RECONSTRUCTION OF ACCIDENTS BASED ON 3D-GEODATA

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Abstract - Beside numerous information about vehicles injuries and environmental data the GIDAS database contains detailed reconstruction data. This data is calculated by a reconstruction engineer who handles about 1000 accidents per year. The spectrum of one reconstruction ranges from simple crossing accidents to complex run-off accidents with rollover events. Especially for complex accident scenarios there is a large effort to design the environment of the accident scene within PC-Crash®. To reduce the reconstruction time by maintaining the high quality of reconstruction 3D-geodata can be useful. Geodata is available for nearly every area in Germany and can be used for a fast and detailed creation of complex accident environments. In combination with the accident sketch areal images of the accident scene can be created and the participants are implemented in the new-built 3D-reconstruction environment. As a consequence, the characteristics of the terrain can be considered within the reconstruction which is especially important for run-off accidents.

INTRODUCTION

To get a significant conclusion, it is necessary to compare the conventional environment creation method in PC-Crash with the 3D-geodata. Therefore it is shown how a reconstruction engineer creates a graphical environment for any accident. Afterwards the method how to convert the 3D-geodata to get a feasible and useful accident scene in PC-Crash will be explained. The current methods of creation in PC-Crash are shown at first.

CURRENT METHODS OF CREATION IN PC-CRASH

Currently different creation methods for the accident scene in PC-Crash are given. The reconstruction engineer has the possibility to create the respective accident environment based on a detailed accident sketch. Thereby the methods differ in effort of creation and ability for the particular accident scene.
At first there is the possibility to assume the grade of the driving surface using a road slope for the 3D-evironment. That is a simple and quickly method to create three dimensional surfaces. The following figure shows the way of creation.

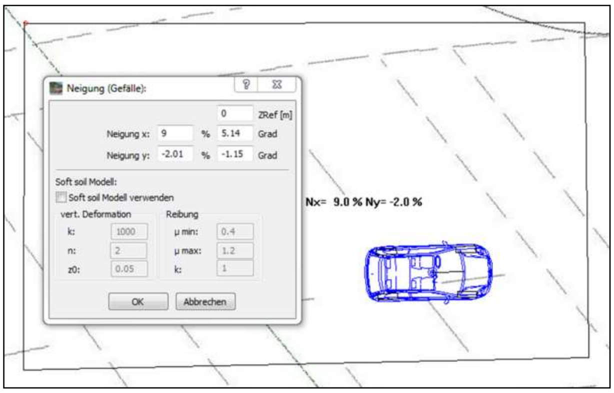

Figure 1: road slope

The road slope is created via a closed polygonal line which describes the sloping area. Afterwards the desired road slopes are defined for the main axes of the PC-Crash area in percent. As needed the sloping area can be displace with the value Z_{Ref} compared to the underground (z=0). This value is defined by the starting point of the polygonal line. The most important benefits of this method are the simplicity and celerity of creation. Unfortunately only road slopes of the main axes can be simulated. Furthermore if road slopes are not given in main axes direction it has to be considered whether it is reasonable to rotate the accident sketch so that the slope lies on the main axes.

Another method of creation is triangulation. In this case two or more faces or edges with different heights are necessary to build a slope. With the command triangulation the faces or edges get linked and a closed slope becomes generated.

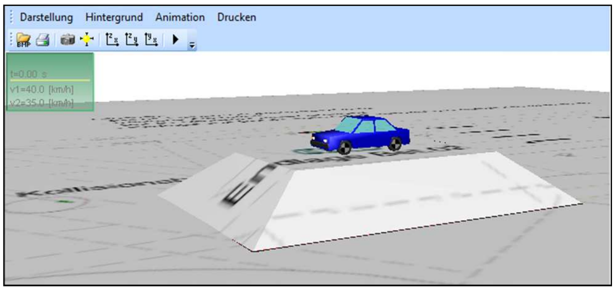

Figure 2: triangulation

Figure 2 shows the triangulation result of two rectangles. On the positive side this method allows itself to create different road slopes independently in the main axes direction of the PC-Crash area. On the other side the time effort of creation is relatively high.

The 3D-road object is another possibility to create a three dimensional surface. It offers to build a whole road surface with embedding of bordering slopes. On the basis of a pre defined spline a lengthwise and crosswise sloping road surface can be designed. Therefore a varied roadway width can be also considered. The bordering area is defined by constant slopes or a slope profile. Figure 3 displays a 3D-road object which is designed by a pre defined spline and a left hand slope profile.

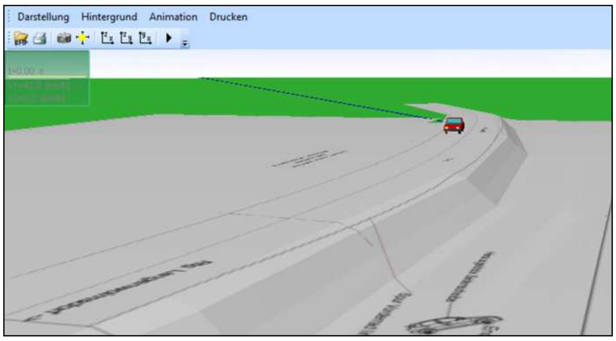

Figure 3: 3D-road object

On the one hand the 3D-road object is a qualified method for creating a 3D-surface in PC-Crash. The creation of vertical curves, slope roads and different bordering slopes are possible without further ado. On the other hand it is not possible to consider changing slope profiles. Furthermore a possibility to create different left- and right hand side bordering slopes beneath a preset of the slope profile does not exist.

All in all the creation of 3D-surfaces in PC-Crash is generally possible. Admittedly limitations according to the different method of creation have to be considered. The effort of creation is relative high and a qualified measuring tool for input proofing doesn’t exist. This is only visual reliable. It appears sensible to analyze alternative methods for creating 3D-surfaces to exclude or minimize the mentioned limitations.

POSSIBILITY OF A CREATION BASED ON 3D-GEODATA

The basic concept of the 3D-model and the visualization of the accident area is 3D-geodata. For the exposition of heights a digital area model is used. The visualization of the accident area is enabled by the use of digital areal images.

Model base: digital area model (Digitales Geländemodell)

The area model is available in digital form at GeoSN (Staatsbetrieb für Geobasisinformation und Vermessung in Sachsen). It is a dot matrix which describes the longitude and latitude coordinates with their particular heights. With the help of the area model a 3D-surface can be created which is the basis for the 3D-environment in PC-Crash.

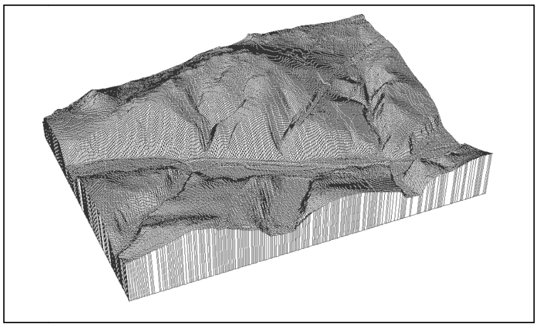

Figure 4: digital area model

The figure 4 shows the area model 2. This title means that the latitude and longitude coordinates are described by a mesh with a mesh size of 2 meters. The tolerance for each height value amounts to ±0,2 meters. The dataset of the census area of the Traffic Accident Research Institute at University of Technology Dresden is as a PC-Crash incompatible file format *.dgm2 existent.

While using geodata it is necessary to analyze which coordinate system for the data is involved. The GeoSN offers different types of systems. For the current area model 2 the ETRS 89_UTM-system is used.
The ETRS 89 (Europäische Terrestrische Referenzsystem 1989) generates the geodetic frame of reference. This system serve as a consistent coordinates description and was introduced in year 1989. It is a geocentric system which does not underlie the influence of area dislocation because it is fixed on the solid Eurasian plate.

The base of the actual coordinate assignment is the present UTM coordinate system. This is a global system which divides the whole earth surface in 6° wide zones. The resulting zones are projected into the same plane and provided with a Cartesian coordinate system. The figure 5 shows the schematic design of the area model 2 based on UTM-coordinate system.

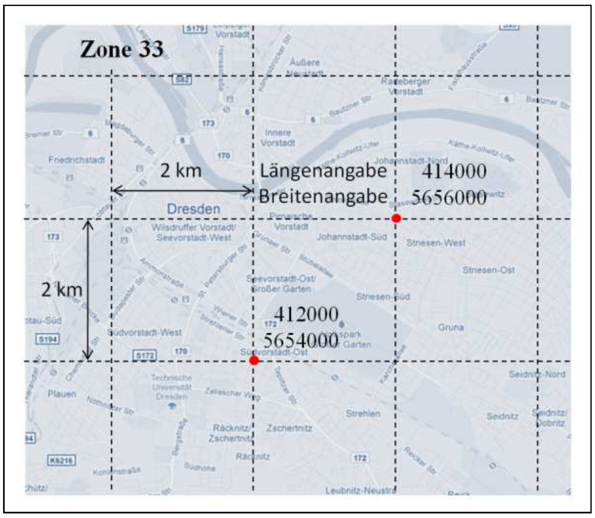

Figure 5: mesh of tiles - DGM 2

As shown in figure 5, the area model 2 is divided in 2 kilometres to 2 kilometres tiles. The title “Zone 33” indicates in which zone of the UTM coordinate system the presented area is located. The identification of a tile is done on her left lower corner with latitude and longitude information. This information is necessary to filter the particular accident scene out of geodata. The combination of ETRS 89 and UTM is European standard. So the portability of geodata in geographic programs is generally warranted. Furthermore the possibility exists to embed the geodata in engineer scientific programs without complex conversion.

Visual base: digital areal images (Digitales Orthophoto)

The digital areal images are available in digital form as *.tif files. In the course of the reconstruction they are used to better visualize the accident area and therefore in connection with the accident sketch constituted an information base for routing and configuration of roads. The actuality of the data must be considered always because the building arrangement might have changed. They are also provided in tiles (figure 5). The areal images are georeferenced images which are equalized and in flat status available. The equalization is effected by a projection of a digital area model over the earth surface. The dimensions of each image amounts to 2 kilometres to 2 kilometres and are afflicted by a ground resolution of 0,2 meter.

Figure 6: areal image

By the accuracy of the areal images, statements of view contact, obstacles and road courses can be made. Furthermore with considering of the practical scale, areal images can be used similarly to a map as for instance regarding the measuring of routes. The usable data also relate to the ETRS 89-UTM-system.

CONVERTING OF 3D-GEODATA

To identify a qualified variant of converting geodata, different alternatives were considered. The most qualified variant is presented. The concrete targets are necessary for the choice of the methodology. It concerns the following:

1 Conversion of the accident coordinates, which is registered by the team of the VUFO
2 Selection of the accident scene out of the 3D-geodata (model, image)
3 Testing the elevation data for breaks
4 Conversion of the model data in a PC-Crash-compatible form

The following figure shows the developed conversion sequence of geodata which is explained in right order subsequently.

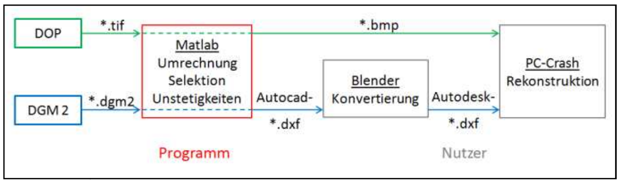

Figure 7: conversion sequence

As shown, the conversion of the accident coordinates selection as well as the testing is automated in a program process in Matlab. The program gets started by the user who provides inputs. These inputs are: accident coordinate, cut out diameter in latitude and longitude direction, import places of 3D-geodata, export names and export places of data (selected model and image).
The coordinate of the accident is documented by the VUFO team with a GPS receiver. By the kind of receiving the coordinates are referenced on the world geodetic system 1984 (WGS 84). Nevertheless the mentioned 3D-geodata requires the reference system ETRS 89-UTM.
Ongoing the selection of accident scene out of 3D-geodata has to be done. This is necessary because PC-Crash can't manage an endless number of data points. For the selection four different cases (figure 8) have to be considered: cutout in one tile (blue), in two tiles with latitude difference (green), in two tiles with longitude difference (pink) or in four tiles with latitude and longitude difference (orange).

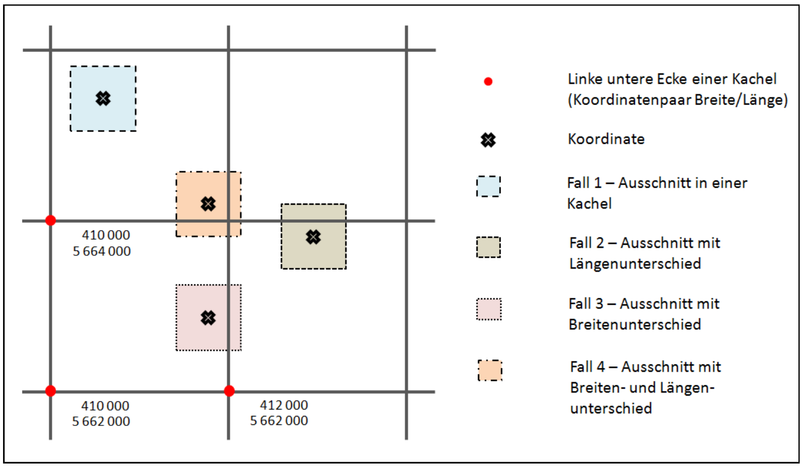

Figure 8: case differentiation of selection

With the pictured case differentiation the selection of elevation and image data is executed. Following the selected areal image can be projected over the respective selected area model (figure 9).

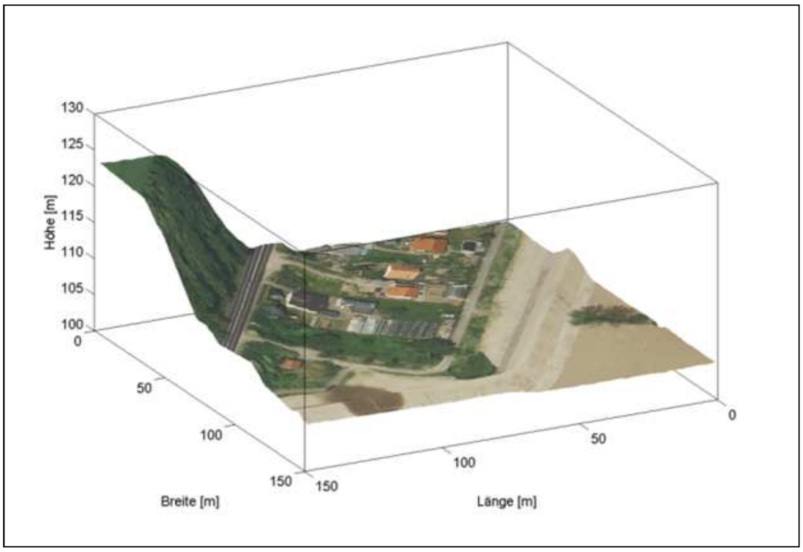

Figure 9: selected cutout

The testing for breaks in the elevation data is executed because the tolerance of ±0,2 meters is given. So it is possible that two adjoining points have a difference of 0,4 meters. 0,4 meters describes more than a half wheel diameter. Therefore such deviations have to be avoided.
The smoothing is realized by sampling of the selected 3D-model. To compare a point towards the closest points, the specified tolerance is used. For this straight lines are defined by direct opposite points (figure 10).

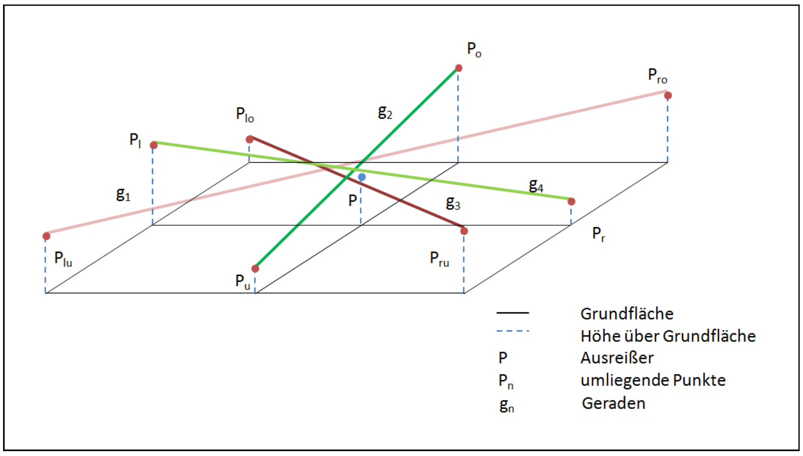

Figure 10: schema of smoothing function

Move the calculated distances of the point in a certain range, the point is adapted in its height. The adaption is realized by an average of the surrounding points. For this the range includes a lower and upper criterion, to obtain the bordering slopes in their dimensions. In this manner, any breaks of the roadway can be identified and adapted. The result of the smoothing function compared with their basic design is shown in the following figure 11:

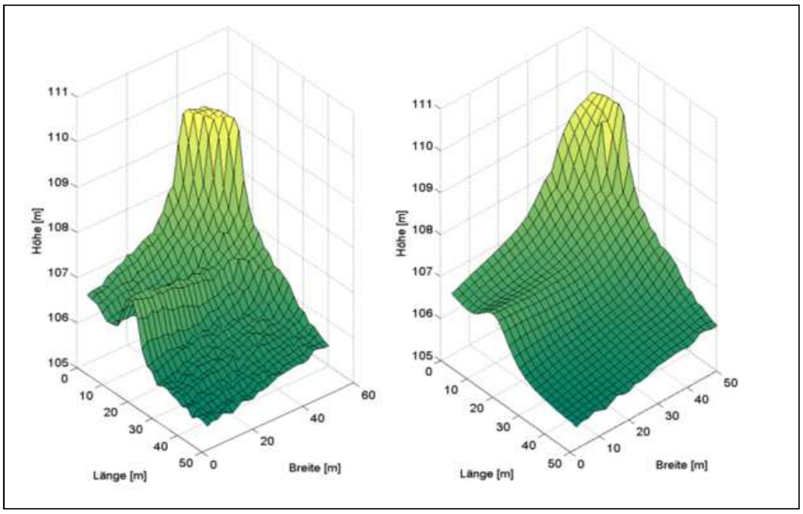

Figure 11: smoothing function

Subsequently using Matlab an AutoCAD-*.dxf file of the selected model data and a *.bmp file of the selected image data is generated. PC-Crash is not able to handle the AutoCAD -*.dxf format of the elevation data, so a further conversion in the so-called Autodesk-*.dxf format is needed. This format stands out due to the PC-Crash-readable arrangement of data. The following steps are performed by the user, so a further optionally editing of the 3D-surface is possible.
The necessary format conversion can be realized by the program Blender. Blender is a program which is used for the modeling, animation and rendering of three-dimensional objects. This program is applicable in non-academic areas, e.g. for creating of animations for games or short films. With this program it is possible to use different types of surface treatments. The elevation data is imported and edited by an intermediate step. In the beginning the imported surface consists of a finite number of squares. PC-Crash cannot form a closed surface based on this. Due to this fact Blender creates triangles out of the squares. Subsequently the surface as an Autodesk-*.dxf file can be exported.
After generating an Autodesk-*.dxf file the import of the elevation data in PC-Crash follows. This is realized by the 3D-road object which only works until version 8.3. Then the Matlab generated *.bmp-image file is loaded and scaled to the user-selected size. Through the conversions in Matlab it is not necessary to shift the surface or image in PC-Crash.

Figure 12 shows a section of the in PC-Crash imported surface and respective image.

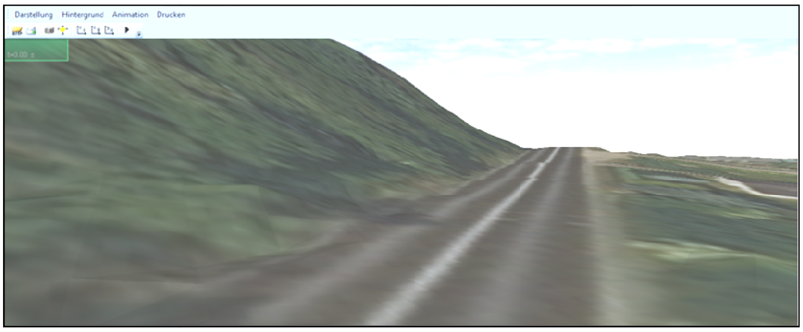

Figure 12: section of the 3D-surface in PC-Crash

The import of 3D-geodata in PC-Crash is realizable. They can be used as a 3D-environment and a reconstruction can be carried out in the same procedure than with conventional methods.

ANALYSIS OF UTILIZATION OF 3D-GEODATA

The utilization of 3D-geodata for the reconstruction could be demonstrated by case studies. For each case the conventional methods of creation are confronted with the 3D-geodata. In this case, the creation time, reconstruction results as well as the whole reconstruction effort are investigated. In total, the following methods are considered: road slope, triangulation, 3D-road object and 2D-evironment.
As an example this is demonstrated for a real accident. The course of the accident can be seen in the following figure 13:

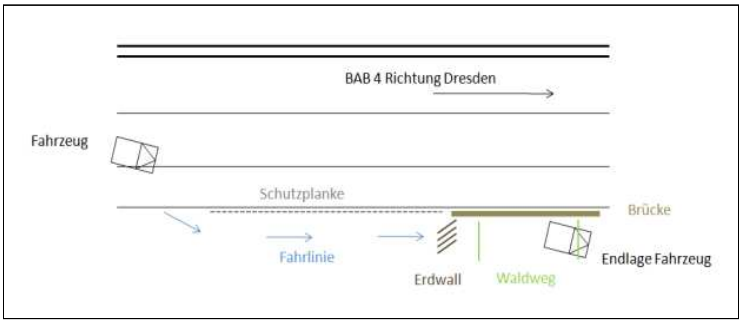

Figure 13: case example

The driver of the vehicle came right off the road because of a micro sleep. He drove through the side room about 120 meters before he crossed an embankment of a highway bridge. As a result the vehicle overturned and fell on the underlying way where the car came in up-side-down end position

3D-environment: conventional method

To create the road course, the 3D-road object is used. Trough this method it is possible to involve the bordering slopes and any road slopes can be specified. Because the driver drove through the side room about 120 meters, multiple slope profiles have been measured by the VUFO team. To recreate a realistic crossing of the embankment, a profile at this point is used for the 3D-road object.
The underlying way can be created by a triangulation. This is only estimated realizable, because there are no information but the depth under the road course. Thus, the following road course, compared to the real one, is created:

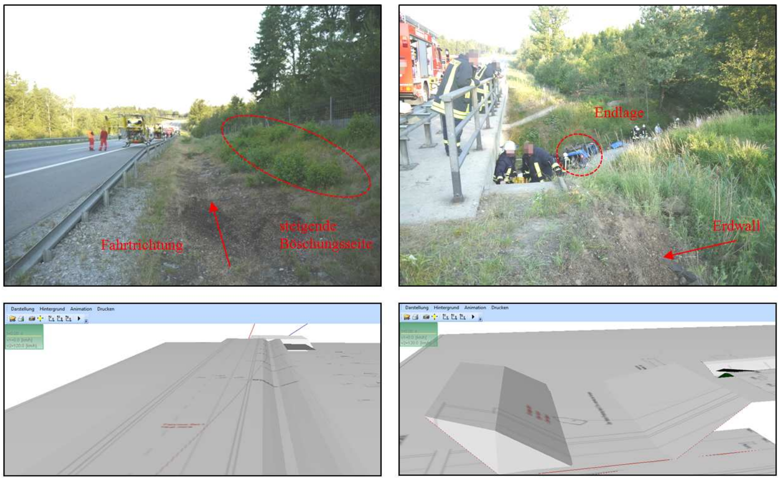

Figure 14: comparison PC-Crash – reality

The crossed embankment could be created by a road slope wherein the values were set iteratively. In total a time effort of three hours was necessary to create the displayed environment in PC-Crash (figure 14).

3D-environment: 3D-geodata

The creation of environment with 3D-geodata is generated according to elucidated schema so that following surface is exported:


Figure 15: PC-Crash – 3D-geodata (1)

Figure 16 shows that the displayed surfaces cannot be used in PC-Crash because the highway bridge does not exist. This is due to the fact that the model data contains only the measured points of the surface of the earth. Building developments like the bridge are not taken into account. So it is a rework of the user with Blender necessary. The bridge borders are redefined and the road surface will be adjusted in height. Following surface can be used for the reconstruction process in PC-Crash:


Figure 16: PC-Crash - 3D-geodata (2)

The creation of the accident environment based on 3D-geodata has taken 30 minutes, inclusive the rework in Blender. Without the additional rework in Blender the export of the geodata as well as the conversion with Blender are feasible in only 10 minutes of work .

Comparison of the reconstruction results

In order to create the nearly same reconstruction for both methods, the input parameters are assumed to be equal. The vehicle has a input speed of 120 km/h and a delay of 3,3 m/s². The end position could be reconstructed with enough accuracy for both methods of creating the environment. By the following diagrams the reconstruction results are compared. First the velocity course is explained. This is specified for both, the conventional method (PC-Crash) as well as the method of 3D-geodata (Geodaten).

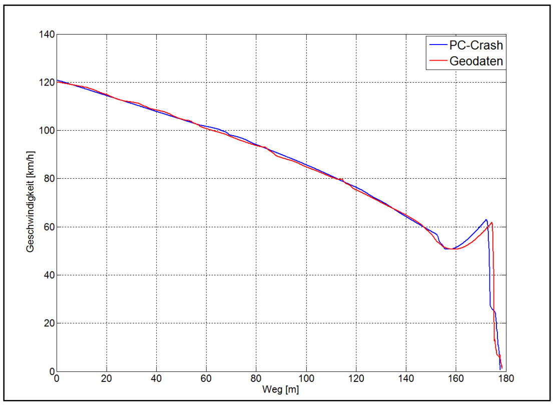

Figure 17: velocity-distance diagram

Figure 17 shows, that under the same input parameters the same velocity-distance curve can be reconstructed. After a distance traveled of about 145 meters, the vehicle drove with 55 km/h over the embankment. Then the vehicle is accelerated due to gravity to about 63 km/h, before it hits the underlying way. The end position was reached after a distance of 175 meters.
The next step is the evaluation of the acceleration profiles. It is done separately for each method of creation. Thereby similarities and differences are discussed.
The following diagram shows the various acceleration curves of the conventional method (left) and of the method based on 3D-geodata (right).

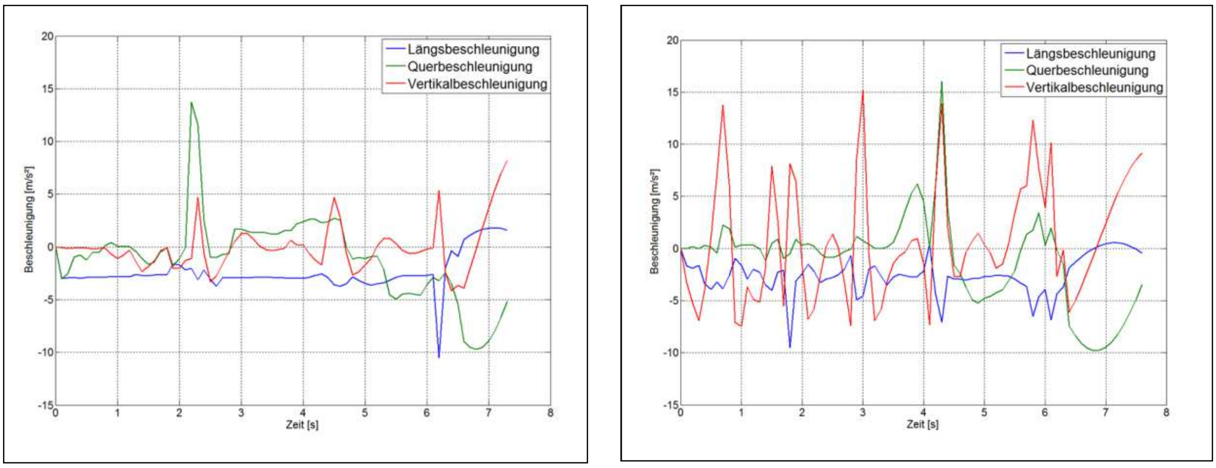

Figure 18: comparison of the acceleration curves

Figure 18 shows, that the longitudinal acceleration increases at the defined reaction point on the set value of 3,3 m/s². The curve of the lateral acceleration results from the go off of the road and from the skidding through the side room. The increased values at 2,3sec can be explained by the impact of the vehicle on the rising embankment side. A smaller collision with a game fence (running parallel to the highway) is shown at 4,3 sec. From the beginning of lift off at about 6,2 sec, is not only a high vertical acceleration recorded as also an longitudinal acceleration of the vehicle. The impact on path at about 7,5 sec is described by a very high delay and a high vertical acceleration.

The fluctuations in the curves of the accelerations are conditioned by the side room, because the vehicle is exposed strong pitching and rolling movements. By the applied smoothing function, the road surface is smoothed respect to their breaks, but they remain unchanged in the side room. This can also cause that strong fluctuations of the transverse acceleration appear. In that case they have to be accepted in favor of dimensions of the bordering slopes.

CONCLUSION

Due to the rudimentary data of the surface-creation of the respective accident location and the problem to assign data in PC-Crash, 3D-geodata was analyzed for the utilization for reconstruction. From the shortfalls of the creating methods in PC-Crash (road slope, triangulation, 3D-road object), the task was to investigate alternative production methods. Different variants have been developed for implementation, which were evaluated for their suitability afterwards. The as ideal identified variant has been implemented in a program run in Matlab, that offers the possibility to extract the respective accident location of a range of 3D-geodata quickly and effectively. By means of a short intermediate step, it is possible for the first time, to use 3D-geodata for the reconstruction of traffic accidents in PC-Crash.

Example studies were carried out wherein the different ways of creating environment were compared. It was determined that the use of 3D-geodata generally results in a significant time saving with the same reconstruction-results. This is highly dependent on the accident situation and was in relation to the example studies approximately 20-150 minutes. In addition it was found out that there are areas in the model data set which are not usable for the reconstruction. However the developed methodology provides opportunities to rework the selected surface with reasonable effort in Blender.

As the benefit of 3D-geodata was determined by example-studies it is recommended to validate the benefit on the basis of road tests.

With the application of 3D-geodata for the reconstruction of traffic accidents, it became clear that such data sets can made available for scientific engineering domain. The use of additional data for creating environment in PC-Crash is useful and has been already partly successfully tested. In this context, data sets which contain information about buildings and road designs are meant. In Dresden the 3D-city model is mentioned as well as the possibility of embedding of Open-Street-Map data. With the aid of such data sets it is readily possible to comprise view-contacts and thus enhance the quality of the traffic accident reconstruction.

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KEYWORDS

PC-Crash, geodata, reconstruction

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