Analysis and Investigation Method for All Traffic Scenarios (AIMATS)

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Abstract - Millions of kilometers are driven and recorded by car manufacturers and researchers every year to gather information about realistic traffic situations. The focus of these studies is often the recording of critical situations to create test scenarios for the development of new systems before introducing them into the market.

This paper shows a novel Analysis and Investigation Method for All Traffic Scenarios (AIMATS) based on real traffic scenes. It also shows how to get detailed information about speeds, trajectories and behavior of all participants without driving thousands of kilometers at the example of conflict situations with animals. Basis of the AIMATS is the identification of the most relevant locations as “Points of Interest” (POI), the recording of the critical situations and their “base lines” at these POI.

This paper presents a new method to identify critical scenarios involving both vehicles and animals as well as preliminary results of a study done in Saxony using this new method.

INTRODUCTION AND STATE OF THE ART

Vehicle based recording

Naturalistic Driving Studies (NDS) record vehicle and driver behaviour using unobtrusive observation or using observation taking place in a natural setting [1]. Data recorded can be used to study vehicle motions and driver behaviours that lead to critical situations or collisions. Data is collected continuously during driving or triggered by critical events. NDS typically focuses on the pre-collision phase, including vehicle and driver states. In contrast, Event Data Recorders are typically triggered by collision events and are emphasizing collection of in-collision phase data.

Field Operational Tests (FOT) have a close relation to NDS. Test vehicle instrumentation is often similar or equal. NDS observe and analyse crash causation while FOT evaluate effects of e.g. Advanced Driver Assistance Systems (ADAS) on critical events and collisions. Consequently, ADAS are typically present and evaluated in FOT while NDS can lead to developing new ADAS addressing previously unobserved crash causations.

Several NDS have been concluded such as the 100-Car study [1] or SHRP2 [2], both conducted in the US, while others (e.g. European UDRIVE [3]) are currently running.

The quantity of vehicle based recording

Animal-Vehicle encounters have been studied in a recent NDS using 48 instrumented vehicles which were enrolled for an average of 5 months each, over a span of 11 months in a collaboration of the Toyota Collaborative Safety Research Center (CSRC), the Virginia Tech Transportation Institute (VTTI) and the Western Transportation Institute (WTI). In total, 35,000 trips covering over 350,000 miles were recorded and 829 animal vehicle encounters were identified [4].

This indicates an encounter rate of less than one animal per instrumented vehicle and week. Even when driving in animal-encounter prone areas, this seems to be realistic as animal encounters and collisions after all are a rare event.

The quality of vehicle based recording

Another issue of NDS- based scenario data are often the limited boundary conditions of a mobile recording platform for example the field of view, the precise determination of the recorder platform (car) position or the possibility to record the traffic situation some seconds before and after a critical situation at the same location. Also, the natural behaviour of participants of the scenario cannot be recorded. For example, a pedestrian or wild animal street crossing without any interaction of cars.

Infrastructure-based recording

A promising approach to record more encounters per time and instrumentation unit is to base the observation not on in-vehicle instrumentation but in the infrastructure. Infrastructure-based observations can easily run for 24h a day, while vehicles are most of the time not recording any data.

Infrastructure-based video recording has been used at Lund University in the 1980s [5], ranging from more qualitative descriptions to attempts of automated analysis [6], for example to describe drivers' speed behaviour at pedestrian crossings [7].

Another project which uses infrastructure-based recording is the AIM- Intersection Project in Braunschweig, Germany [8]. The AIM approach connects the equipment of one intersection with high-level measurement units like radar-, LIDAR- - and camera-based sensors. All these sensors are used to record normal traffic scenarios, critical scenarios and, of course, crashes. Critical events are thus comparable to normal driving situations at this specific location. One disadvantage of this method is the high effort and costs for installing the equipment at the intersection, which makes it not moveable to other critical locations.

Résumé

The recording of critical or normal real traffic situations with existing methods has the following disadvantages:
- expensive equipment of the measuring systems (all)
- limitations in recording parameters (NDS)
- accuracy of recorded parameters (NDS)
- flexible recording locations (AIM)

This paper gives a new possibility for the Analysis and Investigation of all Traffic Scenarios (**AIMATS**) at the example of vehicle and wild animals encounters, developed by Fraunhofer IVI and Toyota Motor Europe. For the first time, this paper presents a method that has all advantages of the methods described above while eliminating most disadvantages. The method makes it possible to record precise data at different POI (points of interest) in a very efficient way.

BASIC CONCEPT OF AIMATS

The Basic concept of AIMATS combines the analysis of comprehensive police recorded accident data and infrastructure-based measurements of traffic situations. Picture 1 describes the global relationships as a toolchain of this new concept.

Hypothesis:

- **If there are accumulation points of accidents of the same type, then there are even more traffic situations of similar sorts but with lower criticality (conflicts).**

- **These situations or scenarios are recordable at these accumulation points or Points of interest (POI).**

- **These scenarios at the POI can be analyzed and can deliver real life critical situations of conflict situations of interest and the baseline of the traffic behavior at this location.**

- **A following automatic analysis of the recorded data gives the possibility to save all scenarios in a user-defined format (e.g. databases, videos, simulation files, etc.).**

- **With a 24/7 observation a statistical extrapolation of the recorded scenarios regarding the baseline can deliver representative results.**

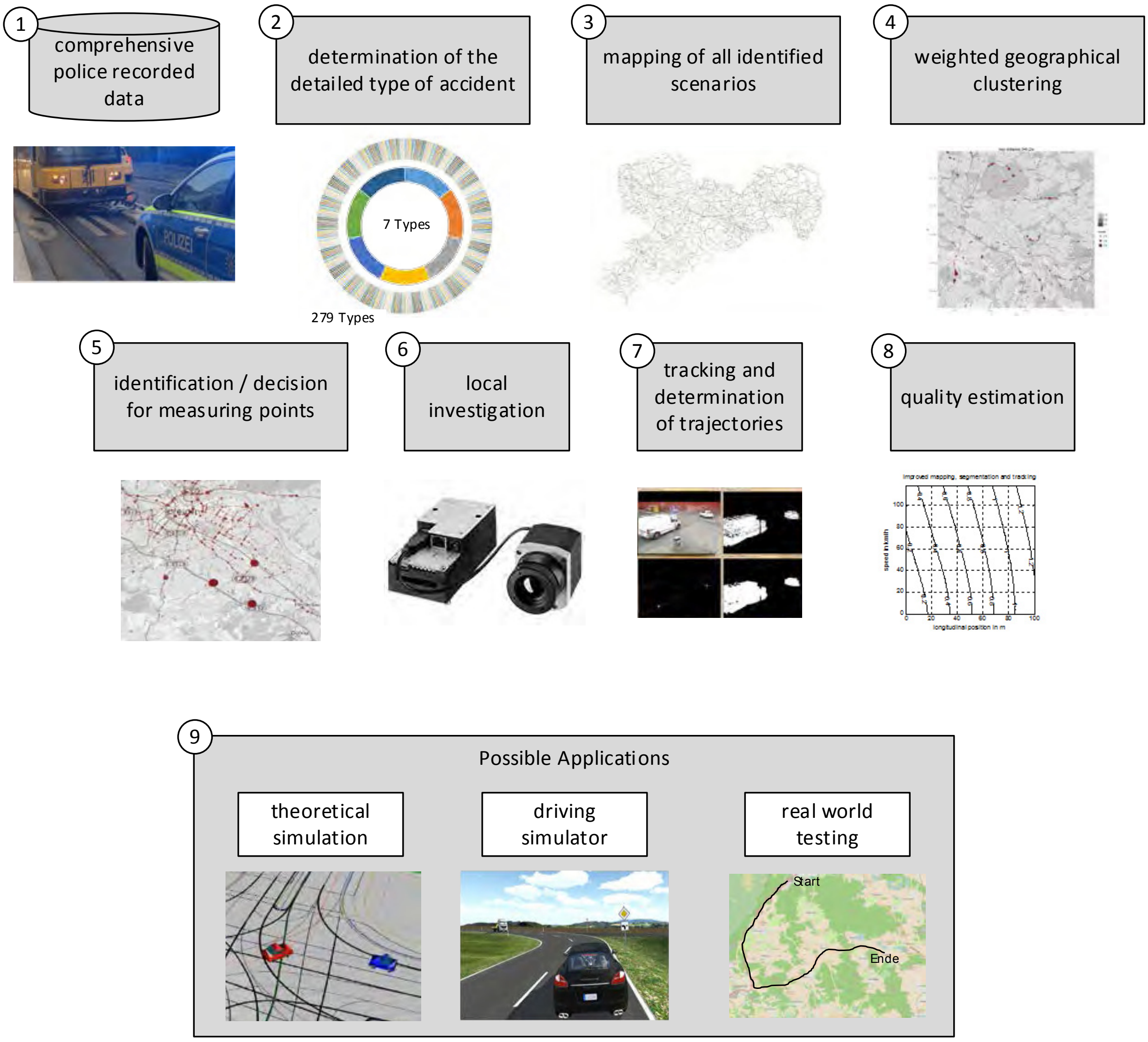

Figure 1: Toolchain of AIMATS

EXPLANATION AND EXAMPLE WITH ANIMAL STREET CROSSING SCENARIOS

The explanation of each step is given using the specific example of a project concerning wild animal street crossings by Fraunhofer IVI and Toyota Motor Europe in 2015.

(1) Comprehensive police recorded data

With support of the Interior Ministry of Saxony and the police, Fraunhofer IVI has access to all police recorded accidents in the federal German State of Saxony (other German states are following). This data is provided every month for traffic accident research work.

(2) Determination of the detailed type of accident by Fraunhofer IVI algorithmic

The basic police recorded data has only 7 main types of accident (e.g. crossing, turn off, and driving). Figure 2 shows the 7 types of accident at the inner circle and the possible precision with 297 Types of accident defined by the GDV [9] at the outer circle. Based on the long-term experience of Fraunhofer IVI in Big Data analysis and statistic data mining. A team of experts developed a method to determine the exact type of accident (297 specifications) for all available accidents since the beginning of 2015. This method was converted into an algorithm, which is able to determine the detailed type of accident on the flow.

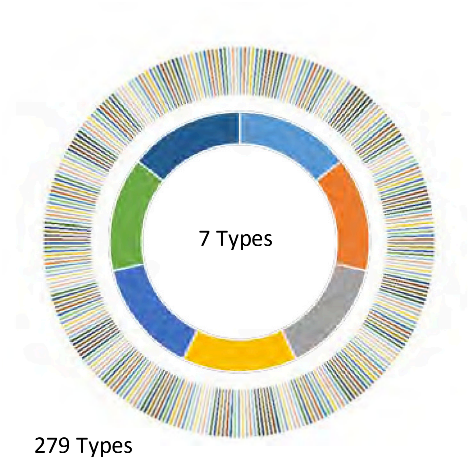

Figure 2: Detailed types of accident

(3) Mapping of all identified scenarios

General: After defining the accident types, a detailed accident analysis of the scenario of interest can be done. The resulting dataset is then mapped in geographical coordinates.

Example: The statistical analysis of the animal crossing project gives about 85,000 accidents with wild animal involvement in Saxony from 2007 to 2014. This was done by filtering the detailed type of accident 751 (animal encounter) and a crosscheck to further variables. All these accidents then could be exactly located with their geographical coordinates, shown in Figure 3. The illustration of the 85,000 accidents with wild animal involvement visualizeses almost the entire road network of Saxony. Every pixel of the illustration is an accident with wild animal involvement.

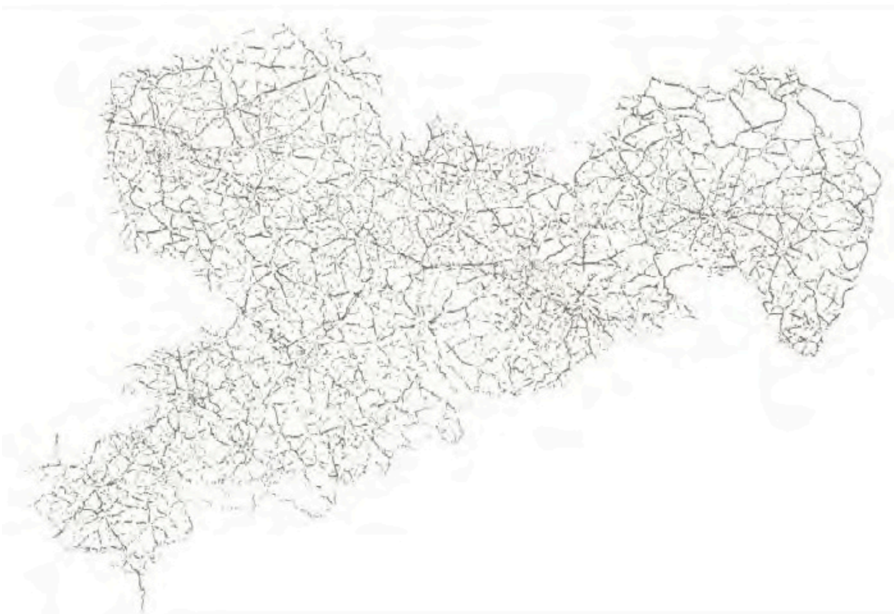

Figure 3: All accidents with wild animal encounters in Saxony (2007-2014)

General: There may be the necessity to analyse other parameters of the database for a detailed cluster analysis in the next step.

Example: For the wild animal street crossing study it is helpful to know the observation times of interest. The following diagrams were very helpful to identify these times and dates.

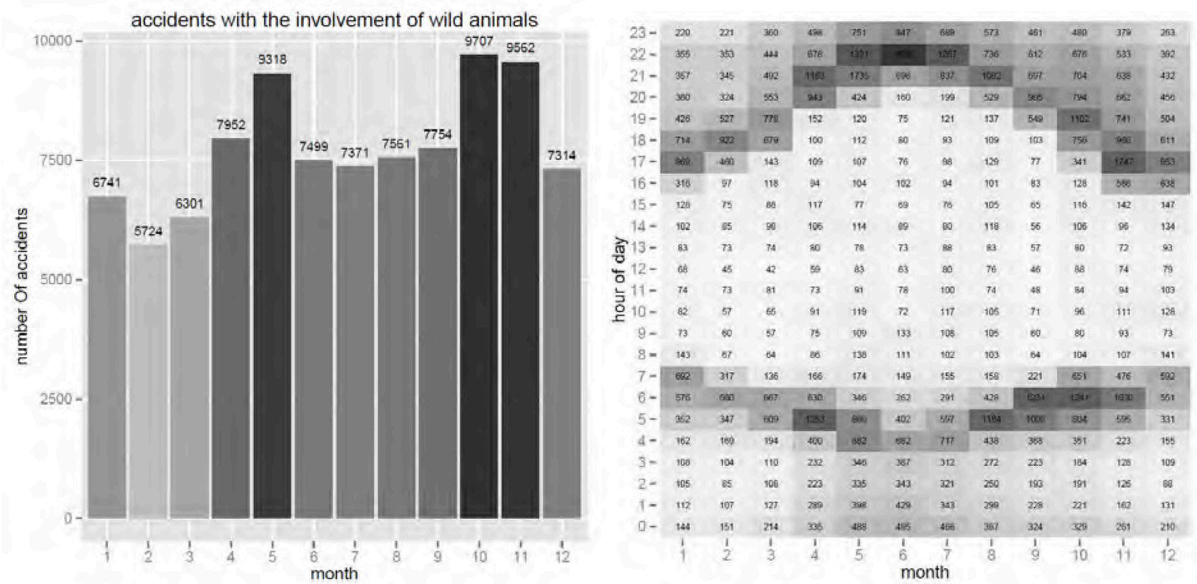

Figure 4: Interesting recording dates and times

On the left side of Figure 4 the dates of interest and at the right side the best observation-times can be identified by using the huge basis dataset.

(4) Weighted geographical clustering

General: To identify possible locations for measuring animal street crossings a weighted geographical cluster analysis was carried out. During the cluster analysis all accidents were weighted by their distance to each other and then grouped in several clusters.

Example: Figure 5 shows the result of cluster analysis of all accidents with wild animal encounters close to Dresden (Saxony). The larger the points the more accidents are grouped in one cluster.

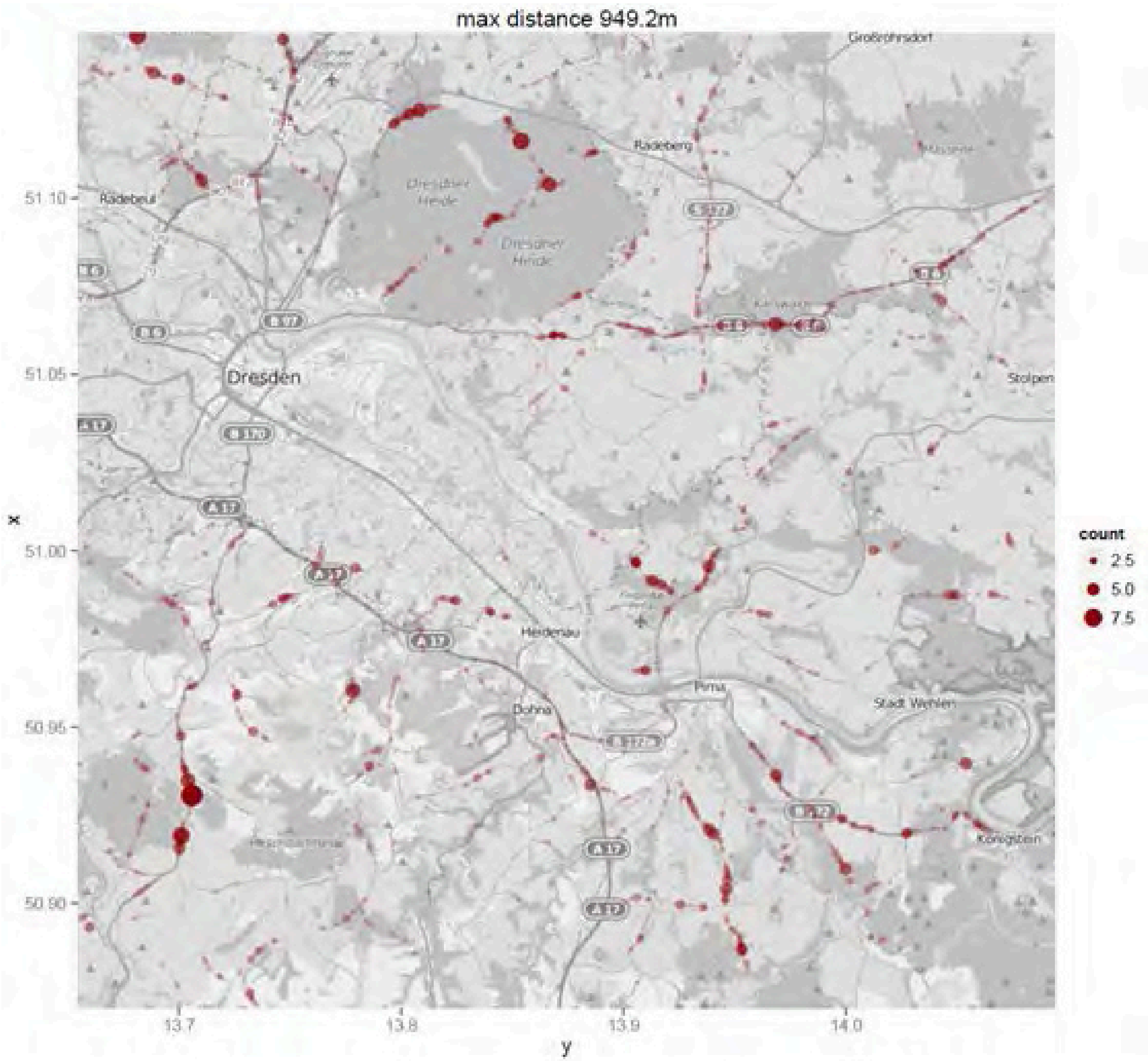

Figure 5: Result of the first cluster Analysis in the north of Dresden (Saxony)

(5) Identification / decision of measuring point

General: After the first detailed cluster analysis the accumulation points have to be identified. The first step for the identification is the grouping of areas of interest based on map material. The second step will be the contact to the local public authorities to get the recording license and find a good place for mounting the equipment.

Example: Four accumulation points were defined for the wild animal wild encounter study (Figure 6). After discussions with the local forest rangers, the measuring point 3 and 4 were chosen, because there were both a subjective higher level of animal-street crossing and good possibilities for mounting the equipment.

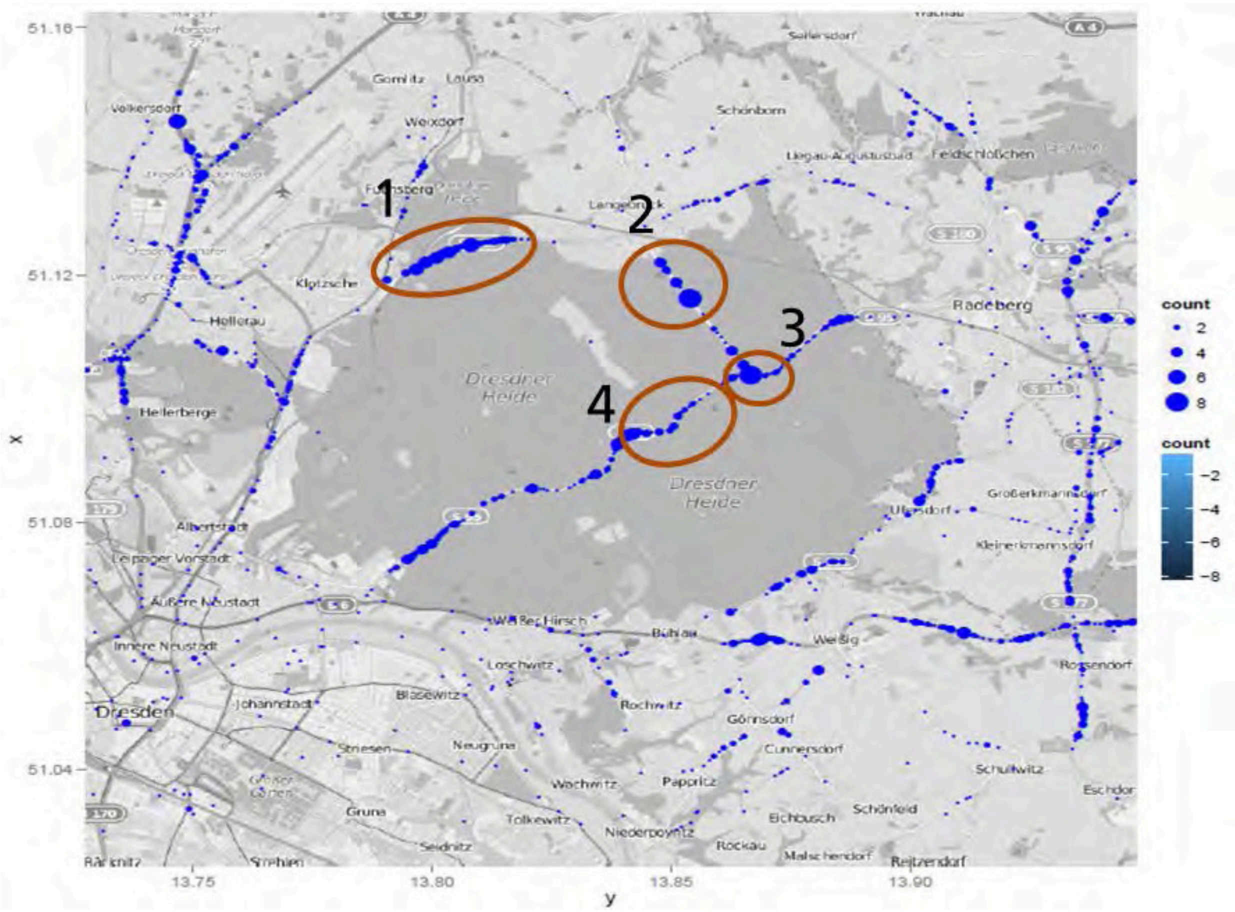

Figure 6: Identification of the POI's

(6) Local investigation

After the identification of the observation sites (POI's), the equipment can be mounted and the recording process can begin.

General: The measuring equipment for AIMATS is designed to work independently from communication and electricity infrastructure. Another requirement was privacy protection for recording human faces or number plates of vehicles. This was solved by using an infrared- based measuring system, which also allows very good video recording by night. To define all recorded scenarios in detail (including braking and acceleration actions) a very high frame rate was necessary. To store the high data volume of 20 GB / hour a mass storage system had to be implemented into the equipment.

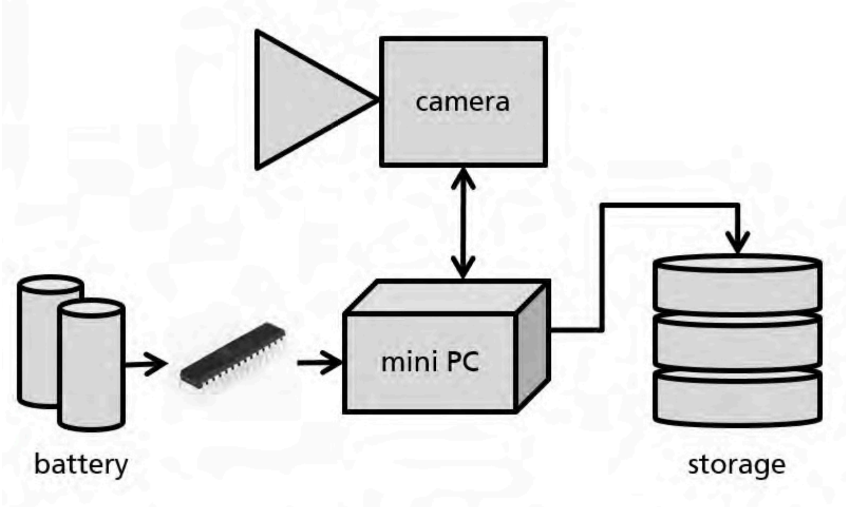

Figure 7: Basic scheme of measuring equipment

For controlling the recording of the infrared camera and the voltage a micro controller (made by Fraunhofer IVI) and a mini Computer (e.g. raspberry Pi) was implemented as well. The recording software on the mini Computer was developed by Fraunhofer IVI and can be used for nearly all kinds of traffic scenario recording. Figure 7 shows the principle layout of the measuring equipment.

Example: For the traffic situations with wild animal crossing a camouflaged jacket was developed in form of a bird house. Figure 8 shows this prototype and its mounting to observe the POI.

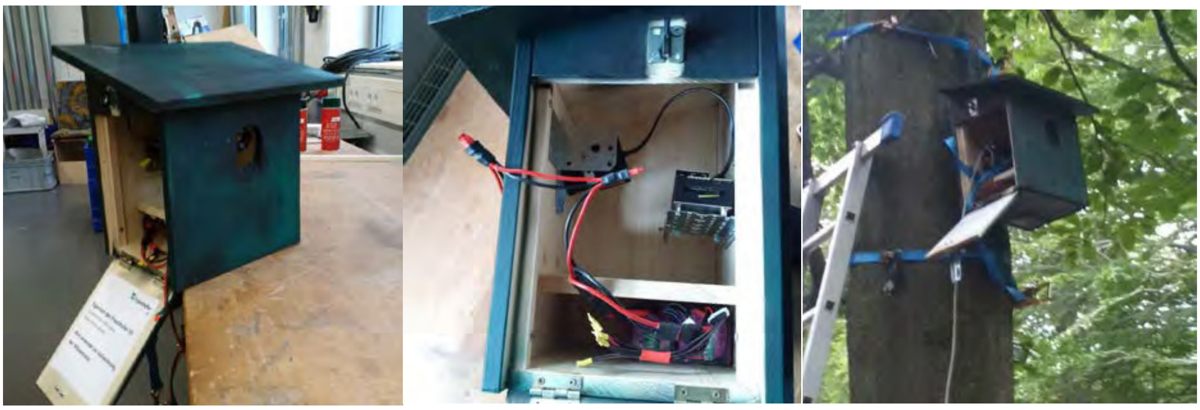

Figure 8: Camouflaged prototype of measuring equipment mounted at POI

The first three hypotheses were confirmed in the first night. Using the AIMATS scheme, the first animal street crossing scenarios including one evasion of a car was recorded.

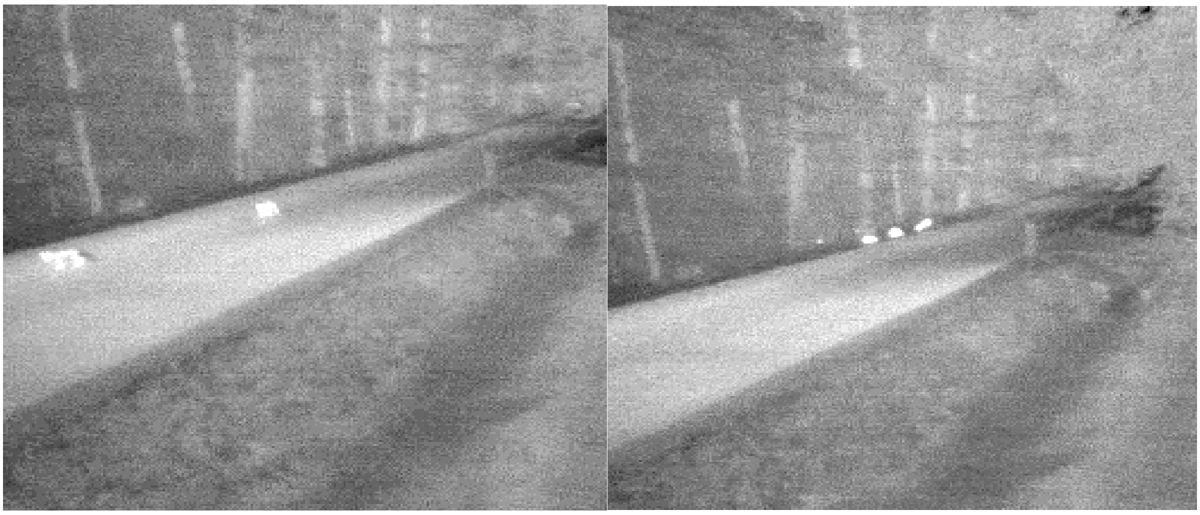

Figure 9: First night infrared observation (foxes at left, wild boars right)

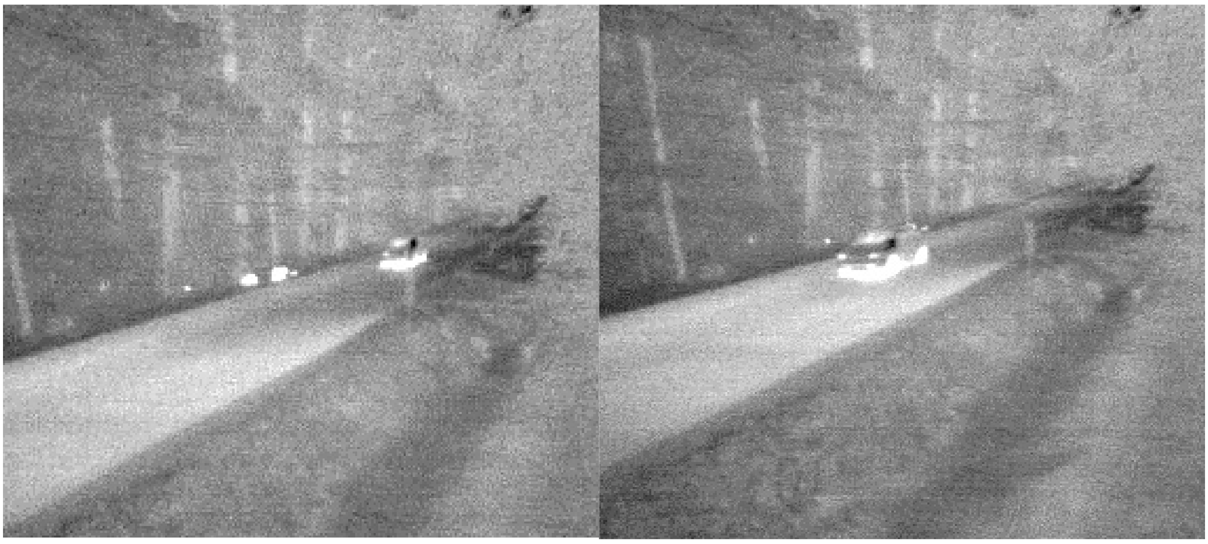

Figure 10: First night infrared observation (evasion of car)

During the project of animal street crossing and animal vehicle encounters the recording process and the stability of the equipment was improved step by step, which results in higher quality datasets. Figure 11 shows a roe and a couple of wild boars during their street crossing process.

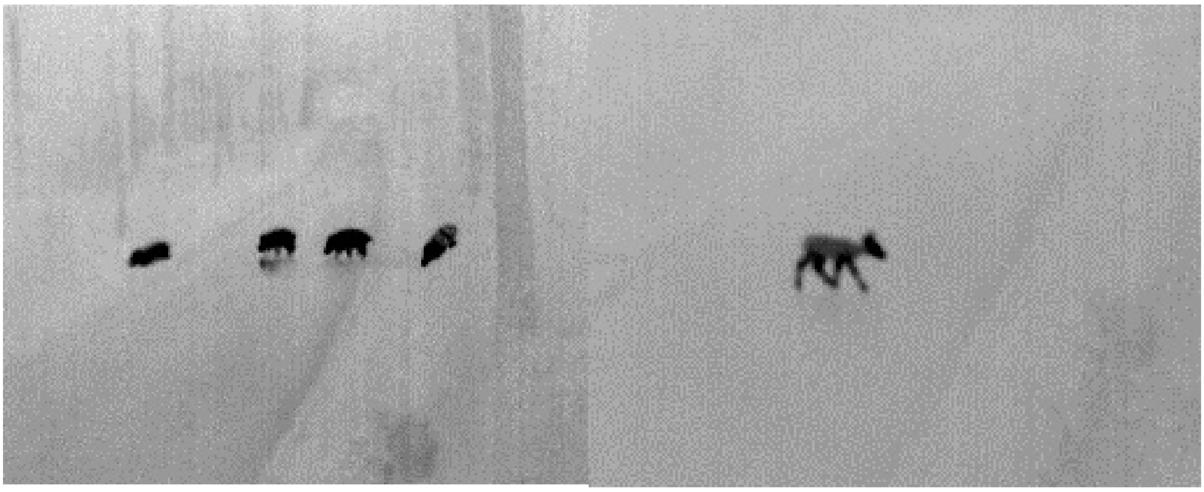

Figure 11: Infrared observations with improved equipment

(7) Tracking using a fox example

The next step to get real life traffic scenarios using AIMATS is the tracking process.

General: Based on long term experience and previous projects in video-tracking Fraunhofer IVI is currently developing an automated algorithm for tracking objects with “mono-view“ and “multi-view” perspectives. This algorithm will be further developed and implemented in the AIMATS- scheme.

Example: The state of the art of the tracking process can be described by the following scene. A fox walks at the right and at the left side of the road in search of food for about 15 minutes.

Figure 12: Tracked points in scene

The algorithm conducts a static background estimation and calculates the difference to the foreground movement of the fox. The background picture is then overlain by information on these calculations. Figure 12 shows the background picture (black & white) and the foreground movement of the fox (red points) every foreground point have its own coordinate and a time stamp.

Identifying the objects in the scene is the basis for the single tracking possibility. An example of the single tracking is shown in the next picture by tracking only the fox.

Figure 13: Single tracking (fox)

The coordinate information was transformed in a 2-D top view. Figure 13 shows the results of this transformation of the tracked points.

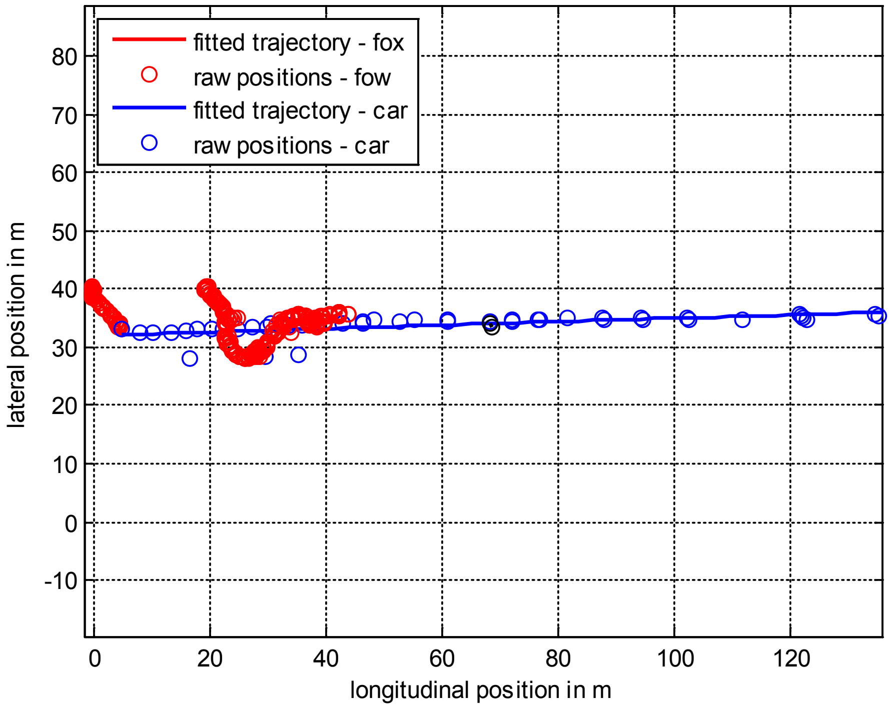

Figure 14: total top view of the scene

As described before every coordinate has its speed value, which can be used to draw the speeds over the positions of all tracked vehicles.

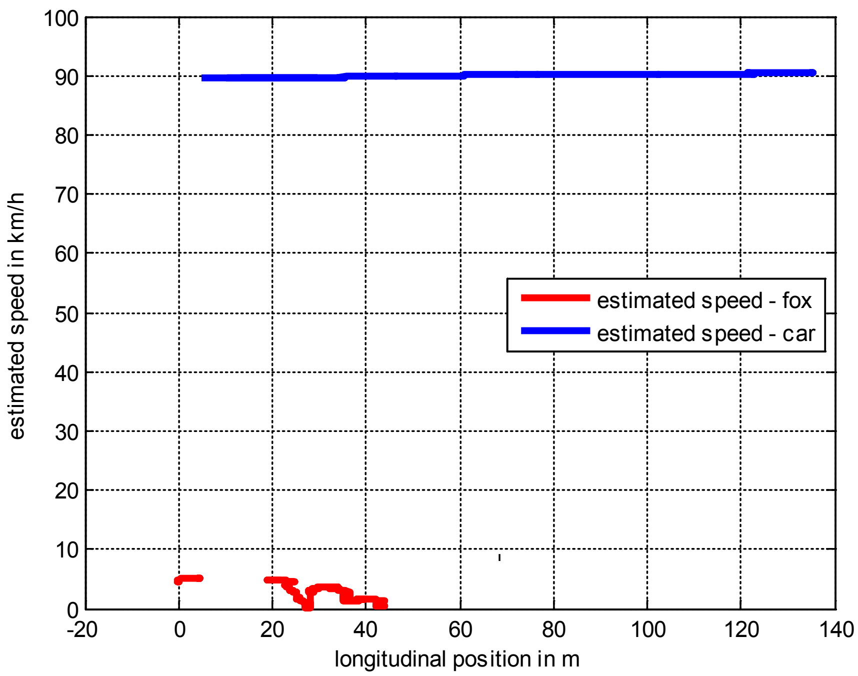

Figure 15: Speed estimation of all tracked objects

Based on the measuring method there are some tracking mistakes which can be eliminated during a post processing.

(8) Quality estimation

The last step in AIMATS is the estimation of the measurement uncertainty (quality) of the calculated trajectories.

General: The calculation of the measurement uncertainty is based on DIN1939. The calculation comprises the camera configuration, the camera pose, as well as segmentation and tracking errors. The longitudinal position and the speed of the tracked object were figured as major influences to the uncertainty of the object speed.

Example: As an example the figure below shows the resulting uncertainty of the calculated speed for the preliminary study. Further optimizations are in progress.

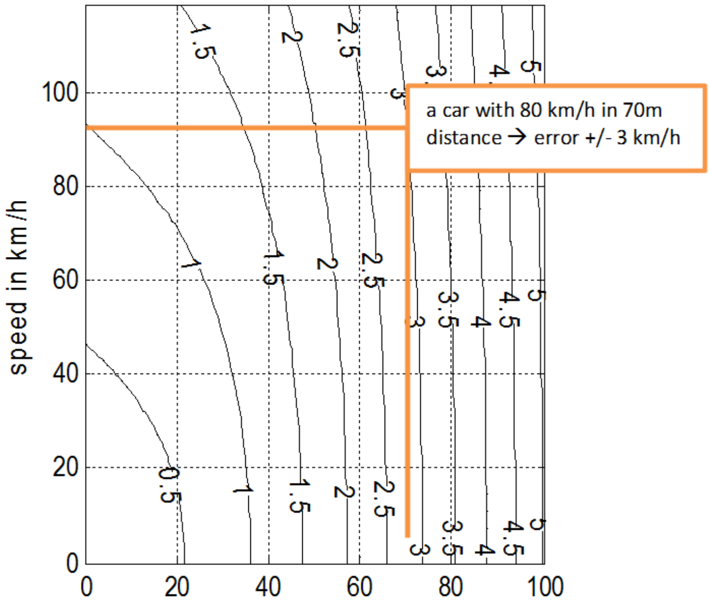

Figure 16: Quality estimation, speed error

DISCUSSION

The described example was the first project, which was carried out as a pilot study in 2015 in order to show the accuracy and the power of AIMATS. During the measuring period of eleven full days at two different locations, AIMATS was able to detect 64 wild animal street crossings including six car animal encounters and three critical situations with car manoeuvres. These three critical car manoeuvres in eleven days are a higher rate than the reported vehicle based observation rate of less than one animal per week [5], and is an encouraging result.

Based on the results of this pre-study Fraunhofer IVI and Toyota Motor Europe plan to carry out a large scale wild animal street crossing observation study in 2016.

AIMATS is adaptable to every traffic scenario which can be found in Fraunhofer accessible national databases. A basic idea of the range of the possibilities delivers still the number of 297 possible different types of accident. This includes the possibility to identify, for example, interesting pedestrian or bicycle situations and the relevant measuring locations. The observation of these locations and the automated creation of representative virtual simulation and driving simulator scenarios based on real traffic scenes can build a good basis for research, development, vehicle testing (incl. definition of tests) and certification processes in the automotive safety and autonomous driving sector.

The basic approach:

“Many accidents of the same type indicate that there is a much larger number of conflict scenarios”

is valid for every traffic situation and leads to very representative locations (POI) for recording real traffic scenarios of interest. Due to the mobile and independent usage possibilities of the Fraunhofer hardware AIMATS can be placed at every POI, if the framework conditions (e.g. get the recording license of the owner of the forest) are clarified.

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