SAT-2.203-1-TMS-02
„DELTA-V“ Based Expert System To Determine The Impact Velocity Between Cars
"DELTA-V" базирана експертна система за определяне на скоростите при удар между автомобили

Daniel Lyubenov, Vladimir Mateev, Polina Atanasova-Petrova
Даниел Любенов, Владимир Матеев, Полина Атанасова-Петрова

DELTA-V based expert system to determine the impact velocity between cars: *This article presents an information on the capabilities of the developed expert system for determining the vehicles impact speeds. The system is based on the Delta-V method – pre impact to post impact speed change of the vehicle. This method is based on the law of mechanical energy conservation and it is commonly used in expert practice for vehicle accident reconstruction. This system provides an opportunity to determine the vehicle post impact speed for different road surfaces. The developed expert system significantly reduces the time for the preparation of expert reports and the admission of errors*
Key words: *Delta-V method; Accident Reconstruction; Vehicles Speed.*

INTRODUCTION

Vehicle accident reconstruction expertise are a key source of evidence in solving legal cases in order to reveal the objective truth in civil or criminal proceedings. The quality of the expertise determines the quality of justice.

In Bulgaria there is not enough contemporary literature and software applications designed for training and work of experts or lawyers, based on new technologies in the automotive and scientific achievements in the field of vehicle accident reconstruction [2].

The aim of this work is to present the possibilities of developed DELTA-V based expert system to determine the impact velocity between cars.

EXPOSITION

In practice, experts use different methods to determine the speed of the vehicle. Each has its advantages and disadvantages, in one case, the accuracy of a method is more, in others less [1, 3, 5, 6]. In Bulgaria, one of the commonly used methods for determining the vehicles speed in accidents is the method "Delta-V", which is based on the law of mechanical energy conservation.

Under this law, the converted kinetic energy *E* for each vehicle during the impact is calculated as follows

$$E = (1+tg^2\alpha)\frac{L}{5}\left[\begin{array}{l}\frac{A}{2}(c_1+2c_2+2c_3+2c_4+2c_5+c_6)+\\+\frac{B}{6}(c_1^2+2c_2^2+2c_3^2+2c_4^2+2c_5^2+c_6^2+\\+c_1c_2+c_2c_3+c_3c_4+c_4c_5+c_5c_6)+2{,}5A^2/B\end{array}\right], Nm \quad (1)$$

where α is the angle between the normal to the surface deformation and vector of a impact pulse; *L* - the width of the deformation, *m*; $c_{1\text{-}6}$ - the depth of deformation of six equidistant sections, *cm*; A and B - crash coefficients, *N/cm* and *N/cm²*.

The change in vehicle velocity ΔV can be written as in equation

$$\Delta V_{1,2} = \sqrt{\frac{2m_{2,1}(E_1+E_2)}{m_{1,2}(m_1+m_2)}}, m/s \quad (2)$$

where $m_{1,2}$ are the full masses of cars; $E_{1,2}$ - the converted kinetic energy.
The after crash (post-collision) velocities can be written as in equation

$$u_{1,2} = \sqrt{2g(\varphi_{1-n}S_{1-n} + \varphi R\omega) \pm V_{y\partial}^{\ 2}}\ ,\ m/s \qquad (3)$$

where $\varphi_{1\text{-}n}$ are coefficients of friction; g - gravity acceleration; R - radius of rotation, m; ω - rotation of the vehicle after the collision, rad; $V_{y\partial}$ - loss (acquired) speed of vehicles after impact

The impact speed (pre-collision velocity) can be written as in equation

$$V_{1,2} = \sqrt{\Delta V_{1,2}^2 - u_{1,2}^2 \sin^2\theta_{1,2}} + u_{1,2}\cos\theta_{1,2}\ ,\ m/s \qquad (4)$$

where $\theta_{1,2}$ are the angles between the velocities of the center of gravity before and after impact.

The main window of the "DELTA-V" based expert system for determination the velocities at impact between vehicles is presented in Fig. 1.

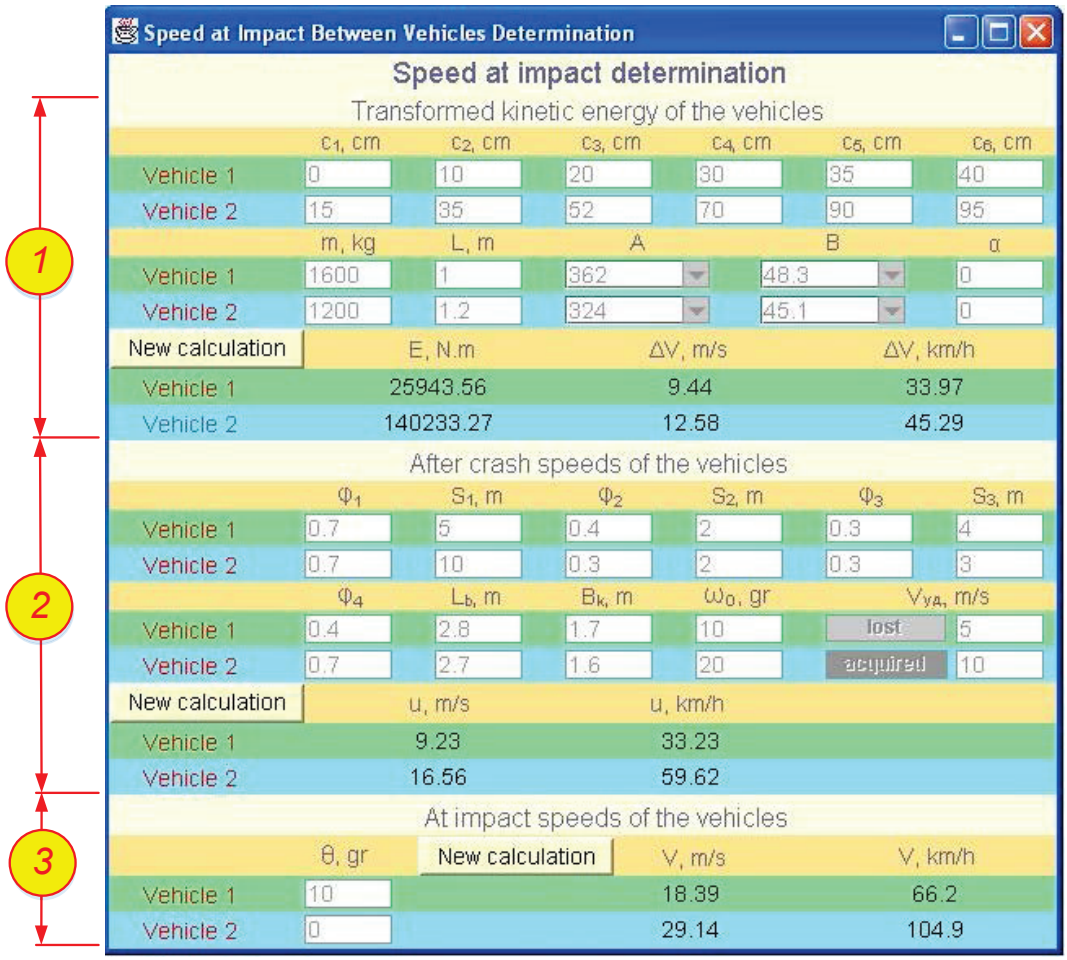

Fig. 1. Main window of "DELTA-B" based expert system

The expert system is developed by means of the object-oriented and platform independent programming language – Java [4]. It makes possible for the application to run on every computer platform that has Java Virtual Machine installed on it both as a standalone application and as an applet integrated into a web page and available on the Internet.

Functioning of the expert system from the user's perspective

The expert system consists of three main panels. The first one (Fig. 1, position 1) is for calculation of the transformed kinetic energy (1) and the change in vehicles speeds at impact (2), the second (Fig. 1, position 2) – for the post-collision velocities (3) and the third (Fig. 1, 3 positions) – for the pre-collision velocity (4).

After starting the system the user fills in panel 1 the measured values for depths of deformation in fields c_1 - c_6 (Fig. 2, position 1), the masses of vehicles m, widths of deformations *L*, crash coefficients A and B, the angle between the normal to the surface deformation and vector of a impact pulse *α* and clicks the "Calculate" button. If it turns out that in some fields are entered non-numeric values a warning message appears stating that the value of the specified field is not numerical (Fig. 2, position 2).

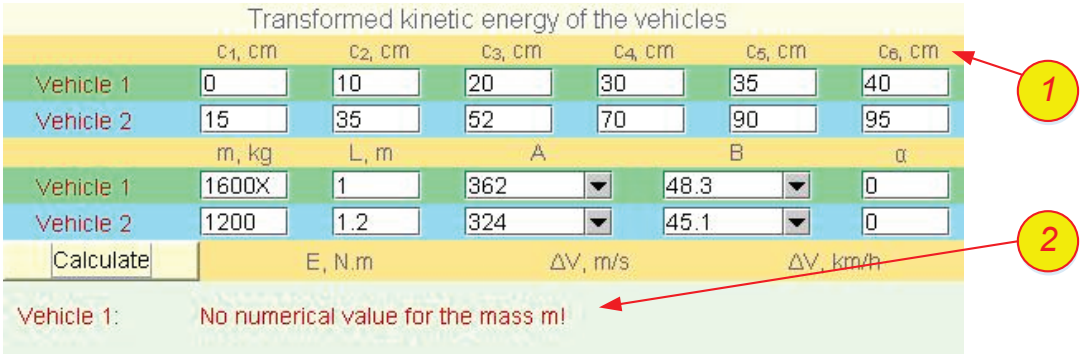

Fig. 2. Warning message for a no numerical value

After checking for no numerical values, starting from the left margin of the top row and ending with the right margin of the bottom line another checking is performed that determines if any value falls within the preset space of values for it or is equal to a value of a number of acceptable values. If some value is unacceptable (Fig. 3, position 1) a message about it appears (Fig. 3, position 2).

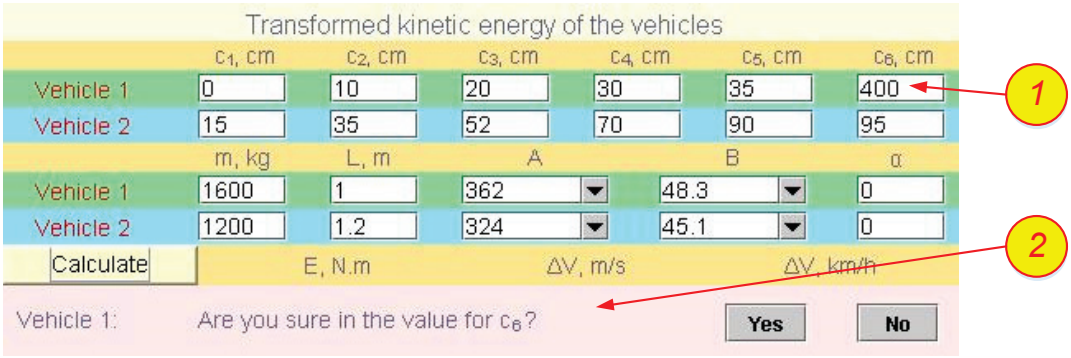

Fig. 3. Warning message for unacceptable value

If the user clicks the "No" button the entered in the field value is deleted (Fig. 4, position 1) and a new message appears (Fig. 4, position 2).

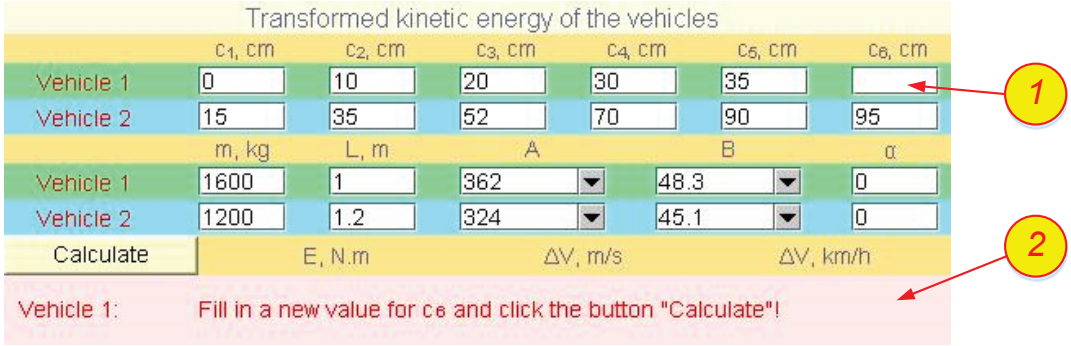

Fig. 4. Warning message for a new value

If the user presses the "Yes" button the entered in the field value is reserved and the message "The value of c_6 is accepted. Press “Calculate” to continue." Pears. So the entered value, though not belonging to a preset space of values for it, is accepted and it will be used in the upcoming calculations.

In order to determine the speeds of the vehicle after the collision in panel 2 (Fig. 5) it is necessary to fill in coefficients of friction φ and corresponding movements of the vehicles S, wheelbase L_b and rear (back) track B_k of the vehicles and rotation of the vehicles after the collision ω_o.

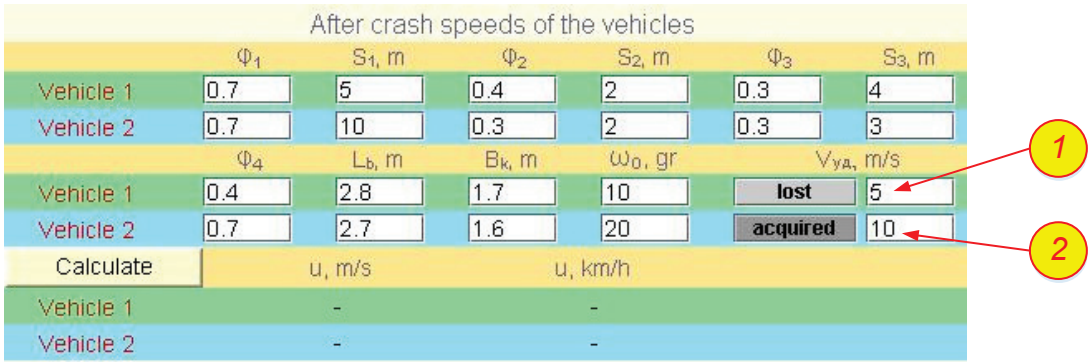

Fig. 5. Panel 2 of the expert system

Longitudinal and transverse bases of the vehicles are required in order to calculate their radii of rotation

$$R = \sqrt{\left(\frac{L_b}{2}\right)^2 + \left(\frac{B_к}{2}\right)^2}, \; m. \qquad (5)$$

where L_b is wheelbase of the vehicles; B_k - rear (back) track of the vehicles.

There is a possibility to determine the speed when driving on three surfaces with different coefficients of adhesion. The impact of the lost (Fig. 5, item 1) or acquired velocity (Fig. 5, item 2) of the vehicles after the collision is taken into account. Described above checks for incorrect or non-numerical values are made in this panel as well.

At impact speeds of the vehicles are calculated in panel 3. For this purpose it is necessary to fill in the angles between the speeds of the mass centers of the vehicles before and after the impact θ (Fig. 6). The other values, necessary for determining the speeds, are automatically generated from the calculations in the previous two panels of the system.

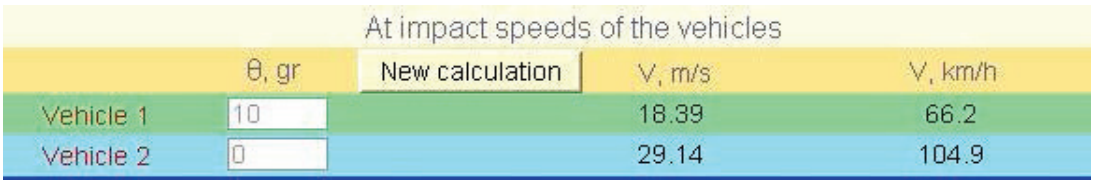

Fig. 6. Panel 3 of the expert system

Realization of the described functionality

For each panel there is an array for correctness of entered data. Each element of this array corresponds to the value entered in a particular text field. At the beginning all elements of the array are initialized to 0, which corresponds to the incorrect data. At every click of the "Calculate" button its elements are reset. Then the data in each field is evaluated and if it’s value is numerical, to the corresponding element in the array is assigned 1. Then the

elements of the array are checked from the beginning to the end and at first meeting of an element showing a non-numerical value, i.e. 0, a message that in the relevant field is introduced non-numerical value appears. After entering a new value these tasks are performed again. This continues until in all text fields there are only numerical values. Then entered in each field value is checked for belonging to a predetermined range of acceptable values. When the checking comes to a value that is not in the preset interval a panel with a message for confirmation of the value appears. If the value is accepted it is stored in an array for accepted values and is noted in an array for acceptable values. It does not matter that the value is not in the predefined interval or set of values. So at the end in all fields there are acceptable values or values, that are accepted explicitly for correct.

The developed expert system for determining speeds at impact between vehicles can be used for a strike of a vehicle in a solid object (tree, pillar, wall, etc.) as well. The system reduces significantly the time for determination of the speeds and allows to determine the influence of various parameters on final results. The system prevents errors in the calculation, thus contributing to improving the quality of expert report.

CONCLUSION

As a result of this work can be made the following conclusions:

Developed "DELTA-V" based expert system to determine the impact velocity between cars.

The system significantly increases the efficiency of work and preclude admission of certain errors.

The system can find a real application in the vehicle accident reconstruction and training of experts.

The article reflects the results of the work on Project No 2016 - FT - 03 on "Study of the simulator for driver training to improve traffic safety", financed by fund "Scientific Research" University of Ruse.

REFERENCES

[1] Lyubenov D.A., Mateev V., Kostadinov S. „Stopping Distance Expert System". University of Rousse, 2013, Volume 52, Series 4, p. 14-18, ISSN 1311-3321

[2] Lyubenov D.A. "A method of vehicle-pedestrian accident reconstruction". International journal "Machines, Technologies, Materials". ISSUE 5/2014, p. 13 - 15. ISSN 1313-0226.

[3] Simon Roberts, Philip Heller, Michael Ernest: Complete JavaTM 2 Certification, Study Guide, SoftPress Ltd. 2001

[4] Uzunov, Hr. "Comparative analysis of methods to study the impact between vehicles". Mechanics of machines № 108, p. 13-16, TU Varna, ISSN 0861-9727, 2014.

[5] Uzunov, Hr., St. Karapetkov. "Evaluation of the strain energy in methods "Expertcar" and "Delta-V". Mechanics of machines, ISSN 0861-9727, Varna, 2016, vol. 115, p. 78-80.

[6] Brach R., M. Brach „Vehicle Accident Analysis and Reconstruction Methods", 2011.

Contacts:

Assoc. Prof. Daniel A. Lyubenov, Department of Transport - University of Ruse, 8 Studentska Str., 7017 Ruse, Bulgaria. E-mail: dliubenov@uni-ruse.bg

Assoc. Prof. Vladimir Mateev, Department of Physics - University of Ruse, 8 Studentska Str., 7017 Ruse, Bulgaria. E-mail: vmateev@uni-ruse.bg

Eng. Polina Atanasova Petrova, Department of Transport, University of Ruse, 8 Studentska Str., 7017 Ruse, Bulgaria, E-mail: patanasova@uni-ruse.bg