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Beyond a Three-Dimensional Digital Rescue Sheet

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***Abstract*—Traffic accidents occur all over the world. They are still among the most frequent causes of death. Introducing electrical vehicles or hydrogen fuel cells, the diversity of cars increases while more and more dangerous components are integrated into the vehicle. If such a vehicle needs brute force opening, these components impede occupants and rescue team. The rescue sheet is a paper-based document indicating location and site of dangerous components for extrication. It needs to be retrieved from databases once the vehicle type is identified. In this paper, we develop a three-dimensional (3D) digital rescue sheet that is based on a standardized terminology of dangerous items and a small set of 3D vehicle models. Our database feeds a mobile app for interactive visualization on smartphones and tablet computers. This core system can be extended by (i) guided optimal navigation (ii) automatic car type identification, and, based on CAN bus information, (iii) vehicle's deformation estimation, (iv) personalized injury estimation, and (v) a comprehensive accident registry. Furthermore, (vi) using the International Standard Accident Number (ISAN), all information can be sent to the rescue team before approaching the accident site. Our system is developed open source and can be extended with further components. It will speed up the rescue process and help to deliver the patients to the hospital within the golden hour.**

Keywords—Accident & Emergency Informatics, Rescue Chain, Digital Health, Terminology, Standardization, 3D Visualization, Personalized Medicine, Accident Registry, eCALL, Golden Hour

I. Introduction

According to the World Health Organization (WHO), approximately 1.3 million people die each year as a result of road traffic accidents [1], which cost most countries 3% of their gross domestic product [2]. The United Nations (UN) General Assembly has set an ambitious target of halving the global number of deaths and injuries from road traffic crashes by 2030 [3]. However, the post-crash response becomes more and more difficult, as the number of vehicle types, engines and safety issues such as battery-powered electrical motors, hydrogen fuel cells, explosive air bag units etc. increases. Such devices endanger occupants and rescue works, if the vehicle needs, for instance, roof opening. Another problem in modern cars is how to identify and disconnect the high-voltage battery.

Hence, improved rescue is an aspect of road safety. Every minute counts during extrication. Any threats to the "golden hour", which is the time between an accident and the delivery of the victim to the hospital [4], must be avoided. In Germany, most tracer diagnosis are linked to a 90-minute interval [5]. Anyway, time is the most important factor in the early rescue chain. Accordingly, Fogue et al. proposed a system for automatic notification and severity estimation of automotive accidents [6].

To speed up the rescue process, the German Automotive Association (ADAC) has promoted a standardized DIN A4-sized "rescue sheet" that holds information on the location of cabin reinforcements, tank, battery, airbags, gas generators, control units, etc. (Fig. 1). To enable accessibility for the rescuers, the printed rescue sheet shall be placed behind the driver's sun visor [7]. It indicates adequate cutting points. Meanwhile, based on the support by Fédération Internationale de l'Automobile (FIA), manufacturers and importers have made such rescue sheets available on the Internet [8]. It is worth to mention that in the emergency services notification module of Fogue et al., standard rescue sheets are part of the vehicle information to highlight the important or dangerous parts of a specific vehicle.

Fig. 1. Paper-based rescue sheet [7].

Paper-based rescue sheets have some limitations though it is the standard at current stage. In case of an accident, it cannot support automatic information transferring to corresponding rescue workers. The owner of an accident car may place it in an unexpected location. It can be no longer be accessible in case of a serious accident or under a certain circumstance, e.g., flood. Therefore, many efforts have been made to develop digital rescue sheets.

To access a rescue sheet from the Internet, several clicks are needed to navigate to the right page on the vendors' side, which costs additional minutes. To speed up the workflow, several apps are available, for instance, the Rescuecode (https://apps.apple.com/de/app/rescuecode/id964333859), the SilverDAT (https://www.dat.de/frs/), the Res-QR app (https://res-qr.de/rk3/), or the Crash Recovery System (https://www.moditech.com/de/crash-recovery-system/rescue-feuerwehreinsatz/).

More recently, Morales et al. have developed an advanced rescue sheet (ARS), which demonstrates the type of vehicle fuel, security elements of the vehicle, and health information of the occupants [9]. They also suggest to visualize a 3D view of the vehicle chassis. More than one year ago, Mercedes-Benz has announced 3D rescue sheets for the company's fleet, but as of today, they still are unavailable (https://rk.mb-qr.com/en/).

In this paper, we present a modular concept beyond a 3D digital rescue sheet with interfaces to electronic emergency calls (eCall), the controller area network (CAN) bus system of the vehicle, and the International Standard Accident Number (ISAN) [10].

II. Core System

A. System Overview

We have designed a modular system for interactive 3D rendering of vehicles and important items. The core system is composed of a standardized terminology and unified symbols, abstracted 3D vehicle models, a rescue sheet database, and the interactive visualization component (Fig. 2).

B. Standardized Terminology

There is a need to further unify the symbols and colors in use to classify the relevant items [11]. Figure 3 shows the English standard translation of current paper-based rescue sheets. These symbols are too detailed and need replacement with simple icons. Furthermore, the terms are incomplete, as novel technologies have approached the marked.

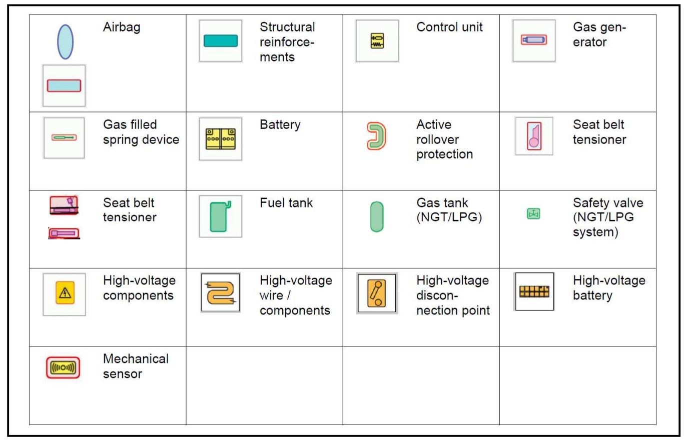

Fig. 3. Rescue sheet standard Englisch translation [7].

For instance, tanks and valves for liquefied petroleum gas (LPG) and natural gas technology (NTG) can be indicated, but those for hydrogen fluid cells (HFC) are missing.

C. 3D Vehicle Models

The number of car manufacturer and the number of new models is steadily increasing. Figure 4 shows data from the German market. According to official statistics from the German government, each year, more than 400 new models are released

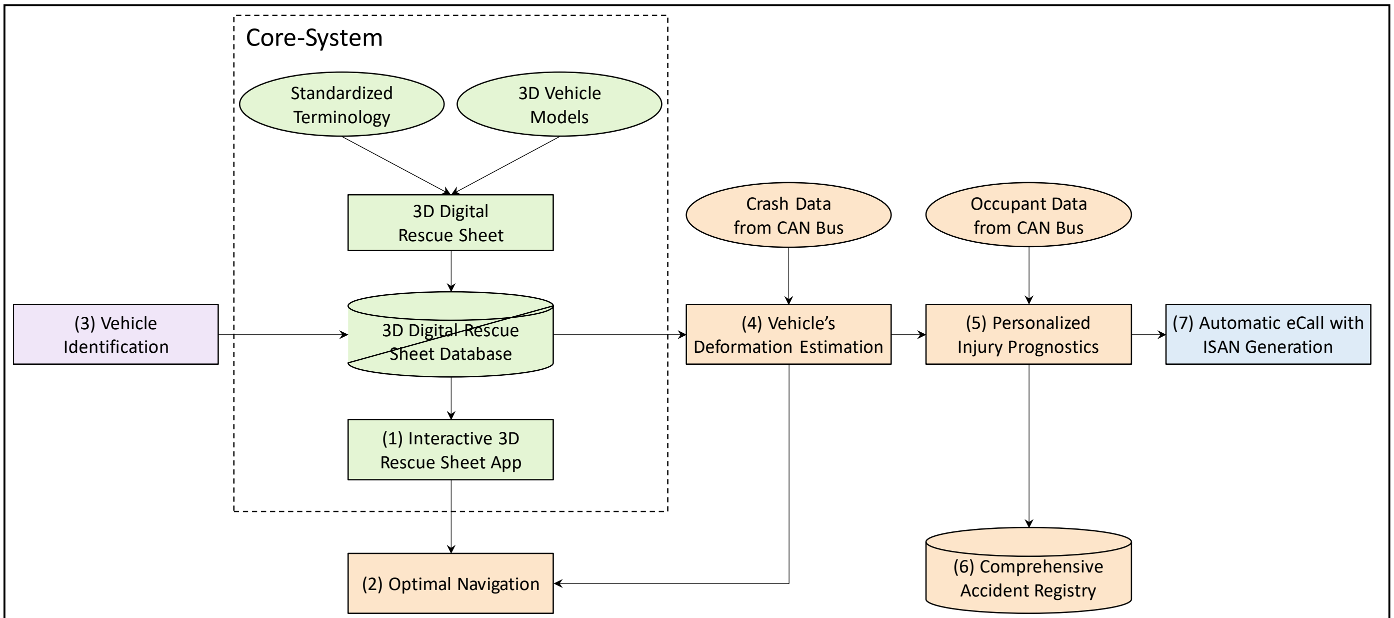

Fig. 2. Overview of the components of the 3D digital rescue sheet. The core system is visualized in green color.

[12]. Furthermore, such models may have up to 60 variants, several of which are relevant regarding airbag configuration etc. [13].

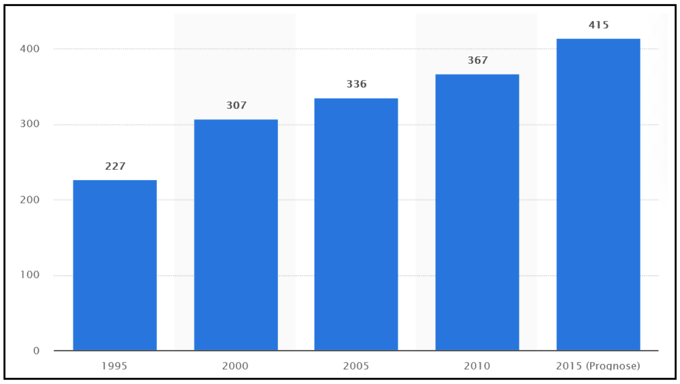

Fig. 4. Number of car models in the German marekt [12].

Therefore, we suggest using abstracted models with less details for a rather generic representation of a type of car, such as limousine, hatchback, convertible, sport utility vehicle (SUV), station wagon, etc. Such models can be assigned to several particular cars and models, even from different vendors. The geometrical details of relevant items, however, are specific for each individual model.

D. *3D Digital Rescue Sheet Database*

In 2013, the number of different models in Germany, Europe, and Asia was 5,615, 2,640, and 1,194, respectively [13].

Therefore, the interactive app of our core system is connected to a cloud database. The generic 3D model and the car-specific items are retrieved from this database on demand. This avoids daily updates of the app and ensures that the latest information is displayed at the site. As we transfer only generalized car models and a few detailed items, the is manageable even in third-generation (3G) networks.

E. *Interactive 3D Rescue Sheet App*

Our idea is to provide the recue team an interactive way to visually explore the car. The 3D models can be rotated, zoomed in and out, and all relevant items can be visible or hidden. In order to simplify the use, in particular for non-two finger touchpads, we provide several standard views, which can be selected easily by tipping the according button on the screen.

III. Extensions

There are many options to extend the core system. Basically, these are navigation, vehicle identification, deformation and injury assessment, and extended eCall with ISAN generation.

A. *Optimal Navigation*

In this module, the app automatically interprets the data and directly visualizes where to cut though the chassis. We expect the algorithms required here to be rather simple, however, in combination with the vehicle's deformation estimation (see Sec. III C), artificial intelligence will be applied.

B. *Vehicle Identification*

There are several options to identify the vehicle (Fig. 5).

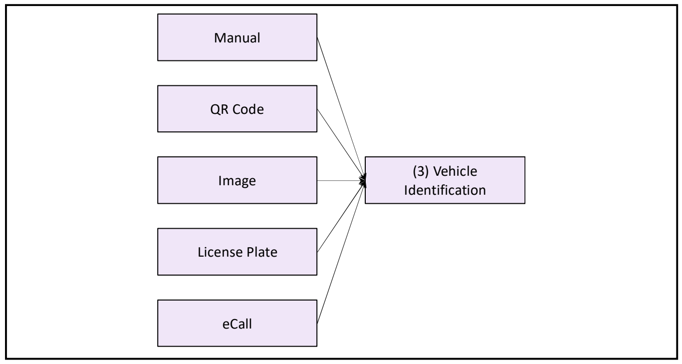

Fig. 5. Options for vehicle identification.

- *Manual*: The current manual way is by selecting the manufacturer, model, and series (model year) from drop down-lists in the Internet or in our app. This, however, is cumbersome and time consuming.
- *QR Code*: The quick response (QR) code is already in use with rescue sheets. Some car manufacturers mount the QR code on the A-pillar, others on the fuel door. As QR codes can be integrated easily into smartphone and tablet apps, this is our first extension for automatic vehicle identification.
- *Image*: Image-based vehicle identification is more advanced. Although our app can rely on the integrated camera, the cars may be heavily deformed in an accident, and prominent image features such as color do not indicate vendor or model. However, applying a trained neural network will reduce the number of options in the drop-down lists.
- *License Plate*: In cooperation with the government, access to license plate data is possible. The national road systems provider knows the car's owner, its type and model, and police usually has instant access to this data. More advanced, an image-based license plate reader can be integrated for fully automatic vehicle identification.
- *eCall*: Since 2018, every car that is newly released in the European market is equipped with eCall. If the airbags are blown, the in-vehicle system (IVS) establishes a 112-emergency voice connection. The responding human operator handles the eCall like any other emergency call. At the same time, a digital minimum set of data (MSD) message is sent over the voice call using in-band modem signals. The MSD is specified in DIN EN 15722 and includes a vehicle description that can be used directly for vehicle identification [14]. In particular, MSD codes the vehicle identification number (VIN) according to ISO 3779 [15] and indicates the country of manufacturing, the vehicle manufacturer (according to ISO 3870 [16]), the vehicle's type or division, and the vehicle's brand, body style, engine, size, and type, model, series, etc. So, if the emergency call is an eCall, the vehicle is already identified.

C. Vehicle's Deformation Estimation

The MSD also provides some information on the mechanical impulses the vehicle was exposed to [14]. However, this data is insufficient for realistic estimation of the vehicle's deformation [17]. If the CAN bus can be connected to the mobile device, more data of the vehicle's built-in sensors become available, which can be used to estimate the deformation of the vehicle more precisely [18, 19].

D. Personalized Injury Prognostics

Even more advanced, MSD and CAN bus data indicate the number, seat position, seat belt status, and other valuable information about the occupants. Bringing this information together with accident registries such as the German In-Depth Accident Study (GIDAS) [20] will allow to predict a personalized injury profile in terms of the Abbreviated Injury Scale (AIS) and the Injury Severity Score (ISS) [21].

E. General Accident Registry

As indicated in Fig. 2, all this information can be fed into a general accident registry. Such a registry would be useful for statistics and shall fulfil the WHO requirements for road safety registries [22].

F. Automatic eCall with ISAN Generation

In a final stage, our vision is to extend the vehicle's eCall towards an automatic eCall without any human in the loop [10, 23]. The vehicle needs to create the ISAN and send it to the automatic eCall receiver (responding system), which than can establish a peer-to-peer connection between the vehicle and our app. Then, all information is transferred while the rescue team is approaching the site, and the 3D visualization of the optimal navigation as well as the order of occupant rescuing already has been calculated before the team approaches the site.

IV. Results

We build a demonstrator for our core system that is composed of so far three different car models, three relevant items, and the client-server infrastructure.

A. Standardized Terminology

ISO 17840 is composed out of four parts [24]: 1. Rescue sheet for passenger cars and light commercial vehicles; 2. Rescue sheet for buses, coaches and heavy commercial vehicles; 3. Emergency response guide template, and 4. Propulsion energy identification. The European New Car Assessment Programme (EuroNCAP) provides a brief summery [25]. However, these definitions need revision for fully automatic processing without human in the loops. We need to revisit the terminology, symbols (icons) and colors for 3D visualization and beyond.

- T*erminology:* The International Classification of Diseases (ICD) in its 11th Revision has a dedicated chapter to describe injuries. It provides extension codes to document the mechanism of injury, cause, and environmental and social context [26]. It defines nine categories of unintentional (i.e., accidental) injuries, including transport injury event. For transport injury events, the codes differ road traffic, land, railway, water and air transport. The extension codes (Chapter X) further specify the dimensions of injury and external causes. We suggest incorporating WHO in the definition of recue-relevant items to define a complete set of biunique terms. According to ISO 17840-3:2015, air tanks and hydrogen tanks are visualized equally, and occupant protection systems and seatbelt pretensioner are differed, violating the required biuniqueness.
- *Symbols*: Actually, ISO 17840-4:2018 redefines the symbols for propulsion energies, which became simpler and more systematic: up to 4 symbols are placed into a rhombus: center and top position define first and second energy source, respectively, and left and right the density towards air and the stored state, respectively. Reference [25] however, presents a catalog of 96 partly quite complex symbols, which are unsuitable for interactive 3D rendering.
- *Colors*: Figure 6 illustrates the color definitions recommended for rescue sheets [24, 25]. These colors do not support transparency and hence, need revision for interactive 3D rescue sheets and beyond. We aim at developing a revised scheme involving all stakeholders such as the International Telecommunication Union (ITU).

Colour	RGB Code*	Components/functions
Yellow	RGB: 255,255,0	Low voltage electrical system/components, including SRS control unit
Orange	RGB: 255,165,0	High voltage (class B voltage) electrical system/components
Blue	RGB: 77,77,255	Occupant protection system, e.g. airbags
Purple	RGB: 152,43,143	Seat belt pretensioner
Red	RGB: 255,0,0	Surrounding colour for triggered systems e.g. airbag, gas inflator or preloaded spring actively triggered by sensor or similar
Lime green	RGB: 0,255,0	Gas, liquid, and pre-tensioned spring components
Sea green	RGB: 0,128,128	High strength zones
Grey	RGB: 127,127,127	Liquid group 1 (Diesel, Bio Diesel, …) tank/lines
Dark red	RGB: 139,0,0	Liquid group 2 (Petrol/Gasoline, Ethanol, …) tank/lines
Green	RGB: 0,176,80	Gas tank/lines (generic)
White	RGB: 255,255,255	Cryogen Gas Group (LNG, …) tank/lines
Light blue	RGB: 0,176,240	Hydrogen tank/lines
Purple	RGB: 204,0,204	Air-condition components/lines
Brown	RGB: 183,120,29	Oil tank/lines
White	RGB: 255,255,255	Air tank
**RGB colour components as expressed in terms of digital 8-bit per channel (from 0 to 255).*		

Fig. 6. ISO color coding principles [24,25].

B. 3D Vehicle Models

The European eCall MSD describes the vehicle type using five bits: currently, the first bit is unused and each following two bits describe the division (i.e., passenger vehicle, bus, truck, motorcycle) and the sub-division (i.e., compact mid-size, full-size), respectively [27]. Within these groups, we suggest to add shape descriptors for limousine, hatchback, station wagon, etc., as already mentioned in Sec. II C.

For our demonstrator, we have implemented so far compact car, limousine, and SUV (Tab. 1). However, the models need further abstraction and generalization.

TABLE I. Initial Car Models for the Proof of Concept.

Type	Vendor & Model	Number of features		
		Airbag	*Battery*	*Fuel Tank*
Compact car	Nissan Note	8	1	1
Limousine	Hyundai Elana	4	1	1
SUV	Mercedes GLK	8	2	1

C. Interactive 3D Rescue Sheet App

As a proof of concept, we have developed a mobile app to illustrate the interactive 3D rescue sheet. We used a gaming software development kit (Unity version 2020.3 personal, Unity Technology, San Francisco, USA) for the main implementation and an open source 3D model engine (Blender version: 2.92.0, Blender Foundation, Amsterdam, The Netherlands) for the 3D views. We run our app on a smart Tablet (MEDION Lifetab with Android 5, Medion, Essen, Germany).

Figure 7 illustrates the main functions of the app. After starting, the user can select vehicle manufacture and model. A query will be sent to the database. Then a matched 3D rescue sheet will be loaded and present in a default view. The user can rotate and zoom the 3D model as well as select/deselect certain components (Fig. 8).

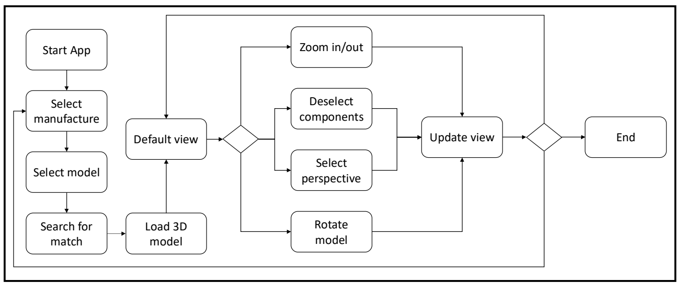

Fig. 7. Workflow implemented to the prototype app of the core system.

V. Discussion

The paper-based rescue sheets accelerated the rescue process and have been established in almost every country in the Europe Union. In the last years, ITU, ISO and others defined standards to recommend symbols, colors and terms to use by all car manufacturers. However, the paper-based sheets have several disadvantages, in particular, they haven't incorporate the emerging advances in the area of the Internet of Things (IoT). We have proposed a framework beyond the 3D digital rescue sheets and implemented a demonstrator of the core system.

However, our approach also has some limitations. Our interactive 3D app needs internet access, usually provided by cellular networks. Not only in Germany, such a network is unavailable in some countryside regions. Therefore, the paper-based systems shall be kept as fallback until a stable network connection can be ensured everywhere.

Another limitation results from our approach of abstracted 3D vehicle models. Compiling a representative set of such models needs support by the vehicle manufacturer, in particular when they shall provide the model's details to be embedded in such a generic 3D representation. However, as most manufacturer now provide paper-based rescue sheets, we hope on their support for the digital version as well.

We see the greatest advantage of our approach by integrating the eCall and the ISAN approach. In future, the vehicle will order instantaneously an appropriate rescue team (number of transport vehicles and physicians, technical equipment, etc.), and the 3D rescue sheet is available before the site is approached. In addition, the accident data can be represented with the 3D rescue sheet. We can link all accident data on the rescue chain using the ISAN.

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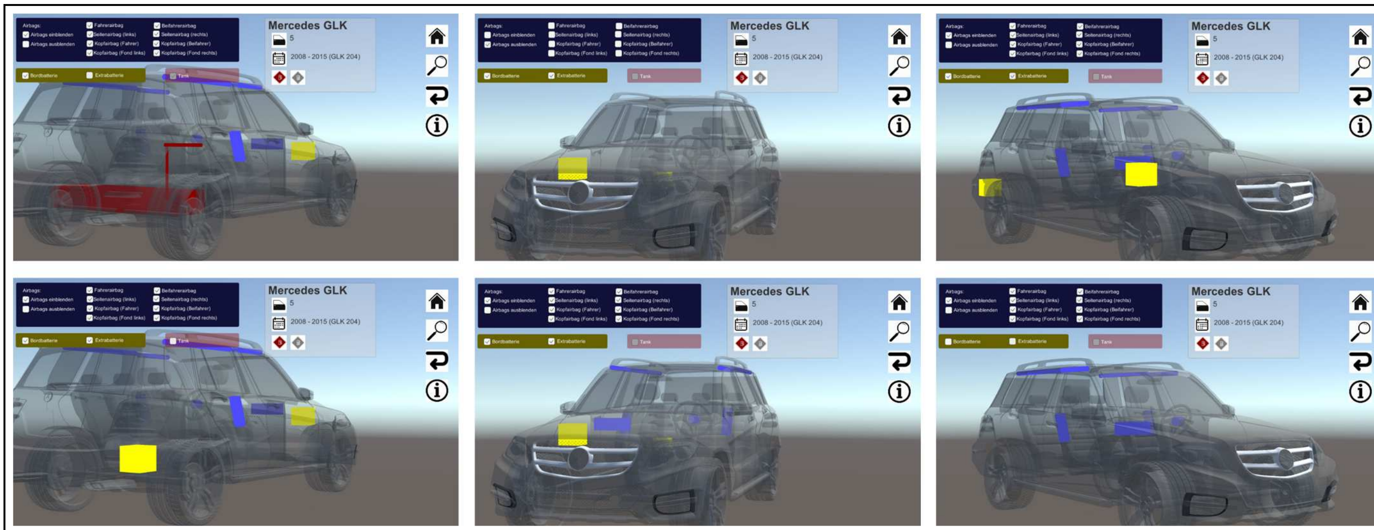

Fig. 8. Screenshots of the prototype app of the core system.

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