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CATCHWORD

Quantified Vehicles

Novel Services for Vehicle Lifecycle Data

Alexander Stocker · Christian Kaiser · Michael Fellmann

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1 From Quantified Self to Quantified Vehicles

Three trends have shown significant impact in recent years: (1) The *Internet of Things* (Wortmann and Flüchter 2015) has become an enabler for a connected world full of smart objects equipped with sensors and supplies enormous and still rising amounts of (2) *Big Data* (Schönberger and Cukier 2013), which can be analyzed and then turned into business value in various areas, including (3) the *Quantified Self* movement as a popular example for everyday life big data analytics (Swan 2009). On a more abstract level, capturing real world events and digitizing them into machine-readable data to satisfy needs or assist humans and machines in decision making, evaluation and comparison of physical world events has become increasingly important. Even a new branch of business has emerged through such big data analytics for data-driven innovations, while information overload has wiped off its negative image and has become the beautiful bride everybody wants to dance with. Schönberger and Cukier's (2013) pragmatic book on the capacity of big data to change the world has become an international bestseller and was referenced by researchers more than 1000 times according to Google Scholar.

In line with these developments, consumer products are increasingly connected to the Internet and have become a major source of data, too. So-called smart, *connected products* (Porter and Heppelmann 2014, 2015) are capable of capturing an increasing amount of data about their product life through all kinds of embedded sensors. The archetype of a smart, connected product is the well-known, widely used, and constantly switched on smartphone. The smartphone has become an interesting hub for sensors of all kinds, and has therefore kicked off the development of new services encapsulated in mobile applications. Some of those applications promise an additional value for the smartphone user by applying algorithms for sensor data analysis if the user is willing to share the required sensor data.

In the age of computing humans have become data-generating subjects, because they consciously or unconsciously leave behind 'electronic traces' when using their computer (Wolf 2013). 'Quantified self-tracking' (later shortened to 'quantified self') is a more current term, referring to an intended collection of any data about the self that can be measured, including biological, physical, behavioral, or environmental information (Swan 2009). Quantified-selfers are a diverse group of early adopters including life hackers, data analysts, computer scientists, health enthusiasts, gamers, productivity gurus, and patients, who track many kinds of data about themselves (Choe et al. 2014). Making use of this data collected through smartphones or wearables in the private domain to learn more about one's body and leisure behavior is an emerging topic and has become a major creator of value (PWC 2016).

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Dr. A. Stocker (✉) · Dipl.-Ing. C. Kaiser
Virtual Vehicle Research Center, Inffeldgasse 21a, 8010 Graz, Austria
e-mail: Alexander.Stocker@v2c2.at

Dipl.-Ing. C. Kaiser
e-mail: Christian.Kaiser@v2c2.at

Prof. Dr. M. Fellmann
Junior Professorship of Business Information Systems, University of Rostock, Albert-Einstein-Straße 22, 18059 Rostock, Germany
e-mail: michael.fellmann@uni-rostock.de

This quantified self-movement, or in more general terms the pattern of collecting personal data via consumer devices and making sense of this data thereafter, has increasingly gained attention throughout many areas – not only in domain of quantified self-tracking services (Swan 2009). Given the fact that vehicles have turned into 'computers on wheels' (Haeberle et al. 2015) and the intimate relation between a driver and a car, it is quite obvious and straightforward to also interpret cars as customer devices. In this way, the pattern of self-tracking via customer devices adopted by the quantified-self community can be transferred to vehicles which in this sense become *Quantified Vehicles*. From this perspective, the data modern vehicles collect holds a huge potential for further exploitation and value creation. The automotive industry is still in the early beginning of leveraging this potential. Quantifying vehicles in terms of analyzing gathered data and developing innovative applications and third party services for the consumer context is currently not the state of the art in the vehicle domain, especially from the perspective of Original Equipment Manufacturers (OEMs). Although a vast amount of data for the purposes of steering, regulating and informing has already been collected, up to now this data is mainly processed to ensure vehicle functionality. Exploring novel application scenarios complementing their core mode of use is hence among the most important topics in the automotive industry. Lifecycle data generated and transmitted by vehicles may further be a part of a future connected world (Swan 2015). They will enable a wide range of application scenarios and business models and therefore have to be considered a valuable area for BISE research.

2 Current Developments: Towards Digital Ecosystems for Quantified Vehicles

The EU funded project termed AutoMat[1] and coordinated by Volkswagen kicked off in April 2015 and is one of the first approaches to establish an automotive big data marketplace for innovative cross-sectorial vehicle big data services. According to the project outline, more than 4000 signals are processed per second inside modern vehicles, and the amount of data transferred by the Controller Area Network (CAN)-Bus[2] inside a single vehicle accumulates to about 500 MB per hour. This continuously generated vehicle lifecycle data embodies a significant business potential not only for vehicle OEMs, but for all kinds of cross-sectoral industries.

However, this potential to use vehicle lifecycle data for purposes other than driving currently remains almost untapped by automotive OEMs. According to AutoMat, the automotive industry has not yet been able to successfully establish an ecosystem for Quantified Vehicle apps equivalent to that of smartphone manufacturers. In its problem statement, the AutoMat project mentions three reasons why OEMs are currently struggling:

- Brand-specific business approaches dominate, and as a consequence there is a lack of brand-independent vehicle lifecycle data.
- Current proprietary vehicle services focus on the individual customer, which results in privacy concerns, and few ideas exist how anonymized vehicle data can be used to establish other services.
- The implied or required collaboration between OEMs on vehicle data and services is considered risky in terms of competition.

Apart from this individual major research project, digital innovation in the Quantified Vehicle domain seems rather to be pushed forward by a steadily growing number of innovation-friendly start-up companies, the majority of them located in the USA. They aim to create market demand by first providing novel platforms, APIs, apps and services. Their market approaches share a few commonalities: all of them provide a basic branded hardware required for capturing vehicle data from the CAN bus and transferring it directly (via embedded 3G/4G modem) or indirectly (via the vehicle driver's smartphone) to a cloud platform. This task is usually conducted by providing a proprietary adapter connected to the standardized Vehicle On Board Diagnostic interface (OBDII standard), which is available in any modern vehicle. Some of these startups even allow third party apps and services to be built on top of vehicle data, which is not gathered by just one single vehicle but by a plethora of vehicles. In the best case, all vehicles would supply a cloud platform vendor with their lifecycle data to enable a digital ecosystem with interesting applications and services for drivers and other stakeholders similar to those ecosystems which Apple and Google have created for smartphone apps. To increase the customer value of such services, vehicle lifecycle data could eventually be enriched by data from other sources including weather data or map data. This creates synergies with the open data movement.

Applications and services provided via an established Quantified Vehicle cloud can generate value for the individual vehicle driver (e.g., assessing personal driving style and offering suggestions how to improve it), for an

[1] AutoMat: Automotive Big Data Marketplace for Innovative Cross-sectorial Vehicle Data Services: http://www.automat-project.eu (Accessed 15 Nov 2016).

[2] The Controller Area Network (CAN) bus is an International Standardization Organization (ISO) defined serial communication protocol that supports distributed real-time control and multiplexing for use within road vehicles (ISO 11898-1:2003).

organization (e.g., easing insurance contracts or supporting fleet management), or even for both, to ensure a sustainable business model. Table 1 below presents a preliminary overview of Quantified Vehicle start-ups and services obtained through desktop research (using a combination of the terms "quantified", "connected", "vehicle", "car", and "startup"). Information regarding funding was collected via crunchbase.com.

In the following, the authors abstract from concrete product and service offerings available so far (cf. Table 1) and sketch the concept of a Quantified Vehicle cloud, which could serve as a basis for novel applications and services. In order to make the concept of "Quantified Vehicles" achieve its full potential, at least four different types of stakeholders have to be considered (Fig. 1):

1. *Primary end users* (individual service consumers) are vehicle drivers who directly benefit from innovative products, visualizations, statistics, gamification aspects, and recommendations based on assessing their shared vehicle lifecycle data. Value generated on the individual level is an incentive to share personal driving data.
2. *Secondary end users* (organizational service consumers) are organizations which indirectly benefit through collected and assessed vehicle lifecycle data from multiple vehicles by consuming special services (e.g. engineering, city planning, advertising).
3. *Service providers* are organizations which provide Quantified Vehicle services for primary and secondary end users, thereby generating revenues (e.g., providing fleet management services, traffic-style dependent insurance services, vehicle maintenance prediction services).
4. The *cloud service provider* (platform provider) operates the required infrastructure for the Quantified Vehicle ecosystem and allows service providers to establish their services based on vehicle lifecycle data

Table 1 Overview of Quantified Vehicle start-ups (source: own presentation)

Company	Value proposition	Personal use	Business use	Revenue model	Funding
Automatic.com San Francisco (USA), founded 2011	Connect the car to the rest of the digital life. Empower drivers with knowledge about themselves and their cars so they can drive more safely and smartly	Connect the car to a world of apps (car problem diagnosis, fuel efficiency, location and emergency service, Web dashboard, third party apps)	Not explicitly mentioned	Light version: $49.55 for car adapter and free apps for iPhone and Android Pro version: $129.95 for car adapter, unlimited 3G syncing for 5 years, crash alert service	$24 m in 3 round from 12 investors
moj.io Vancouver (CAN) and Palo Alto (USA), founded 10/2012	Be a smarter driver. Open platform for connected cars, enables a suite of apps to empower and inform car drivers	Access to marketplace for connected car apps (location tracking, vehicle diagnostics, recalls and maintenance, driving analytics, accerlerometer), API	Aiming to launch carrier-branded car services	Not explicitly mentioned	$10.3 m in 2 rounds from 6 investors
vin.li Dallas (USA), founded 2014	Your car, your way: Brings an endless range of apps to your car, from safety over entertainment to onboard wifi	Highspeed wifi, all kinds of smart car apps and services downloaded from an own appstore. More than 40 apps and integrations. App ecosystem for the car	Not explicitly mentioned	Not explicitly mentioned	$7 m in 2 rounds from 6 investors
zendrive.com San Francisco (USA), founded 2013	Improve driving for everyone through better data and analytics: Use smartphone sensors to measure the driver's behavior	Powerful analytics using machine learning algorithms, driver and fleet analytics. Collision detection, insurance support, etc. Provider of SDK and API	Insurers, car-sharing, valet services, platform partners	Free for 1–4 drivers, $4 per driver/month for 5–249 drivers, no prices communicated for 250 + drivers (fleets, insurance partners, platform partners)	$20 m in 3 rounds from 14 investors
zubie.com Sullivans Island (USA), founded 05/2012	We make driving safer and worry-free: Connect car to the Internet to deliver real-time information to the smartphone	Driving insights, behavior alerts, leaderboard, maintenance alerts, engine diagnostics, low battery alert, roadside assistance, live map, trip tracking, motion monitor, perks, fuel finder	Solutions for insurance and car dealers, low cost fleet tracking, GPS tracking, vehicle health, driver performance	Personal use for $99.95 per year Business use starts at $17.95 per month (including $49.95 for device)	$25.87 m in 5 rounds from 8 investors

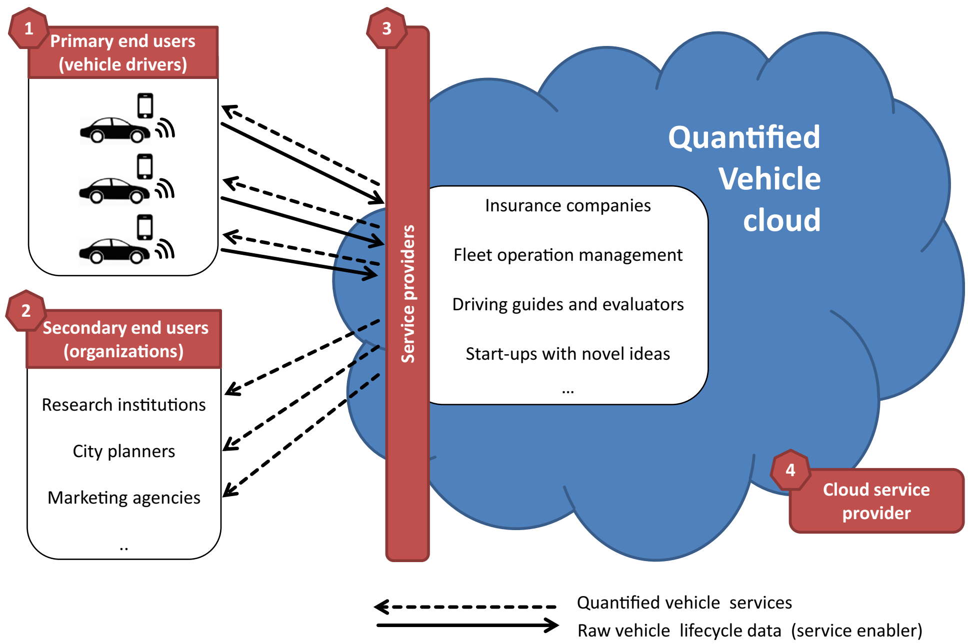

Fig. 1 A digital ecosystem for quantified cars (source: own presentation)

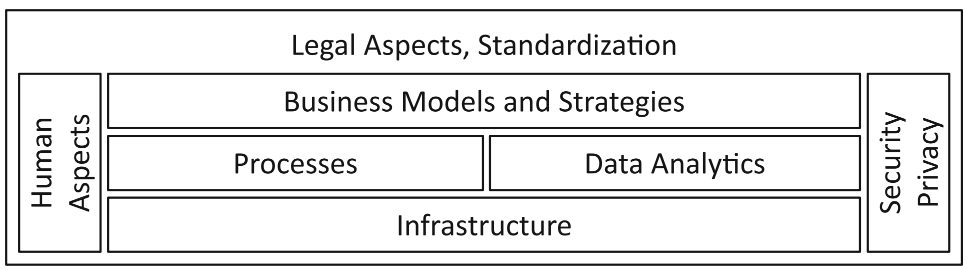

Fig. 2 A research framework for Quantified Vehicles (source: own presentation)

as well as primary and secondary end users to consume these services and share their vehicle lifecycle data in return.

3 Relevance of Quantified Vehicles for BISE Research

As an interdisciplinary subject, conducting research in the Quantified Vehicle domain requires the integration of different disciplines, ranging from vehicle enthusiasts, mechanical engineers, electrical engineers, information designers, and computer scientists. As recent advances in information technology are a core enabler for Quantified Vehicles, BISE faces a wide range of research challenges through the emergence of Quantified Vehicles, from business model design to the ideation, conceptualization and development of Quantified Vehicle apps and services.

Relevant aspects and their relations are illustrated in Fig. 2 that may serve as an initial research framework for Quantified Vehicles. Quantified Vehicles will require new infrastructures such as interfaces for sensor data and data storage capabilities. Based on this foundation, vehicle lifecycle data can be collected. With this data, new processes and new insights will emerge, which use this data in conjunction with appropriate data analytics techniques. On top of this, new business models and strategies are possible. Though Quantified Vehicles as such is a technology-driven subject, cross-cutting concerns such as human aspects (e.g., needs, intentions, expected benefits) as well as security and privacy issues cannot be neglected. Finally, the overall design space for Quantified Vehicles will be constrained by different legal aspects and by standards representing commonly agreed technologies and practices.

3.1 Infrastructure, Processes, and Data Analytics

Modern vehicles gather an enormous amount of data and information, raising manifold challenges concerning storing, securely transferring and analyzing this enormous amount of lifecycle data, which have to be solved. Moreover, problems of information integration will arise. In this regard, the integration of Quantified Vehicle data and services into existing enterprise information systems (EIS) such as Enterprise Resource Planning (ERP) systems will require novel approaches, e.g., for business analytics and visualization. To leverage the potential of vehicle lifecycle data, e.g., to improve decisions of the stakeholders, the way in which they are presented is of utmost importance. Intuitive visualizations, different point of views on the data, comparison possibilities and statistics amongst others, should be integrated into EISs alongside the administration of the vehicles itself.

3.2 Business Models and Strategies

Quantified vehicles will enable novel apps and services and cause vast opportunities for business model innovation in various fields (Cichy et al. 2014). However, the ideation, design, and evaluation process of useful and valuable services and apps as well as standardization issues of data and interfaces are a major challenge to be tackled in an interdisciplinary way, which can be supported by BISE researchers through providing appropriate methodology. Novel innovation approaches including, e.g., hackathons (Briscoe and Mulligan 2014) can provide means for quickly transforming ideas into experienceable demonstrators for Quantified Vehicle apps and for evaluating their business potential together with end users.

Vehicle lifecycle data can be used to enable a broad portfolio of value-added consumer services including vehicle diagnostics, driving dashboards, or concierge services. Novel applications and services can generate value on the level of the individual driver as the primary beneficiary (e.g., benchmark driving style and offer suggestions on how to improve it), on the level of an organization as the secondary beneficiary (e.g., traffic prediction for smart cities), and on that of the society (e.g., reduced fuel consumption or sharing approaches).

Future research is required to determine the willingness of drivers to pay for Quantified Vehicle services and apps and to identify incentives for all stakeholders to share their vehicle lifecycle data. For example, it may be the case that the benefit of other stakeholders such as vendors or insurance companies dominates the value proposition – i.e., that individual users are not willing to pay for new data collection features of vehicles. Hence it has to be investigated in how far incentives to buy a "Quantified-enabled Vehicle" via transfer payments are possible.

3.3 Human and Societal Aspects

On the level of the individual driver, quantified vehicles offer a series of new possibilities to investigate driving behavior and drivability with respect to enhancing driving style, driving safety, and security. Quantified Vehicles enable new ways to investigate driver reaction and driver emotions by using computational approaches. In this way, also pleasure of use or additional stress and distraction may be measured. Obtaining easier access to vehicle lifecycle data would encourage a larger group of researchers to use this data for better understanding driver experience and driver behavior (Wilfinger et al. 2013).

On the level of the society, it has to be investigated what the merit of Quantified Vehicles could be in terms of safety, environmental impact as well as possible dangers such as increased surveillance possibilities that create new potentials for misuse and unethical behavior.

3.4 Security, Privacy, Legal Aspects, and Standardization

Quantified Vehicle ecosystems can only be successful if a critical mass of drivers shares their driving data. Hence, privacy concerns have to be mastered to support the emergence of third party services with sufficient data to create representative statistics. If no data is shared, no value is generated. Raising awareness in the society on what kind of data vehicles generate, process, store, and potentially transmit to a vehicle manufacturer is an important task which can be supported by researchers.

The 'My Car My Data' campaign[3] started by Fédération Internationale de l'Automobile (FIA) educates car drivers about potentials and pitfalls of connectivity. One strategy is to let drivers decide about if and what data should be shared with whom to be used in what kind of third party services. This raises the question if new data protection laws are needed or if existing regulations in the IT-domain are still sufficient. The legal status of Quantified Vehicle data (e.g., in legal procedures) has to be determined, which creates cross-disciplinary research opportunities for IT-oriented researchers cooperating with legal scholars. New legal questions will emerge, e.g., whether vehicle data is trustworthy in a legal sense (as replacement for the 'driver's logbook') and can serve as basis for vehicle tax calculations.

Finally, in terms of technology, standardization may be the key to progress and may prevent competing and incompatible solutions. In this regard, it has to be investigated if current standards such as CAN and OBD that were developed in the late 1990s of the previous century are still sufficient to establish digital ecosystems for Quantified Vehicles. Researchers should look into the degree to which information services should be standardized to foster the development of Quantified Vehicle ecosystems. The W3C for instance has established an own automotive working group[4] to create Web standards for the automotive industry.

[3] MyCar MyData: http://mycarmydata.eu (Accessed 15 Nov 2016).

[4] Automotive and Web at W3C: http://www.w3.org/auto/ (Accessed 15 Nov 2016).

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