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Classification Method for Vehicles with a Maximum Permissible Weight up to 3.5 Tonnes

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ABSTRACT

Detecting and distinguishing vehicles with a maximum permissible weight up to 3.5 tonnes, among others required in the TLS 8+1 classification, due to the similar dimensions of selected vehicle groups is often a relatively complex process that requires the use of extensive classification methods. Detection of commercials vans is particularly important. Their parameters are similar to lorry vehicles and their incorrect classification, eg in systems of weighing vehicles in motion, results in the lack of information on exceeding the permissible total weight. The article presents the selected classification method and its effectiveness.

KEYWORDS: vehicle classification, weigh in motion, data mining

1. Introduction

Classification of vehicles is an important element of control systems which are increasingly used in road transport. An example is a weigh in motion system (WIM). WIM stations measure the basic parameters of the vehicle and verify if there are any violations of the permitted standards. A particularly important element of the verification process is the definition of the vehicle class on the basis of which the permissible total weight of the vehicle is determined. Two classification methods are commonly used in WIM systems, according to the COST 323 specification [1] and TLS 8+1 [2]. In the case of the 8+1 classification it is required, inter alia, to distinguish motorbike, car, commercial van, car with trailer, lorry, lorry with trailer, articulated lory and buses.

The current situation on the transport market, in particular the lack of the need to have a tachograph in vehicles up to 3.5 tonnes, results in a significant increase of van vehicles in the commercial transport. Often, this type of vehicle also exceeds the permissible total weight, which significantly affects the level of road safety. An overloaded vehicle of this type does not retain its traction properties and causes a significant threat to other users of the road network. In TLS 8+1 classification, the class, which includes delivery vehicles, with a permissible gross weight up to 3.5 ton without trailers is the class 11 (commercial van). According to the TLS specification, this category includes, among others, the following vehicles: Fiat Ducato, Citroen Jumper, Ford Transit, Iveco Daily 40C, Mercedes-Benz Sprinter, Vito and Viano, Opel Vivaro or Volkswagen Transporter. These vehicles, due to their dimensions, are often assigned to the lorry class, thus causing the process of incorrect assignment of the permissible weight. What is important in the TLS specification, an example of a truck are Iveco Daily 40C and Mercedes-Benz Sprinter with increased dimensions and wheelbases, which additionally makes it difficult to distinguish this type of vehicle. What is more, the research carried out, inter alia, in the works [4, 5] indicate the difficulties in the classification of this type of vehicle. In addition, due to the systematically increasing dimensions of passenger vehicles and the presence of SUV, minivan, pick-up vehicles, erroneous assignment of the vehicle class occurs frequently. It is important to search for classification methods with the highest possible accuracy, in particular for vehicles with a permissible gross weight up to 3.5 tonnes. Increasing the classification accuracy will improve the operation of control systems such as WIM systems and will increase the detection and elimination of vehicles that do not meet the required standards.

2. Data characteristics

As a research data used information about parameters of vehicles registered by selected WIM systems. According to the approach presented in [4], data regarding category 11 (commercial van), 7 (car), 3 (lorry) and 5 (buses) were selected. A data was divided into a training and a test set. The basic characteristics of the data are shown in Tables 1 and 2.

Table 1. Characteristics of the training dataset [own study]

	Veh. category	3	5	7	11
Vehicle length [cm]	Avg.	995,4	1302,7	458,5	667,6
	Std.dev.	107,2	100,5	36,5	73,7
	Median	1000,0	1260,0	455,0	680,0
1. axel distance [cm]	Avg.	502,9	628,4	262,6	386,5
	Std. dev.	64,4	38,4	16,1	43,3
	Median	483,5	612,0	262,0	403,0
1. axel weight [kg]	Avg	4583,3	4650,1	745,4	1423,7
	Std. dev.	1510,3	947,4	179,5	212,2
	Median	4732,0	4690,0	741,5	1406,0
Axels no	No. of 2 axel veh.	80	79	100	99
	No. of 3 axel veh.	19	22	0	0

Table 2. The testing data characteristics [own study]

	Veh. category	3	5	7	11
Vehicle length [cm]	Avg.	957,1	1332,5	454,4	643,3
	Std.dev.	104,7	109,5	32,9	76,5
	Median	970,0	1310,0	460,0	640,0
1. axel distance [cm]	Avg.	491,0	641,8	262,0	376,3
	Std. dev.	63,0	43,6	13,6	44,9
	Median	480,0	633,0	262,0	375,0
1. axel weight [kg]	Avg	4513,5	4985,0	775,2	1404,2
	Std. dev.	1575,2	918,7	156,5	200,7
	Median	4387,5	5114,0	767,0	1367,0
Axels no	No. of 2 axel veh.	87	71	99	101
	No. of 3 axel veh.	13	29	0	0

Comparing the presented values (Table 1 and Table 2), slight differences between the training and testing data can be observed. In the case of both datasets, the size of data for particular categories was on the level of about 100 vehicles, together providing a collection of over 800 vehicles. Comparing the parameters of individual classes, it can be notice a distinction between classes especially considering the length of the vehicle (Fig. 1) and the distance between the first and the second axel (Fig. 2).

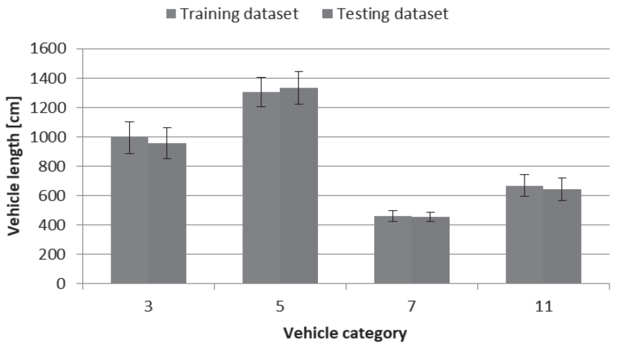

Fig. 1. Average vehicle length for training and testing dataset [own study]

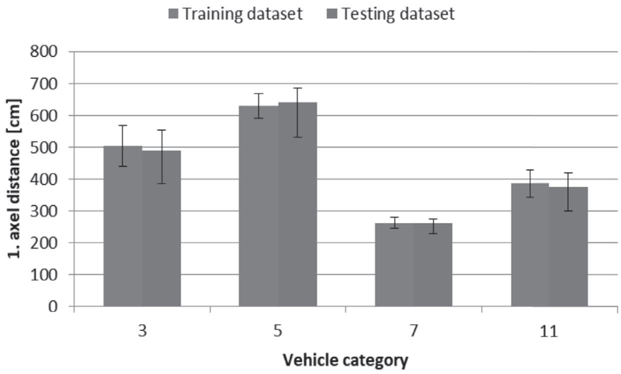

Fig. 2. Average 1. axel distance for training and testing dataset [own study]

Selected dataset was also dominated by two-axle vehicles. Only three-axle vehicles were registered for the lorry and buses. The parameter related to the weight of the first axel also has significant differences for particular classes, although due to the possibility of occurring commercial van (11) with significant overweight, it was decided not to include this parameter in the vehicle classification process.

3. Classification method

3.1 Discriminant analysis

In the first approach, it was decided to use the method presented in the paper [4]. This method assumes using discriminant analysis (DA) to determine the distribution of features in the space of the principle components created on the basis of the selected independent variables. In order to implement the method the Sklearn library was used [6]. As an input data following features were chosen: vehicle length, 1. axel distance and axels number. Distribution of objects in space of the first two eigenvectors is presented at Fig. 3.

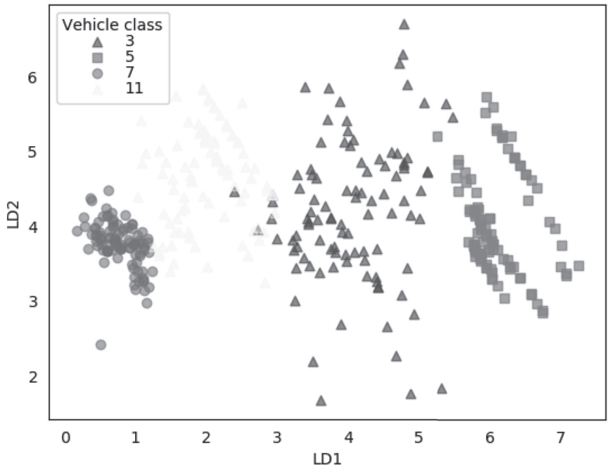

Fig. 3. Distribution of objects in space of the first two eigenvectors for the training data set [own study]

In order to evaluate the effects of assigning a given object to a particular class, Mahalanobis distances from centroid of class area to the vehicle DA vectors was used [4]. The obtained accuracy for the training dataset is shown in Table 3.

Table 3. Verification of training data set classification efficiency rate [own study]

Category (8+1)	Samples	Efficiency rate
3	100	89%
5	101	99%
7	100	99%
11	99	89%

In the next step, the method's effectiveness for the test set was verified. Distribution of testing data is presented at Fig. 4 and the obtained accuracy is presented in Table 4.

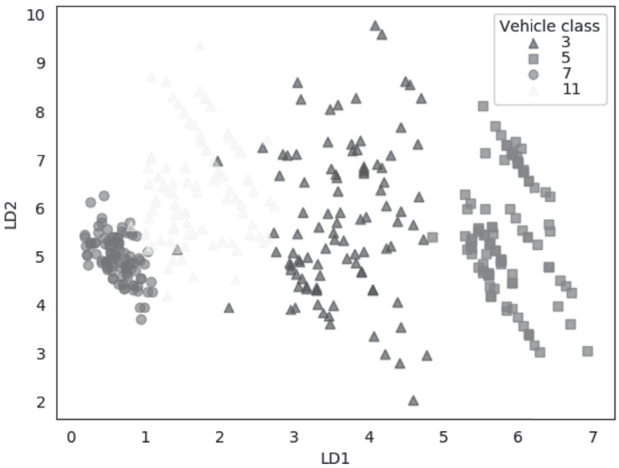

Fig. 4. Distribution of objects in space of the first two eigenvectors for the testing data set [own study]

Table 4. Verification of testing data set classification efficiency rate [own study]

Category (8+1)	Samples	Efficiency rate
3	100	78%
5	100	99%
7	99	100%
11	101	86%

As a result of the DA method, the overall accuracy of the classification was 89%. The lowest effectiveness of the method was noted for the class lorry vehicles (78%) and the class commercials van (86%). These values indicated the need to search for other methods for the classification of this type of vehicles.

3.2 K-nearest neighbors algorithm

In the next approach, it was decided to use k-nearest neighbors method. This algorithm assumes determining the class of a given object based on a number k nearest neighbors. In order to implement the method also Sklearn library was used [6]. The parameter k was adopted at level 5. As part of the kNN method omitted the parameter related to the number of axes - the carried out tests showed a practically irrelevant impact of this feature on the accuracy of the classification. Distribution of objects and classes using kNN method is presented at Fig. 5. The obtained accuracy for the training dataset is presented in Table 5.

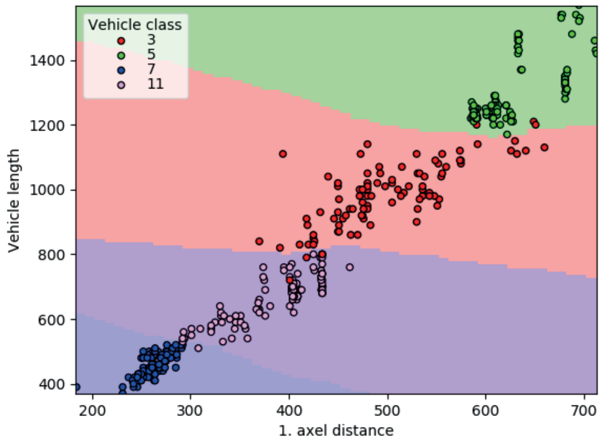

Fig. 5. Distribution of objects and class using kNN method the training data set [own study]

Table 5. Verification of training data set classification efficiency rate [own study]

Category (8+1)	Samples	Efficiency rate
3	100	91%
5	101	100%
7	100	100%
11	99	98%

Next the effectiveness of the kNN method for the testing dataset was verified. Distribution of object for testing dataset is presented at Fig. 6 and the accuracy is presented in Table 6.

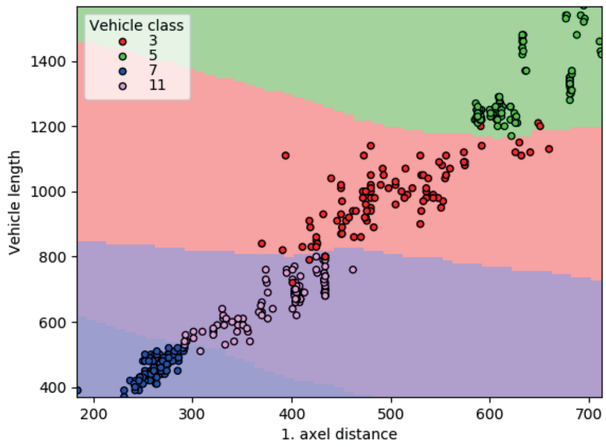

Fig. 6. Distribution of objects and class using kNN method the testing data set [own study]

Table 6. Verification of testing data set classification efficiency rate [own study]

Category (8+1)	Samples	Efficiency rate
3	100	94%
5	101	99%
7	100	100%
11	99	96%

The application of the kNN method allowed to get a much higher, in comparison to the DA method, accuracy of classification. In this case, the classification accuracy was 97%. For the class 11 (commercial van), which is the most important from the point of view of the work, the efficiency amounted to level 96%.

3.3 Results

Detailed results of the effectiveness assessment of the proposed vehicle classification methods are presented in Table 7 and 8. In the case of classification using the DA method (Table 9), the biggest mistake was due to incorrect assignment of lorry to the class of van vehicles (22 errors per 100 cases). There were also significant discrepancies in case of distinction between classes 7 and 11 - 14 out of 100 cars were classified as commercial van.

Table 7. The result of the classification using DA method [own study]

The class specified by an expert	The class specified by DA method			
	3	5	7	11
3	78	0	0	22
5	1	99	0	0
7	0	0	99	0
11	0	0	14	87
Total				

Table 8. The result of the classification using kNN method [own study]

The class specified by an expert	The class specified by kNN method			
	3	5	7	11
3	94	1	0	5
5	1	99	0	0
7	0	0	99	0
11	0	0	4	97
Total	95	100	103	102

For the kNN method (Table 10), the classification error of class 11 and 3 is definitely smaller. In only five cases lorry vehicles were classified as a commercial vans. In the case of passenger cars, only 4 cars were incorrectly attributed to class 11.

4. Conclusion

Presented in the paper method of classifying vehicles using the k-nearest neighbors allowed to obtain a high accuracy of operation. What's more even for class of commercials vans the method showed a very good performance. The correct classification of this type of vehicle is particularly important for an automatic control systems such as the weigh in motion system. As demonstrated in the work, using only two basic vehicle parameters (vehicle length and axel distance), obtained results which are exceeding the requirements of the A1 accuracy according to TLS 2012 (over 90% for delivery vehicles, trucks and buses, and 97% for passenger cars). In order to confirm the high accuracy of method with a confidence level of at least 95% as a future work, it is planned to increase the number of particular datasets to ensure a statistic reliability of the results.

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