

MARVIN – MODEL FOR ASSESSING RISKS OF ROAD INFRASTRUCTURE

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ABSTRACT

The project MARVIN is about assessing the relation between road infrastructure and road accidents. A large amount of data about the Austrian roads was gathered with the RoadSTAR (Road Surface Tester of arsenal research). This data was put into a database associated with accident data. The result was a database of about 12.500 km of road where all the road parameters (skid resistance, cross fall, gradient, texture, roughness, curve radius, etc.) belonging to a certain accident can be retrieved.

One approach is to take a piece of road where accidents happened and to find a very similar section of road with roughly the same parameters. These pieces of roads can be an interesting lead to reduce the number of accidents caused by road conditions. It could be the case that on a certain part of road a lot of accidents happened while on another segment, very similar in road parameters, no accidents happened at all. In this case there can be other parameters (that are not in the database) that influence the road safety such as speed limits or traffic density etc.

MARVIN is also planned as an open platform to integrate more relevant data like traffic flow data or weather data.

MARVIN is a new tool for crash-causes-research, to identify “virtual” road sections with a high crash risk potential or “virtual” hot spots. It is possible to realize route graphs which show all kinds of infrastructure parameters and located accident events. This is a practical tool to audit existing roads as well as planned roads and to develop accident preventive measures in terms of road constructions and road infrastructure.

Regarding to the accident risk of powered-two-wheelers (PTWs) the tendency of a significant influence of the road construction and the quality of the road surface on motorcycle accidents, can be shown in the first results of pilot studies and analysis.

INTRODUCTION

The goal of the project MARVIN is to find a relation between road infrastructure and road accidents. The data used for this research project are data about surface characteristics and data about the alignment of the Austrian roads which were gathered with the RoadSTAR (Road Surface Tester of arsenal research) and accident data. The basis of MARVIN is a database of about 12.500 km of road where all the relevant road parameters (skid resistance, cross fall, gradient, texture, roughness, curve radius, etc.) belonging to a certain accident can be retrieved.

With MARVIN we strike a new path in crash-causes-research, as “virtual” road sections with a high crash risk potential or “virtual” hot spots can be identified. Another aim of the project is to demonstrate the connection of different parameters for accident sources using mathematical models, the clarification of accident events on similar route sections and develop innovative accident prognoses and derived preventive measures.

SUBSTANTIVE PAPER

The basic idea of MARVIN is to find accident-causal combinations on the base of combinations of RoadSTAR measurements (Road Surface Tester of arsenal research) with accident data or parameters to explain a dependence of the accident events in connection with road geometry and surface condition parameters. A main point is the development of algorithms to find “similar” road sections and their visualization in geographic information systems.

Among other things, aims of MARVIN are the recognition and description of fundamental connections between road surface parameters and accident risk for certain accident types, a more specific discussion about the issue “risk appreciation of street infrastructure” (with the help of a “virtual” road search and the visual representation as graphs in the road system, potentially dangerous road sections can be determined or planned streets can be simulated) and an objective safety-check by made/planned measures to elevate of the road safety.

The data material supplied by RoadSTAR is unique throughout Europe with regard to quality, resolution and area coverage. This data pool enables arsenal research to carry out exhaustive observations as to the connection between road infrastructure and accidents. Thus the analysis of the causes of an accident don't have to take

individual places of accident or places of accident accumulation as a starting point, but can cover the whole network. Subsequently models for the prediction of accidents are developed from these data.

By the development of RoadSTAR more accurate findings of the road surface conditions can be obtained, thus making a material contribution to traffic safety.

Information about the RoadSTAR – Road Surface Tester of arsenal research



- ① Measuring wheel incl. braking torque measurement
- ② Pneumatic cylinder
- ③ Wetting unit
- ④ Prewetting system
- ⑤ Gearbox for producing 18% slip
- ⑥ Water tank
- ⑦ Device storage
- ⑧ Drivers cabin - digital data acquisition

The RoadSTAR was developed by arsenal research experts in close cooperation with the Stuttgart Research Institute of Automotive Engineering and Vehicle Engines. The RoadSTAR allows the most important surface properties and road geometry parameters to be measured under normal traffic conditions at measuring speeds between 40 km/h and 120 km/h (standard speed 60 km/h). Measuring runs are additionally recorded digitally on (DV) video tapes. All measured values are tagged with differentially corrected GPS coordinates. The RoadSTAR is mounted on an ÖAF 2-axle truck. Engine power is sufficient to allow the RoadSTAR to measure a road with a skid resistance of $\mu = 1.0$ and a gradient of 8 % at a speed of 80 km/h with a full water tank holding 6000 litres.

The RoadSTAR allows following important surface properties and road geometry parameters to be measured under normal traffic conditions:

Skid Resistance:

- 18% Slip (Standard)
- Temperature of the road surface
- Blocked wheel
- Temperature of the measuring tire
- Antilock Braking System (ABS)

Macro-Texture:

- MPD (Mean Profile Depth)
- ETD (Estimated Texture Depth)

Transverse Evenness:

- Rut depth (left, right)
- Theoretical waterfilm thickness
- Profile depth (left, right)
- Waterfilm width
- Rut width
- Waterfilm volume
- Rut Volume

Roughness:

- IRI (International Roughness Index)
- FFT-Analysis
- RN (Ride Number)
- Longitudinal Profile

Road Geometry:

- Curvature
- Height profile
- Crossfall
- Gradient
- dGPS-coordinates

Visualisation in Geographic Information Systems

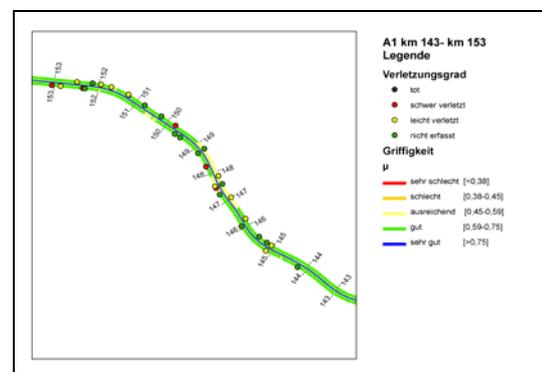


Figure 1. Visualisation, Route graph example 1

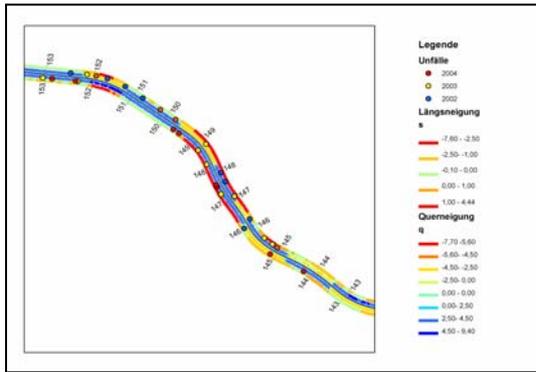


Figure 2. Visualisation, Route graph example 2

The combination of parameters (as shown in route graphs at Figure 1 and Figure 2) enables a timely and economic initiation of the necessary redevelopment measures. The examination of connected data and the comparison with similar points in the residual road network results in the possibility to derive measures for an economic mitigation of existing and (as a preventive measure) potential accident hot spots.

Significant visualisations of crash-causal-combinations on route graphs (automatically generated by measured dGPS-data inclusive inertial navigation gyre) can be done; information on road geometry, road condition and accidents can be presented in different graph-layers.

The traditional approach for accident analysis in Austria is to look at so-called “accident hot spots”. Hot spots are sites where accidents occur most frequently. The positions of these hot spots in Austria are calculated from the accident database. In Austria about a fourth of the car accidents causing personal injury happen on hot spots in the year 2000. Hence about 75% of the accidents are mostly ignored by just researching the accidents happening on these hot spots. It is plausible that groups of similar accident sites exist, of which none is a hot spot yet. Such a group of almost identical sites could be called a “virtual” hot spot, which is not seen as a hot spot by traditional accident research, because it does not identify these sites as similar.

Models for the evaluation of the risk potential of traffic infrastructure (project MARVin) are being developed. The project MARVin engages in the relation of traffic condition and accidents and includes the analysis of the road condition, location and event of the accident. Selective and historic analyses can be conducted thus linking present accident and road condition data. In case of an accident road geometry/road condition can be coordinated with the help of geometric design.

The main step is to take a road section where accidents happened and to find very similar road sections with roughly the same infrastructure-parameters in the whole road network (“Similarity Search”). These sections of roads can be an interesting lead to reduce the number of accidents caused by road conditions. It could be that on one road section a lot of accidents happen while on another piece, very similar in road parameters, no accidents happened at all. In this case there can be other parameters (that are not in the database) that influence the road safety such as speed limits or traffic density etc.

MARVin for Road Safety

Another important tool of MARVin is to search for “virtual” road sections in the whole road network (Figure 3 and Figure 4). It is possible to create an artificial road (e.g. specific road geometry and road condition-parameters) and to find similar, but existing road sections. This is important for a safety-check of planned roads (Road Safety Audits) and to show potential hazard areas which indicates changes of the planning as an economic accident preventive measure.

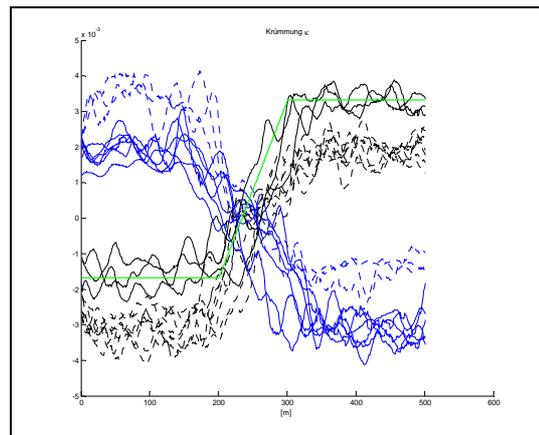


Figure 3. Curvature of a “virtual” road (green)

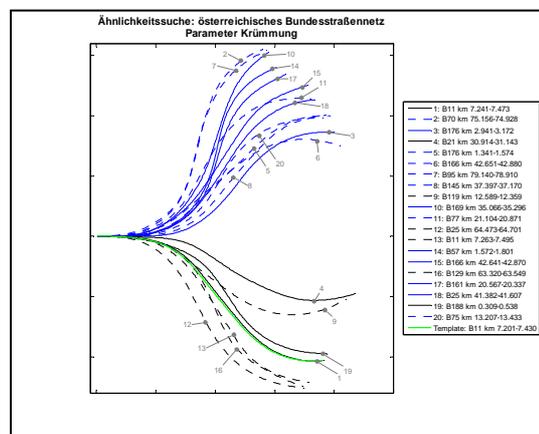


Figure 4. Resulting similar road sections

The problem of the automatic recognition of similar road sections was extensively solved with a method which has his origin in automatic speech recognition, the so called Dynamic Time Warping (DTW). Dynamic Time Warping yields a robust similarity measure for time series with similar shape even if they are out of phase. In general DTW is a method which allows finding an optimal alignment between two given (multivariate) sequences (e.g. time series) with certain restrictions. In our case DTW yields a nonlinear similarity measure of different parameters of a candidate with a given road section (template). In contrast to the methods which were developed in the first project phase (similarity search with Dynamic Time Warping) which always need an existing distance as a start value, new possibilities were examined to implicate the whole amount of the accidents impartially ("unbiased") for dependences. Diagrammatically this is conceivable as follows: the parameters of every accident (discrete, as for example the accident type from the accident report or the road surface type from the RoadSTAR data or continuous real values, like skid resistance or rut depth) are considered as coordinates in a high-dimensional space. Correlations will be remarkable by the different density of the points (= accidents) in certain areas or by the variances. Based on this, methods were searched and were examined to sight the enormous data amount manual-visual (about 40000 personal damage accidents or accident records per year, 12 years approx. 490000 points in 50 or more dimensions) or to analyze purely computer-assisted. This amount in accident data together with the RoadSTAR-road conditions data to be processed parallel, cause an arithmetic expenditure and computing power which should not be underestimated.

For a manual-visual selection normalized (multidimensional) histograms are provided. Here the samples of the database are represented not as points in the space, but are summarized into classes. The numbers of the class member events are represented for the two-dimensional case with the help of a colour scale.

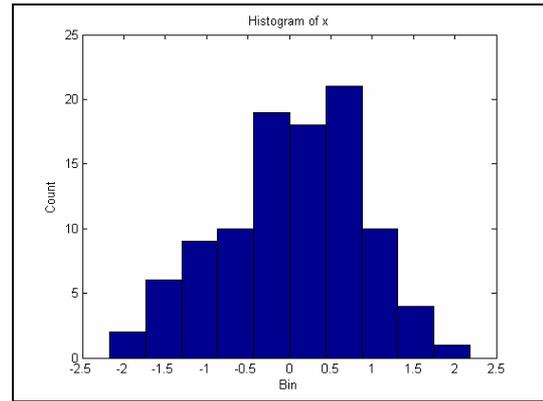


Figure 5. Histogram in one dimension

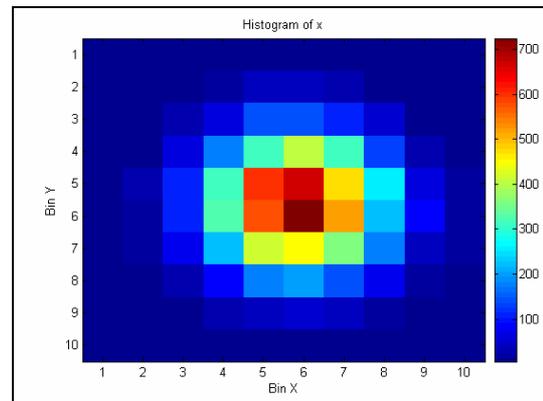


Figure 6. Histogram in two dimensions

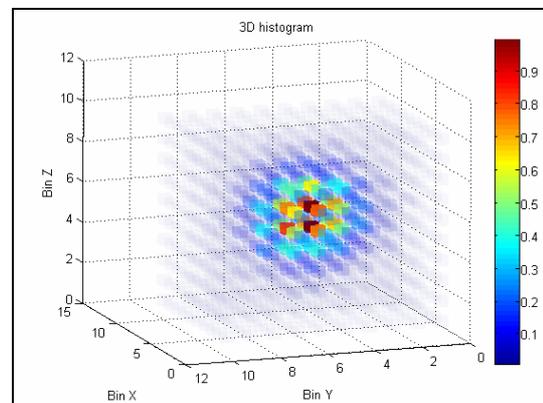


Figure 7. Histogram in three dimensions

Connections in two dimensions can be shown very well. For the three-dimensional case the applicability is already limited by the covered sight (Figure 5, Figure 6 and Figure 7). For additional dimensions above all discrete dimensions can be represented side by side. However, the use for the recognizability of connections will be more doubtful with increasing number of the represented dimensions and in no case 50 dimensions are representably in this way. That means that this method does make sense, when coarse connections

and the primarily decisive dimensions are identified in a different ways, which can be made completely with statistical methods or by plausible acceptances of known critical combinations (e.g. skid resistance, rain and rut depth).

At the examples shown at the top, connections of RoadSTAR parameters and accidents can be represented very openly; a comparison with evaluations of specific accident types or similar road sections will lead to unambiguous accident-specific dependences of the street parameters. With MARVin it is possible to strike a new path in the crash-causes-research and our goals for the future are written down in the commitment of the European Road Safety Charter, as written below.

MARVin for Motorcycle Safety

The first practical work with MARVin tools was a road safety check of a typical motorcycle route, to find out correlations between the number of accidents on specific sites and the road infrastructure parameters. The interesting, but not so much surprising result was, that the quality of this road was high (high skid resistance, perfect radii relations and curvature, etc.). All these parameter show, that because of the high quality this road is a magnet for the motorcyclists. Sure, it doesn't mean that a lower quality will make the accident situation better. The significant facts for high risk potential of this road are the number of riders each day and the driven speed. Especially on weekends speed enforcement campaigns can lead to an accident reduction.

Another use example of MARVin was the analysis within the frame of the development of a national directive for motorcycle safety. A detailed all over check of motorcycle accident events on rural roads from 1999 to 2004 and their correlation to curve radii have shown a unique result (Figure 8).

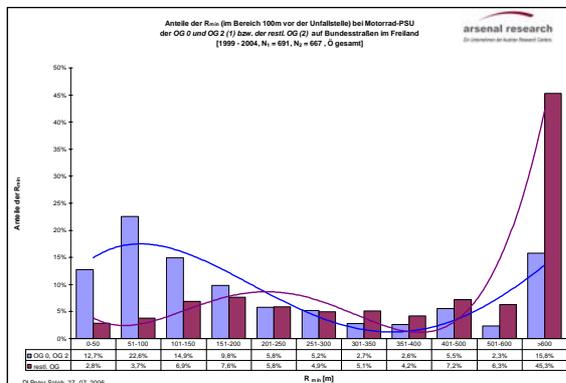


Figure 8. Curve radii and accident types

Specifically abandon accidents mostly occur in small radii between 50 and 150 meters; the maximum ratio of abandon accidents in curves is exactly in the radius 100 m, followed by 110 m.

Specifically detailed analyses of relations of various curve radii (as shown above), the curvature and the changing crossfall in road sections and their influence on PTW accident events are necessary. The so called "Similarity Search", which identifies similar accident events on similar road sections, will also be used within these analyses. Moreover the simulation and search of virtual or existing road sections in the whole road network with a high accident-risk potential are possible.

In a possible PTW-project which is proposed in the 7th Framework Programme of the EU, a work package will be the identification of the correlation of radii relations on motorcycle accidents. Specifically double bends and double bends with small straight lanes between the two radii will be analysed in detail.

European Road Safety Charter



With some 170 highly qualified staff members, arsenal research has established itself as a European research center in the future-oriented fields of mobility and energy. The organization's primary objective is to boost the innovation capabilities of its partners by providing them with applied research and development and by linking regional, national and international innovation systems.

Our experts for road safety and traffic telematics crucially contribute to an early recognition of sources of danger in and on traffic infrastructure strive for innovative solutions and their implementation within cooperative networks and are also available for consultations regarding road safety. That's way it is for us a self-evident fact to sign the European Road Safety Charter with the following commitment:

Our goals are:

- Explanation of so far unexplored accident causalities
- Demonstration of the connection of different parameters for accident sources using mathematical models

- Clarification of accident events on similar route sections
- Accident analysis and crash-causes-research specifically regarding powered two-wheelers
- Innovative accident prognoses and derived preventive measures

We reach these aims by:

- Linkage of the road conditions data with accident data based on the locality of the accident
- Development of suitable mathematical models for the verification of accident causalities
- Implementation of accident-cause-research within Road Safety Inspections and Road Safety Audits
- Specific measures to create awareness in combination with driving education, based on detailed accident statistics and conclusions of accident analyses of motorcycles
- Identification of connections between data on road accidents and traffic infrastructure and development of specific preventive measures

CONCLUSIONS

With the research project MARV in it is possible in different ways and with different analysis to find out significant correlations between road accident events and the quality of the infrastructure. The whole road network and all accidents are included in the analysis.

Now the research has progressed so far that the developed tools can be applied practically and can be tested.

Within the frame of the development of a national directive for motorcycle safety, two projects are treated with MARV in tools.