Piotr CZECH *, Krystian WILK, Rafał ŁUKASIK
Silesian University of Technology, Faculty of Transport
Krasińskiego St. 8, 40-019 Katowice, Poland
**Corresponding author*. E-mail: piotr.czech@polsl.pl

THE ATTEMPT TO USE THE MLP NEURAL NETWORKS TO MARK THE WORK OF THE MOTOR-CAR BODY DEFORMATION AS A RESULT OF ROAD COLLISION WITH A LIMITED AMOUNT OF DATA

Summary. In the article the result of the attempt to use the MLP neural network to define the state of the motor-car body deformation as a result of road collision is presented. As the research parameter the size of damage of the car of the aggrieved party was assumed, defined by the work of the motor-car body deformation W_{def}. The elements of the mechanism of the damaging event determining the size of the damage were the interior factors of the system. The research was conducted on one thousand cases submitted to liquidate in the Silesian branch of one of the insurance companies. The conducted research checked the functioning of the neural network in case of limited amount of initial expert data.

PRÓBA ZASTOSOWANIA SIECI NEURONOWYCH MLP DO WYZNACZANIA PRACY DEFORMACJI NADWOZIA POJAZDU, JAKO SKUTKU KOLIZJI DROGOWEJ PRZY OGRANICZONEJ LICZBIE DANYCH

Streszczenie. W artykule przedstawiono wyniki prób zastosowania sieci neuronowej typu MLP do określenia stanu deformacji nadwozia pojazdu samochodowego będącej skutkiem kolizji drogowej. Jako parametr badawczy przyjęto rozmiar szkody określony pracą deformacji nadwozia pojazdu poszkodowanego W_{def}. Elementy mechanizmu zdarzenia szkodowego determinujące rozmiar szkody stanowiły czynniki wewnętrzne układu. Badaniem objęto tysiąc przypadków zgłoszonych celem likwidacji w śląskim oddziale jednego z zakładów ubezpieczeń. W przeprowadzonych badaniach sprawdzono działanie sieci neuronowych w przypadku występowania ograniczonej liczby danych rzeczoznawczych.

1. INTRODUCTION

In recent years in Poland a considerable growth in number of exploited means of transport is observed together with the insufficient speed of the road infrastructure expansion [3]. The national registry shows, that the number of registered vehicles is 17 million and is still growing. Such condition is caused mainly by the import of the used vehicles [1]. As a consequence of such situation the traffic is becoming heavily congested and as a result, among other factors, the number of road collisions is very high. The aim of this paper is an attempt to use the artificial neural networks to define the work performed during motor-car body deformation W_{def}, as a result of a collision of two cars in traffic, with a limited amount of expert data [4].

2. MARKING OF THE WORK OF MOTOR-CAR BODY DEFORMATION

As a result of the collision of two or more vehicles a change occurs to the main part of kinetic energy of their system on the work of permanent deformation of the motor-car bodies of the colliding cars. The after-collision condition of the vehicle's motor-car body deformation constitutes the main research material used during the reconstruction of the road incident [12, 14].

Work of a permanent motor-car body deformation of a vehicle W_{def} is marked, among other, with the use of analytic method, possessing the features of the universal formula. It enables to define the value of work deformation of motor-car body on the basis of the geometric parameters of the deformation area, using the rule:

$$W_{def} = \frac{1}{2} \cdot b \cdot h \cdot k \cdot f^2_{trw} \tag{1}$$

where: W_{def} – work of deformation [J], b – mean breadth of the deformation measured in the perpendicular direction towards the direction of the operation of collision force impulse vector [m], h – mean height of the strain area of deformation [m], f_{trw} – mean depth of the dent measured towards the normal of the deformation [m], k – unitary stiffness of the motor-car body (coefficient of the strength structure) [N/mm^2]

The value of the unitary stiffness is determined by the motor-car body features. It takes into consideration the influence of the overall dimensions of a vehicle and the technical condition of the carrying structure and the motor-car body panelling [4, 9]. Index of the motor-car body stiffness takes the following values for private cars:

- small: $k = (13,5 \ldots 22,6) \cdot 10^5$ [N/mm^2],
- medium: $k = (9,1 \ldots 13,5) \cdot 10^5$ [N/mm^2],
- large: $k = (5,2 \ldots 7,2) \cdot 10^5$ [N/mm^2].

In expert's practice it often happens that the expert does not have the possibility of precise measurement conduction on the real object of the damage and possesses only the photo documentation of the damages of a car prepared by the insurance company.

In technical practice of the damage liquidation by the insurance companies the dimensioning of the damage area of a vehicle is conducted with the use of measuring ledge which enables the estimation of the deformation geometry mainly in the field of mean breadth and height (b and h). The mean value of the depth of the damage area (f_{trw}), however, is usually not calibrated. Due to that fact, in the process of event course reconstruction, the marking of the depth of deformation is often impeded and requires from the expert the use of planimetry methods or use of computer programmes to the graphic machining of the photos [10, 11].

In the conducted research an attempt was made to omit the inconvenience being the lack of data concerning the depth of the deformation area in the process of marking the work of deformation as a result of road collision.

3. THE ASSUMPTIONS OF THE EXPERIMENT

Nowadays in literature one can encounter examples of the wide use of systems which use artificial neural networks to solve complicated tasks from various technical, medical or economical fields [2, 5-8, 13]. The main feature of artificial neural networks is the possibility to model any nonlinearity, with the preservation of the resistance to interruptions and the ability to generalise the knowledge gained in the process of learning to the analysis of new cases of a given phenomenon [8, 13].

Due to that fact, in hereby paper an attempt was made to use the artificial neural networks to mark the values of work of the motor-car body deformation W_{def} – without the necessity to define the parameter of the mean depth of the motor-car body deformation area f_{trw} – which is hard to measure in practice.

The research was conducted on the basis of the insurance company documentation consisting of the data gained in the process of liquidation of one thousand cases of road incidents.

In the conducted experiments the usefulness of artificial neural networks to define the work of motor-car body deformation was checked. In the research a neural network of a multi-layer perceptron (MLP) was used. A variant of a network with one hidden layer and with two hidden layers was examined. In each case the influence of the number of neurons on the standard of the achieved compatibility of the answers with the pattern was checked. It was assumed that for each hidden layer there is a possibility of the appearance of 5, 10, 15, 20, 25 and 30 neurons. Additionally the usefulness of 12 different methods of network teaching was checked (table 1).

Table 1

Specification of algorithms of neural network teaching

No of algorithm	Name of algorithm
1	Gradient descent backpropagation
2	Gradient descent with momentum backpropagation
3	Gradient descent with momentum and adaptive learning rate backpropagation
4	Resilient backpropagation (RPROP)
5	Conjugate gradient backpropagation with Fletcher-Reeves updates
6	Conjugate gradient backpropagation with Polak-Ribiere updates
7	Conjugate gradient backpropagation with Powell-Beale restarts
8	Scaled conjugate gradient backpropagation
9	One step secant backpropagation
10	BFGS quasi-Newton backpropagation
11	Levenberg-Marquardt backpropagation
12	Bayesian regularization backpropagation

For each of the methods the best variant of network architecture was set. In the hidden layers the tangent curve neurons were used.

The inputs of neural networks were constituted of the following data:

- type of motor-car body of the vehicles of the sufferer and the perpetrator,
- the age of the vehicles of the sufferer and the perpetrator,
- the weight of the sufferer and the perpetrator,
- type of the damaging event,
- type of collision,
- mean breadth of the deformation measured in the direction of the tangent of the collision,
- mean height of the deformation.

The places, where the damaging events took place, were divided into two types: built-up area and outside built-up area.

The motor-car bodies of the vehicles were classified as: mono-box, two-box or three-box.

The type of collision is meant by the collision of cars in movement and the crash into a stopping car.

A type of a damaging event is either a crash into the back of other car, crash into the side of a car, crash into the front of a car or crash into the corner of a car.

In the output of the neural networks the value of work of motor-car body of a sufferer’s car was defined.

4. THE RESULTS OF THE EXPERIMENT

With the choice of the complexity of the network it was observed, that the multiplication of hidden layers with the appropriately high number of neurons improves the correctness of the artificial neural network. It is a result of the network’s possession of a bigger number of connections, which can store a bigger number of models and use the memorised knowledge in a better way. The achieved results enable also to notice the cases, where with the increase in number of neurons in the first hidden layer, the error initially drops and then rises. It occurs due to the fact, that the network is overeducated and it loses the ability to generalise. Such a network is complex enough to memorise the presented models in the process of teaching. It is not able, however, in the process checking, to generalise this knowledge on similar models.

The example influence of the network complexity on the error value of testing is shown on figure 1.

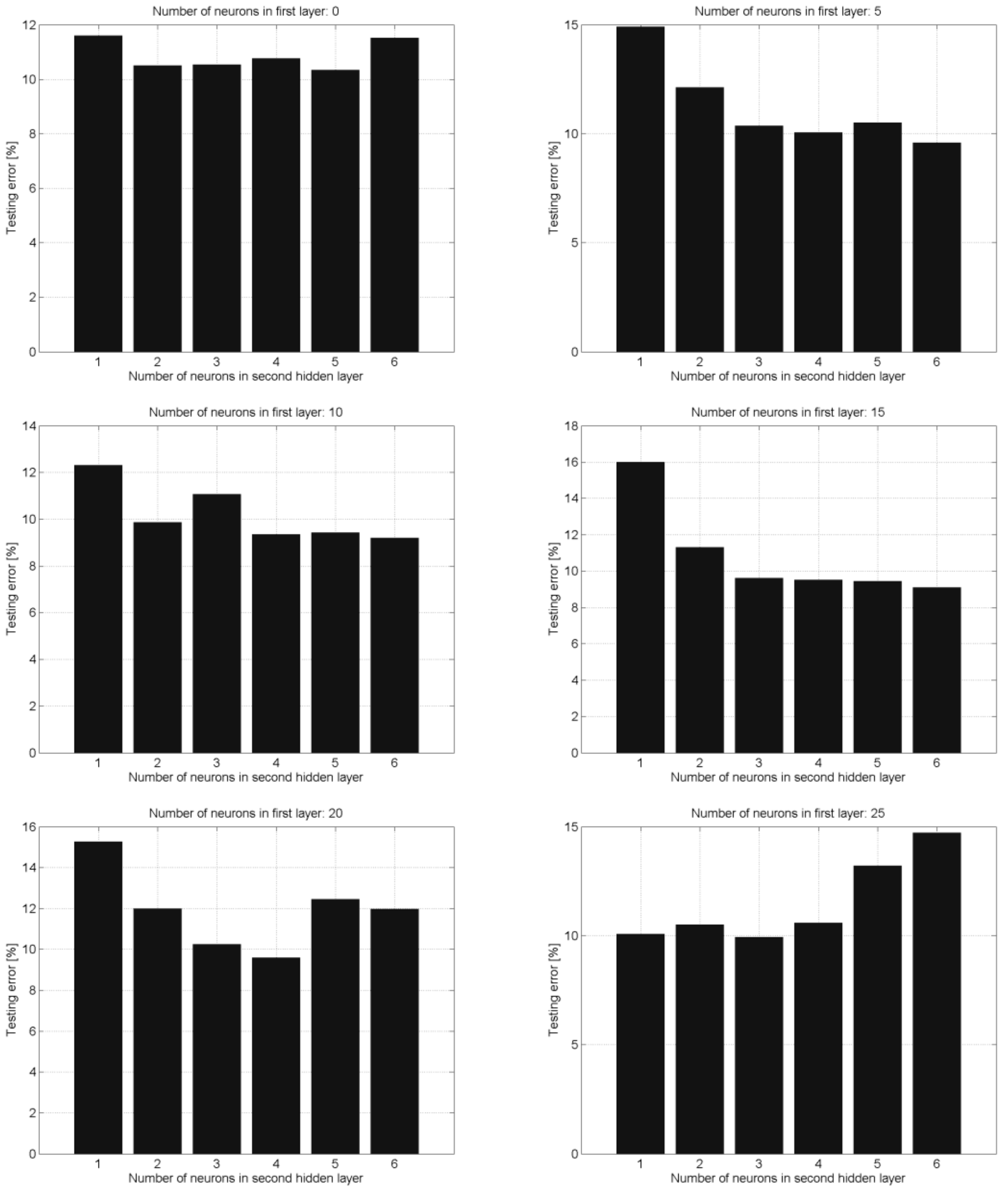

Fig. 1. The example of the network architecture on the value of testing error
Rys. 1. Przykładowy wpływ architektury sieci na wartość błędu testowania

In figure 2 the best results achieved for the successive algorithms of teaching the neural networks were presented.

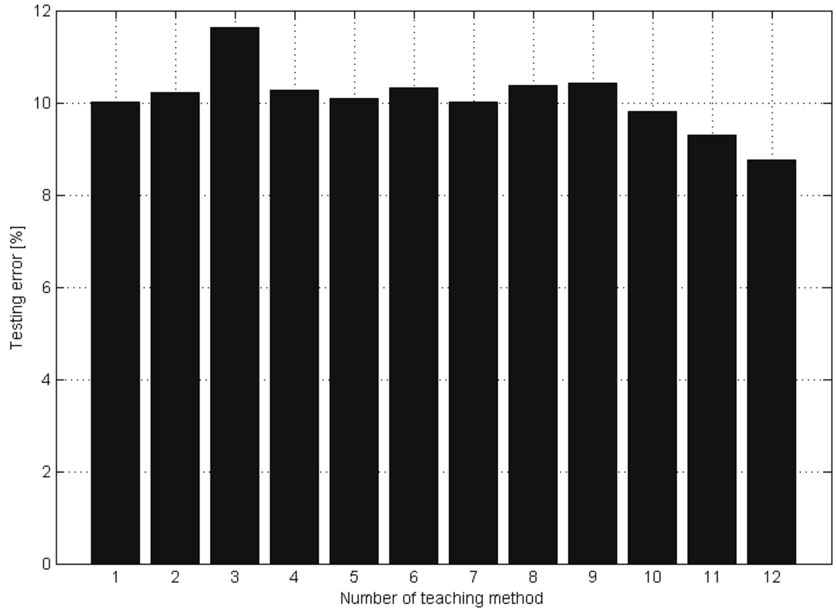

Fig. 2. The best results achieved for different algorithms of teaching the neural networks (limited amount of data)
Rys. 2. Najlepsze uzyskane wyniki dla różnych algorytmów uczenia sieci (ograniczona liczba danych)

The achieved results show the small role of the choice of algorithm of teaching a neural network of MLP type. The best achieved results for networks taught with various algorithms vary between 8÷12%.

In order to check what influence on the correctness of working of a neural network has the use of limited amount of input data – the lack of variable defining the depth of the deformation area (f_{trw}), the experiment was conducted again with the use of input data completed with the mentioned parameter. The achieved best results were shown in figure 3.

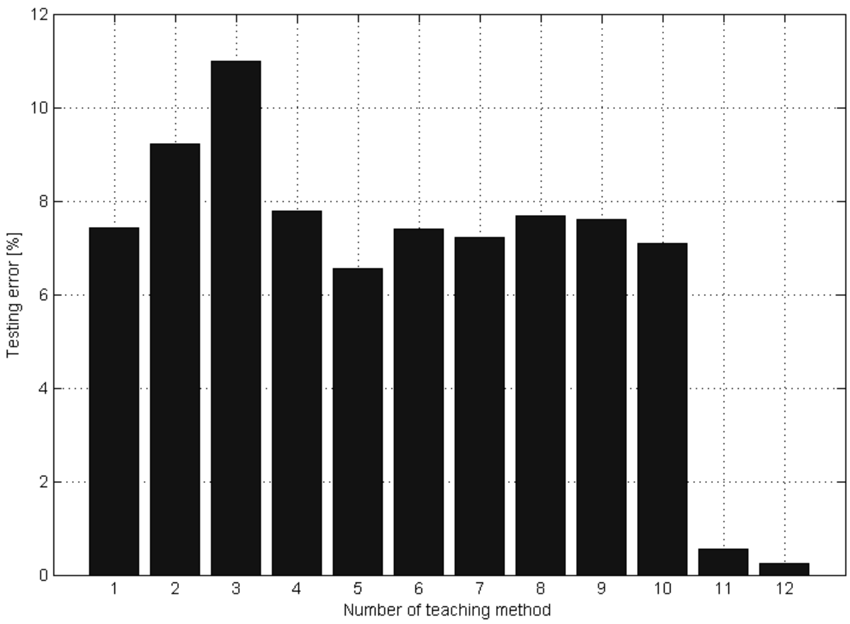

Fig. 3. The best achieved results for various algorithms of network teaching (complete amount of data)
Rys. 3. Najlepsze uzyskane wyniki dla różnych algorytmów uczenia sieci (kompletna liczba danych)

When comparing the achieved results, the smaller error percent for networks taught with the use of full set of data connected with the trace of deformation of the motor-car body after a road collision can be noticed. For most checked algorithms of teaching the error reached a level up to 3% lower than for network taught with the use of the same teaching method, but without the data concerning the depth of the deformation. In case of application of the algorithm number 11 and 12 in the process of teaching, and with the use of full set of input data, one could manage to achieve the neural networks characterised by the error of testing on the level below 1%.

5. SUMMARY

The conducted experiments showed the possibility of successful application of artificial neural networks type MLP in order to define the work of motor-car body deformation as a result of road event. Simultaneously, it was proved, that the application of neural networks enables the defining of the work of motor-car body deformation in case of the lack of data concerning the mean depth of the dent measured in the direction of the normal of the collision. Due to that the car experts and the representatives of insurance companies will be able to define the work of motor-car body deformation only on the basis of photos included in the documents of a road event, without the need of information concerning the depth of the deformation trace. The neural networks with the best chosen architecture, depending on the applied method of teaching, showed the error on the level of 8÷12%. However, possessing the full amount of data including the information concerning the depth of the motor-car body deformation one can use the neural networks to mark the work of the motor-car body deformation with the error on the level lower than 1%.

Bibliography

1. Czech P., Barcik J.: *Aspekty prawne indywidualnego „importu” używanych samochodów*. Przegląd Komunikacyjny 9/2007, pp. 30-34.
2. Czech P., Łazarz B., Wojnar G.: *Wykrywanie lokalnych uszkodzeń zębów kół przekładni z wykorzystaniem sztucznych sieci neuronowych i algorytmów genetycznych*. Wydawnictwo ITE, Radom, 2007.
3. *Główny Urząd Statystyczny: Rocznik Statystyczny Rzeczypospolitej Polskiej 2006*. Zakład Wydawnictw Statystycznych, Warszawa, 2006.
4. Kończykowski W.: *Odtwarzanie i analiza przebiegu wypadku drogowego*. Info-Ekspert, Warszawa, 1994.
5. Korbicz J., Kościelny J., Kowalczuk Z., Cholewa W.: *Diagnostyka procesów. Modele. Metody sztucznej inteligencji. Zastosowania.* Wydawnictwa Naukowo-Techniczne, Warszawa, 2002.
6. Lula P.: *Jednokierunkowe sieci neuronowe w modelowaniu zjawisk ekonomicznych*. Wydawnictwo Akademii Ekonomicznej w Krakowie, Kraków, 1999.
7. Nałęcz M., Duch W., Korbicz J., Rutkowski L., Tadeusiewicz R.: *Sieci neuronowe. Biocybernetyka i Inżynieria Biomedyczna*. Tom 6. Akademicka Oficyna Wydawnicza EXIT, Warszawa, 2000.
8. Osowski S.: *Sieci neuronowe do przetwarzania informacji*. Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa, 2000.
9. Owsiański R.: *Szacowanie energii deformacji nadwozia samochodów osobowych*. Paragraf na drodze 6/2007. Instytut Ekspertyz Sądowych, Kraków, 2007, pp. 33-48.
10. *Problematyka prawna i techniczna wypadków drogowych*. Instytut Ekspertyz Sądowych, Kraków, 1998.
11. *Wypadki drogowe. Vademecum biegłego sądowego*. Instytut Ekspertyz Sądowych, Kraków, 2006.
12. Prochowski L.: *Mechanika ruchu*. Wydawnictwa Komunikacji i Łączności, Warszawa, 2005.

13. Tadeusiewicz R.: *Sieci neuronowe*. Akademicka Oficyna Wydawnicza, Warszawa, 1993.
14. Zieliński A.: *Konstrukcja nadwozi samochodów osobowych i pochodnych*. Wydawnictwa Komunikacji i Łączności, Warszawa, 1998.

Received 1.06.2008; accepted in revised form 27.03.2009