Safety of Technogenic Environment

doi: 10.7250/ste.2014.015

2014 / 6

Structuring of Information Base for Designing Fire Equipment

Roman Zinko, *Lviv Polytechnic National University*

***Abstract* – Proper ordering and structuring help process large volumes of knowledge quickly, identify key trends and changes in design, and offer effective solutions of the current issues. Using term by term disjunction allows processing large amounts of knowledge, and representation of the predicate presented as a graph provides a clear visualization. The example of the application of the above-mentioned method while creating a new fire truck to fight forest fires is provided.**

***Keywords* – Fire truck for forest fire fighting, knowledge structuring, term by term disjunction method.**

I. Introduction

Work of vehicles involved in disaster management has significant differences if compared to the vehicles of general purpose. The differences lie in the need to use the dynamic characteristics of the car maximization while driving to the site of an emergency, to realize the possibility to reach a place of disaster taking into account characteristics of vehicle passing ability (in the case of off-road) or mobility (in the case of narrow roads). Efficient elimination of the emergency consequences should be also considered (presence of the needed equipment, energy availability, the ability to effectively use the existing equipment) [1] – [2]. Accordingly, the creation of highly efficient designs of such equipment must be preceded by structuring and analysis of the information in the firefighting area. Proper ordering and structuring will help process large volumes of knowledge quickly, identify key trends and changes in design and offer effective solutions of the existing problems.

II. The Analysis of Recent Studies

Creation or improvement begins with a review of literature on the investigated problem. Now there is a tendency to accumulate vast knowledge on a particular subject. The exploratory bots that search using the keyword are used on the Internet while looking for the information on a specific problem. Such principle is efficient for relatively small databases. In the case of specific studies on request by keyword search robot can provide several thousand responses, which take hundreds of screen displays. The perception and organizing of such a bulk of information is very difficult and time consuming.

Heuristic methods are used for systematization and classification of knowledge. These methods implement procedures with rational meaning in terms of human point of view [3]. In optimization methods, a quality parameter is set in explicit form which should be converted into the extreme of the set of admissible partitions [4].

Agglomerative methods consistently combine separate objective groups (clusters) [5] and divisive methods dismember groups into separate objects [6]. Agglomerative and divisive methods are time consuming and difficult to use for large bulks. In addition, the results of such algorithms work (their graphical representation) are difficult to analyze visually.

That is to say that there is a need for the development of new systematization and classification methods, which would allow to efficiently structure knowledge in the selected fields of science and technology.

III. General Regulations

When ordering the information related to improving the design of machines, questions relating to problems in the functioning of machines are proposed to be grouped into interrelated sets: a set of features, features and characteristics of features. Then the elements of the sets can be formed into separate zones (clusters) by using the real term by term disjunction. This regulation makes it possible to divide the total amount of knowledge into certain logic areas and representation of the formed predicates graphically provides the opportunity to visualize the investigated problem and quicker perceive certain sub-topics in full considering the entire informational material. Such regulation is effective for large bulks of knowledge. To demonstrate the essence of this regulation, we will provide an example using only a small number of elements.

Let us suppose it is needed to create a knowledge base on the issue of facilitated vehicle start. Literature review provides an opportunity to identify the issues that belong to this problem by a set of attributes: vehicle start can be facilitated by changing the weight components, rolling resistance, and change of the traction wheels efforts. These principles are realized by using traction devices, mass distribution of vehicle, changing the characteristics of wheels. Structurally provided principles are implemented by connection of road-train components via free, elastic, elastic-damping method or by compounding masses of vehicle gradually, parallel or cascaded. Changes in resistance or transfer efforts can be achieved by a pressure difference in wheel parts or by torque increase.

So let us write down the "Set of features" $R = \{ri\}$, which has 3 items – meaning of the attributes set, i.e. $i = 1,..,3$, where $r1$ – weight change; $r2$ – change in rolling resistance; $r3$ – change of efforts.

The set of "Features" $U = \{ui\}$ also has 3 items – values of attributes, i.e. $i = 1,..,3$, where $u1$ – coupling devices; $u2$ – mass distribution of vehicles; $u3$ – characteristics of the wheel.

TABLE I

RELATIONSHIP BETWEEN KNOWLEDGE LOCALIZATION AREA *QI* AND SUBJECT VARIABLES *L, U, R*

Set of features	Features	Characteristics of feature	Areas of knowledge localization
*r*1	*u*1	*l*1	*q*1
*r*1	*u*1	*l*2	*q*2
*r*1	*u*1	*l*3	*q*3
*r*1	*u*2	*l*1	*q*4
*r*1	*u*2	*l*2	*q*5
*r*1	*u*2	*l*3	*q*6
*r*1	*u*2	*l*4	*q*7
*r*1	*u*2	*l*5	*q*8
*r*1	*u*2	*l*6	*q*9
*r*2	*u*3	*l*7	*q*10
*r*3	*u*3	*l*7	*q*11
*r*3	*u*3	*l*8	*q*12

The set "Characteristics of features" $L = \{li\}$ has 8 pieces – values of attributes, that is $i = 1,...,8$, where $l1$ –the free connection method; $l2$ – elastic connection method; $l3$ – elastic-dumping connection method; $l4$ – gradual mass combination; $l5$ – parallel mass combination; $l6$ – cascaded mass combination; $l7$ – pressure difference in wheel parts; $l8$ – Increased torque.

Let us introduce the set $Q = \{qi\}$ of knowledge areas *qi*, $i = 1,..,12$, i.e.: $Q = \{qi\}$, $i = 1,..12$.

A paradigmatic table that reflects the relationship between the knowledge localization area *qi* and subject variables *l, u, r* is featured below (Table I).

Let us describe what it means, for example, knowledge localization area $q1 = r1u1l1$=weight change$^\vee$ coupling devices$^\vee$free connection method. The meaning of the expression: facilitated vehicle start is achieved by changing weight using traction devices that connect train elements freely. $q5 = r1u2l2$ = change in weight$^\vee$ distribution of vehicle masses$^\vee$ elastic connection method. The meaning of the expression is: facilitated vehicle start is achieved by changing its combined masses weight, which are connected elastically.

Knowledge localization area q is expressed through the value of subject variables *r, l, u* as follows:

$$r1u1l1 = q1\ ;\ r1u1l2 = q2\ ;\ r1u1l3 = q3\ ;$$
$$r2u2l1 = q4\ ;\ r2u2l2 = q5\ ;\ r1u2l3 = q6\ ;$$
$$r1u2l4 = q7\ ;\ r1u2l5 = q8\ ;\ r1u2l6 = q9\ ;$$
$$r2u3l7 = q10;\ r3u3l7 = q11;\ r3u3l8 = q12$$

Let us perform term by term disjunction of a possibly greater number of the related equations [7]. Introduction of term-by-term disjunction using the related equity is based on the need to obtain local areas of knowledge. Such areas may include more than one calculated limited number of attributes and problem domains of research.

$$r1u1(l1 \vee l2 \vee l3) = q1 \vee q2 \vee q3;$$
$$r1u2(l1 \vee l2 \vee l3 \vee l1 \vee l2 \vee l3) =$$
$$= q4 \vee q5 \vee q6 \vee q7 \vee q8 \vee q9;$$
$$r2u3l7 = q10;\ r3u3(l7 \vee l8) = q11 \vee q12.$$

Let us form a function of transition from the problem domain knowledge area q to local area of expert studies m, professional activities of whom include this area of research q. That means that we define knowledge that can be characterized as facilitated vehicle start using the method of connection from the total amount of knowledge in the dominant set.

$$q1 \vee q2 \vee q3 \vee\ q4 \vee q5 \vee q6 = m1;$$
$$q7 \vee\ q8 \vee\ q9 \vee q10 \vee q11 \vee q12 = m2\ . \qquad (1)$$

Taking into consideration the fact that the dependence between knowledge problem domains *q* and subject variables *r, l, u* and the relationship between subject areas of knowledge *q* and the local area studies of expert *m* (1), depending on local areas m on subject variables *r, l, u* are as follows:

$$m1 = r1u1(l1 \vee l2 \vee l3) \vee r3u2(l1 \vee l2 \vee l3);$$
$$m2 = r1u2(l4 \vee l5 \vee l6) \vee r2u3\,l7 \vee\ r3u3(l7 \vee l8).$$

Predicate *P* (*r, l, u, m*) that describes the relationship between the local area studies of expert *m* and subject variables *r, l, u* is as follows:

$$P(r,l,u,m) = m1r1u1(l1 \vee l2 \vee l3) \vee$$
$$\vee\, m1r1u2(l1 \vee l2 \vee l3) \vee m2r1u2(l4 \vee l5 \vee l6) \vee$$
$$\vee\, m2r2u3l7 \vee m2r3u3(l7 \vee l8)$$

The rapid growth of heterogeneous information requires a search for new ways of their compact presentation. One of the important approaches is visualization that is the way of data presentation in a two-dimensional or three-dimensional moving and fixed images. Most part of the information that is available for humans cannot be represented in two- or three-dimensional form without losses. Therefore, it is important to solve the problem of reducing these losses, i.e. the preservation of informativity in the construction of multi-dimensional data in a convenient for human perception form. The predicate P can be visually represented as a graph (Fig. 1). Graphic representation shows that local research areas where

research is dominant for characteristics of features *l*1, *l*2 and *l*3 (methods of connection of vehicles) is accumulation of similar knowledge. That is, research in this area is being conducted intensively and remains relevant.

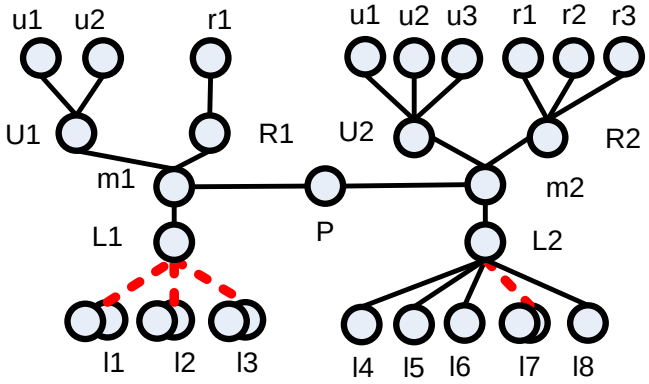

Fig. 1. Predicate *P* that describes the base of knowledge on the issue of facilitated vehicle start based on the vehicle parts connection.

Forming the function of the transition from domain knowledge area *q* to local area of expert studies *m* with another dominant demand, a broader one, for example, facilitated vehicle start with the use of weights, the local field studies will be as follows:

$$q1 \vee q2 \vee q3 \vee q4 \vee q5 \vee q6 \vee q7 \vee q8 \vee q9 = m1;$$
$$q10 \vee q11 \vee q12 = m2 \ . \qquad (2)$$

Predicate *P* (*r*, *l*, *u*) will be as follows (Fig. 2):

$$P(r,l,u,m) = m1r1u1(l1 \vee l2 \vee l3) \vee$$
$$\vee m1r1u2(l1 \vee l2 \vee l3 \vee l4 \vee l5 \vee l6) \vee$$
$$\vee m2r2u3l7 \vee m2r3u3(l7 \vee l8)$$

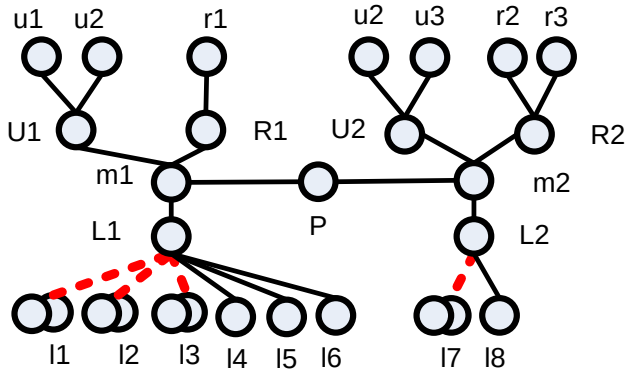

Fig. 2. Predicate *P* that describes the knowledge base on the issue of facilitated vehicle start based on a combination of elements of one vehicle.

Analysis of the literature representing a local area of research, presented in Fig. 1, which are constructions of traction devices, allowed us to offer a new design (Fig. 3).

Traction device consists of a trailer hitch 1, which ends with slide bar 2, direction 3, connected to traction body 4. On the slider 2 restrictive buffer 6 and 7 shoe plate are set and on the guide 3 there is limiting buffer 8 and supporting plate 7, and on the guide 3 – limiting buffer 8 and supporting plate 5, trailer hitch 1 and hauling body 4, pneumo cylinder 9 is also connected to double acting shock absorber 10. Pneumo cylinder 9 is connected to receiver 12 through control valve 11. Control valve 11 is connected to control unit 13. The sensor of load-bearing capacity 14 and acceleration 15 are also connected to the control unit 13.

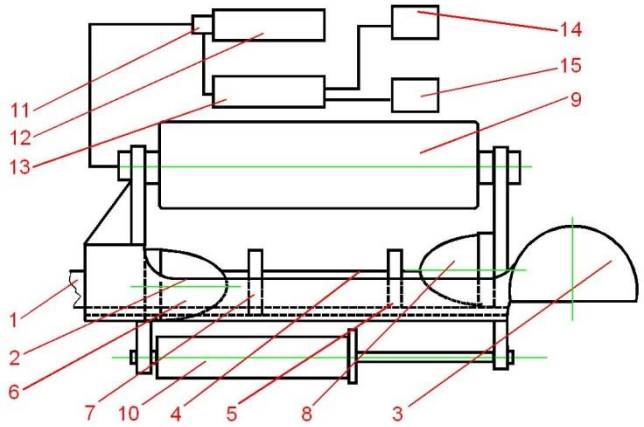

Fig. 3. Traction device.

In case of the expansion of the research area, presented in Drawing 2, the analysis of the additional literature on the particular subject allowed us to offer another constructive variant of facilitated vehicle start problem solution (Fig. 4).

Complete dismemberment of the vehicle body and frame in a longitudinal direction, which is provided by the use of the gap in attaching elastic and shock-absorbing elements [8] was suggested. Therefore, while taking off by means of loaded vehicle body mass inertia, the vehicle will start first and then after selecting the gap the loaded body mass will join the vehicle mass.

A device that provides the separation of the vehicle body and frame contains rolling elements 1 that are installed with the possibility of longitudinal movement on the guides 2 on the vehicle frame. This movement is limited by retaining buffers 3. The bracket with slot 4 is connected to the sidewall of body, in which a slider 5 is set with some gap. The slider 5 is connected to the end of the spring 6 and damping element 7. Another end of the slide is attached to the bearing part 9 and connected with car body.

In both cases, direction of research, related to the study of wheel propulsion, which is the influence of pressure difference in the parts of the wheels on the improvement of vehicle performance properties, was not included to the expert research area. Graphical representation of systematic knowledge on this subject provides an opportunity to draw attention to this area of research.

Based on the analysis of the literature sources on this subject, the construction of multi-section inner tube, which decreases the resistance to wheel movement in off-road conditions, was proposed, as well as the possibility of further movement even when several sections of the inner tube [9] were damaged (Fig. 5).

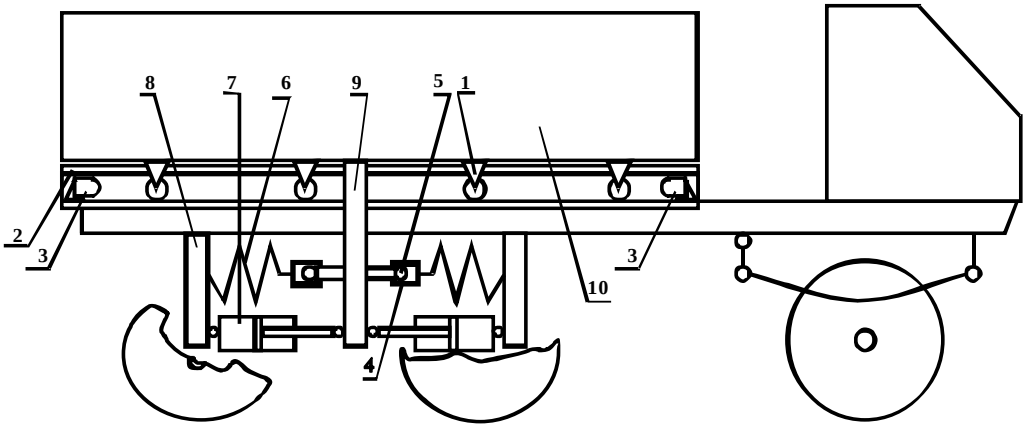

Fig. 4. Structural scheme of the patented device for attaching the vehicle body: 1 – rolling elements, 2 – guides, 3 – retaining buffers, 4 – bracket with a slot, 5 – slider, 6 – spring, 7 - damping element, 8 – external bearing parts, 9 - average support; 10 – body.

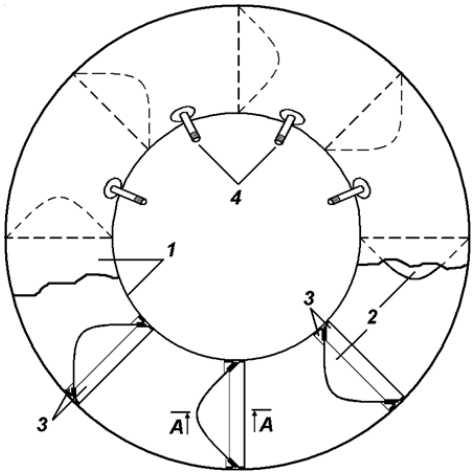

Fig. 5. General view of the multi-section inflatable bladder.

Tire inner tube for car contains a solid inflatable bladder 1, which is divided into separate sections with the use of partitions 2. Partitions 2 are connected with an inflatable bladder 1 by elastic fastening elements 3, which look like rubber belts. A nipple for filling air 4 is inserted in each section.

In the course of established structure research, well known methods were used [10–12] in which great attention was paid to a mathematical model and application package creation. With help of these programs it is possible to carry out a number of basic researches faster and more fully, saving lots of resources and time. To test the adequacy of mathematical model and the application package, created for the model implementation, a three-level test was accepted. That testing system consisted of the following steps [13]:

- checking the adequacy of models and packages based on the analysis of test problems of vehicle statics;
- checking the adequacy of models and packages based on the analysis of test problems of the car dynamic movement;
- comparing the results of the known research to the obtained results;
- comparing results of numerical and field experiments.

The first two stages of confirmation of the model adequacy and the application package, functioning of the investigated vehicle with the improved structural elements, demonstrated the correctness of the constructed model, the logic accuracy and clarity of their record.

In order to confirm the results of theoretical studies, a partial pilot experiment on the model was conducted, which lied in comparing the numerical values of the model and the application package with numeric values of the real vehicle characteristics basing on which the control values of the vehicle parameters are obtained. The pilot experiment was conducted in order to obtain only the basic values and parameters of the experimental sample, required for the application package debugging. This made it possible to save labor costs and time during the examination.

To conduct the pilot experiment, truck ZIL-131 was used. Later on for the implementation of tasks and goals of the pilot experiment standard body was substituted with experimental sample, which contained two loads that can be transported on rails (Fig. 6).

Fig. 6. Truck ZIL-131 with elastically connected elements and set complex of measuring equipment.

The conducted researches were put into the basis for the development of a new fire car model, which is specialized on fighting the forest fires (Fig. 7). Vehicles are composed on the chassis with average load-bearing capacity and have a modular linking [14]. Some modules have elastic joints. Additionally, the vehicle can transport trailer, the traction device of which also uses the principle of step-by-step elemental taking off. The wheels are equipped with multi-section tires, which provide movement even when several sections are damaged. A manipulator, used for self-loading of specialized modules, demolition of logjams while driving to place of fire extinguishing, is set on the fire-truck as well as remote trunk for fighting the fire.

Fig. 7. Sketch of the car for forest fire extinguishing.

IV. Conclusion

The usage of the method of term by term disjunction will simplify the process of the choice of research directions. It will make it possible to distribute the general scope of knowledge on the research problem into separate logical areas, and to present the formed predicates in the graphical form making it possible to visualize the research problem and quicker perceive the filling of information material by this or that subsection of the thematic field.

Using term by term disjunction has facilitated the conceptual design of special fire trucks for extinguishing forest fires.

References

[1] Y. Yakovenko, K. Yakovenko, "Conceptual approaches to creation and technical solutions of foreign fire-trucks of new generation," *Security systems*, vol. 12, no. 2. p. 58–63, 2000.

[2] M. Lavrivskyy, R. Zinko, I. Lozovyy, "Problems of development of manipulators as hinge-jointed mechanical systems," *Fire safety*, no. 13, p. 58–64, 2008.

[3] V. Ivanov, "Heuristic model in mechanical engineering," *Odessa: Baknva Press.* 2012.

[4] K. Jajuga, "Optimization in Fuzzy Clustering," *Control and cybernetics*, vol. 24, pp. 409–419, 1995.

[5] N. Paklyn, *Clustering algorithms in the service of Data Mining.* [Online]. Available: http://www.basegroup.ru/clusterization/datamining.htm. [Accessed: May 10, 2014].

[6] G. *A.* Fung *Comprehensive Overview of Basic Clustering Algorithms.* [Online]. Available: www.cs.csi.cuny.edu. [Accessed: Apr. 12, 2001].

[7] M. Bondarenko, "Theory of intelligence," *Kharkiv:SMIT, 2006.*

[8] I. Vikovych, J. Cherevko, M. Cherevko, R. Zinko, I Lozovyy, "Device for fastening body of the vehicle," *The patent for useful model Ukraine* no. 472747, Aug. 11,2008.

[9] A. Boiko, R. Zinko, I. Lozovyy, "Air-tube for car tires," *The patent for useful model Ukraine*, no. 41910, June. 10, 2009.

[10] I. Vikovych, R. Zinko, Y. Cherevko, "Generalized algorithm of research in physical modeling," *Announcer Zhitomir state technical university*, vol. 2, no. 46, pp. 37–43, 2008.

[11] M. Lavrivskyy, R. Zinko, I. Lozovyy, "Methods of experimental research of fire-truck of modular linking for fighting forest fires," *Announcer National Forest technical University*, no. 20.2, pp. 74–80, 2010.

[12] B. Kulakovskyy, E. Kazutyn, V. Mendelev, "Study of effect of aggregates and systems of basic shassis, dimensionally-weight parameters of fire superstructure on exploitative properties of fire-trucks," *Extraordinary situations*, vol. 2, no. 2(8), pp. 18–29, 2013.

[13] R. Zinko, "Testing a mathematical model of the motion and the forklift," *Journal of University of Technology skirts*, vol. 3, pp. 129–134, 2000.

[14] M. Lavrivskyy, R. Zinko, I. Lozovyy, "Formation of specialized container for fire trucks of modular layout," *Fire safety*, pp. 141–147, 2009.

Roman Zinko graduated from the Lviv Polytechnic University (Ukraine) in 1992. He holds the degree of Candidate of Technical Sciences. He is an Assistant Professor with the Institute of Engineering Mechanics and Transport, Department of Engineering and Operation of Machines. In 2013, he received the Doctoral degree. The title of the Doctoral Thesis was "The Use of Morphological Environment for the Research of Technical Systems".

Roman Zinko works on the creation of energy saving machines and mechanisms in the technological processes. Among the researched objects, there are means of transport, robots crushers, low-speed wind-driven power units. He has written more than 110 scientific, scientific and methodological papers and patents.

Address: LPNU, apt.8 Bandera Street, Lviv, Ukraine.

E-mail: rzinko@gmail.com