Assessment of the Impact of Traffic Police Preventive Interventions

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Abstract. Free publicly available datasets describing weather and traffic accidents in the Czech Republic have been used for the training of a feed-forward neural network so that it could predict the level of the number of traffic accidents and their cost from weather, weekday, and month. The neural network learns the data for each of the 14 Czech regions separately and also the idea of cross-validation is utilized. The data for each learning task have been separated into Training Set, Development Test Set, and Test Set. Then a statistically significant number of experiments with neural network to get the accuracy of the prediction of the Test Set that happens when the accuracy of the Development Test Set is maximized have been conducted. The aim of the research is to learn whether this methodology can statistically detect any significant difference of the accuracy of prediction between the Test Set formed from days with interventions reported by the Czech Police and the randomly selected Test Set using the assumption that the neural network learns dependencies not affected by preventive interventions.

Keywords: Cross-validation, statistical hypothesis testing, feed-forward neural network, traffic accidents.

JEL Classification: C32, C45, R41, R50
AMS Classification: 68T, 62H

1 Introduction

It seems to be obvious that preventive traffic police interventions reduce the number of traffic accidents – after all, it is their purpose to do so. This work attempts at scientific treatment of them. The research on this topic worldwide confirms their positive effects on the reduction of accidents. Found studies focus on particular elements increasing security like safety belts [4], road adjustments [2], legislation, educational campaigns [9], the effect of police interventions on crime mitigation in particular geographical areas [1], the effect of sobriety checkpoints in reducing alcohol-related fatalities and injuries [5] by means of systematic reviews of existing studies. An attempt for economic analysis of effectiveness of anti-alcohol interventions is given in study [3] using a methodology presented in [10]. Article [14], which compares the number of deaths caused by traffic accidents per population of 100,000 people before and after the enforcement of usage of seat belts, motorcycle helmets, general traffic laws, and mass media educational campaigns, is perhaps closest to the research presented in this paper. Both researches study a particular country and use its national traffic police data. While [14] studies the effect of long-term educational and law enforcement programs, this paper tries to assess the immediate local effect of traffic police interventions on the number of traffic accidents and related economic damage.

2 The aim of the research and its methodology

The aim of this research is to find out whether the use of neural network and statistical tests of its output could detect any significant difference between days with and without preventive police interventions in terms of the number of traffic accidents and related economic damage.

While statistical tests like Pearson's chi-squared tests [15] can detect the dependence of the pair of variables, e.g. temperature on the number of accidents, neural network can work with multiple variables. Feed-forward neural network reads a number of input variables and adjusts its parameters so that its output is as close as possible to some other variables that should be predicted. Statistically prevailing dependencies determine its working. When neural network learns the number of accidents on days among which only a small part are days with traffic police interventions, its prediction is not affected by traffic police interventions. This property of neural network can be used to compare the number of traffic accidents and related economic damage on days with and without preventive traffic police interventions. If the accuracy of its prediction on days with interventions is significantly lower than its accuracy on days without interventions, it could mean that the interventions made some difference.

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3 Data

Datasets used in this study include weather from the National Centers for Environmental Information [6, 7], traffic accidents published by the Police of the Czech Republic on their web page [12], and reports on preventive traffic police interventions [13]. Because the immediate effect of traffic police interventions is local, all data should also be local. Available data sources allow division of data into 14 Czech regions, see e.g. [8].

3.1 Weather

Properties and processing of weather data are published in paper [11] which describes the research on which the research published in this paper is based on.

Weather dataset [6, 7] is structured by several Czech meteorological stations. For each of the 14 Czech regions the closest meteorological station has been used to get the data about mean temperature, precipitation and snow depth in this region for a particular day. Precipitation and snow depth have been transformed into binary values meaning either no or some precipitation or lying snow throughout a day in a particular region.

3.2 Traffic accidents

Of all available information in traffic accidents dataset [12] the total number of accidents and the total cost of economic damage per day for each of the 14 Czech regions have been selected as the values that will be predicted by the neural network.

Like in [11], the nominal values of the number of accidents and economic damage have been transformed into three categories “low”, “medium”, and “high” because this kind of output is the most appropriate for the neural network to learn. Before this transformation, like in [11], the nominal values in each of the 2 datasets had been fitted by quadratic curve and transformed into differences from this curve because the trend of these values has a rising tendency throughout the years. Unlike in [11], the trend curve has been estimated for each region separately using all available days including the Test Set. The Test Set has been included because in the current task we do not question the ability of the neural network to predict future events from past events but its ability to detect different accident incidence by the difference in its accuracy for 2 methods of forming the Test Set:

- Method 1, referred to as “Interventions” in further text, forms the Test Set from days with interventions.
- Method 2, referred to as “Random” in further text, forms the Test Set merely from randomly chosen days.

After getting values in the form of differences from trends, 2 border values for the number of accidents and 2 border values for economic damage dividing these values into 3 above-mentioned categories have been stated in each region separately, so that each region has approximately the same number of values in each category for each of these 2 datasets.

3.3 Preventive traffic police interventions

Reports on preventive traffic police interventions in [13] have to be read through to get a list of days on which preventive traffic police interventions happened. Of all preventive police activities, only the situations when traffic police went out on some road and interacted with drivers have been selected. Reading through police reports is very labor-intensive because of a large number of these reports and because of different structures of web presentations on different Czech regional police departments. Some regional police departments have their preventive activities separated from other reports and some departments have only a list of all reports which includes all police activities, not only prevention of the traffic police. Currently there are some 50 thousand reports that should yet be read through to get more days with preventive traffic police interventions on the list. See Table 1 for details.

3.4 Time span and division into Training, Development Test, and Test sets

Previous research [11] uses data from 2009.02.10 to 2016.04.19. Current research uses days until 2017.04.13. This means that for this research 2985 days can be used.

For each region 3 sets have been created. Training Set is formed from 2000 oldest days. Development Test Set is formed from 631 newer days. Test Set is formed from 354 days. If Method 1 (see Chapter 3.2) is used, all days with some preventive intervention in the region are present among these 354 days. The intention of this division is to have these three sets of the same size in each of the Czech regions so that the results of further processing are comparable. All days in the Test Set of the “Liberecký” region are days with preventive traffic police interventions. All other Czech regions have in their Test Set besides all found days with interventions some filler days chosen at random. See the number of found days with interventions in Table 1.

Region	Number of found days with interventions	Total number of reports	Number of reports not yet processed	Web
Jihočeský	283	917	0	http://www.policie.cz/krajske-reditelstvi-jihoceskeho-kraje-prevence.aspx
Jihomoravský	23	22174	21454	http://www.policie.cz/sprava-jihomoravskeho-kraje-zpravodajstvi.aspx
Karlovarský	71	256	0	http://www.policie.cz/akce-a-projekty-prevence.aspx http://www.policie.cz/akce-a-projekty-akce.aspx
Královéhradecký	280	23970	16006	http://www.policie.cz/kralovehradecky-kraj-zpravodajstvi.aspx http://www.policie.cz/clanek/krajska-reditelstvi-policie-kralovehradecky-kraj-archiv-zpravodajstvi-archiv-zpravodajstvi.aspx
Liberecký	354	14172	0	http://www.policie.cz/krajske-reditelstvi-policie-lbk-zpravodajstvi.aspx
Moravskoslezský	186	254	0	http://www.policie.cz/sprava-severomoravskeho-kraje-akce-a-projekty.aspx
Olomoucký	340	800	0	http://www.policie.cz/prevence-v-olomouckem-kraji.aspx http://www.policie.cz/zpravodajstvi-olk.aspx
Pardubický	101	865	0	http://www.policie.cz/clanek/akce-a-projekty-668803.aspx
Plzeňský	170	482	0	http://www.policie.cz/sprava-zapadoceskeho-kraje-akce-a-projekty.aspx
Praha	128	365	0	http://www.policie.cz/cinnost-a-akce.aspx
Středočeský	61	5836	4515	http://www.policie.cz/sprava-stredoceskeho-kraje-zpravodajstvi.aspx
Ústecký	80	715	0	http://www.policie.cz/sprava-severoceskeho-kraje-akce-a-projekty.aspx
Vysočina	88	340	0	http://www.policie.cz/krajske-reditelstvi-policie-kvs-prevence.aspx
Zlínský	12	8694	8279	http://www.policie.cz/clanek/zpravodajstvi-policie-zlinskeho-kraje-150757.aspx
Total	2177	79840	50254	List of found reports on author's page

Table 1 Data sources for traffic police interventions existing on 2017.05.03

4 Algorithm for the detection of the effect of preventive interventions

Neural network is used to predict the level of the number of traffic accidents and related economic damage for each day. As mentioned in Chapter 3.2, this level is encoded into 3 categories, and neural network learns to predict the correct category from the input data for a particular day. A process of learning of the single dataset will be referred to as "experiment" in further text. The neural network starts its training from the state with random weights which are its parameters. The result of its training depends on its initial state. It is possible to get the reliable information about the accuracy of its predictions only as a result of statistically significant number of experiments. That is why the neural network has been learning each region and dataset 100 times. In each experiment the neural network learns 3000 times each day in the Training Set and records the accuracy on the Test Set when its accuracy on the Development Test Set is maximal. The results of these experiments are statistically tested for significant difference between two methods of forming the Test Set explained in Chapter 3.2.

4.1 Neural network

A feed-forward neural network which has been programmed in C language for study [11] has been adjusted for this study. As in [11], it predicts separately the category of the number of accidents and the level of economic damage from month, day of week, temperature 219 days ago, temperature 32 days ago, temperature for the current day, precipitation and snow depth using 3 sets of data, the Training Set, Development Test Set, and Test Set.

4.2 Statistical test

100 experiments with the Test Set formed by Method 1 "Interventions" and 100 experiments with the Test Set formed by Method 2 "Random" produce two sets of the number of correctly predicted categories. The Welch test (1) [15] compared to Student's *t*-distribution with ν degrees of freedom (2) [15] has been used for testing whether their means (averages) are the same, which is the null hypothesis. This hypothesis is rejected if the *p*-value of the absolute value of the Welch test $|W|$ is smaller than probability 0.01, which means that the probability of rejecting this hypothesis when it is in fact true (i.e. the probability of Type I error) is not higher than 0.01. Symbols in equations (1), (2), and (3) with index 1 are for the results of Method 1 and symbols with index 2 are for the results of Method 2.

$$W = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad (1)$$

The number of correctly classified categories will be used as *X* variables in (1). The other symbols in (1) are standard deviations s, i.e. variances are s^2, and n is the number of values, which is equal to 100.

The degrees of freedom looked up in Student's *t*-distribution table are given by equation (2) [15].

$$\nu = \frac{(q_1 + q_2)^2}{\frac{q_1^2}{n_1 - 1} + \frac{q_2^2}{n_2 - 1}} \quad (2)$$

Symbols q_1 and q_2 in (2) are given by relations (3) [15].

$$q_1 = \frac{s_1^2}{n_1} \text{ and } q_2 = \frac{s_2^2}{n_2} \quad (3)$$

P-values of Student's *t*-distribution table have been computed in MS Excel by function "TDIST(ABS(*W*),*ν*,2)". In versions newer that Excel 2007 function "T.DIST.2T(ABS(*W*),*ν*)" should be used.

5 Experimental results

Results of neural network training are shown in Tables 2 and 3.

Region	Interventions	Random	Welch test	Degrees of freedom	*p*-value
Jihočeský	102.89	105.05	-1.987550	180.9364	0.048377
Jihomoravský	120.71	123.75	-2.563290	194.1532	0.011126
Karlovarský	88.36	87.30	0.990696	197.9978	0.323049
Královéhradecký	**99.19**	**103.57**	**-3.876580**	**181.8908**	**0.000148**
Liberecký	**98.05**	**102.89**	**-4.890000**	**187.0085**	**0.000002**
Moravskoslezský	129.49	132.19	-2.480470	193.3255	0.013977
Olomoucký	110.21	108.80	1.325444	173.5115	0.186772
Pardubický	105.86	106.28	-0.343750	197.9976	0.731399
Plzeňský	100.72	98.53	1.929005	196.5972	0.055175
Praha	**206.17**	**216.16**	**-7.868450**	**188.6962**	**2.75E-13**
Středočeský	122.19	120.27	1.573078	193.5211	0.117339
Ústecký	**123.19**	**126.95**	**-3.072680**	**196.4378**	**0.002423**
Vysočina	99.73	99.76	-0.023600	196.6765	0.981195
Zlínský	107.05	107.30	-0.212290	197.7608	0.832097
Average	115.27	117.06	-1.535746	191.1794	0.235934

Table 2 Average number of correctly classified categories of the number of accidents in the Test Set formed by methods "Interventions" and "Random" in 100 experiments. When *p*-value is smaller than probability 0.01, the differences in the results of the 2 methods of training are considered statistically significant and their rows are displayed in bold.

Region	Interventions	Random	Welch test	Degrees of freedom	*p*-value
Jihočeský	99.77	97.83	1.508743	190.0103	0.133026
Jihomoravský	110.40	109.37	0.813440	195.8868	0.416958
Karlovarský	86.98	86.96	0.010070	175.3466	0.991977
Královéhradecký	**86.39**	**93.20**	**-5.422930**	**195.4249**	**1.72E-07**
Liberecký	**86.29**	**90.67**	**-3.502020**	**190.1538**	**0.000576**
Moravskoslezský	111.71	110.69	0.828421	193.7296	0.408456
Olomoucký	95.38	98.34	-2.363840	181.2100	0.019146
Pardubický	99.58	96.64	2.181468	197.8164	0.030333
Plzeňský	92.94	95.38	-1.971900	197.1722	0.050020
Praha	**164.06**	**168.78**	**-3.450240**	**195.8160**	**0.000686**
Středočeský	109.37	108.17	0.858778	196.4307	0.391512
Ústecký	113.31	112.62	0.500988	197.5765	0.616939
Vysočina	92.22	95.20	-2.515220	197.3088	0.012695
Zlínský	91.61	91.33	0.188017	194.4475	0.851060
Average	102.86	103.94	-0.881159	192.7379	0.280242

Table 3 Average number of correctly classified categories of the cost of economic damage in the Test Set formed by methods “Interventions” and “Random” in 100 experiments. When *p*-value is smaller than probability 0.01, the differences in the results of the 2 methods of training are considered statistically significant and their rows are displayed in bold.

We can say from Tables 2 and 3 that in regions where the *p*-value of the absolute value of the Welch test is smaller than probability 0.01 the traffic police preventive interventions have significantly influenced the number of accidents or economic damage with the probability of 1 – 0.01, i.e. with a 0.99 level of confidence.

6 Discussion of results

The average accuracy for all regions equal to the Average of Method 2 “Random” from the lower row of Tables 2 and 3 divided by the size of the Test Set equal to 354, as stated in Chapter 3.4, is equal to 33% for the number of accidents and to 29% for the economic damage. In study [11] the accuracy of prediction of the category of the number of accidents is in the range of 53% to 64% and the accuracy of prediction of the category of the cost of economic damage is in the range of 43% to 50% of days in the Test Set. Inspection of graphs with the values of the number of accidents and the values of the cost of economic damage with their quadratic trends suggests that the poor results of the neural network in this research is caused by bad fit of the quadratic trend to the data in some regions. Only the “Praha” region has the accuracy of all of its datasets within the range of the results in [11] and its quadratic trends seem to be fitting well both the number of accidents and the cost of economic damage datasets.

However, the poor accuracy of neural network may not hinder its ability to detect the effect of preventive interventions. The following evidence about the method of assessment of preventive interventions presented in this paper can be derived from Tables 1, 2, and 3.

Facts that speak against the methodology:

- In some regions the accuracy of “Random” is lower than the accuracy of “Interventions”. The rationale why the accuracy of the recognition of the “Random” dataset should be higher than the accuracy of the recognition of the “Interventions” dataset is explained in Chapter 2.
- Relatively large quantities of days with interventions do not always result in recognition of “Random” being more accurate than the recognition of “Interventions” dataset, see e.g. the “Olomoucký” region in Tables 1 and 2.

Facts that speak in favor of the methodology or at least make some sense:

- The average number of correctly recognized categories for all regions equal to the Average from the lower row of Tables 2 and 3 is higher in the “Random” method than in the “Interventions” method.
- In all statistically significant regions (in bold) the number of correctly recognized categories of the “Random” method is higher than the number of correctly recognized categories of the “Interventions” method.
- Statistically significant regions in Table 3 are subset of statistically significant regions in Table 2. This makes sense because the recognition of economic damage has always been more inaccurate than the recognition of the number of accidents.

- The “Praha” region, that has the highest accuracy in both “Interventions” and “Random” methods and in both the number of accidents and the economic damage datasets, has the smallest area of the all Czech regions, see e.g. [8]. Most interventions did not cover the area of the whole region, so interventions in smaller region should have greater impact for that region.

7 Conclusion

The original method based on statistical processing of the results of the prediction using neural network for the detection of the impact of traffic police preventive interventions has been presented. According to this method, preventive interventions in the period of 2009.02.10 to 2017.04.13 in regions “Královéhradecký”, “Liberecký”, and “Praha” seem to have significant impact on the number of traffic accidents and the cost of economic damage. Possible improvements to this method include finding more days or more appropriate days with preventive interventions and higher order, maybe cubic, polynomial for regression of the time series of predicted variables.

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