ACCIDENT ANALYSIS BASED SAFETY FUNCTION DEVELOPMENT

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ABSTRACT

The development of modern automotive safety functions is strongly driven by reducing development effort, component costs, tight scheduling and especially the expectation of high function efficiency.

As improving safety is a shared vision of governmental authorities and industry, the industry is called upon to exhibit proven evidences of function efficiency – even before a dedicated function works in field.

The given challenges can be mastered by involving the latest results of accident analysis into the development process. The extensive use of in-depth accident data enables optimized function design with focus on efficiency and related component costs. Hence, an accident analysis based methodology for the development of active safety functions is derived. The power of this method will be demonstrated by the application on an exemplary use case.

MOTIVATION

Usually the development process is characterised by recursive steps within the prototype phase. This is typically caused by the complex interdependencies of product liability, heterogeneous use cases and related component costs. A more efficient development process can be achieved by answering the following questions:

- **How to focus precisely on accident situation with statistical relevance?**
- **How to shift recursions from prototyping to simulation phase (Frontloading)?**
- **How to derive requirements for components in order to balance costs and performance optimally, all this at an early stage of development?**

Accident analysis is the key to a development method for safety functions which copes with the given challenges

MAIN PROCESS OF FUNCTION DEVELOPMENT

An appropriate method to address the above mentioned challenges is the accident data based development process. The process mainly consists of two phases:

Phase 1: Macro-data is analyzed in order to identify relevant accident scenarios. Accident kinds, causes and the function placement into the accident chronology (e.g. according to the ACEA model) are used to support the function design.

Phase 2: The function draft is implemented into a simulation environment. The reproduction of real world accident scenarios thus enables recursive development. Within this phase detailed in-depth accident data is used to support the well known development methods.

PHASE 1
A) MACRO DATA BASED ASSIGNMENT OF SAFETY FUNTIONS

The distribution of accident kinds and related causes allows focusing on relevant function approaches. Figure 1 shows the statistical relevance of accident kinds and accident causes in Germany. The top event for fatalities can be widely adressed by instsllation of an ESP®. Accidents with oncomming traffic might be adressed by means of C2x related functions. Since the accident situation on crossings is rather complex, in this paper we choose this accident kind for the introduction of the development method.

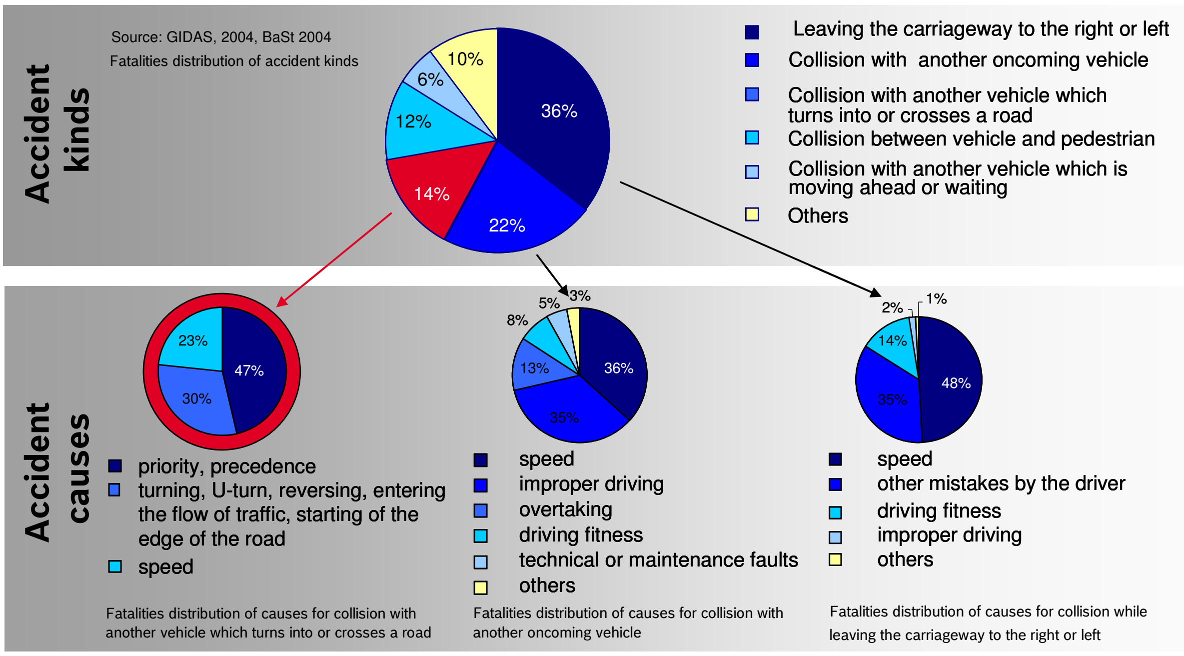

Figure 1. Fatalities vs. accident kinds and causes (Germany)

B) MACRO DATA BASED FUNCTION APPROACH

The function design highly depends on the operating phase within the ACEA accident chronology. Functions acting in early stages of the accident chronology usually address rather the accident causes than the kinds (e.g. speed warning). Functions acting in late phases of the crash chronology typically focus more on accident kinds (e.g. side airbag deployment).

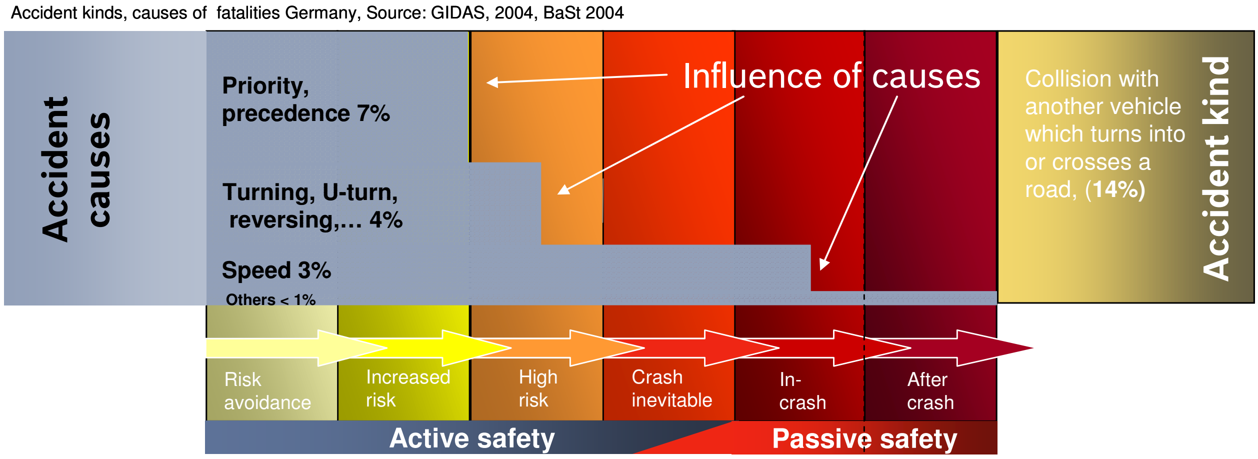

Figure 2. Fatalities in Collision with another vehicle which turns into or crosses a road

Figure 2 shows the example of a “collision with another vehicle which turns into or crosses a road” and its related causes, equalling 14% of fatalities in Germany. Hence, the influence of the accident causes along the accident chronology has to be analyzed and carefully checked against the initial function approach.

PHASE 2
SIMULATION BASED SYSTEM DEVELOPMENT WITH IN-DEPTH ACCIDENT DATA

After selecting in phase 1 the function focus and its alignment to the accident timeline, the function and the required components have to be designed and tailored to the real world use case.

In preparation of phase 2 the accident scenarios are chosen according to the envisaged use cases by several criteria like accident kinds, accident types, collision types or others. After the selection process the chosen accident scenarios have to be statistically aligned to official national accident databases (in Germany provided by the “Federal Highway Research Institute of Germany”- BAST). This alignment is done under consideration of the selected criteria.

From the selected in-depth accident data, the use cases are transferred to a simulation tool, were function algorithm and system component specification can be optimized for maximum real world performance and best cost-benefit ratio.

The availability of in-depth accident data is essential for this process. For Germany data from the German In-Depth Accident Study (GIDAS) with typically up to 3500 items for each accident are available. Further regional in-depth databases can be used in order to achieve a more global function shape. For data transfer from the accident data bases to the simulation tool, an automatic tool should be used for workload reasons.

Only now, in a third step, recursive optimizations adapt the selected system to variable boundary conditions, using first samples.

As a result, precisely defined requirements components are obtained, balancing costs and performance. In parallel a proven efficiency of the function is provided. Thus many recursions could be shifted from prototyping to simulation phase (Figure 3).

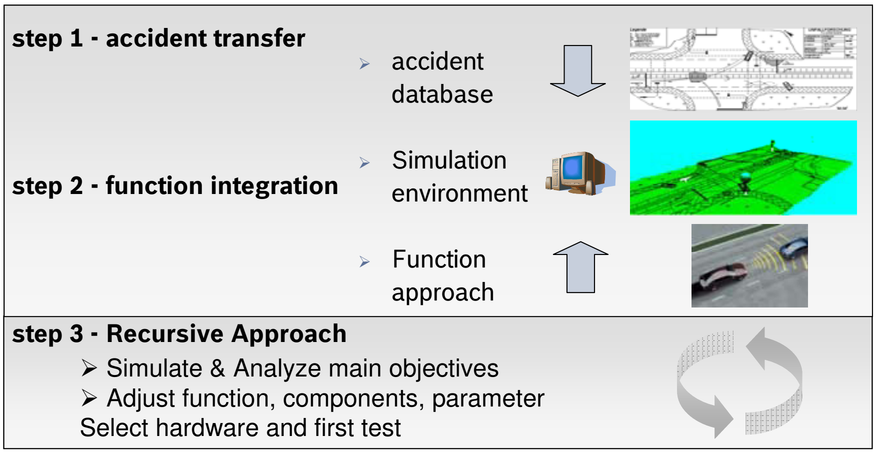

Figure 3. Base and process of function development

Below, the development process shall be exemplified by designing a system for avoidance or mitigation of a “collision with another vehicle which turns into or crosses a road”.

DEVELOPMENT STRUCTURE FOR SIMULATION BASED FUNCTIONS DEVELOPMENT

For the system development according to step 2, two main development objectives can be identified: **Objective 1**: **Function algorithm analysis** in accordance to the selected use cases and related features. **Objective 2**: **Sensor parameter analysis** in accordance to the selected use cases (Figure 4). The discrimination of objectives together with a careful selection of the accident items transferred to simulation enable a considerable reduction of effort in terms of accident data transfer.

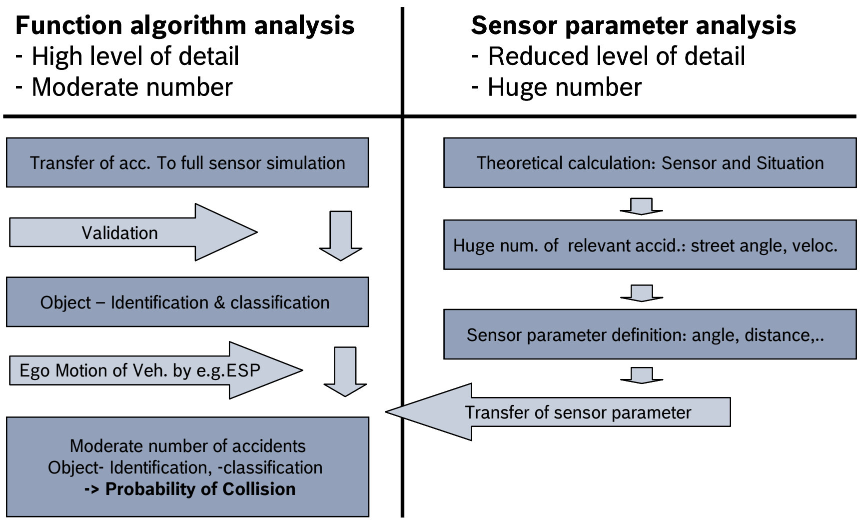

Figure 4. Development structure

Function algorithm analysis

The development of the function algorithm demands highly detailed real world scenarios in order to reveal all sensor relevant factors and their influences on the concerned system.

Exactly reconstructed road- and accident conditions and their comprehensive validation is the base for reliable statements of this analysis (Figure 5). It has to be ensured that every targeted use case is covered.

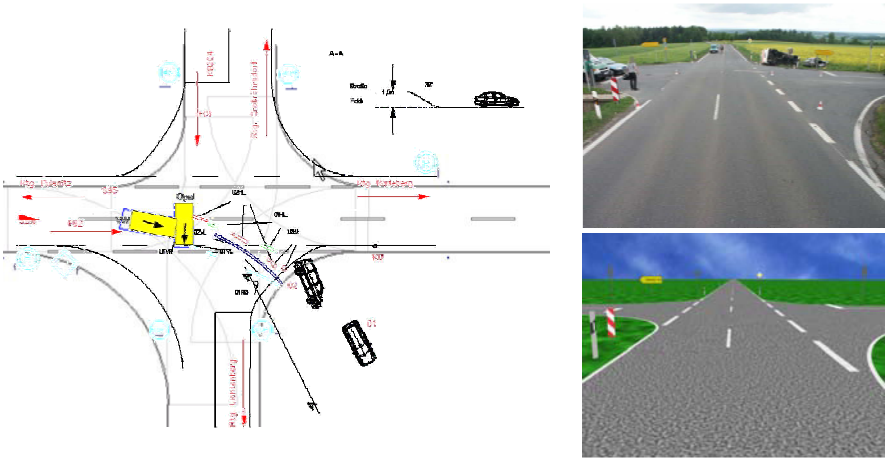

Figure 5. Integration and validation of accidents

Sensor parameter analysis

The sensor parameter analysis targets amongst others two main characteristics of surround sensing systems: field of view and detection range. Weighty statements are only achieved if all influencing items - in the given example velocity of vehicles, view angles including occluding objects, friction of road, road dimension and some others - are exactly reconstructed (Figure 6).

In doing so, the number of chosen accident scenarios needs to be representative and aligned to the respective macro data base.

As a result a data base providing the required sensor parameters for enabling accident avoidance or mitigation within the targeted use cases is obtained.

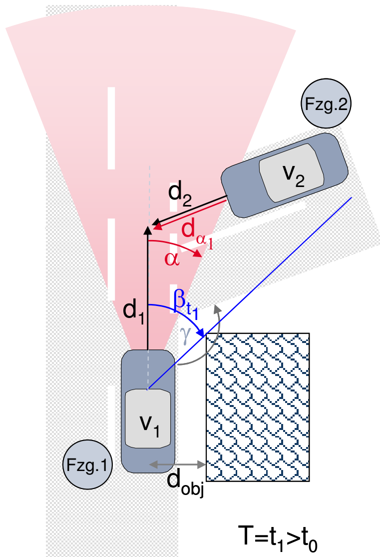

Figure 6. Reduced item sensor analysis

SENSOR SELECTION AND DESIGN

Based on the results of the use case analysis and the required sensor parameters (FOV) an adequate sensor concept for the system has to be designed and assessed. Since in the automotive technology field various sensor principles and sensors exist - generally speaking- this process has to be carried out for each of them.

As an example we show some results of the assessment of a video sensor.

In consideration of the relation between field of view and detection range a sensor specific coverage graph as shown in Figure 7 can be derived from the accident data base. Independent variables for this characteristic curve are:

- number of imager columns of the camera
- focal length of the camera
- expected size of most relevant objects in the world
- minimum required object size for detection (in pixels)
- system setup time (system response plus driver reaction time)
- minimal functional impact for accident mitigation or avoidance

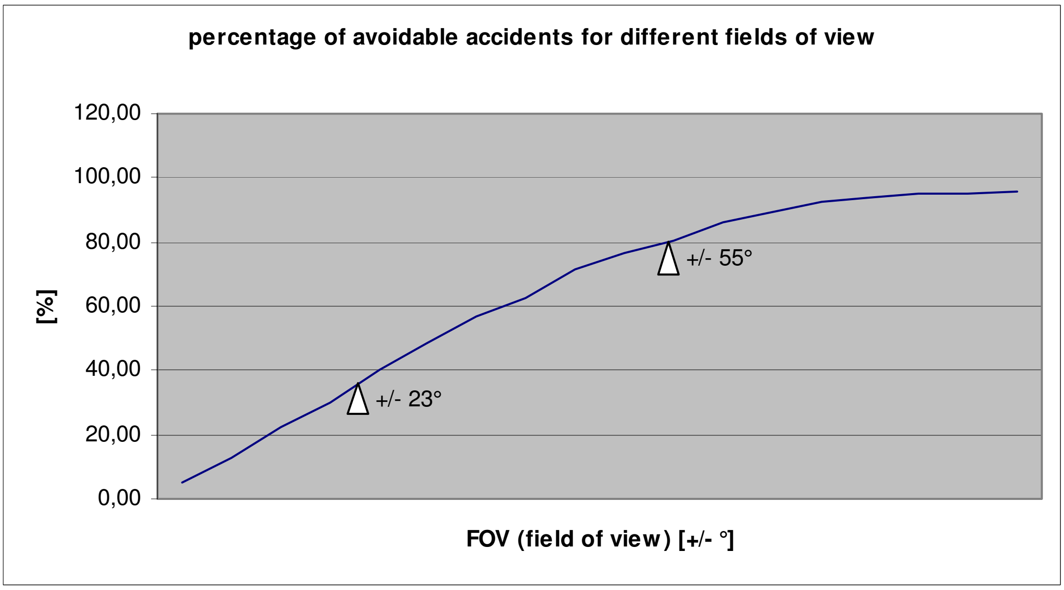

Figure 7. Coverage graph

The derived coverage graph in Figure 7 indicates, for which FOV which percentage of accidents can be addressed. For example a FOV of about ± 55° results in coverage of 80% of the analyzed accidents. A FOV of a typical front looking LDW-camera (about ± 23°) yields to a coverage of about 35% of avoidable accidents. Thus, the expected system performance for any video sensor setup can be specified.

SYSTEM EVALUATION

When looking at the scenario of the evaluated accidents, it becomes clear that for a video sensor an algorithm for object detection is needed, which is independent of shape and position of the critical objects within the image. In addition to that it would be very helpful if the algorithm was very sensitive to motion within the image, because the possible collision object in the exemplary accident kind usually moves laterally towards the driving corridor of the ego vehicle. Hence, the Bosch Dense-Flow algorithm can be applied. Measurement results can be seen in Figure 8. (2),(3).

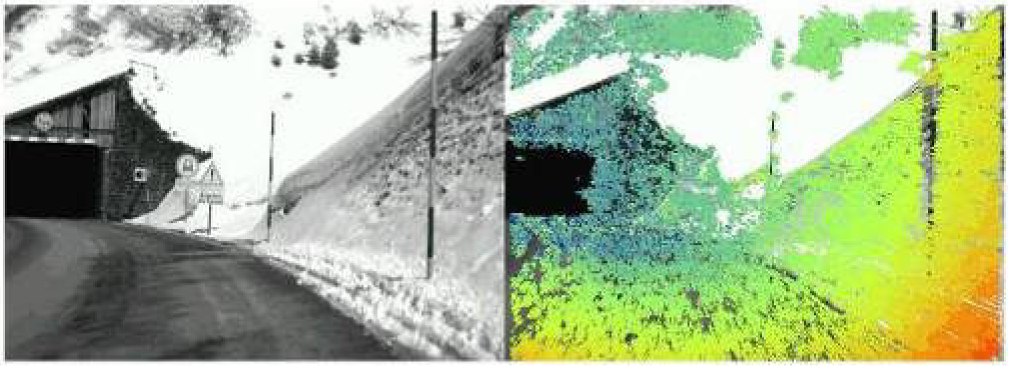

Figure 8. Dense optical flow field (Bosch Dense-Flow)

One inherent problem when dealing with accidents is that it is very difficult to set up a realistic test scenario. To test the performance of the detection algorithm, a selection of accidents from the GIDAS data base was simulated in high detail. The set-up of an accident scenario in the simulation environment was done by combining accident data with accident images resulting in generated synthetic videos of the accidents including all the relevant objects in accordance to the real world data. An example of such a simulated scene is shown in Figure 9.
Figure 10 shows the detection performance of the algorithm on that simulated scene. This approach allows testing the algorithm under realistic conditions such as distance, speed and visibility without any risk of physical or even human damage. In addition to that, by means of this procedure any accident can be simulated repetitively in exactly the same way in order to optimize the detection algorithm.

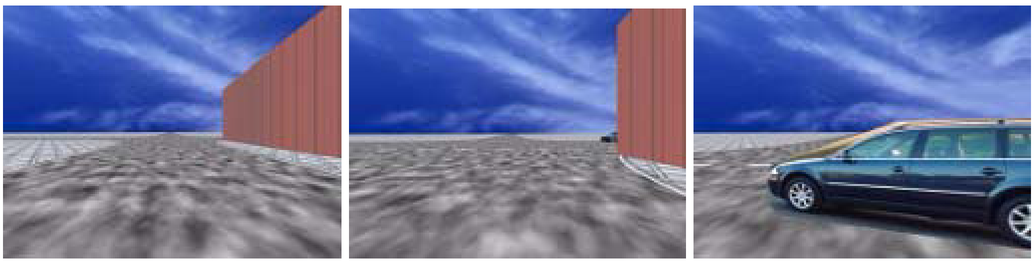

Figure 9. Sequence of a reconstructed and simulated real accident

Figure 10. Detection of crossing vehicle in simulated scene

REAL WORLD PERFORMANCE

After finishing the system design and its assessment the simulation results need to be verified against real world performance of the system. The evaluation of the real world performance

requires real world measurements for the considered sensor concept with focus on false positive and true negative rate.
For the verification of a video sensor, a standard video camera for vision based driver assistance applications was used in real world scenes.
Figure **11** shows such a scene with the detection of a crossing vehicle.

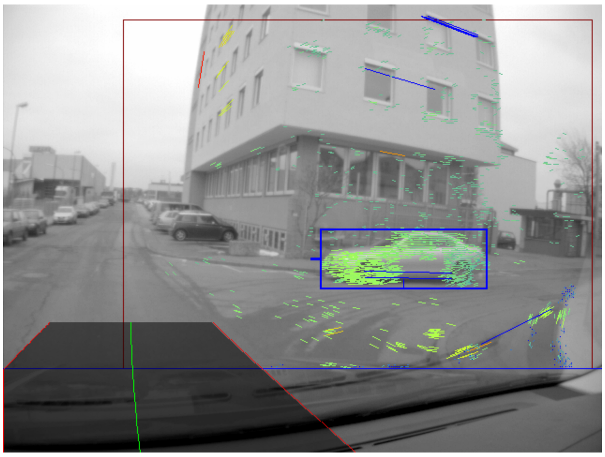

Figure 11. Real world performance of the detection algorithm (parameter setting tuned for demonstration purposes)

The Time To Collision (TTC) calculation which enables a warning strategy base on two main data sources

1) The ego motion estimation - derievd from video data and ESC data
2) The object relation estimation based on various approaches

- Trigonometrical distance calclations presuming a flat road and using the camera angles, and the target vehicle bottom line
- Object scale change over time
- Object direction estimation based on the optical flow measured on the surface of the targeting objects (Figure 12)
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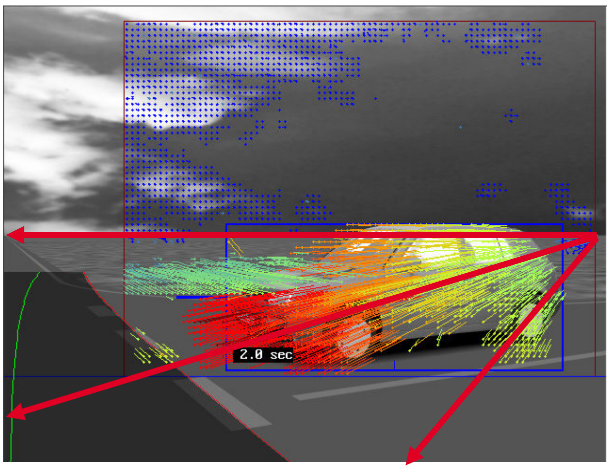

Figure 12 optical flow measured on the surface of identified object (simulated artificial scene)

SUMMARY AND OUTLOOK

A development method was presented that allows an optimal design of a vehicle safety system based on real word accident data. Real world performance is optimally balanced to system cost in the early definition phase. Recursions during the specification process and thus development costs are minimized. The expected system performance is staging for marketing and management decision processes (Figure 13).
Moreover, the method provides an excellent knowledge base when tailoring a safety system to OEM specific needs

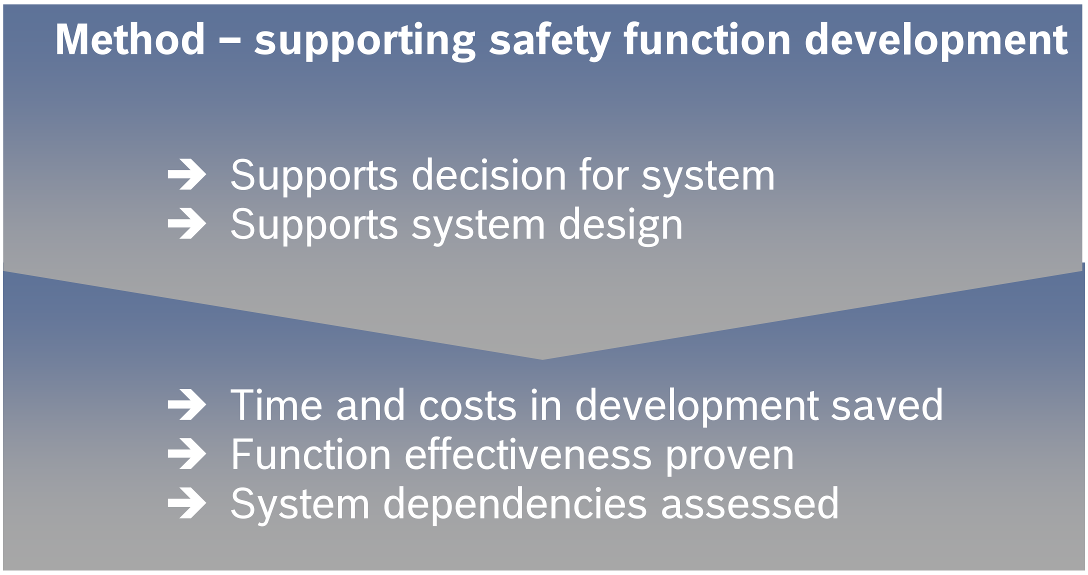

Figure 13 support method safety function development

ACKOWLEDGEMENT

Thanks to the GIDAS Cooperation for sharing and supporting our vision of efficient accident reduction.

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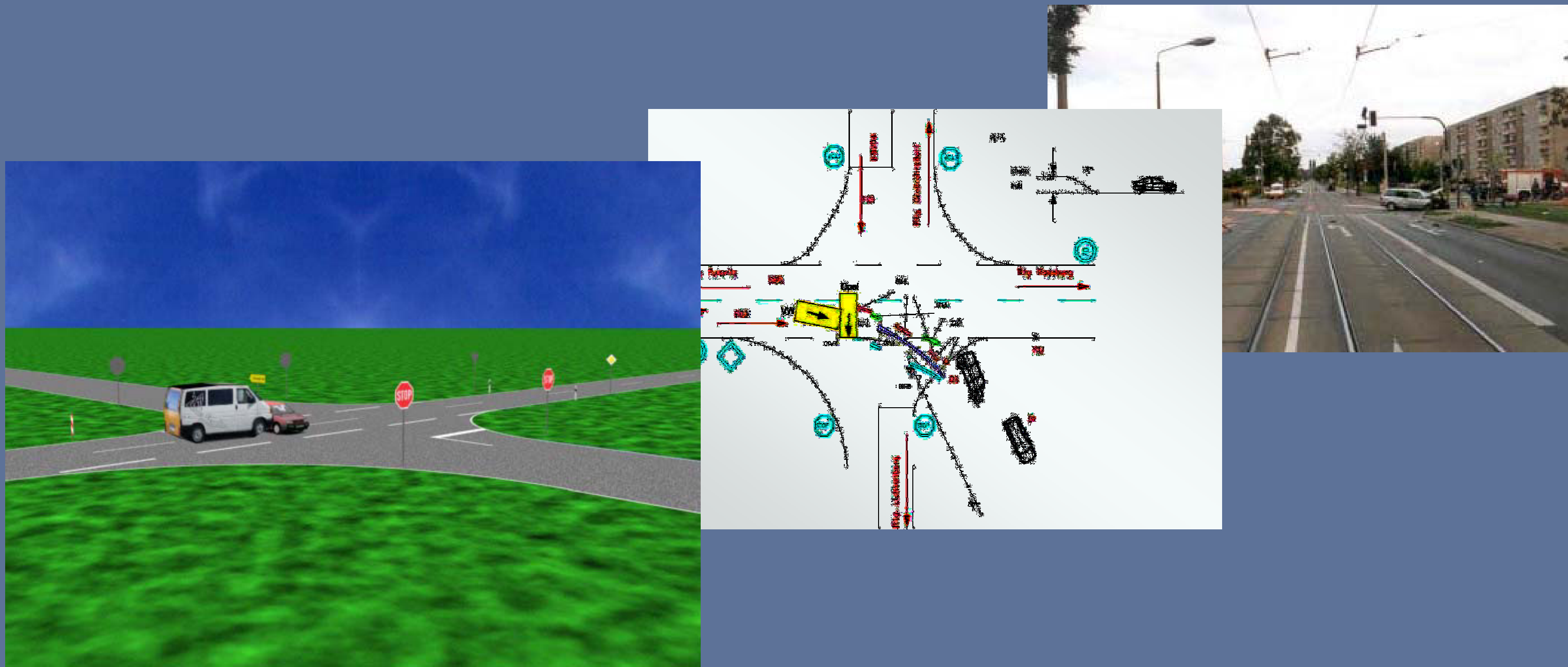
(3) R. Hartley and A. Zisserman, Multiple View Geometry in computer vision, 2nd ed. Cambridge Press, 2003.

Methodische Nutzung der Unfallanalyse zur Entwicklung von Sicherheitsfunktionen



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Eckpunkte der Systementwicklung

- **Funktionszielstellung**
  - Statistische Nutzenrelevanz
- **System Design**
  - Anforderungen an Komponenten basierend auf Nivellierung von Kosten und Performance
- **Effizienz im Entwicklungsprozess**
  - Verschiebung der Rekursionen aus Prototypenphase zur Simulationsphase (Frontloading)

- **Instrument - Intensive Nutzung der Unfallforschung**

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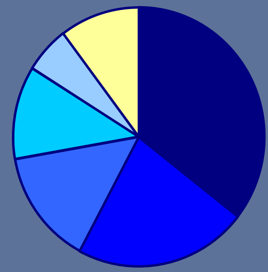
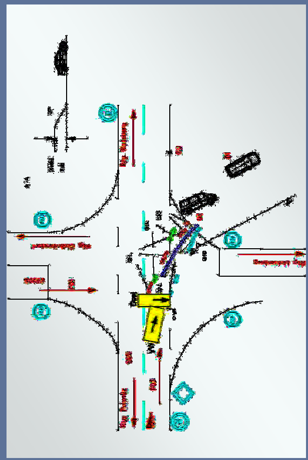
Prozess

Phase 1 Makrodatenanalyse



- ➔ Wirkfeld und Fokus – Warum und Was?
- ➔ Unfallchronologie – in welcher Phase?

Phase 2 Detaildatenanalyse



- ➔ Reproduktion realer Unfallszenarien
- ➔ Implementierung der Rohfunktion in Simulationsumgebung
  - ➢ Rekursive Entwicklung des Funktion

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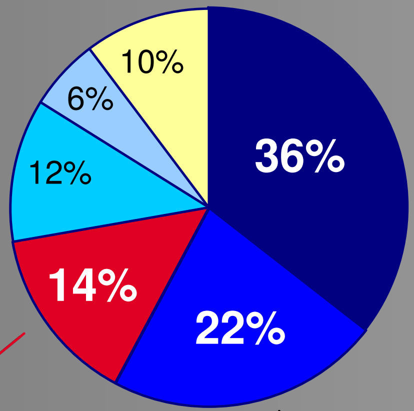
Unfallanalyse & Sicherheitsfunktionen

Phase1 Makrodatenanalyse

Unfallarten

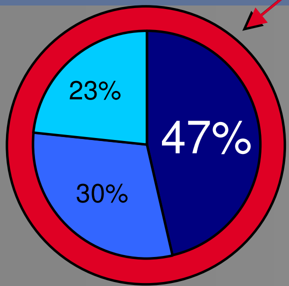
Quelle: GIDAS, 2002- 2004,

Todesfälle Verteilung von Unfallarten

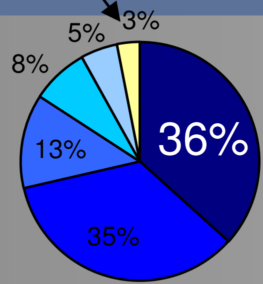


- Abkommen von der Fahrbahn
- Kollision mit entgegenkom. Fzg.
- Kollision mit anderem Fzg. das einbiegt oder kreuzt
- Kollision zwischen Fzg und Fußgänger
- Kollision mit anderem Fzg, das vorausfährt oder wartet
- Andere

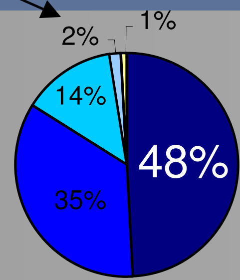
Unfallursachen



- Vorfahrt
- Abbiegen, Wenden, Rückw. Fahren, Ein- + Ausfahren
- Geschwindigkeit



- Geschwindigkeit
- Straßenbenutzung
- Überholen
- Verkehrstüchtigkeit
- Techn.. Mängel, Wartungsmängel
- Andere



- Geschwindigkeit
- Andere Fehler beim Fzg.führer
- Verkehrstüchtigkeit
- Straßenbenutzung
- Andere

➔ Nutzen – Fokus auf statistisch relevanten Funktionen

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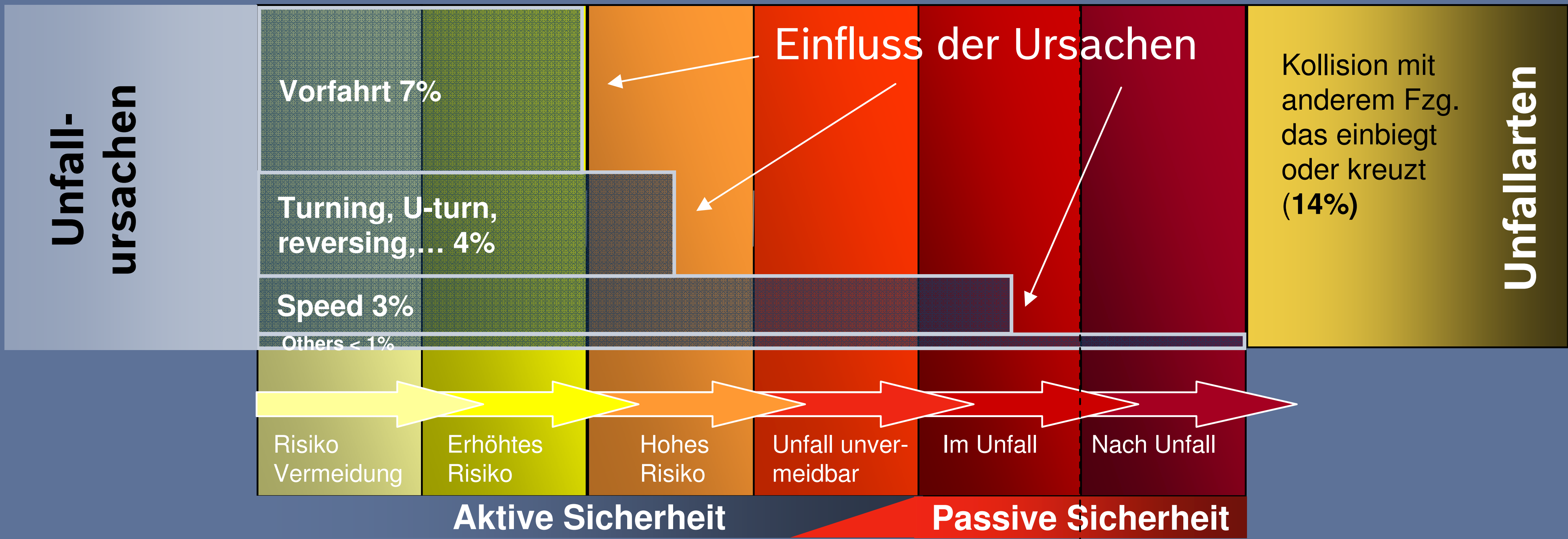
Phase1 Makrodatenanalyse

Beispiel: Betrachtung der Unfallchronologie

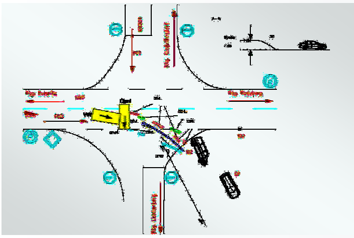
Unfallarten, Unfallursachen für Todesfälle in Deutschland, Quelle : GIDAS, 2002- 2004,



→ Nutzen – Schärfung Designfokus

Phase 2 - Detaildatenanalyse

System Design



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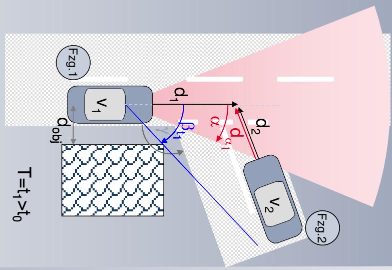
Datenbasis Funktionsentwurf



Sensor /Aktor

- ➔ Blickwinkel (FOV)
- ➔ Entfernung

Algorithmus

- ➔ Unfallsimulation

Rekursiver Ansatz

- ➔ Algorithmus + Szenen
- ➔ Sensorparameter

- ➢ Simulation & Analyse der Kernfragestellungen
- ➢ Anpassung Funktion, Parameter,…

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Sensor Auswahl and Design – Beispiel Video

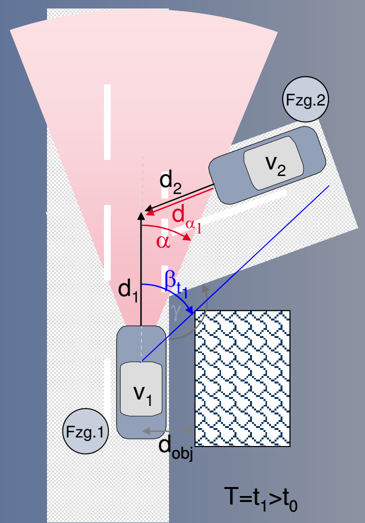
Sensor Parameter

➔ FOV, Abstand,...

Funktionaler Rahmen

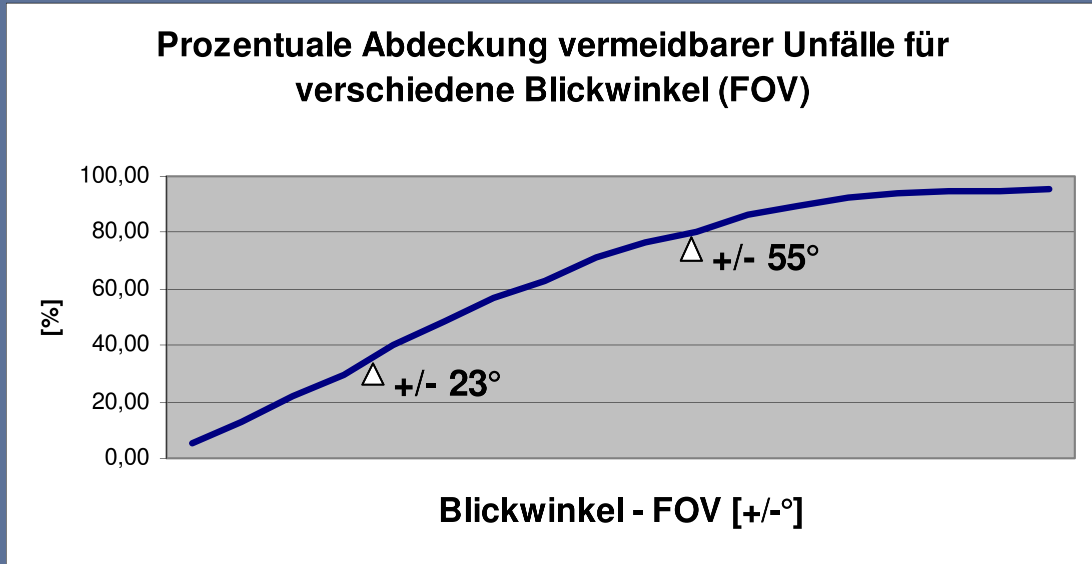
➔ Min Objektgröße,

➔ Reaktionszeit,...



Effektivität des Systems

➔ z.B. Abdeckung vermeidbarer Unfälle



➔ Nutzen – Direkter Link: System ⟺ Performance

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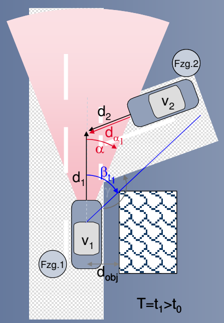
Real-world & Systemevaluierung

Sensor
➔ **Video (FOV)**



Algorithmus
➔ **Power Flow**

Unfalldatensimulation
➔ **Use Case Performance**


Sequence

Prototyp and Test
➔ **Real-world Performance**
➔ **Fehlwarnungen**
  ➢ **Weiterentwicklung**

Systemevaluierung

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Zusammenfassung

Methodische Nutzung der Unfallanalyse zur Entwicklung von Sicherheitsfunktionen

- ➔ Unterstützung in Systementscheidung
- ➔ Unterstützung im Systemdesign

- ➔ Kosten- und Zeitersparnis in Entwicklung
- ➔ Nachweis der Effektivität der Funktion
- ➔ Systemabhängigkeiten sind bewertbar

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Danke für Ihre Aufmerksamkeit!