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METHOD OF RECOGNITION OF FORMS WHEN TRYING TO SELECT STREET DIRECTION

ABSTRACT

Roads are one of the main factors which influence road traffic safety. They influence the time of the realisation and the costs of the transport itself by their technical and exploitation characteristics. The right selection of a street will highly affect the costs of transport that can be reduced, and the speed of realisation that can be increased. The paper presents one of the methods of recognition of forms which is later on also tested on an example of selecting the type of the street. The aim of this paper was to show the possibilities of using the recognition of forms in the traffic and transport system. This way of selection and classification is needed when it is necessary to decide fast about the direction of movement, particularly in special circumstances.

KEY WORDS

recognition of forms, type of street, traffic flow direction, selection

1. INTRODUCTION

Introducing and using of new computer techniques and technology led to the development of a new scientific branch – the recognition of forms.

Different techniques and methods of recognition were formed by solving concrete problems independently from one another. The most widely spread one is the statistic theory of recognition of forms.

The recognition of forms is a process of reaching a decision, which is used to recognise a new input form as a member of one of the given types, so that we compare its characteristics with the characteristics of the known type.

The forms are dealt to as mathematical n-times magnitudes that consist of an organised series of numbers, where every number represents a value of a certain measurement on the pattern. The order of the measurements must be chosen in advance and spontaneously. Every value of the measurements represents one co-ordinate point in n-dimensional space, which is called a measuring space. The organised n-time magnitudes are called measuring vectors.

The problem of recognition of forms appears when we want to determine two or more types of forms in the measuring space.

The following phases occur with the appearance of problems in the method of recognition of forms:

- Separating characteristic magnitudes for observation forms

  The choice of characteristic magnitudes and their number depend on the complexity of the problem of the abilities and experiences of the man who defines the problem of recognition of forms. Their bad choice influences inconveniently the definition of the hypersuperficies of the decision, the dimension of the measuring space, calculating operation, the separability of the types and there is a large number of mistakes when the decisions are taken.
- The reduction of dimensionality

  The dominating magnitudes are separated by the help of some mathematical methods from spontaneously chosen number, characteristic magnitudes.
- Taking decisions or classification

  The aim of this phase is the maximum number of precise recognitions and searching of optimal hypersuperficies of decision. The natural upgrading of this phase is the exchange of initial patterns or the studying of the model.

2. THE MODEL OF RECOGNITION OF FORMS

2.1. Separability of the types

If type **c** is given in the measuring space and if there are **N**-measuring vectors in each type (Figure 1).

To be able to formulate the criterion of separability we should first define inter-classical and in-classical outspreading.

Abbreviated coefficients of separability are calculated in the same way as the coefficient of separability **J**, so that we omit the components of the measuring

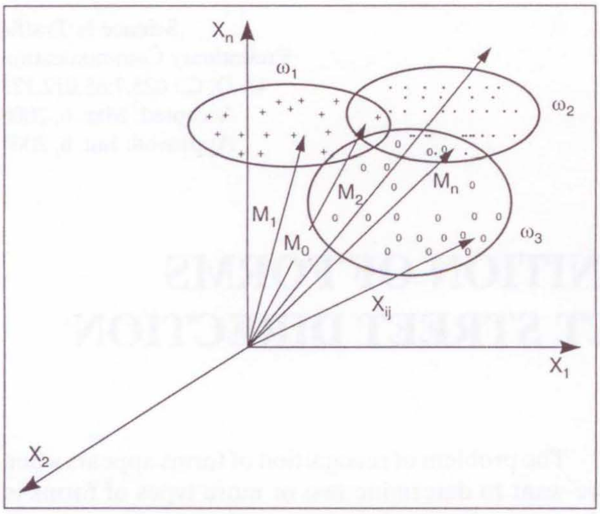

Figure 1 - The separability of the type in the measuring room

vectors one by one, which is done by reducing the dimension one by one. When all the **Jj, j = l**, of the **n** reduced coefficients of separability are calculated, the influence of an individual component of the measuring vector on the separability of the types is provided.

The component of which the difference between the coefficient of separability **(J – Jj)** is the biggest, has the greatest influence. If the difference is very slight – small, it means that the component of the measuring vector does not influence significantly the separability of the class, which enables us to expose or reduce the dimensionism of the measuring vector.

2.2. Optimal linear reduction of the dimensions of the measuring space

One of the essential problems in recognised form is the optimal reduction of the dimensionality of the initial information.

The initial **n**-dimensional vector **x** may develop without mistake into the following form:

$$X = \sum_{i-1}^{n} Y_i \Phi_i = \Phi Y$$

where:

$\Phi = [\Phi_1, \Phi_2, \ldots \Phi_n]$ – the basis vector

$Y = [Y_1, Y_2, \ldots Y_n]$ – the reduction vector

because vectors are ortonormal or:

$$\Phi_i^T \Phi_j = \begin{Bmatrix} 1 \text{ for } i = j \\ 0 \text{ for } i \neq j \end{Bmatrix}$$

the reduction vector can be expressed as:

$$Y_i = \Phi_i^T X, i = 1, ..., n$$

The optimal choice of vectors, in case it made the relation satisfactory, would be:

$$S_x \Phi_i = \lambda_i \Phi_i, i = 1, ..., n$$

where:

$$S_x = S_2^{-1} S_1$$

λ_i, Φ_i – character values and character vectors matrices S_x

To be able to define the optimal reduction of the dimensionality it is necessary to calculate the characteristic values and the vectors of the matrix S_x, and then to arrange the characteristic values in order of height:

$$|\lambda_1| \geq |\lambda_2| \geq \ldots \geq |\lambda_n| \geq 0$$

To minimise the medium quadratic error we drop the lowest characteristic values:

$$\varepsilon^2(m) = \sum_{i-m+1}^{n} \lambda_i$$

If the reduction was done on the m-times power dimension (m < n), the quadratic error will be equal to the sum of the dropped characteristic values. If the characteristic values are

$$\lambda_{m+1} = \lambda_{m+2} = \ldots = \lambda_n = 0$$

then the vector is

$$Y = [Y_1, Y_2, \ldots Y_n]^T$$

the dimensions **m (m < n)** with the error $\varepsilon^2 = 0$ which represents vector **x**.

The coefficient of separability in **m**–dimensional space is equal to:

$$J(m) = \sum_{i-1}^{m} \lambda_i$$

λ_i are in the first **m** highest characteristic values of the matrix $\mathbf{S_x}$.

If

$$\sum_{j=m+1}^{n} \lambda_j = 0$$

we get

$$J(n) = J(m) = \sum_{i-1}^{m} \lambda_i$$

and the vector

$$Y^T = [Y_1, Y_2, \ldots, Y_m], \quad Y_i = \Phi_i^T X$$

and it represents the original vector as to the separability of the types.

The reduction of the dimensions of the measuring space to **m (m<n)**, the elimination of the vector's components that have the lowest influence on the separability of the types, enable the graphical representation of the reduction vectors in the measuring space. The classification is made possible by the linear classification.

2.3. The classification of the vector

In the method of recognition of forms there are many methods for qualification of the unknown vectors. One of the general ways is the introduction of classifiers with the sum of the discrimination functions g_i (x), i=1,.... The most advantageous method of this way is the classifier L – of the nearest neighbour.

The second way is the distribution of the measuring space onto the section c decision $R_1, \ldots, R_c$. The sections are separated by the hypersuperficies of the decision. The simplest method of the unknown vector classification is by means of the linear classifier.

2.3.1. The classification of vectors by means of L-classifier

L–classifier (airlike) for the discrimination function uses airlike function of similarity d_i (x). The lowest value d_i (x), i=l, ..., c means that it belongs to type **i**.

The criteria of determination is:

Let it be

$$X = (X_1, \ldots, X_n)^T$$

The initial vector that we have to classify is

$$X_{ij} = (X_{ij1}, \ldots, X_{ijn})^T$$

j-times initial pattern of the **i**-times type (Figure 2).

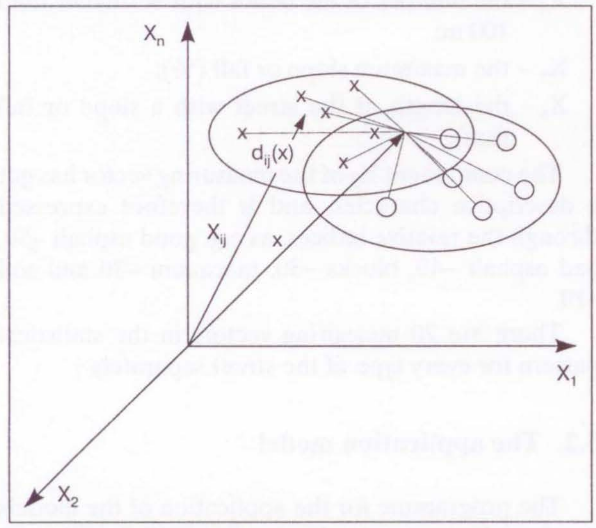

Figure 2 - The classifier L - of the nearest neighbour (airlike)

The square of the Euclidean interval X_{ij} in **n**–dimensional space is equal to:

$$d_{ij}(X) = \sum_{k=1}^{n} (X_k - X_{ijk})^2, \quad j = 1, \ldots, N$$

We can calculate the quadratic interval of the initial vector **X** from all the **n** patterns of i type, irrespective of the type to which **X** belongs. If the index is **j = 1, ..., N** they regroup, so that the pattern X_{ij}, which is the nearest to the vector **X**, gets the index **j = 1**, and the furthest one **j = Ny** so that we get:

$$d_{i1}(X) \le d_{i2}(X) \le \ldots \le d_{iL}(X) \le \ldots \le d_{iN}(X)$$

Using the first few **L** of the lowest squares of the intervals we define the function of similarity of the vector **X** to type **i**.

$$d_i(X) = \sum_{j=1}^{L} d_{ij}(X), \quad j = 1, \ldots, N$$

$$\min d_i(X) = d_r(X) \to X \in \omega_r, \quad i = 1, \ldots, c$$

The lowest value of the function of similarity determines which type the unknown vector **x** will most resemble.

2.3.2. The classification of the vector by means of the linear classifier

If we want to carry out the classification of the unknown vector with the help of the linear classifier we have to distribute the measuring space to the **c** section $R_1, \ldots, R_c$ and define the hypersuperficies of the decision.

In two-dimensional space the hypersuperficies of the decision is a straight line (Figure 3). The expression is:

$$Y_1 = aY_2 + b$$

When we define the hypersuperficies, we first draw in the reduction vector **Y** of all the types **I, I=l, ..., c**, and then we withdraw the hypersuperficies of the decision, so that the types move aside leaving an interval in the space.

The decision-making is done in the following way: We transform the unknown vector into the reduction one with the expression $\gamma = \Phi \cdot X$, then we calculate the values

$$Y_1(X) \quad \text{and} \quad Y_1'$$

on the hypersuperficies of the decision with the help of the expression:

$$Y_1' = aY_2(X) + b$$

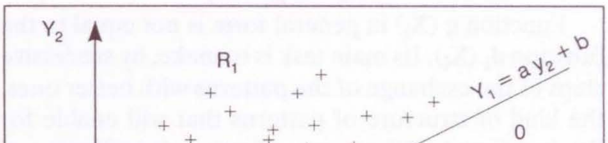

Figure 3 - The linear classifier in the two-dimensional room

We parallel

$$Y_1'$$

to

$$Y_1(X)$$

and decide:

If $Y_1' > Y_1(X)$ then vector **x** exists in section $\mathbf{R_1}$ or it belongs to the first type ω_1;

If $Y_1' < Y_1(X)$, vector **x** exists in section $\mathbf{R_2}$ or it belongs to the second type ω_2;

If vector **x** exists on the hypersuperficies of the decision or if $Y_1' = Y_1(X)$, the decision is not unit and the vector can be joined to any type whatsoever.

2.4. The exchange of the initial patterns

Let the initial vector **x** be added to the type **i** by the expression:

$$d_i(X) = \sum_{j=1}^{L} d_{ij}(X), \quad i = 1, ..., c$$

$$\min d_i(X) = d_r(X) \rightarrow X \in \omega_r, \quad i = 1, ..., c$$

The exchange of the patterns is understood as the searching followed by certain criteria of **N** patterns of the type $\mathbf{X_{ij}}$, **j = l, ..., N**, setting the aim of finding the worst representative of the class. If it is $\mathbf{X_{iq}}$, then its index **q** is joined to the new member $\mathbf{X_i}$, which takes its place. The same one is withdrawn under the proviso that the number of patterns remains the same. If $\mathbf{X_i}$ is the worst representative of the class, then it keeps **n** of the old patterns.

The criteria used for carrying out searching of the name is the criteria of exchangeability. If the function **g** $(\mathbf{X_i})$, which is estimated by vector $\mathbf{X_i}$, is defined, the criteria of exchangeability will be:

$$\min g(X_{ij}) = g(X_{iq}), \quad j = 0, 1, ..., N$$

$$\text{for } q \neq 0 \quad X_i \rightleftarrows X_{iq} \quad \text{the exchange is being held;}$$

$$\text{for } q = 0 \quad X_i \rightleftarrows X_{i0} \quad \text{no exchange is being held,}$$

$$\text{because } X_{i0} = X_1.$$

Function **g** $(\mathbf{X_i})$ in general form is not equal to the function $\mathbf{d_i}$ $(\mathbf{X_i})$. Its main task is to make, by successive steps of the exchange of the patterns with better ones, the kind of structure of patterns that will enable for the function $\mathbf{d_i}$ **(X)** a more effective classification of the new initial patterns.

3. THE SOLUTION OF THE PROBLEM

3.1. The selection of the problem

Streets are one of the main factors that influence the traffic safety. They influence the time of the realisation and the costs of transport itself by their technical and exploitation characteristics. The right selection of a street will highly affect the costs of transport that can be reduced, and the speed of the realisation that can be increased. There are many streets in the street-network that have similar characteristics. Because of that, it is very difficult to recognise the most advantageous ones. One of the possible methods, the selection of street for direction, is also the method of recognising the forms. To make the use of the stated model possible, it would be necessary to determine the types of streets and the characteristics of the sizes needed for the selection of the measuring vectors.

The types of streets are defined by the statistic method DELPHI. The experts have carried out the estimation of certain streets in the street-network. This gives us the initial information for further work..

Two types of streets are defined:

ω_1 – the type of the advantageous streets;

ω_2 – the type of the disadvantageous streets;

On the basis of this the measuring vector $\mathbf{X = (X_1, ..., X_6)^T}$ with the components

(technical and exploitation characteristics of the streets), which highly influence the safe and economic course of transport is formed, namely:

X_1 – the length of the street (km);

X_2 – the width of the street (m);

X_3 – the kind of the street basis;

X_4 – the number of the bends with R smaller than 100 m;

X_5 – the maximum slope or fall (%);

X_6 – the length of the street with a slope or fall (km).

The component $\mathbf{X_3}$ of the measuring vector has got a descriptive character, and is therefore expressed through the relative indices, as e.g. good asphalt –50, bad asphalt –40, blocks –30, macadam –20 and soil –10.

There are 20 measuring vectors in the statistical pattern for every type of the street separately.

3.2. The application model

The programme for the application of the models developed on a personal computer IBM PACKARD BELL, PENTIUM II, PLATINUM, using Windows NT programme language and includes a greater number of smaller inter-connected programmes (Figure 4).

First the coefficient of separability is calculated. The effect of the individual components on the separability of the types is defined. Then the method of classification is chosen. The model works on two methods of classification, linear and L–classifier. Before classification, optimal linear reduction of the dimensionality of the measuring space is done, with

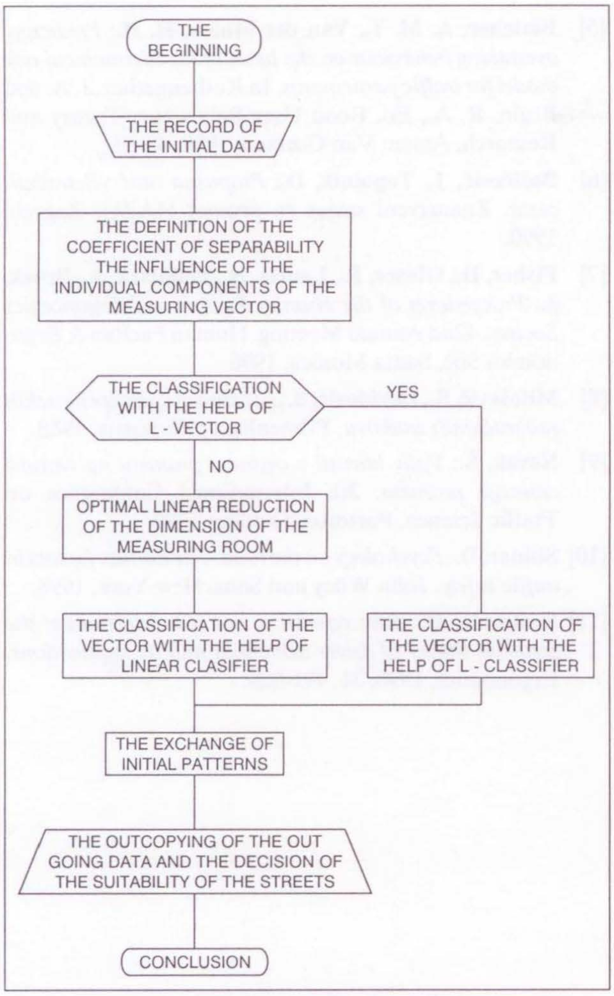

Figure 4 - The programme flowchart

the help of the linear classifier. After the classification is finished the exchange of the initial patterns is done.

An example of the operation of the model is enclosed, showing only the most necessary values of the output sizes.

The value of the coefficient of separability is equal to $\mathbf{J_0 = 4.0008}$, which means that the separability of the types is good (Insert 1). The component $\mathbf{X_3}$ of the measuring vector, the type of the street basis has the biggest influence on the separability of the types because $\mathbf{J_3 = 0.9078}$, and the smallest component $\mathbf{X_2}$ of the measuring vector, the width of the street, because $\mathbf{J_2 = 3.6572}$. The optimal linear reduction of the dimensionality is at $\mathbf{m = 2}$ with the error $\varepsilon^2 \cong 0$

Which means that the reduction vector **Y** represents vector **X** without error. The separability of the types and the hypersuperficies of the decision in two-dimensional space can be seen in Figure 5. The reduction vectors of the types are given in Insert No. 2.

The classification of the vectors is done with the help of linear in **L**–classifier. Both vectors are shown in Insert No. 3. In the first case the initial vector is better than the initial patterns, and the exchange a is

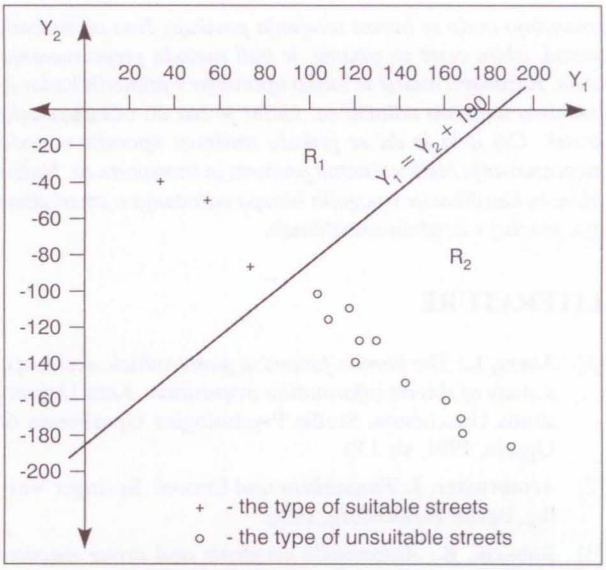

Figure 5 - Graphic review of the type vector in two-dimensional room as to the hypersuperficies of the decision

being held, but in the second one the exchange is not being held.

Working with this programme is very simple. The reiterated procedure is used for the record of the vector and the selecting of the method of classification. That leads to all of the output results.

4. CONCLUSION

The paper shows one of the methods of recognition of forms, which is later on also tested on an example of selecting the type of the street. That model can be also used in such cases when it is necessary to make a decision at once or when there is only short time left to make a decision. Our practice consists of many tasks for which the model of the recognition of forms can be used to reach their solution. Such cases are numerous in different medicine branches, economy, traffic, mechanical directions and in the army.

The aim of this paper is to show the possibilities of using the recognition of forms in the system of traffic and transport. This way of selection and classification is needed when it is necessary to decide fast about the direction of movement, particularly in special circumstances.

POVZETEK

METODA PREPOZNAVANJA OBLIK PRI IZBIRI CESTE

Cesta je eden od glavnih faktorjev, ki vplivajo na varnost cestnega prometa. Svojim eksplotacijskim karakteristikami vpliva na čas izvedbe in stroške transporta samega. Pravilna izbira ceste bo v veliki meri vplivala da se stroški transporta *zmanjšajo in da se hitrost izvajanja povišuje. Ena od možnih metod, izbira ceste za gibanje, je tudi metoda prepoznavanja oblik. Razdelani model se lahko uporablja v primerih kadar je potrebno trenutno odločiti oz. kadar je čas do odločitve zelo kratek. Cilj dela je da se prikaže možnost uporabe metode prepoznavanja oblik v sistemu prometa in transporta oz. Način izbire in klasifikacije v pogojih hitrega odločanja o smeri gibanja, posebej v izrednih okoliščinah.*

LITERATURE

[1] **Aberg, L.**: *The human factors in game-vehicle accidents: a study of drivers information acquisition*. Acta Universitatis Upsaliensis. Studia Psychologica Upsaliensia 6. Upsala, 1991, str 130.

[2] **Armbruster, J.**: *Flugverkehr und Umwelt*. Springer Verlag, Berlin-Heidelberg, 1996.

[3] **Babarik, B.**: *Automobile accidents and driver reaction pattern*. Jour. Of Applied Psychology, 1998, 42, 362-366.

[4] **Bach, H. Bickel, H., Biehl, B.**: *Validierung von Testverfahren zur Fahrer-analyse am Unfallkriterium*. Zeitschritt für Verkehrs-sicherheit, 1995,21 27-38.

[5] **Böttcher, A. M. T., Van der Molen, H. H.**: *Predicting overtaking behaviour on the basis of the hierarchical risk model for traffic participants*. In Rothengather, J. A. and Bruin, R. A., Ed. Road User Behaviour: Theory and Research, Assen: Van Gorcum, 1998, 48-65.

[6] **Božičević, J., Topolnik, D.**: *Propusna moć višetračnih cesta*. Znanstveni savjet za promet HAZU, Zagreb, 1990.

[7] **Fisher, D., Glaser, R., Laurie, N., Pollatsek, A., Brock, J.**: *Proceedings of the Human Factors and Ergonomics Society*. 42nd Annual Meeting. Human Factors & Ergonomics Soc, Santa Monica, 1998

[8] **Miloševič, S., Davidovič, S.**: *Istraživanje percepcije nekih saobraćajnih znakova*, Primenjena psihologija, 1988.

[9] **Novak, Š.**: *Vpliv hitrosti v cestnem prometu na varnost cestnega prometa*. 3th International Conference on Traffic Science, Portorož, October 1999.

[10] **Shinar, D.**: *Pcychology on the road. The human factors in traffic safety*. John Wiley and Sons, New York, 1998.

[11] **Summala, H.**: *Risk control is not risk adjustment: the zero-risk theory of driver behaviour and its implications*. Ergonomics, 1998, 31, 491-506.