of an external aggressive environment and optimise transportation, loading, unloading and warehouse processes.

Since additional outer packaging in the course of transport operations, while not losing ability to perform basic functions, acquires a worn appearance and does not allow to visually evaluate the condition of the goods inside it, it is not a preferable option for recognition of damage.

Meanwhile, if there is significant visually noticeable damage to the external packaging, for example, deformation or traces of flooding of the intermodal container, chemical or thermal effects on the packaging film of palletised goods, then such damage can be recognised, and the cargo inside can be referred to as probably damaged.

Transport packaging is a casing for transporting goods and protecting them against damage. One or more goods may be put in the transport package. Unlike consumer and outer packaging, the goods are packed in transport packaging at the final stage of production, at the point of departure, but the packaging itself is not transferred to the final buyer.

Transport packaging can be of various size, shape, and design, made of wooden materials, metal, paper and corrugated cardboard, polymers, glass and other materials. Various types of cardboard packaging is among the most popular types of transport containers.

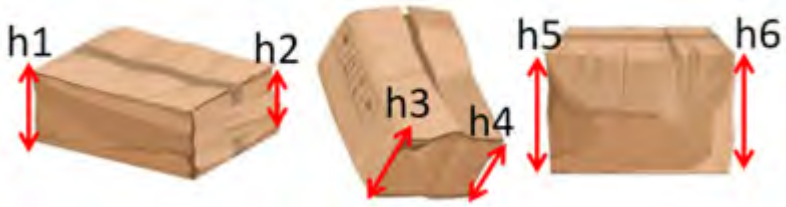
While the cargo damage recognition system is capable to detect any damaged cargo by its external appearance of the package if the damage is visually noticeable, this study is focused on the recognition of damaged cardboard packaging of the correct shape.

Transport packaging may consist of an external body and internal lids, inserts, liners, fillers, cushioning pads, and other elements. Due to the protective functions and design features of the transport package, its damage does not always cause damage to the cargo.

Thus, damage to the packaging can be divided into package damage indicative of damage to the cargo, package damage requiring additional inspection and package damage not implying damage to the cargo.

Specialists directly performing loading and unloading operations and while gaining experience learn to attribute damage to packaging to one of three types, based on the state of

a) Rupture



b) Deformation

c) Soaking

Pic. 8. Parameters of damage to packaging [developed by the author].

damage. It is possible to transfer these skills to an intelligent expert system by defining or establishing criteria for damage to the packaging, indicating the likelihood of damage to the cargo.

Such parameters, for example, to identify damage caused by external forces to the cardboard package, can be the length and width of the breakage, the depth of the dent, the area of soaking, the value of the deformation (Pic. 8).

When the package is broken, the length l1 will indicate a high probability of damage to the cargo inside the package, the length l2 – the need for additional check, the length l3 does not imply damage to the cargo (Pic. 8a).

In case of deformation of the package, the ratio of heights h1 and h2 will indicate damage to the cargo, the ratio of heights h3 and h4 will indicate the need for additional check, the ratio of heights h5 and h6 – the absence of damage to the cargo (Pic. 8b).

When the package gets wet, the spot area s1 will indicate damage to the cargo, the area s2 – the need for additional inspection, the area s3 – the absence of damage (Pic. 8c).

The limit values of the parameters l, h and s are set experimentally, then adjusted in the process of accumulation by the neural network of data on damage to the package, indicating damage to the goods, and then those values become characteristics of damage patterns.

According to the results of a year-long expert assessment of damage to goods transported in cardboard packaging with corner inserts of foam

material and additionally packed with consumer polyethylene packaging, it was revealed that when the package's rupture is more than 15 centimetres long, in 80 % of cases the cargo is damaged. With ruptures of less than 15 centimetres, in 90 % of cases, the cargo remained intact. When more than 30 % of the package area was soaked, traces of moisture were also found on the cargo.

In the presence of an inner package, depending on its type, damage to the outer packaging, indicating damage to the goods, may be attributed to damage to the package, requiring additional inspection or not implying damage to the goods.

Since visual inspection, except in obvious cases, does not permit to establish for certain whether the cargo is damaged or not, damaged packaging indicates only the likelihood of damage to goods. The condition of the cargo in the damaged packaging requires additional checking, as in the case of detection of damaged packaging by a specialist performing loading and unloading operations.

While accumulating experience, the neural network will learn to recognise barely noticeable damage to the load and minor deformations.

This will contribute to improving the quality of the entire process of cargo transportation, since it is possible to exclude even the slightest change in the appearance of the package only by improving the transportation process and the related cargo operations. Timely made, before delivery to the consignee, recognition of damaged packaging helps to increase the efficiency of all transportation processes of the logistics company.

In some cases, the neural network will be forced to recognise a package that has artificial signs of damage as damaged. For example, when the lower part of the package has a pattern similar to the traces of soaking. This task is solved by synchronisation with the image of the package obtained during loading at the place of production of goods, which in turn will require the introduction of appropriate technologies throughout the supply chain and the integration of neural network systems into a single ITS.

The introduction of ITS, capable of recognising damaged cargo not only at the point of departure, but also at all points of transhipment and during loading, will determine at what stage of the logistics process the cargo was damaged.

If the cargo in the package was damaged not in the process of transportation, the proposed concept allows to exclude the fault of the carrier and confirm high-quality transportation.

The proposed concept allows not to install new expensive equipment. In addition to video surveillance cameras, which might already be installed at the sites of cargo operations, only devices for the functioning of the neural network are needed.

Besides, it will be possible to collect and process large statistical data on the localisation and causes of cargo damage, which may contribute to a significant change in the situation with the damage to goods during transportation and cargo operations.

The scientific effectiveness of the development of the concept is associated with the accrued knowledge in the field of identifying damaged goods by the external appearance of packaging in the process of performing logistics operations through the machine vision and convolutional neural networks.

The technological efficiency of the proposed method can be determined through a comparative analysis of the rapidity of cargo condition control operations and the level of necessary qualification of the personnel of supply chain companies. These indicators positively characterise the proposed method in comparison with others.

Evaluation of the economic efficiency of the proposed method is possible using qualitative and quantitative indicators.

CONCLUSION

The study has demonstrated the possibility of identifying damaged goods by the external appearance of their packaging using artificial neural networks.

The proposed concept is based on technologies that make it possible to train a neural network to recognise damaged loads, as this is done by a person, a specialist in this field, based on his knowledge and experience. This approach to identifying damaged goods and the cause of damage is not currently widely used.

The vector of the study corresponds to the general trends in the development of cargo transportation and logistics processes using tools recognised as advanced by the predominant part of the scientific community.

Following the review of existing developments in the field of recognition of various objects, including those with complex shapes, small sizes and remote from image fixation tools, conclusions were drawn about the feasibility of using high-

precision neural networks to train ITS to recognise packaging that has even slightly changed its appearance.

The study also describes the characteristic signs of some damage.

The study resulted in the idea of using artificial intelligence tools to recognise damaged cargo by the external appearance of the package.

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