The Connected Vehicle and Its Impact on the Development of Electromobility

Nick G. Rambow
Corporate Strategy Development, Headquarters of Robert Bosch GmbH, Gerlingen-Schillerhoehe, Germany
ESB Business School, Reutlingen, Germany
nick.rambow@t-online.de

Kira Rambow-Hoeschele
Marketing and Sales | Automotive Strategy, Headquarters of Robert Bosch GmbH, Gerlingen-Schillerhoehe, Germany
Glasgow Caledonian University, Glasgow, UK
kira.rambow-hoeschele@de.bosch.com

***Abstract*—In the automotive industry, several disruptive technological developments are currently going on. One of them is the transformation of the car into a third living space due to a variety of connectivity features that is being developed and added to cars. Those features also foster the attractiveness of electric cars and play an important role in the development stage as an intelligent integration of them needs to be ensured.**

Keywords-connected vehicle; electric mobility; car; autonomous driving; car sharing

I. Introduction

The Internet of Things (IoT) is one of the most important technological developments in today's business world being defined as a new technological paradigm that aims to connect anything and anyone at any time and any place, giving rise to innovative new applications and services. Several studies estimate an enormous economic impact that IoT will create. Especially in the mobility sector, the IoT has the potential to create a substantial transformation.

The automotive industry is currently trying to find answers to four important technological trends: connectivity, autonomous driving, sharing and services, and electrification. Being one of the main drivers of this industry transformation, the IoT is of high importance not only for original equipment manufacturers, but for their suppliers as well.

Those new technological developments will directly affect a substantial part of society in the near future with 470 million connected cars driving on the roads until 2025 [1].

The conversion of vehicles to electromobility demands well-conceived concepts and strategies for new electrified mobility concepts. Not only is the impact of electromobility on power system infrastructure critical, but also power system design and operation need to be revised such that future electrified mobility concepts succeed. To ensure this, intelligent connectivity features need to be built in into the cars of the future.

In this paper, a variety of connectivity features is being discussed. However, as a large variance of features exists, this study focuses on human-centric IoT features, which are those features with which the customer has direct touchpoints and for which sensitive personal data is used. Examples are features with integrated face recognition, voice recognition, body screening, or in general features involving human interaction.

II. Technical and Economic Considerations

A. General

With an increasing level of connectivity standards in cars, a variety of new features that are primarily built on personal data will be available. For some features it might be useful or even necessary to have a digital identity that incorporates private information to elaborate their full potential. However, as the usage of digital identities is a highly controversial topic, it is of importance to keep it in mind when the individual feature categories are being introduced in the following.

When discussing digital identities, it is crucial to consider that high security standards need to be ensured in order to use them without major concerns. In case of a digital identity, scientists define three ways how it could be accessed in a car: first, through what we know (passwords), second, through what we have (keycards), and third, through what we are (biometric data).

As biometric scanning, including face and voice recognition, is considered one of the safest ways to identify persons, it could be used in a variety of ways in the future as it fulfills several important criteria. First, biometric data is universal as every person possesses it. Second, it is distinctive as every human is unique. Third, it is simple to use as nothing else besides the person being present is necessary [2, 3, 4].

However, even without a biometric scanning, many features will be available in the future that will be seamlessly integrated into the car. With the help of cameras and sensors inside and outside of the car, cloud platforms, artificial intelligence (AI), smartphone integration, data from social media, and many more input variables, the car will change in a way it has never changed before [5].

To cluster the large variance of human-centric connectivity features that might be introduced in the future, five feature categories are being introduced in the following: personal assistant, health, convenience, security and safety, and legal and insurance.

B. Personal Assistant

The first potential transformation that the car might undertake in the future is the conversion into a highly customized personal assistant that supports its passengers in a broad variety of situations in life. The idea is that while one is using a car, one's personal assistant is constantly learning from oneself. Every individual will have its own profile which can be infused into any car one owns, rents, shares, or drives. The assistant uses context and additional smart data from different sources such as mobile devices, social media or personal conversations and utilizes them to create recommendations to improve and facilitate the life of its users [6, 7, 8, 9].

The assistant builds up a relationship with its user through the capability of empathic thinking leading to a more and more personal experience over time. Passengers will have conversations with their cars like they have conversations with humans today. To make this feel more natural for individuals, the assistant might even adapt its voice to, for instance, the parents' voice as people feel more comfortable around a familiar voice. Through those and other conversations, the car will be able to identify and analyze the personality of its users and will try to obtain a comprehensive picture of its passengers to serve them in the most supportive way possible [10, 11, 12].

There is a variety of application fields of the personal assistant. In the following some of the most important features are introduced. First, the integration of smart home applications is a promising field. In the future, it will be possible to actively steer functions such as lighting or heating of one's house while being in the car. Moreover, the car could either recommend going shopping, as it communicates with the refrigerator realizing that certain food is missing, or it could automatically purchase the food according to one's diet plan or meal recommendations based on one's health profile. Other exemplary features are surveillance features of one's home to grant certain people access by opening the front door or to check whether all windows are closed [13, 14, 15].

Second, the field of connected navigation and location-based services opens up a variety of possibilities to facilitate the life of car users. By combining and analyzing different input variables such as calendar entries or conversations the car might recommend optimized routes. For example, when recognizing that an important phone call is scheduled while driving, the car might select a route with the best possible phone connection.

Furthermore, various services specifically developed for electric cars will be introduced to optimize the driving experience such as intelligent charging assistants. Through community-based parking, finding a parking slot will be easier in the future as algorithms will calculate the probability of free parking spaces based on current data collected by cars at the destination, calendar entries, or other location-based information.

With the help of historic data, drivers will be able to choose routes depending on a variety of variables such as number of accidents in the past or safety ratings of regions. In addition, the car might make intelligent route proposals based on individual priorities such as picking up a coffee on one's route to work in the morning or it might suggest car sharing with other people that choose an almost identical route frequently. In addition, when localizing the car, last mile deliveries to or into the car will be made possible through the help of face scans and individual access permissions for the car [16, 17, 18, 19, 20].

Third, with more and more automated driving functions being available, infotainment features will gain in importance. The assistant will make personalized recommendations for entertainment such as education, music, or films. Also, one will be informed about potentially interesting events, locations, or social activities to help optimizing one's weekday or weekend schedule based on preference and personality analysis. With an extended infotainment system, passengers might receive personalized advertisements in exchange for services and will be able to purchase goods in the car which could be picked up autonomously by the vehicle when not being occupied [21, 22, 23, 24].

C. Health

The second field of change are health features that will move into the car. With the help of cameras, infra-red sensors, microphones, wearables, and other sensors in the car, on one's body, or inside one's body the car will be able to measure and analyze health parameters of its passengers and to use them in various ways. In this context, it needs to be differentiated between current status monitoring functions that measure the health and the driving ability in the short-term and diseases monitoring functions that collect data over time to diagnose or predict potential diseases [25, 26, 27, 28].

Features included in current status monitoring are the analysis of the passengers' focus on driving, their emotional status, and their physical health status. By tracking the eyelids, head pose, iris movements, mobile phone usage, or the upper body position, the car will recognize whether its driver is focused enough on driving or one should rather have a rest before continuing the ride. Then, the car might make corresponding recommendations or might suppose to switch to autonomous driving mode.

To measure the emotional status of its passengers, the car will use input variables such as driving patterns, number of occupants, tone, content, and volume of their voices, body language, facial expressions, choice and volume of music, force of car doors being closed, social media, messages, or calendar information. Based on the analyzed mood, the car will be able to adapt music, lighting, scents, temperature, and further variables to reduce stress levels of its passengers, to energize them, or to prepare them for a better sleep after arrival. Furthermore, it might give recommendations such as calling a good friend in a state of sad emotions [29, 30, 31, 32].

To measure the current physical health status, a variety of input variables is used. Exemplary health parameters are pulse, heart rate variability, body temperature, respiration rate, apnea detection, dehydration level, blood sugar level, or blood pressure. When an emergency, such as the driver passing out or suffering an epileptic seizure, is recognized the car can automatically switch into autonomous mode or slow down the car safely to prevent an accident. The car could then drive the passenger autonomously to the next hospital while informing the hospital of its arrival, sending important patient data in advance to save precious time.

Moreover, after an accident current patient data can be sent to ambulances and doctors prior to their arrival and in case a doctor is driving on the same route he could be notified and asked for first help. Further features include the detection of alcohol-influenced behavior or fatigue measurement to give recommendations to the driver to not start driving or to take a rest [33, 34, 35, 36, 37, 38, 39, 40, 41].

In the long-term, diseases can be diagnosed or predicted with the help of algorithms and individual electronic health records that are enriched at any point in time a passenger is using the car. Thus, it will be possible to make assumptions about physical as well as psychological diseases.

Through a health cloud that is supported by machine learning, medical knowledge and data can be combined to find correlations between information that might not even be known yet. Passengers could actively ask the car for advice or they could be notified only in case of a severe threat being recognized. As a result, the car could give recommendations to improve the individual health such as optimizing the daily schedule by adding sports or changing task orders to reduce stress. Also, only passive alerts could be sent to the primary care physician to keep him informed.

Among potential physical diseases that could be recognized are diabetes, irregular heart rates, hypertension, sleep apnea, atrial fibrillation, or a heart attack. Potential psychological diseases include depression, Alzheimer, or Parkinson. The empathic car could also try to find causes for diseases such as depression and talk to the passenger to improve his current state. Whereas those are only some examples of diseases that could potentially be recognized, the number of correlations of symptoms and diseases will increase with more and more data being fed into the health cloud [42, 43, 44, 45, 46, 47, 48].

D. *Convenience*

The features of the third functional area might lead to higher convenience for passengers in the car. Through biometric scanning, the car will be able to identify its passengers enabling several features. Moreover, the car will recognize the age and gender of unknown persons and will observe the number of passenger present. Passengers with a known profile could have personalized settings for the steering wheel, the mirrors, the seat position, the infotainment, the lighting, or the room and seat temperature. The latter one might also be adapted in accordance with the passengers' calendars, their clothing or the weather at their destination.

Furthermore, biometric information could serve as a digital key to authenticate the individuals accessing the car, being especially interesting for fleet management or car sharing. Remote access via an app could be given to new drivers and a haptic key would not be needed anymore. Also, when analyzing one's biometric data, the car might give recommendations to change certain settings such as the seat position to drive more convenient. Furthermore, as the driver of the car is recognized at any time, driving style profiles will be created that can be used for recommendations by the car to change specific patterns to, for instance, drive more fuel-efficient [14, 35, 49, 50, 51, 52].

E. *Security and Safety*

The fourth field of application that might be transformed due to higher connectivity standards includes security and safety features. Through cameras inside and outside of the car, people could be identified. This could lead to less theft of cars and a quicker detection of criminals using a car. With the help of geofencing and position tracking stolen vehicles could be found, hijackings could be recognized, and parents or fleet managers might have the option to track their children's or drivers' driving behavior allowing them to oversee the car's speed, routes, driving time, or the number of passengers inside.

Moreover, any kind of financial transaction could be made safer through biometric identification inside the car. For example, this feature could be used to pay for an online purchase, to make a money transfer, or to pay for refueling the car. Furthermore, biometric identification could be used to sign contracts or other official documents digitally [53, 54, 55, 56].

F. *Legal and Insurance*

The fifth application field concerns feature linked to legal and insurance aspects. As car data could be transferred in real time at any moment, frauds could be identified and sanctioned whenever occurring. Examples for fraud detection are the recognition of over speeding, mobile phone usage, or drunk driving. As driving behaviors can be analyzed and scored considering different variables such as safety or environmental friendliness, taxation rates for cars could be adapted in accordance.

Furthermore, the analysis of driving behaviors could transform insurance models from rather static classifications into usage- or behavior-based payment models. Drivers who, for instance, drive slower and have a reduced risk of accidents need to pay lower insurance premia than drivers with riskier driving patterns. Also, due to a variety of sensors it will be easier to reconstruct accidents and to manage claims as frauds such as accidents on purpose will be revealed right away. As the car's status will be analyzed at any time and accidents or other damages will be tracked instantly, recommendations for safe routes and places could be made and insurance premia could be adapted in case of a change in usage-behavior [57, 58, 59, 60, 61].

III. Conclusion and Future Works

To conclude, the current development of connectivity features and electric cars is closely interlinked. Many features are beneficiary or even necessary for a successful introduction of electric cars to the mass market to make them more attractive for costumers. There is a large variety of connectivity features that is going to be introduced to the market. However, as many of those features require private or highly sensitive data, ethical frameworks and high cyber security standards are of importance. As this paper was primarily focused on human-centric IoT features, more research could be conducted about further connectivity features. Also, ethics and security linked to those features could be discussed.

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