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Article

Connected Car: Quantified Self becomes Quantified Car

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Abstract: The automotive industry could be facing a situation of profound change and opportunity in the coming decades. There are a number of influencing factors such as increasing urban and aging populations, self-driving cars, 3D parts printing, energy innovation, and new models of transportation service delivery (Zipcar, Uber). The connected car means that vehicles are now part of the connected world, continuously Internet-connected, generating and transmitting data, which on the one hand can be helpfully integrated into applications, like real-time traffic alerts broadcast to smartwatches, but also raises security and privacy concerns. This paper explores the automotive connected world, and describes five killer QS (Quantified Self)-auto sensor applications that link quantified-self sensors (sensors that measure the personal biometrics of individuals like heart rate) and automotive sensors (sensors that measure driver and passenger biometrics or quantitative automotive performance metrics like speed and braking activity). The applications are fatigue detection, real-time assistance for parking and accidents, anger management and stress reduction, keyless authentication and digital identity verification, and DIY diagnostics. These kinds of applications help to demonstrate the benefit of connected world data streams in the automotive industry and beyond where, more fundamentally for human progress, the automation of both physical and now cognitive tasks is underway.

Keywords: automotive; quantified self; sensors; connected devices; big data; automation; cognitive relief; biometrics; self-driving cars; connected car

1. Introduction

The automotive industry could be facing numerous sweeping and interlinked changes in the next several decades. Not only are there many different potential changes facing the industry, but unlike most other industries, the automotive industry, while incorporating modern Internet network-enabled technology (like automation, global manufacturing, connected online inventories, worldwide supply chain, *etc.*), has not yet been forced to completely and fundamentally reinvent itself as other industries have in the last few decades (for example, publishing, music, entertainment, film, technology manufacturing, consumer electronics, financial services, health, and education). Compared to other industries, the automotive industry has taken advantage of many efficiency improvements afforded by the Internet and technology, but has largely remained in the same structure, as opposed reorganizing its whole ecosystem. There could be a reconceptualization of how the core activity is organized, coordinated, and executed. A number of factors like increasing urban and aging populations, the advent of self-driving cars, automotive 3D printing of spare parts, energy innovation, and new models of transportation service delivery could push the automotive industry into new configurations, perhaps ultimately towards futuristic concepts like that depicted in Figure 1 of an advanced biopod personal transport system.

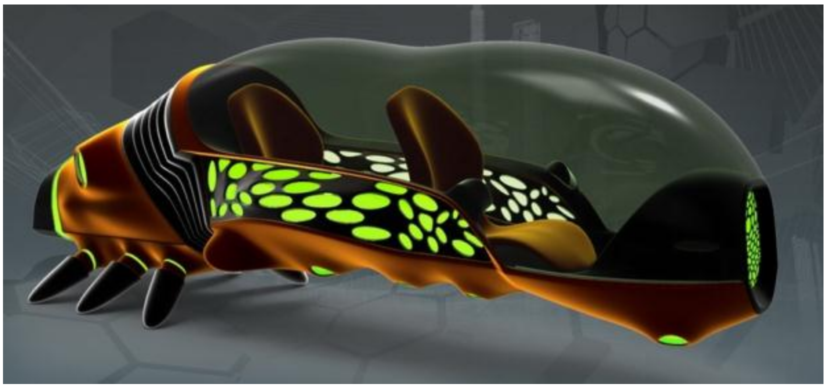

Figure 1. The BioThink Futuristic Vehicle for Mega-Cities: An image to inspire and frame the context of this paper as an open-ended contemplation of the future of personal transportation. Image credit: M. Ghezel [1,2].

Part of the reason that the automotive industry has not been so dramatically forced to modernize in new ways could be the hard-asset nature of automotive manufacturing. Whereas the advent of digital assets in the publishing, information, and entertainment businesses meant that traditional centralized providers were destabilized when any individual worldwide could tweet news, write a blog entry, snap an Instagram image, post a YouTube video or a SoundCloud music file, the automotive industry is different. The hard asset resource requirements and lack of Internet-model scalability available to the automotive industry through digital assets means that it is much harder to source the materials, parts, and knowledge to build your own car, insert it into the insurance, regulatory, and financial ecosystem, and enter the industry as an independent automotive manufacturer with the possibility of scaling such that your production could be consumed by millions and potentially take the place of traditional providers. Automobiles are still hard assets, not digital assets, so industry configuration dynamics are necessarily different, yet still open to destabilization.

1.1. Demographics: Increasing Urbanized and Aging Populations

One influencing trend is demographics. The world population continues to expand, and is estimated to grow from its current 7.1 billion (November 2014) to 9.6 billion in 2050 before leveling off [3]. Not only is the population growing but so too is urbanization; since 2008 over half of the world's population has been living in cities, and this trend is forecast to continue with over 5 billion people living in urban areas in 2030 [4]. The other major worldwide demographic trend is the aging of populations, for whom different kinds of personalized transportation solutions may be required [5]. Simultaneously, there is a worldwide increase in the total number of cars on the road, which is also expected to continue to grow, surpassing 1 billion in 2011 [6], and estimated to reach 1.7 worldwide autos in 2035 [7]. Increased urbanization and more autos on the road contribute to traffic congestion; the U.K. for example expects that traffic will increase by two fifths by 2040 [8]. Social trends and the preferences, habits, and needs of various groups and cultures are of demographic concern, for example "Generation Z/Millennials" may have different transportation services needs than do worldwide aging populations.

1.2. Self-Driving Vehicles

A second influencing trend is self-driving vehicles, vehicles with increasing autonomy and self-operation capabilities like the ability to sense the environment and navigate without human inputs. One industry analyst firm, Navigant Research, predicts that 75% of vehicles sold in 2035 will have some sort of autonomous capability [9]. The progression is from advanced driver assistance systems to semi-autonomous systems, to fully autonomous driving. The first vehicles with some degree of self-driving capability are expected to come to market by 2020, with sales volumes for autonomous vehicles thought likely to become significant by 2025. Even the notion of a car is being reconceptualized from a "dumb" conveyance to what could be a robust interactive platform. For example, technology like the space-astronaut robot Kirobo (developed by the University of Tokyo, Robo Garage, and Toyota) could provide both automated driving and interactive communication in the personal transportation systems of the future [10].

Given the high degree of legal and regulatory barriers, there is tremendous uncertainty about how self-driving technology might roll out in the automotive industry. There could be a significant reshuffling of existing partnerships and power alliances depending on which manufacturers are able to launch winning adoption technologies that reach mature levels of mainstream uptake. The dynamics by which the industry has been organized could change completely. It is also unclear how the different constituencies; automotive manufacturers, software vendors, legal and insurance providers, public municipalities, and consumer-individuals, will interrelate in the new self-driving ecosystem. From the standpoint of industry strategy, it would be important to have a large and systemic view of potential factors in transitioning to self-driving fleets. The regulatory stance of governments will also be crucial, and likewise the corresponding insurance, regulatory, licensing, and financing models. The energy selections that power self-driving vehicles could be an important determinant in industry reconfiguration, and an early indication of which may be the winning manufacturers. For example if the consumer trucking industry were to shift to self-driving vehicles using synthetically-generated algal fuel, there would be implications throughout the supply chain; for vehicle manufacturers, fuel producers and infrastructure, vehicle orchestration and maintenance, and financing, insurance, and regulation.

1.3. Transportation Service Delivery Ecosystem

A third influencing factor on the future automotive industry is the overall ecosystem for transportation service delivery. Already on-demand easy-to-use efficiency and sharing-economy transportation models like Zipcar, Uber, Lyft, Sidecar, Getaround, and LaZooz have started to shift consumer conceptualization of transportation services into a more flexible sense of multi-modal use. Simultaneously, smart city transportation ecosystems are starting to be rethought with different service delivery models such as greater real-time notification, predictive crowd-loading, and personal pod transport. One such smartcity project is envisioned for Masdar City in Abu Dhabi in the United Arab Emirates. This is a 50,000-person designed community relying on solar and other renewable energy where one element is to be an on-demand personal pod transportation network where any local destination would only be a few minutes away. The demand for personally-owned autos could decrease in a blended world of self-driving vehicles, sharing-economy vehicles, and new concepts in personal transport via public networks. Already more than half of the worldwide population lives in urban areas where it may be inefficient and undesirable to own vehicles directly. The key message is that a variety of system-level changes may start to pervasively reshape what has been a largely monolithic structure in automotive manufacturing and sale for over a hundred years (perhaps since the Ford Model T Assembly Line innovation in 1913).

1.4. Outline and Structure of this Paper

In this frame of potential wide-spread change facing the automotive industry, with consumers increasingly having high (and rapidly growing) expectations of previously offline devices syncing with their digital lives, there are a number of ways in which "killer apps" could drive automotive sensor integration forward. This paper examines the trend and potential implications of the connected car, and automotive sensor integration with the connected world. The connected world is the idea that the many different kinds of computing devices (like automotive navigation systems, tablets, TVs, *etc.*) are all continuously Internet-connected and uploading data streams to the cloud that can be integrated for any manner of application, from real-time traffic alerts broadcast to a smartwatch, for example. Some new and emblematic examples of the connected world are first the Amazon Echo [11], a voice-activated home information appliance, conceptually an always-on always-accessible Siri that could sync with the connected car to notify when it is time to leave for an appointment based on current traffic conditions. A second application is JIBO, the world's first family home robot developed by Cynthia Breazeal at MIT's Media Lab. The project was able to pre-sell 4800 units on Indiegogo for $2.3 million [12]. JIBO serves as a social robot and personal assistant, taking photos and video of family events, performing administrative tasks, and providing information, reminders, educational support, and companionship. The connected world is thus the seamless computing layer that now covers the world; the device-agnostic input-output-enabled continuously-connected data-rich computing layer that has pervasive and global reach. Specifically here, QS-auto sensor applications that link quantified-self sensors (that measure the personal biometrics of individuals like heart rate) and automotive sensors (that measure driver and passenger biometrics or quantitative automotive performance metrics like speed and braking activity) are discussed.

This work is intended as an exploration of some of the kinds of applications that connected world data flows make possible. It is a look at the development of the Connected Car concept, and at some of the features and functionality of potential integrated QS-auto sensor applications, and their future possibilities and implications, and does not support, advocate, or offer any advice or prediction as to the direction and viability of these types of solutions. The objective is to provide an overview of the nature, scope, and type of activity that is occurring in the area of QS-auto sensors, and envision its wide-ranging potential application. The account may necessarily omit, misstate, understate, or otherwise misrepresent activity in the sector, either already-launched solutions or those in development. This is a general outline and wide survey of potentiality, not a comprehensive review of existing developments. It is intended as a conceptual articulation of potential future.

This paper is structured to first introduce the automotive industry in its current context of potential dramatic change in the upcoming decades, and how the connected world of continuous computing may be interrelated. The concept of the quantified self and wearable sensors is discussed. Second, five potential killer applications of linked QS-auto sensors are presented in the areas of fatigue detection, real-time assistance for parking and accidents, anger management and stress reduction, keyless authentication and digital identity verification, and DIYdiagnostics. Third, potential limitations are considered, together with a conclusion about future possibilities and implications.

1.5. Connected World: Fifth Disruptive Computing Paradigm

One model of understanding the world is through computing paradigms, where a revolutionary new organizing paradigm has arisen in the order of one per decade (Figure 2). First, there were the mainframe and PC (personal computer) paradigms, and then the Internet revolutionized everything. Mobile and social networking has been the most recent paradigm. The current model in development is the Connected World, perhaps starting first and foremost with the Connected Car. A Connected Car is a vehicle that is equipped with Internet access, and is also usually within a wireless local area network which allows the car to receive and communicate information, and share Internet access with other devices both inside and outside the vehicle. A Connected Car made after 2010 may have an infotainment head unit, essentially an in-dashboard system with a screen from which operations can be seen or managed by the driver by touch or voice command. The types of operations that may be possible include music or audio playing, smartphone apps, navigation, roadside assistance, voice commands, contextual help and offers, parking applications, engine controls, and car diagnosis.

The Connected Car is one part of the larger Connected World of computing currently in development. Modern reality is increasingly becoming a seamlessly connected world of multi-device computing with wearables, Internet-of-Things (IOT) sensors, smartphones, tablets, laptops, quantified self-tracking devices (*i.e.*, Fitbit), personal robotics, smarthome, smartcar, and smartcity sensors often linked through big data deep-learning algorithms crunching in the background to make predictive recommendations. Connected world research firm GSMA estimates that 100% of cars will be connected to a cellular network (via embedded chips on board the vehicle) by 2025 [13]. Simultaneously, a new form of decentralized information technology, blockchains, trustless permanent cryptographic public ledgers underlying digital currencies like Bitcoin, is potentially emerging as the economic layer the web never had. Blockchains might not just be for digital currency transactions among humans, but also for the orchestration and remuneration of the machine economy, the infrastructure for explosively-growing M2M (machine-to-machine) communication, including between Connected Cars and their environments [14]. One vision for how this could work has been set forth by IBM, who calls for IOT "device democracy" using blockchains for transaction processing, business model development, and trust administration in the IOT economy [15,16].

The Connected World including the Connected Car could be the next major disruptive technology and worldwide computing paradigm, to the order of the Internet in terms of the potential for pervasively reconfiguring all of human activity as did the Web, automating mental drudgery and ushering humans into a higher level of existence. Further, the Connected World of the continuously-connected computing layer (wearables, IOT, smartcar) and the economic layer (the blockchain "Internet of Money" to manage the "Internet of Things" [17]) could be deployed and adopted much more quickly than other technology paradigms given the network effect of so many individuals already being linked worldwide through Internet and cellular network technologies.

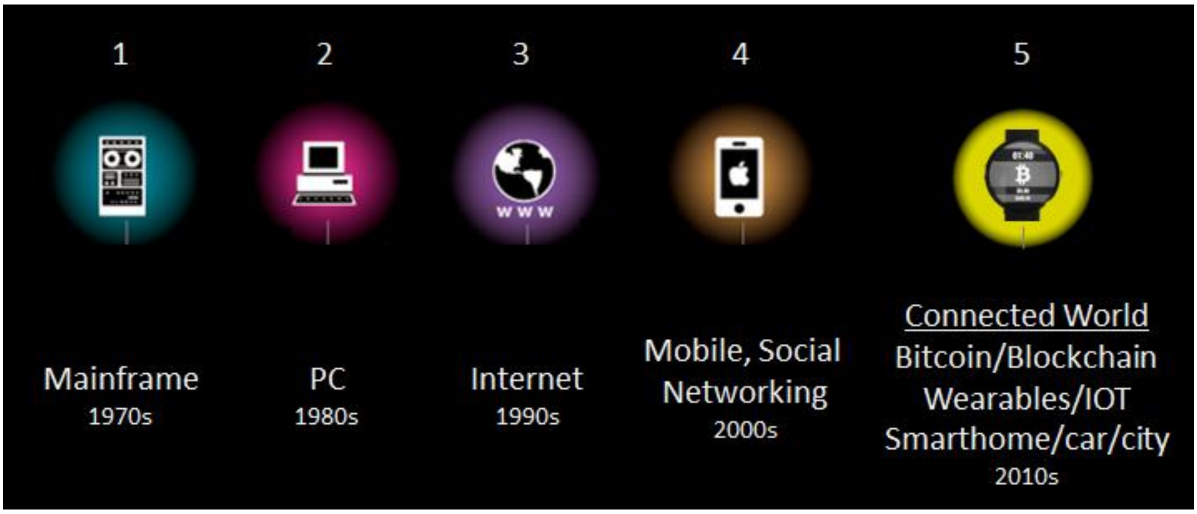

Figure 2. Disruptive Computing Paradigms: Mainframe, PC, Internet, Social-Mobile, Connected World. Expanded from O'Reilly Radar (by Mark Sigal) [18].

Just as Paradigm 4 functionality, social-mobile (*i.e.*, mobile apps for everything and sociality as a website property (liking, commenting, friending, forum participation)), has become an expected feature of technology properties, so too could Paradigm 5 functionality. Paradigm 5 functionality could be the experience of a global and continuously-connected seamless physical-world multi-device computing layer, with a blockchain technology overlay for economic transactions.

2. What is the Quantified Self

"Quantified self" means measuring data about the self. This could be personal biophysical metrics like heart rate and blood pressure, or activities like exercise and time spent playing video games; any kind of quantifiable (measurable, recordable) metric about the self, for example the wearables pictured in Figure 3. Generally then, the quantified self is a term for an individual engaged in tracking any kind of biological, physical, or behavioral data about himself or herself. Other examples include wearing a Fitbit (conceptually, a connected electronic pedometer), using bathroom Wi-Fi connected scales, and recording exercise work-outs with fitness tracking apps like MapMyRun. A key underlying assumption is that having access to these kinds of data confers the ability to take action based on this information. Many quantified self-trackers do so out of curiosity and novelty, and some have a specific goal like optimality or quality-of-life-improvements, for example seeking highly personalized interventions in areas such as cognitive alertness, productivity, depression, and sleep quality [19–23].

Figure 3. Examples of Quantified Self Devices: Withings Pulse sleep monitor and the Vital Connect Health Patch [24,25].

There is a large and growing quantified-self community with over 100 worldwide meet-up groups, and conferences and videos [26]. Participants are interested in self-knowledge through numbers and present short presentations at the meetings about their self-tracking projects answering three questions: "What did you do?" "How did you do it?" and "What did you learn?" A wide variety of areas may be tracked and analyzed, for example, weight, energy level, mood, time usage, sleep quality, health, cognitive performance, athletics, and learning strategies (Table 1). Health is an important but not exclusive focus, and objectives may range from general tracking to pathology resolution to physical and mental performance enhancement.

Table 1. Sample List of Quantified Self Tracking Categories and Variables. (Reproduced with permission from K. Augemberg [27]).

Physical activities: miles, steps, calories, repetitions, sets, METs (metabolic equivalents)
Diet: calories consumed, carbs, fat, protein, specific ingredients, glycemic index, satiety, portions, supplement doses, tastiness, cost, location
Psychological states and traits: mood, happiness, irritation, emotions, anxiety, self-esteem, depression, confidence
Mental and cognitive states and traits: IQ, alertness, focus, selective/sustained/divided attention, reaction, memory, verbal fluency, patience, creativity, reasoning, psychomotor vigilance
Environmental variables: location, architecture, weather, noise, pollution, clutter, light, season
Situational variables: context, situation, gratification of situation, time of day, day of week
Social variables: influence, trust, charisma, karma, current role/status in the group or social network

An argument can be substantiated that the quantified-self movement is mainstream as a 2013 Pew Internet study found that 7 out of 10 U.S. adults track one or more health metrics for themselves or others [28]. Gartner forecasts that the quantified-self device market (*i.e.*, Fitbit and other wearable sensors) will be $5 billion by 2016 [29]. Already in 2012, there were 40,000 smartphone health applications available [30], facilitating the 60% of U.S. adults that are tracking their weight, diet, or exercise routine, and the 33% that are monitoring other factors such as blood sugar, blood pressure, headaches, or sleep patterns [31,32]. Many individuals are also making use of health social networks; social networks specialized to the situation of health conditions, allowing users to find others with concerns like theirs, and discuss symptoms and treatments, and generally receive community support.

3. Automotive-Quantified Self Integrated Sensor Applications

3.1. Killer App #1: Fatigue Detection

The first killer app linking quantified-self and automotive sensors is fatigue detection. Fatigue is a large and potentially preventable cause of accidents. The British Royal Society for the Prevention of Accidents estimates that driver fatigue may be a contributing factor in up to 20% of road accidents and up to a quarter of fatal and serious accidents [33]. Already, several non-QS sensor solutions are standard features in modern cars, for example “lane drift” or “blind spot” alarms. A variety of QS sensors could help even more, by being worn by the driver or incorporated into the vehicle, perhaps in the seatbelt, seat, doors, steering wheel, or dashboard. Some of the early warning signs of driver fatigue are a slower heart rate and breathing rate, and posture slump. With the goal of detecting these early warning signals, Plessey Semiconductor has developed electrocardiography (ECG) sensors that can be embedded under the fabric in a car seat to record changes in electrical potential at a distance [34]. By measuring the driver’s ECG, the sensors can pick up Heart Rate Variability, which measures how stable the heart rate is from beat to beat. The sensors can then detect when a driver becomes sleepy because the heart rate slows down considerably [35]. Plessey’s latest product, developed in partnership with Nottingham Trent University, is EPIC (Electric Potential Integrated Circuits), a car seat that can monitor heart rate, breathing, and alertness to advise the driver when it is time to take a break [36] (Figure 4). Another solution is the Harken seatbelt which contains “smart fibers” woven into the material that monitor the driver’s breathing and heart rate while simultaneously canceling out the potentially confounding signal of vehicular motion [37]. Ford researchers have also developed a heart rate monitoring seat with electrode sensing technology that can check a driver’s heart activity [38].

One key innovation that has made this possible is next-generation quantified-self sensor technology. Now there are many different kinds of unobtrusive sensors that can register heart rate. This is a dramatic improvement from the previous generation of technology where electrodes had to be in direct contact with the skin to obtain an accurate reading. Respiration sensors similarly measure cardiopulmonary activity, and posture sensors such as from Lumo Back can detect and communicate driver slump. A research team at Washington State University has been focusing on car-based QS sensors, including developing a means of sensing steering wheel movement, which is more variable when drivers are drowsy [39]. When early warning signals are detected through QS body-based wearable sensors or auto-based sensors, interventions can be provided. Interventions could include verbal alerts, puffs of air, playing music, or seat vibration. The idea is using linked QS-auto sensors to help reduce accidents and unsafe driving due to driver fatigue by using fatigue prediction measures coupled with real-time intervention.

To integrate and test QS and automotive sensors together in applications that may improve driver alertness and reduce distracted driving, Toyota has developed a Driver Awareness Research Vehicle (DARV 1.5), pictured in Figure 4. The test vehicle integrates Microsoft Surface and Kinect, and Infosys biometric software to allow the driver, passengers and vehicle to work together to achieve safer driving [40]. Some of the safety features include a "driver lock-in" mechanism to track the driver's body frame and automatically enable or disable functionality based on who is interacting with the navigation panel, safe driving "scores" based on decision-making while driving, and the possibility of integrating wearable computing such as smartwatches. These QS-automotive sensor applications are supported by research indicating that real-time feedback can improve driving performance [41].

Figure 4. Toyota's DARV 1.5 and Plessey's EPIC Seat Sensors. Image credit: Toyota's Collaborative Safety Research Center [42] and the Motor Report [43].

3.2. Killer App #2: Real-Time Assistance: Parking and Accidents

3.2.1. Real-time Parking Assistance

A second killer application area for QS-auto sensors is real-time assistance, in a variety of contexts including parking and accidents. Autonomous parking technology has already been a feature for some time in modern vehicles, for example Ford's Active Park Assist that coaches the driver with a prompt of when to stop, shift into reverse, and let the system take over and park. The vehicle calculates and executes the appropriate movement trajectories, and positions the vehicle properly relative to the curb or other parking infrastructure. The steering is performed by the system, and the driver only needs to brake and shift [44]. Parking in the garage (a boon in today's tight urban parking spaces) is similarly automated: the car drives itself into the garage with ultrasonic parking sensors and cameras, and also reverses out by itself [45]. These kinds of automated parking assistance features could be a precursor to self-driving vehicles, and further autonomous operations where the driver need not be present, for example, an automated valet feature where the vehicle self-parks and self-retrieves on demand.

Regarding urban navigation and parking, up to 75% of city center congestion may be caused by drivers looking for parking. Studies of congested downtown areas conducted in 2011 found that it took on average between 3.5 and 14 min to find a curb space, and that between 8 and 74 percent of the traffic was looking for parking [46]. Parking technology has arisen as a sector, where mobile parking reservation apps attempt to facilitate driver parking. Companies like ParkWhiz and SpotHero offer real-time QR-code-based parking reservations via apps with a user-friendly mapping overlay to quickly review prices and select garages close to the destination (Figure 5). As of January 2015, the apps are available to 10–20 U.S. cities. The apps have typically been offering parking spot prices at one third to one half the cost of drive-up parking in city centers (for example, $14 all-day parking *vs.* $28 in downtown Chicago) [47]. Reservations can help reduce urban congestion, and also many city-center parking garages are now equipped with electronic sensors that track which parking spaces are available on which floors. Data from these systems could be used to develop additional functionality and connect to data flows outside the garage. For example, one application could be linking parking garages to on-board vehicle navigation systems, automatically syncing as drivers enter the garage to show and guide drivers to available spots, or even better the vehicle autonomously parking itself. This could help alleviate the cognitive load of the "last mile" problem, where the driver needs to become oriented to a new garage, watch for traffic, and think about and look for parking directly.

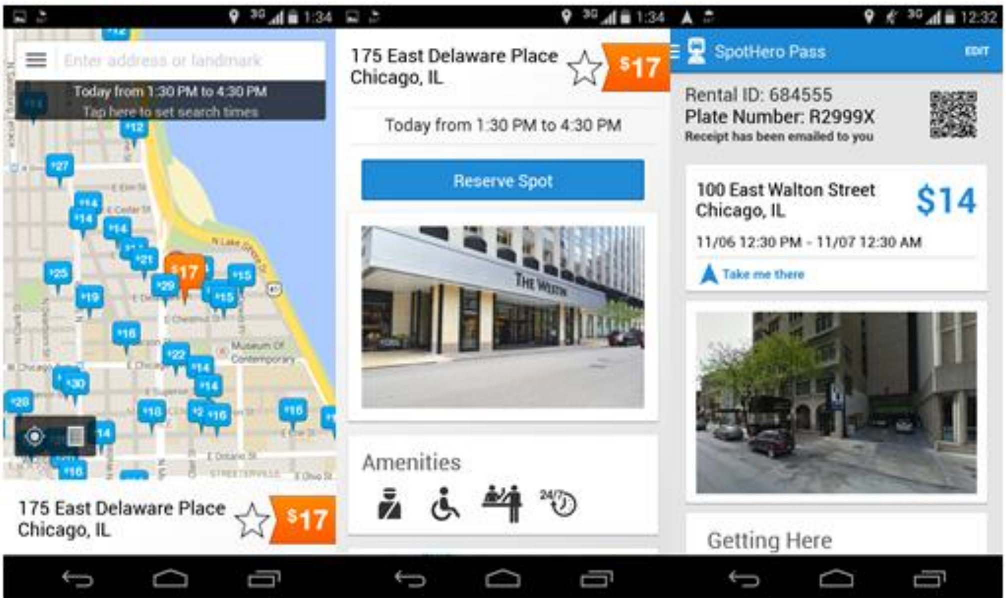

Figure 5. Real-time On-demand Parking Reservation Services: User-friendly Mobile Apps to Review, Select, and Pre-pay for Parking Spots. Image credit: SpotHero [48].

A more sophisticated application could be not just fulfilling real-time user requests for parking reservations, but taking advantage of connected data flows to be automated and predictive. A mobile app, detecting that a driver is en route to a crowded city center, could automatically send a request, generated per the driver's connected calendar, querying the garages closest to the destination address and seamlessly obtaining a reservation (especially at garages already pre-approved in the app because the driver has parked there before), then audio-alerting the driver ("You have a reservation at the Jackson Street Garage, now providing turn-by-turn guidance…").

Parking spots could be reserved and pre-paid ahead of time in other ways too. When arriving at the garage, smart parking gates could automatically recognize the car (per VIN scan or code swatch in the automotive system broadcasting the VIN data or other unique identifier) and issue a parking ticket, or the driver could present a QR code to the parking terminal from their smartwatch or mobile phone.

Companies like SureSpot are already offering these kinds of services: the SureSpot smart terminal scans pre-purchased tickets directly from smartphones, and allows users to pre-book spots via mobile app. When returning to the vehicle, drivers could be similarly guided to exits (possibly again autonomously coordinating the "first mile" as the driver is now en route to the next location (as indicated by the connected calendar or voice command, (*i.e.*, "Home")). Final parking fees could be settled with automatic exit scans, or with smart readers and QR codes; either of which could be linked to user eWallets (like Bitcoin eWallets) or credit card information. Like with Uber, consumers could be notified directly after the transaction closing of the amount and any follow-up required. Parking validation could be similarly automated, with drivers obtaining a QR code or other smart code from vendors or other validating parties.

One innovative business model in the mobile parking app industry, MonkeyParking [49], has been raising an interesting variety of social, economic, political, and regulatory concerns. Essentially, another entrant in the peer-to-peer sharing economy, the app seeks to connect drivers looking for parking with other individuals who are leaving a parking spot, or who own an available driveway. The app allows parking spot suppliers to put the spot up for auction, and whoever bids the most wins the spot. The typical space has been selling for $5–7 and MonkeyParking takes a 20 percent commission. These sharing economy businesses like Airbnb and Uber are forcing a reconsideration of regulatory issues, and so far there is some indication of newcomers successfully standing up to legal attacks from incumbents [50]. In the case of MonkeyParking, though, the firm was ordered to shut down in San Francisco in September 2014 on the grounds that auctioning public spaces was dangerous and illegal, which prompted the company to focus on other markets like Los Angeles [51].

3.2.2. Real-Time Accident Assistance

Aside from parking, navigation, and traffic management, another obvious use case for real-time assistance applications is accidents. Crash response technology is already an established application of automotive sensing, however vendors are just starting to consider the integration of QS sensors and other cloud-based data stores such as EMRs (electronic medical records). One of the largest telematics services (e.g., GPS-based) is the OnStar Automatic Crash Response system developed by General Motors in the U.S. [52]. The system automatically calls a live representative at the service center if an airbag deploys, or anyone in the car may push a button to call the service, or consumers can call the center remotely (in the case of theft). Though the GPS telematics, the vehicle's location can be queried at any time. As of November 2014, the service counted millions of customers, and was handling 185,000 calls per day, including automatically responding to nearly 5000 worldwide crashes every month [53].

In Europe, a similar system is being developed, Automatic Emergency Call (eCall), to automatically message emergency call centers in the case of a vehicle crash. The message would be in a standardized format with GPS data and other information [54]. The eCall system has been controversial and may be introduced with different levels of data collection in different countries, for example perhaps in the U.K. only allowing the eCall system to transmit the car's location at the time of the accident and not storing any residual data. On one hand, individuals are concerned about technology keeping track of their activities in Big Brother style: how fast they drive, how hard they brake, and the number and types of trips they take. On the other hand, the accident response, safety, and anti-theft value propositions of real-time car-tracking are sound, and some drivers welcome the possibility of insurers using their personal automotive tracking data to tailor premiums to their driving style.

The basic accident alert functionality of OnStar and eCall could be expanded more robustly with next-generation integrated QS-automotive sensor technology. When there is an accident, automotive crash alert systems could collect more data about the situation. On-board sensor systems could automatically assess the impact of a crash and predict human injury and property damage. In the case of medical emergency, crash alert sensor data could be used by the vehicle to automatically contact first responders, specifying the level of trauma, and contacting the appropriate center based on the magnitude of the damage (Level 1 Trauma Center is most-serious, to Level 5 least-serious). Detailed automotive sensor data could be transmitted by the automotive system directly to trauma centers, hospitals, ambulances, first responders, and law enforcement systems. The identity of the driver and any passengers could be included, and their EMRs automatically retrieved from their own health service provider networks. Given the sensitivity of user identity and health data, these kinds of automatically connected systems would need to be extremely secure and developed with different levels of privacy concern in mind. However, providing drivers with a potential savings discount in insurance costs from opting-in to such safety systems could spur widespread adoption.

For the class of accidents that do not require medical assistance, autos might be able to assess this fact immediately, and perform some basic health check confirmations on both the vehicle and the passengers. Concussion analysis and other assessment algorithms using the on-board or linked QS biometric sensors would be of obvious benefit. The health check data could be securely transmitted to the driver's health record. Another class of apps could then be invoked automatically, to the extent that the driver has pre-permissioned this, to request road-side assistance through local vendor service quotes. The automotive sensor network may know the gross class of problem(s) (*i.e.*, flat tire, dead battery) and be able to transmit this and other more detailed information (like make, model, parts numbers, detailed settings, overall configuration, last servicing information) seamlessly to vendors. The user app might offer output like "Tom from Ellis Towing (4.5 star rating) can be there in 10 min for $45—Click here to request." Service completion like payment and vendor rating could occur as the next automated steps in the app (as in the Uber model). An included side module could be "request Uber" or "call a cab" as part of real-time roadside assistance apps.

There are several existing real-time roadside assistance apps such as Verizon Roadside Assistance and AAA's My Roadside Attendant (Figure 6). Others include Tow Truck Finder, RepairPal, Auto Repair Expert, State Lines, and Gas Cubby [55]. All offer some sort of real-time ability to assess and seek assistance for accidents, service, repairs, and other automotive situations. These kinds of apps could be provided by independent third-party vendors, or white-labeled and customized for individual automotive manufacturer programs such as the Mazda Assist app [56]. Roadside assistance could be just one potential service in an overall suite of customer service applications for vehicle lifecycle management that would also include ongoing monitoring and maintenance, and purchase and sale. Loyalty programs and links to financing options could be used to finance the apps.

Figure 6. Real-time Roadside Assistance Apps. Image credit: Verizon [57] and AAA [58].

3.3. Killer App #3: Anger Management and Stress Reduction

A third killer app for linked QS-auto sensors is improving the driver's mental and emotional state, particularly for anger management and stress reduction. Wearable and auto-based QS stress sensors linked to the automotive system may be able to detect not only a driver's physical state, but also to some degree, their mental state. It may be possible to use metrics like heart rate, blood pressure, respiration, galvanic skin response, and glucose level, while also knowing that the person is in a driving context, to predict his or her mental state. It can be determined that the person is likely to be more stressed out than usual, or may be in an angry state. Even better, since intervention might be possible, QS sensors could be used to identify someone in the triggers and beginning stages of what could become an angry state ahead of time. Similar to the slate of drowsy driver interventions, a series of actions could be automatically undertaken by the automotive system to change the driver's state (and also passenger state). In this case, the objective would be alleviating anger build-up and stress. The interventions could be state-interrupting by the system asking the driver a question to break the angry state and focus the person on something else, offering breathing exercises, and playing music. Stress-management could be a dynamic ongoing process between auto and driver, for example the BMW i8 continually detects traffic en route and makes stress-reduction recommendations to the driver based on this [59].

MIT's Media Lab goes even farther in this direction, with its "empathic vehicles" project called AutoEmotive [60]. Here, sensors attempt to detect a range of driver emotions, and predictively manage the onset of motorist anger and stress [61]. Research indicates that emotion-sensing might be helpful in reducing road rage incidents [62]. Sensor technologies like a "cardiocam" (a device for heart rate monitoring plus facial-recognition and eye-tracking) are added to the inside of the car to assess the driver's state, with interventions applied as a result. AutoEmotive contemplates eventually extending the project beyond the use case of just one driver, to capture the emotional state of all drivers on the road, in multiple cities, with appropriate opt-in permissioning. These kinds of personalized tracking information could provide the means for more liveable cities, allowing communities to use "group data" to work towards collective quality of life goals [63].

3.3.1. Heart Attack Detection and Intervention

The same QS sensor metrics linked to automotive sensors for anger management and stress reduction apps could be used for another important function, detecting heart attacks. Medical emergencies are implicated in 1% of vehicle accidents, and this figure is growing as active adults drive more years, and commute distances continue to lengthen [64]. One solution is using QS-auto sensors in smart steering wheels to detect abnormal heart rhythms. Toyota has developed an ECG steering wheel to monitor the driver's heart rate [65]. With the driver's hands placed on the steering wheel, the system can detect any abnormal heart activity and automatically slow the car down to reduce the risk of a serious collision. This is a quintessential example of the comprehensive functionality of integrated QS-auto sensors together with an automated intervention. Technische Universitaet Muenchen (TUM) and BMW have similarly developed a smart steering wheel that measures the driver's vital signs [66], as shown in Figure 7.

Figure 7. Smart Steering Wheel to measure Driver Vital Signs and Smarthome Connected Lighting signals when it is "Time to Leave" for an appointment [67,68].

3.3.2. Daily Health Check

In addition to high-stakes situations like heart attack detection, another application and benefit of having linked QS-auto sensors is that this system could provide and log the results of daily health checks for the driver and passengers. The regular use of the car has the indirect benefit of keeping individuals in place physically for fixed amounts of time in a way that is conducive to registering daily health checks. Related to this idea, Lexus already has sensors that help maintain optimal vehicular temperature using infrared sensors to monitor the temperature of each occupant with the LEXUS LS600h Climate Concierge, and these kinds of sensors could provide more extensive daily health checks [69]. QS-auto sensors could measure heart rate, respiration, blood pressure, skin conductance, glucose levels, and other metrics, and send the data through the cloud to the driver's personal EMR and QS data portal.

Even the collection of a few daily health metrics could provide a baseline norm for individuals and would be an improvement over the present situation which is typically a few measures taken only rarely at doctor's office visits. As the Pew Internet study reported, seven of 10 U.S. adults are measuring some sort of health metrics daily, but it is generally a manual process. The big data era is already increasing the number of data points that are feasible to collect automatically, and this could be important in the realization of preventive medicine, beyond the Connected Car context. It is no longer just the top 10 metrics (like blood pressure, heart rate, respiration, V02max, galvanic skin response, and glucose levels) that could be the basis for assessing health quality, pathology, and intervention. Apple Health Kit, for example, automatically captures 200 health metrics via the iPhone (and maybe soon the Apple smart watch) and seamlessly uploads them to the cloud for subsequent on-demand parsing and analysis. Automated daily health checks conducted by the smart infrastructure of our daily, lives like QS wearables and the Connected Car, could greatly enhance the measurement, monitoring, and proactive management of health.

3.3.3. "Leave on Time" Stress Reduction App

One benefit of QS-auto sensor applications is that they offer a broad-based method and approach for addressing not only the most important known problems in a field like automotive safety, but also open the possibility of solving "fuzzier" systems-level problems. In the case of automotive safety, the first tier of causes may be established and straightforward, like drunk-driving, drowsy driving, or heart attack. However, the next tier of causes is not as clear cut. Distracted driving as a sub-category of automotive safety is a good example of this more qualitative kind of problem that integrated QS-auto sensors might also be used to resolve. For example, in considering the list of causal factors in distracted driving, one immediate key influence is "being late". It is clear that reducing a driver's sense of stress at knowing that he or she is late could help to promote safety. QS-auto sensors linked with other data streams could be used to develop stress-reduction solutions like a "Leave on time" app.

In the "Leave on time" app, the connected world of available data streams could be used to link an individual's online calendar with real-time traffic data and other smartcity data to deliver reminders and notifications to smartwatch, smartphone, desktop, or smarthome, for example with Philips Hue personal wireless lighting systems (Figure 7) indicating when it is "Time to Leave" for a scheduled appointment. If conditions have changed, the automatic alert system could notify that this is the case. The goal is to have the driver leaving with plenty of time per current real-time conditions to progress to an appointment with as low a level of stress as possible. The connected world QS-auto sensor infrastructure would then record if the driver actually did "leave on time," as well as the stress level during the trip. Stress reduction could be incentivized and rewarded with both health insurance and automotive insurance discounts.

3.4. Killer App #4: Keyless Authentication

A fourth killer app for QS-auto sensors is keyless authentication. Keyless authentication is one use case in the broader category of digital identity registration, verification, and confirmation [70]. With connected world QS-auto sensors (*i.e.*, that are continuously Internet-connected), any variety of applications requiring real-time confirmation could be possible. Even without continuously-connected apps and hardware, secure pre-approval for certain actions could be obtained. For example, a customer could be automatically recognized when arriving at a car rental lot, and his or her pre-booked rental agreement synced in an app that then grants access to the rental car. This could mean that nearly all renters could proceed directly to cars, instead of waiting at the counter. Loyalty program-based car pick-up could also be quicker and be more secure. Likewise QS-auto sensors could also automatically detect and process rental car returns, *sans* human agent, or with a human agent being on hand only for exception cases. Similarly, when a guest walks into a hotel, the hotel app should know that he or she has arrived, automatically register the guest, and send a QR code to the smartphone for guest room access during the stay (which could also be coordinated with automatic Internet privileges, minibar access, fitness center and business center entry, and payment tabs at the bar, pool, and restaurants). Automated check-out could be an enhanced version of already fairly streamlined check-out processes.

From a more detailed technical perspective, keyless authentication systems could be used for automated car rental, especially for one-time or short-term access. This kind of vehicle access could be via Bluetooth, QR code, Bitcoin blockchain technology (with robust digital identity confirmation services such as Onename, BitID, or Bithandle), and/or smartwatch fingerprint readers for an added layer of verification. The driver's smartphone, smartwatch, or smartring [71] could communicate with the auto's hardware via Wi-Fi, Bluetooth, NFC, or other short-range point-to-point communications protocol. Vehicle hardware could consist of a door-unlocking system connected to the user hardware, possibly with a dashboard-based smartcard or windshield-based electronic sticker with signal-reading capability. One already-launched solution for keyless authentication (Figure 8) is the Bluetooth-based Getaround Connect (Getaround, the sharing economy peer-to-peer car rental company, like "AirBnB for cars"). Now with the recent Bluetooth Low Energy (BLE) consuming less battery power, Bluetooth can be continuously or propitiously enabled on smartphones and smartwatches. This could lead to improved security and ease as drivers walk directly to accessing their vehicles at night and in inclement weather without having to fumble for keys. Like other modern Connected Car facilitation services, registering vehicles for keyless authentication would likely include their being listed in a cloud-based registry, and automatically enabled for other functionality such as real-time GPS tracking.

Figure 8. Keyless Authentication and Vehicle Access. Image credit: Getaround [72].

3.4.1. Vehicles as Smart Property Transacted on the Blockchain with Smart Contracts

Extending the basic concept of keyless authentication is *smart property*: the more advanced idea of using blockchain technology for the registry and exchange of all physical-world assets like homes and vehicles. The decentralized open ledger (the blockchain) could be used to register not just digital currency and financial markets transactions like stock sales, but the transaction of every asset class and type. Property could be physical-world hard assets like a home, car, bicycle, or computer; intangible assets like a stock shares, copyrights, or reservations; or digitally-created assets like software and graphic design images [73]. Whatever the asset, it could be registered in a blockchain with a unique signifier, such that its ownership could be controlled by whomever controlled the private key to that asset. For vehicles, the VIN number could be encoded into the blockchain transaction that registers it, creating a unique private key and registration transaction tied to that VIN number, and thus enabling asset confirmation and control. Blockchains could be an inventorying and control mechanism throughout the supply chain. As autos are manufactured, their VIN numbers could be registered into blockchains, with the private key transferring from manufacturer to bank or finance company to owner to subsequent owner, and so on, in this universal custody chain format.

Once registered, an asset can be sold by transferring the private key to another party, possibly using blockchain-based smart contracts as part of a larger transaction. For example, a pre-established smart contract could automatically administer monthly loan payments, and transfer the ownership of a vehicle title from the financing company to the individual owner when all payments have been made. Similarly, interest rates in financing agreements could reset automatically per a separate blockchain-based smart contract checking a pre-specified website or data element (called an oracle) for obtaining the interest rate on certain future days.

The general key idea of smart property is controlling asset ownership and access by having it registered as a digital asset on the blockchain and controlling access to the private key. In some cases, the functionality could be even more specific as physical-world hard assets could be controlled quite literally in real-time with the blockchain. How this could work is that the doors of physical property like vehicles and homes could be "smart-matter" enabled by embedding technology like software code, sensors, QR codes, NFC tags, iBeacons, Wi-Fi access, *etc.* so that the property could be controlled in real-time as a user seeking to access the property would present their own hardware or software token to match with the one on the asset. One access confirmation method could be with pre-configured access tokens good for a fixed time. Another more secure method could be the user submitting a real-time access request, which would trigger the blockchain-based smart contract to confirm the requester's identity, and send back an acknowledgment or token access mechanism to the physical asset, such as an eWallet token or one-use QR code to open a rental car door or hotel room door. Blockchain technology offers the ability to reinvent identity authentication and secure access in ways that are much more granular, safe, and flexible, and oriented to real-time demand. The blockchain is an elegant integration of physical-world hardware technologies with digital Internet-based software technologies [74].

Registering vehicles as blockchain-based smart property, for asset inventorying and transfer, and real-time authenticated access on demand, could be an improved way of implementing current mechanisms of keyless entry. Rental companies like Zipcar and Getaround allow keyless access, as do automobile vendors like BMW, Volvo and Tesla. At present, keyless authentications services where the driver can use mobile phone apps to unlock and start vehicles with the swipe of a finger have fallen vulnerable to thieves easily rewiring the relevant on-board microchips and stealing the car [75], however a real-time outcall to the blockchain to confirm authorization could possibly make keyless access much more robust and secure.

3.5. Killer App #5: DIYdiagnostics and DIYmaintenance with CarChip and Automatic

The fifth killer app for QS-auto sensors is DIYdiagnostics. Just like consumers having access to their own biometric and genomic data with mobile apps and services like 23 and Me has helped to facilitate a DIYhealth and DIYgenomics revolution, consumer-users having access to their car's automotive data could spur a wave of DIYdiagnostics and improved DIYmaintenance. Data access and Internet network models have allowed many industries to become DIY (do-it-yourself) as consumers have access to data to explore on their own and take empowered action as a result. Some of the first industries where the Internet enabled action-taking by individuals were stock-trading, financial management, and mortgages in the 1990s. The availability of the underlying information, and websites presenting it, meant that consumers no longer had to rely exclusively on stock brokers and mortgage brokers. In the 2000s, a wave of DIYscience efforts emerged in graduated tiers of consumer engagement. At a low level of engagement, network models meant that individuals could contribute their spare computing cycles to distributed community computing projects like SETI@home and Folding@home. Participating with their own free time, citizen scientists could engage at a slightly higher level in image identification, and data collection and analysis tasks for scientific projects, such as Galaxy Zoo and the National Audubon Society Christmas Bird Count. At an even more sophisticated tier, citizen-scientist amateurs compete to develop computing and analysis models for core science problems directly, such as protein and RNA folding. The main platforms for these challenges are Fold.it and eteRNA, which counted a work force of 37,000 citizen science participants in 2013 [76].

The ongoing trend and model of consumer-users having access to data, especially about their own activities, is an open opportunity that could be developed more fully in the automotive industry. The idea is "Quantified Self" becomes "Quantified Car," and more so, that data streams from the two activities might be integrated. Some DIYdiagnostics solutions for accessing and analyzing automotive data are starting to be available such as the CarChip Connect (USD $99) and the Automatic Link (USD $99.95) featured in Figure 9. The CarChip Connect is an engine performance and driving monitor that and reads and stores data from the car's on-board computers such as trip details, engine parameters, and gas mileage. The hardware module plugs into the dashboard, and data is retrievable by USB cable [77] The Automatic Link plugs into the same on-board data port, and beams the car computer data seamlessly to an iPhone app via Bluetooth [78,79].

Figure 9. DIYdiagnostics: CarChip Connect and Automatic Link. Image credit: Davis Instruments [77] and Automatic [78].

Just like mobile apps have made DIYhealth and DIYscience easy and fun, these kinds of "QS car chips" could link on-board diagnostic data to consumer apps for information, fun, gamified competition, and pro-active preventive maintenance. A customer-vendor relationship management process could be put in place for ongoing linkage between dealers and owners. Consumers could login to see their vehicle page with maintenance records, suggested and scheduled maintenance, and valuation information (for example linked to vehicle lifecycle planning about upgrading, reselling, upselling, *etc.*). The vehicle management app could extend to a mobile app with a module for maintenance planning, booking, cost estimates, *etc.*; and a road-side assistance module (possibly a white-labeled generic road-side assistance app), and a diagnostics module. The owner's car diagnostics chips could send data to the cloud or directly to the mobile app, and be aggregated into early warnings and planned (and possibly automatically booked) maintenance appointments. Gas consumption by station analysis could be a metric of interest to consumer-users allowing them to "QS" (*i.e.*, analyze) which gas from which gas stations resulted in better engine performance and mileage. Gas mileage analysis is a general metric-of-interest to automotive QS'ers, and all manner of data related to car engine performance, and tire and brake safety.

Auto QS apps could be useful for both hardcore quantifiers and the general user. For the average consumer, a mobile automotive app could be helpful in sending asynchronous reminders (*i.e.*, later when the individual is not driving). The car could tweet the user more granular detail about performance, mileage, gas-purchasing or charging-station recommendations (per calendar integration), immediate required maintenance, and more gradual projected maintenance over time, including the estimated costs, and the risks and higher costs associated with delayed maintenance. Seasonal recommendations could be sent to check tire wear and pressure, coordinating user schedule openings and preferences with those of vendors. DIYdiagnostics, service planning, resale value, and road-side assistance could be just some of the potential modules in an overall vehicle monitoring and maintenance app suite (Figure 10). The result of DIYdiagnostics could be pro-active cost-savings and empowerment for vehicle owners; the data-supported ability to take action for preventive maintenance and vehicle safety. Special-purpose diagnostic chips like the CarChip Connect and Automatic Link could be used, or possibly any general-purpose wireless microcontroller for web-enabled DIY projects, like Arduino, Raspberry Pi, Electric Imp, or Pinoccio [80] boards.

Figure 10. Vehicle Monitoring Apps. Image credit: PLX Devices [81].

4. Limitations

There are many types and forms of limitations in considering the Connected Car, which is essentially a specialized form of the more general situation of the Connected World, a universal continuously-connected world of personal activity data flows. There are all of the usual concerns related to political agendas, regulation, economics and business cases, social equity (equitable access to new technologies), technology adoption, and logistics. However, perhaps the biggest worry to elaborate further here as it is a newer one that is less covered is data privacy and security. A fully-connected world could be scary at a completely new level. The current big data era is already uncomfortable (with examples like consumers receiving diaper coupons before knowing that they were pregnant), but a continuously-connected world could be even more disconcerting, for example, by predicting what you will do before you do it (e.g., a vendor automatically delivers your lunch without your having consciously thought about it). This could be quite possible, and is an obvious implication and capability of connected data flows linked with machine learning and predictive modeling. There could be another order of resolution of more information known about all persons, where it becomes completely impossible from a practical perspective to remain anonymous in any situation. On one hand, this is potentially uncomfortable and detrimental. On the other hand, there is tremendous possible benefit from these new capabilities for services that could possibly make our lives easier and more fulfilling, as technology and information provide a new sort of "fourth person perspective" of ourselves and our activities [82].

The key to moving forward could be in developing new sensibilities and maturing as a society, creating systems of check-and-balances for the effective mutual interaction of humans and information. Right now as individuals we can feel powerless as institutions seem to be in control of our data. We need counterbalances that introduce appropriate structures for personal data rights, and privacy and security. One important shift proposed by data scholars and activists is a move to user-owned and controlled data rather than institutionally-owned and controlled data [83]. External institutional parties own and control our personal financial data and health data at present, and could similarly own and control Connected Car data. Secure and permissioned control over personal data by consumer-owner individuals might be realized through decentralized models like blockchain technology, public data commons, personal data rights agencies, and other advocacy models.

5. Conclusions

Overall, the automotive industry could be facing a situation of profound change and opportunity, including how it might interrelate with the connected world of ubiquitous computing. This paper attempts to examine the development of the Connected Car concept, and some of the features and functionality of potential integrated QS-auto sensor applications. Application ideas are presented that link quantified-self sensors and automotive sensors to help envision how the connected car and the automotive industry may evolve in concert with the connected world ecosystem. The potential killer apps for QS-automotive sensor integration are fatigue detection, real-time assistance for parking and accidents, anger management and stress reduction, keyless authentication and digital identity verification, and DIYdiagnostics.

The importance and value of integrating multiple data streams becomes clear through this discussion of killer apps in the context of linked QS-auto sensors. Different applications require different data streams, and they can all be linked. User quantified-self biometric data, automotive sensor data, smartcity data, vendor network links, and community or group data are just some of the many connected world data streams that may be integrated in the applications of the future. The connected world paradigm is thus strengthened, where the key theme is the ability to link any and all data streams together on-demand. The core functionality is not just a QS sensor and an automotive sensor together, but these plus smartcity traffic data and parking garage data, and online calendar and contacts as elements in a higher-level application. This means that a new class of complex solutions could be developed to more adequately respond to fuzzy systems-level real-life problems. There is tremendous sophistication and intricacy involved behind the scenes in being able to automatically play music to combat driver drowsiness. Integrated connected world data stream applications thus could enable a completely new tier of human activity and quality of life.

One obvious effect of connected world integrated data streams could be a more efficient world: the less-costly more effective use of human, natural, and computing resources. Another higher-level effect is the possibility of automating more operations. In our human dealings with the world, more interactions could be made seamless, and taken out of cognitive purview [84]. This continues the trend of technology's purpose of making life easier, not just in mechanical tasks (as we previously understood the role of technology), but now importantly in cognitive tasks too (as we are now starting to conceive of technology's use). The level of where we are operating now with technology concerns the ability to automate lower-level cognitive tasks, like planning and coordination, which the Connected Car can greatly facilitate. Conceiving of automation in this new way (as both mechanical task relief and cognitive processing offload) suggests that we might shift the whole way we conceptualize and interact with the world.

A second more concrete way that we might shift the whole way that we interact with the world—per integrated connected world data flows, big data machine learning, and predictive modeling—is moving from a mode of reactive response to one of predictive action. Previously, the only mode of action was reactive, reacting after the fact when information became available. Instead now there is the increasing possibility of responding to data in real-time, and requesting additional needed real-time data on demand, and also, not just reacting better in the present, but developing predictive action plans for the future. A mature moment in the big data era in the future could be that all known processes are predictively modeled. This could include all human biological and social organizational processes (traffic, fuel consumption), and natural processes (weather, planetary systems, *etc.*). Even now, the way that we interact with the world is becoming increasingly predictive, with continuous updates to real-time situations. Behind the scenes, big data operations could start to be parsed with increasing frequency into the level of human-consumable information and recommendations, and delivered seamlessly to mobile apps, wearables, and the Connected Car ecosystem. These possibilities of cognitive relief and predictive action-taking help to demonstrate the potential future benefits of the Connected World where integrated QS-auto sensor applications are but one first step.

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Conflicts of Interest

The author declares no conflict of interest.

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Appendix: Summary of Top Five Killer Quantified Self-Automotive Sensor Applications

A. Fatigue Detection

Fatigue is implicated in 20% of accidents. Early warning signs are a slower driver heart rate and breathing rate, and posture slump. These could be detected through wearable sensors or auto-based sensors, and an intervention provided (verbal alert, seat vibration, music, or puff of air).

B. Real-Time Parking and Assistance

Up to 75% of city center congestion may be caused by drivers looking for parking. Parking garage data could be connected to on-board navigation systems to show and guide drivers to available spots, and further reserve and pre-pay for spots where a user presents a QR code on a smartwatch or smartphone to a smart parking gate like from SureSpot to obtain the parking ticket.

A related idea is real-time automatic road-side assistance, where automotive sensors would assess crash impact and predict damage. Then as required, the vehicle could alert local trauma centers (tier 1–5) and first responders. If the accident is less serious, if the driver has permissioned such a service, an app could automatically request local vendor service quotes.

C. Anger Management and Stress Reduction

Anger reduction is the most obvious area for improvement where most simply the driver's mental state could be read from sensors and interventions provided such as breathing exercises, music, and question-based (re-focusing) intervention.

Smart steering wheels with heart sensors could be used to detect heart attacks. Medical emergencies are implicated in 1% of accidents, and this number is growing with active adults driving longer, and commute distances lengthening.

Wearable or auto-based sensors could provide a daily health check that is completely transparent to the driver measuring heart rate, respiration, blood pressure, skin conductance, and glucose levels, and sent through the cloud to the driver's personal EMR or QS data portal.

Addressing stress as a complex adaptive system, multiple data streams could be integrated into a "leave on time" app since a key stressor in distracted driving is being late. An individual's online calendar could be connected with real-time traffic data so smartoffice, smarthome, or smartwatch alerts could communicate to leave earlier for an appointment. It could also be confirmed if the driver did in fact leaver earlier for the appointment, and the level of drive-time stress. Financial incentives could be offered for both health and automotive insurance discounts for reduced stress and smart driving.

D. Keyless Authentication

Keyless authentication could facilitate one-time or short-term access, for example for automated car rental. Vehicle authentication and access could be via Bluetooth, QR code, blockchain technologies, and/or smartwatch fingerprint readers for an added layer of validation. These methods could be a more secure improvement to current keyless access methods.

E. DIYdiagnostics

DIYdiagnostics accessed with tools like the CarChip Connect and Automatic Link could be a killer app. Just like having access to data helped to galvanize DIYscience and DIYhealth, similar data access could be welcomed by drivers. On-board diagnostic data could be collected and linked to user-friendly consumer apps for pro-active notification and preventive maintenance. Asynchronous reminders (later while the driver is relaxing at home) could consist of the vehicle tweeting the driver detail about its condition and potential maintenance, including the projected cost per different future time points if the maintenance is delayed.