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Information System for Police Force: Application for analyzing traffic accidents data

Marek Kvet, Michal Kvet, Peter Pukalík, Filip Sudora, Miroslav Bušik, Michal Tvrdý
University of Žilina, Faculty of Management Science and Informatics
Univerzitná 8215/1, 010 26 Žilina, Slovakia
marek.kvet@fri.uniza.sk, michal.kvet@fri.uniza.sk, ORCID 0000-0001-5851-1530

***Abstract*—This research paper focuses on the creation and integration of enhanced features into a traffic accident data entry and correction application. We discuss both the initial development of the application and the recently introduced functionalities specifically designed for documenting traffic accidents. The application forms a crucial component of a broader project aiming to establish an information system that enables law enforcement agencies to effectively record, analyze, and address incidents of crime, criminal activity, and traffic accidents.**

Keywords—traffic accidents, pedestrian-related traffic accidents, police forces, traffic data statistics, traffic accidents monitoring, web design, desktop application

I. Introduction

Data analytics and advanced statistical approaches play an irreplaceable crucial role in modern data science and sophisticated applications in many areas of human life supporting safety and comfort of served population [1, 2, 5, 6, 15]. The amount of data needed to be stored and processed has been rising very fast and thus, the attention of programmers and other scientifically oriented experts has been paid to the completely sophisticated spectrum of data science [3, 4, 7, 8]. Because of data analyzing necessity, the international project [18] was introduced and it is currently being implemented. Its core consists in using advanced database and statistical technologies in sophisticated data analysis [9, 10, 11, 12, 13]

In this paper, we will focus on specific dataset, which comes from the traffic police environment. The main goal of this study is to provide the reader with a statistical analysis of available data.

The application for analysing traffic accident data is part of a larger project called the Police Information System Project. The whole project is divided into three parts, the aim of which is to create a comprehensive web application focused on crime monitoring. The other two groups focus on processing data on crimes on the territory of the Slovak Republic and crime analysis in Europe.

The application we will describe in the following section of this paper is composed of two separate modules. The first one is a desktop application designed primarily for entering and correcting erroneous traffic accident data. The second module is a web application aimed at presenting the collected data in the form of reports, graphs, and tables. The presentation part of the application is implemented using the frontend framework React and the .NET platform for the backend part.

II. Current State

The development of the application has focused on the processing and correction of erroneous data on accidents involving pedestrians and visualization of data in tabular and graph form. The data analysed and evaluated in this part of the project are provided by the Police of the Czech Republic. The data on accidents involving pedestrians were written to a single .csv file for the whole Czech Republic. At the same time, the data published for a given month also contains data from previous months in a given year (e.g. the data published for the month of December contains the complete data from the respective year).

Traffic accidents involving pedestrians were defined to year 2022 in the provided file by the following items summarized in Table I.

TABLE I. DESCRIPTION OF RECORDED DATA

Entry	Description
p1	Identification number
p29	Pedestrian category
p30	Pedestrian status
p31	Pedestrian behaviour
p32	Situation at the accident site

For each item, a list of values it can take is defined. These values are recorded in the form of a codebook. An example of a codebook can be seen in Table II.

TABLE II. DIAL OF VALUES WITH DESCRIPTION FOR ENTRY P29 (PEDESTRIAN CATEGORY)

Value of entry p29	Description
1	Man
2	Woman
3	Child (up to 15 years)
4	Group of children
5	Another group

Development has so far focused on the desktop part of the application. The .NET framework was used together with WPF (Windows Presentation Foundation) technology to create modern and interactive user interfaces for Windows applications. For data storage we used a database from Oracle.

A. Entering records into the database

The main extension of the application was the need to modify the existing editor to allow the storage of the provided data in raw format in our database.

Through this editor, the user can upload complete data on both single accidents and accidents involving pedestrians to the database. If an erroneous data is captured, the entire record will be logged, in which the erroneously uploaded record can then be corrected. The editor for entering data into the database is shown in Fig. 1.

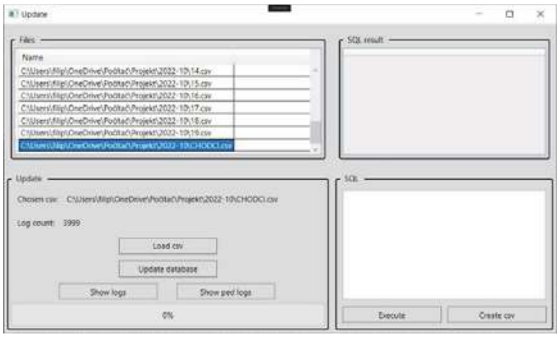

Fig. 1. Editor for entering data into the database

B. Correction of incorrectly inserted records

Another added functionality was aimed at the correction of erroneously entered or wrongly entered data into the database. Such functionality is depicted in Fig. 2. The user will see the incorrectly entered entries highlighted in red. It is then possible to correctly select one of the correct values and insert the entire record into the database.

Fig. 2. Editor for correcting erroneous data

C. Displaying available data in tabular form

A new functionality of the application is a clear display of available records of traffic accidents involving pedestrians in tabular form (see Fig. 3). This new option allows users to present information in a structured form directly in the application. The user has all the data organized into rows and columns, which allows him to compare, sort and define filters to display only the desired set of records easily and clearly. The filtered records can then influence the graphical display of the results.

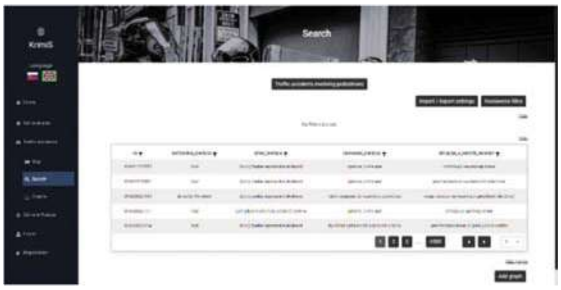

Fig. 3. Application page showing data in tabular form

The new functionality allows the user to gain a more comprehensive view of the data structure and provides tools for efficient data manipulation. These tools in turn facilitate the creation of graphical visualizations, contributing significantly to better understanding and interpretation of the data.

D. Analysing data using different attributes

This functionality allows the user to visually represent and explore the relationships between different attributes (e.g. pedestrian category, pedestrian condition, pedestrian behavior and accident situation) using graphs, providing insight into their interactions and trends. Fig. 4 represents the window for setting the graph. The user can create different types of graphs, such as bar or line graphs, and customize them according to their needs. This functionality allows for quick and intuitive detection of patterns, detection of outliers and identification of trends in the data. The user can easily select data based on various attributes and analyze it in the context of individual graphs. This opens the door to discovering new insights, extracting relevant information and making decisions based on thorough data analysis. The final graph is depicted in Fig. 5.

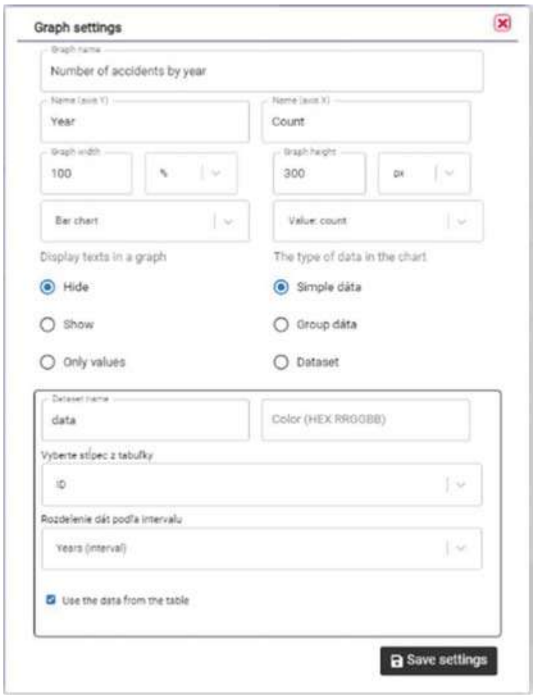

Fig. 4. Window for setting the graph

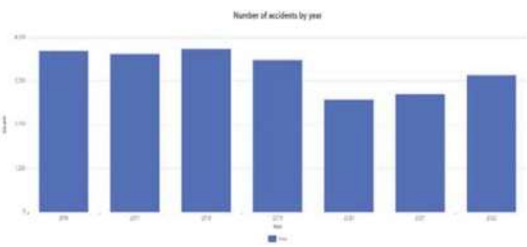

Fig. 5. Graph created according to the specified settings

E. Filter and report storage functionality

Additional functionality of the application allows the user to save, share and reuse custom filter settings and generated reports. This feature simplifies and speeds up the process of selecting and applying filters, as well as generating and managing reports, improving efficiency and convenience when working with data. The user can save their preferences and get instant access to the desired results, contributing to better organization and repeatability of analytical tasks.

The resulting reports can also be exported to .png format, or the report data can be copied to a spreadsheet, for example.

III. Application Development

By prioritizing web technology, the presentation layer of the whole project is developed on a common web domain krimis.fri.uniza.sk. Therefore, it was necessary to create a new pages that would allow the user to visualize and analyze data easily and clearly through the creation of graphs, reports.

A. Extension of processed data

In 2023, the Police of the Czech Republic started to publish data with a changed structure (new data were added). For this reason, it was necessary to extend and modify the current data model and adapt the backend and frontend to that.

TABLE III. Description of extended data

Entry	Description
p1	Identification number
p29	Pedestrian category
p29a	Reflective elements at the pedestrian
p29b	Pedestrian on a passenger carrier
p30	Pedestrian status
p30a	Alcohol present in pedestrian
p30b	Type of drug in a pedestrian
p31	Pedestrian behaviour
p32	Situation at the accident site
p33c	Sex of the person
p33d	Age of pedestrian
p33e	Nationality of pedestrian
p33f	Provision of first aid
p33g	Consequences

This will allow the user to analyse accidents involving pedestrians in greater detail. There was also change in format of data files that we process.

B. Making predictions

The application can predict the future development of traffic accidents involving pedestrians based on a larger amount of data. A small example of prediction can be seen in Fig. 6. This capability allows users to forecast the likelihood of these incidents based on the available data.

In our solution, we have prepared support for time series data prediction. The prediction itself presents us with an informed estimate of the possible occurrence of accidents involving pedestrians in the future. We have implemented two methods of data prediction.

The auto-regression model is a model that determines the value of a process at any time step t using a linear combination of the last p values (called the memory model). This prediction is a linear function of the previous p values of the time series. By properly selecting the model parameters, the auto-regression model can be used to predict the next value in the time series if the current and previous p values are known.

Fig. 6. Data predictions

Singular spectrum analysis (SSA) - is a technique based on decomposition of the time series into components. The goal of SSA is to decompose the original time series into the sum of a small number of interpretable components, such as slowly varying trend, oscillatory, and structureless noise. Prediction can then be performed based on the estimated components.

By implementing multiple models, users can compare the results of both and choose the one that is more suitable for them. It is also useful in situations where data behaves differently at different times or under the influence of different factors. This way we are prepared for different scenarios and can better react to changes in the predicted dataset.

During the implementation of this part, it was necessary to solve a problem when we were missing data in some time periods (no traffic accident involving pedestrians occurred in the given time period) and so the time series was incomplete. We solved this by being able to fill in the missing values. We were careful to have the correct number of days in each month, accounted for leap years, and only filled in data up to the last month in which data was last recorded.

C. Adding statistical indicators

Basic statistical indicators (see Fig. 7) are another way of looking at the data being analysed. They allow the data to be summarised into numerical values, making it easier to understand the characteristics of the data. They can be used to compare different datasets (collections of data). For this reason, we have prepared the possibility for the user to find out the following statistical indicators:

- Minimum - determines the minimum value in the dataset,
- Maximum - determines the maximum value in the dataset,
- Average - the sum of all values in the dataset divided by their number,
- Median - the middle value in the dataset that divides an ordered dataset into two equal halves,
- Mode - determines the value or values that occur most frequently in the dataset,
- Variance - determines the degree to which the values in the dataset are dispersed from the mean,

- Standard Deviation - determines the measure of how the data is distributed around the mean,
- Kurtosis - determines a measure that describes whether the distribution of the data is uplifted or flattened compared to a standard normal distribution,
- Skewness - indicates whether the data are asymmetric or symmetric around the mean,
- Percentile - a value that divides an ordered dataset into nth percentile groups,
- Sum - expresses the total sum of all values in the dataset,
- Count - expresses the total number of values in the dataset.

EXPORT

Base statistics

	The name of the statistic	Value
>	Maximum	411
<	Minimum	4
$\bar{x}$	Mean	237.58
$\tilde{x}$	Median	236
Mo	Mode	222
σ^2	Variance	6281.4
σ	Standard deviation	79.26
κ	Kurtosis	1.75
γ	Skewness	-0.53
π_{25}	Percentile (25)	202.08
π_{50}	Percentile (50)	236
π_{75}	Percentile (75)	283.75
$\sum$	Sum	17106
#	Count	72

Fig. 7. Basic statistics

D. *Spatial data visualization*

Analysing spatial data on traffic crashes can help identify areas with high concentrations of traffic crashes. Therefore, we implemented two ways to visualize traffic accidents on map. It is also possible to import/export saved filters and filter traffic accidents according to different criteria and combinations of these criteria. For example, we can filter based on region, severity of the accident, amount of damage, date, and time. Based on the specified parameters, points will be displayed on the map.

The base map allows us to show individual traffic accidents. The traffic accident marking can be coloured in five different colours. These colours indicate the occurrence of the worst casualty (see Fig. 8). For some traffic accidents there is no consequence data available, so they have the colour set to blue.

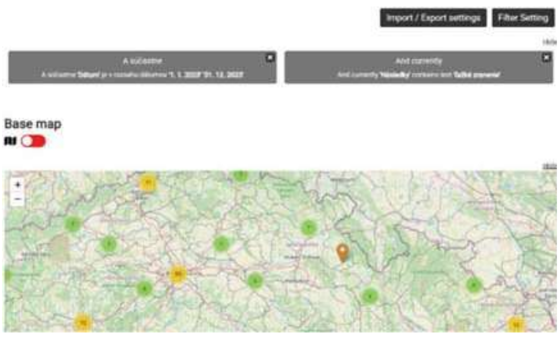

Fig. 8. Base map with applied filters

Upon clicking on a point, information about the accident is displayed, such as the date and time, type and cause of the accident, number of fatalities, seriously and lightly injured persons, and persons without injuries, and finally, the total material damage of the accident. At the same time, traffic accidents are grouped into clusters for clarity. Fig. 9 depicts additional information for individual traffic accident.

Fig. 9. Additional information displayed for individual traffic accident

Two heat maps have been added to the web site, one is classic, and the other is a point heat map, switching between the individual maps is done via a toggle button. Both maps display the total traffic accidents in the territory of the Czech Republic. For more details, see Fig. 10 and Fig. 11.

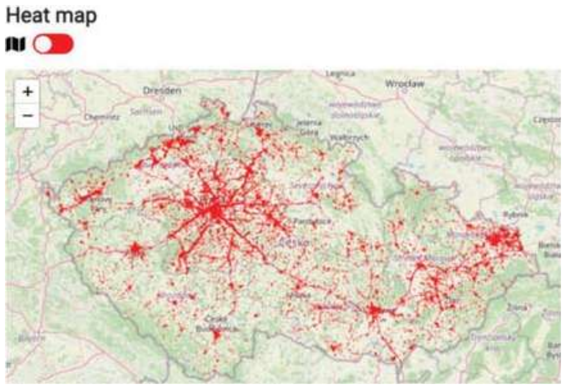

Fig. 10. Detailed heat map of traffic accidents in the Czech Republic

The heat map provides a visual representation of areas with a high concentration of traffic accidents, allowing easy identification of areas at risk. The heat map is easy to interpret and allows comparison of different areas in terms of the number of accidents.

Fig. 11. Heat map of traffic accidents in the Czech Republic

Advantages of using a heat map include reduced memory requirements, allowing space to display more data. Combined with a base map that shows individual traffic accidents, it can provide a clear way of analysing traffic accidents in the area.

E. Management of reports

Every application that aims for support of analysis of data should be able to provide user way to create and customize reports. For that reason, we implemented page named Reports Centre that provides necessary functionality to manage and create reports.

Initial page consists of table that shows all reports created by logged-in user and all public reports created by other users of the application.

In addition to the usual operations (such as creating, deleting, and editing a report), the user is also given the option to clone the report. This functionality allows the user to edit publicly available reports under their account and clone their own reports. A report can take on one of the following types:

- Private - can only be seen by the logged in user who created it,
- Public - seen by all users of the analytics tool who are logged in.

In addition, the user can see the title, description in plain text, and the time the report was last modified (see Fig. 12).

Fig. 12. Page displaying all reports created by user and all public reports

After opening report, the user is presented with page that has following structure:

- Report header - allows the user to change the report title and displays the date the report was created.
- Report toolbar - changes the available tools relative to the mode being displayed:
    - View - provides the user in this mode to download the report to pdf, switch the report to edit mode, and close the report.
    - Edit - allows the user to set the private/public report type, set a global filter applicable to all graphs in the report, save changes made, switch the report to preview mode, and close the report.
- Report body - consists of:
    - Report Description - allows the user to enter a description of the report using the WYSIWYG editor, which is a way of editing text (or the entire document) where the displayed form of the text is roughly identical to the resulting text.
    - Grid showing report sections - collects graphs created in other parts of the analysis tool and the text box section. The sections can be positioned on the grid and resized (both width and height) at will.

The detail of a report in edit mode is depicted in Fig. 13.

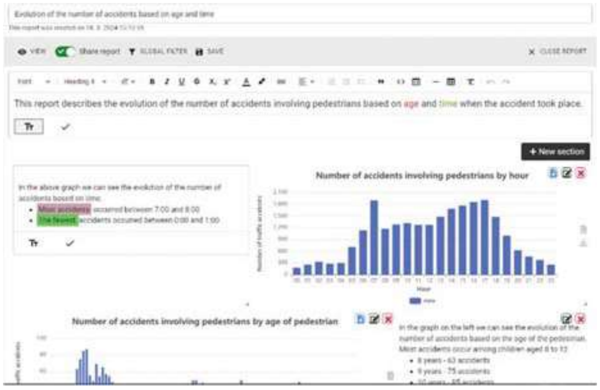

Fig. 13. Detail of report in edit mode

We have added support for three types of sections that the user can manage in the report:

- Graph - allows you to view the graph exported from the Search subpage (or Data Analysis subpage). It can also be exported to another report.
- Graph with predictions - allows you to view a graph with predictions exported from the Data Analysis subpage. It can also be exported to another report.
- Text field - can be added to the report via the New Section button. Like the report description, the text field provides a WYSIWYG editor option.

F. Design of smart navigation

The aim of this navigation is to provide users with the safest route between two selected points on the map. The navigation will not only search for the most optimal route based on the total length but will also consider current weather and accident data. It will compare the weather data with the accident data and will try to find a match between the two types of data to rank each route.

To implement this feature, we have analysed the technologies we will use for the navigation. We used QGIS to get data on first and second class roads and highways in the Czech Republic. We put this data in the form of vertices and edges to make it more beautiful in real maps. We then entered this data into the NEO4J graph database. After inserting the two types of data, vertices and edges, this database also provides a plugin where Dijkstra's algorithm for finding the route with the smallest evaluation is already implemented. However, during the analysis and design, we found the shortcomings of this algorithm, so we are working on our own algorithm. Next, we have found a way to retrieve weather data. Using the WEATHER API, the weather data will be retrieved. It is the interface that offers the freest calls per month. We have also proposed a way how this weather data will be collected. To avoid the case when the navigation will be used many times and the number of API calls will exceed the free limit, we designed a table in which for the largest cities in the Czech Republic weather data will be collected at least twice a day. It depends on how many cities the data will be collected for, and the number of calls for each city per day will be determined accordingly. Next, we found a framework to create a frontend for this navigation. Using Leaflet, the resulting safest route will be displayed on a real map, and the route will also display icons that will alert the driver to various things related to the accident.

IV. Future Functionalities of the System

The application is currently divided into a web and a desktop part. It would be advisable to incorporate the data entry process into the web part of the application. With this transfer, the user will be able to conveniently enter data directly through the web browser, thus simplifying and speeding up the whole process. It will also allow access to the data to be entered from any location with an internet connection, which will enhance flexibility and mobility when working with the data. After the design part of smart navigation, we want to implement all mentioned features. In addition to all we will implement its own information icons. Just as Google Maps has icons for restaurants, gas stations or landmarks. Smart navigation will have its own icons that will alert the user to the section where an accident has happened, so that they can adjust their driving and avoid a potential accident. After transferring the process of entering data into the database to the web part of the application, it will also be necessary to ensure that only authorized users can access operations potentially modifying the data in the database. In future iterations of the system, we envision the addition of new sections within the Reports Centre to enrich the user experience and extend the functionality. These sections will empower users with enhanced reporting capabilities, enabling deeper analysis and more customizable reports.

V. Conclusions

The modifications to the traffic accident data management application that have been implemented represent the next step in the development of an information system for the police force. Although the system has been improved, there is still a need for further enhancements. Such as introducing authorization, addition of new section in report centre and much more. Therefore, we will continue with new features to create a comprehensive information system that fully meets the needs and requirements of the Police Department.

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EverGreen DATA Analytics

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