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Andreas Riener, Myounghoon Jeon and Alois Ferscha

## 17 Human-Car Confluence: “Socially-Inspired Driving Mechanisms”

**Abstract:** With self-driving vehicles announced for the 2020s, today’s challenges in Intelligent Transportation Systems (ITS) lie in problems related to negotiation and decision making in (spontaneously formed) car collectives. Due to the close coupling and interconnectedness of the involved driver-vehicle entities, effects on the local level induced by cognitive capacities, behavioral patterns, and the social context of drivers, would directly cause changes on the macro scale. To illustrate, a driver’s fatigue or emotion can influence a local driver-vehicle feedback loop, which is directly translated into his or her driving style, and, in turn, can affect driving styles of all nearby drivers. These transitional, yet collective driver state and driving style changes raise global traffic phenomena like jams, collective aggressiveness, etc. To allow harmonic coexistence of autonomous and self-driven vehicles, we investigate in this chapter the effects of socially-inspired driving and discuss the potential and beneficial effects its application should have on collective traffic.

**Keywords:** Socially-behaving Vehicles, Collective Driving Mechanisms, Driver-vehicle Confluence, Social Actions

### 17.1 Introduction

Motivated by the expected need for solutions to solve problems related to the coexistence of autonomous and manual-driven cars, this chapter aims at discussing the vision of driver-vehicle symbiosis and its potential applications such as collective information sharing, ride negotiation, traffic flow and safety improvements, etc. Critical variables such as driving performance and workload are the motivational forces to include human factors in future information and communication technologies to reflect the singularity of a user. This calls for an interdisciplinary approach and this chapter tries to outline how this could be implemented.

After a brief review of the psychological view about the driver-car relationship and its transition in Section 2, the rest of this chapter discusses the status quo of social aspects of driving and proposes how socially acting vehicles and socially-inspired traffic can contribute to road traffic to make it safer, more efficient, and more convenient. Section 3 describes driver-car entanglement (i.e., the relationship between individual drivers and ITS or ETS) and Section 4 delineates social traffic and collective, adaptive systems (i.e., the relationship between a driver and another driver, and the higher network relationship among drivers, cars, and infrastructure). Also in Section

4, a sample scenario of the symbiosis between drivers using a collective awareness system is provided, followed by a conclusion with a future outlook in Section 5.

## 17.2 Psychology of Driving and Car Use

So far, vehicles have been ignorant of (or not able to be aware of) social aspects; it has been mainly the individual drivers with their desires, intentions, preferences, or usage patterns that are responsible for unpredictable social behaviors and, thus, need to be represented by a driver-vehicle related research model (Ferscha & Riener, 2009). With regard to sustainability, it is important to mention that the willingness to reduce traveling by car or to change over to alternative modes of transport highly depends on the social status and attitude of a person. In other words, altruistic population groups are more willing to change usage behavior as opposed to egoistic, anti social persons (Gatersleben, 2012). The awareness of the first group that their car use causes environmental problems seems to induce guilt, which leads to a sense of obligation to use, for example, a more environmentally friendly means of transportation (Bamberg, Hunecke, & Blöbaum, 2007). This social awareness seems to be absent or just ignored in the second group.

### 17.2.1 From Car Ownership to Car Sharing

First, even though a car does not express anything for itself, many individuals feel that their car has a strong symbolic appeal (Joshi & Rao, 2013). The type of car one drives could be an indication of the person's personality and the decision for buying a car is often made by the social value ('status symbol') of the new car. There is evidence that "cool cars" reinforce the self-confidence of drivers and a recent study shows that females find males driving a luxury car more attractive than those driving a compact car (Dunne2010). The social value of vehicles is also represented in the latest sales figures in 2013: US car makers established a new sales record of (heavy) pick-up trucks and German premium brands Audi and Porsche also set new sales records (Zeit Online, 2013). On the other side, this might also be a warning bell to make people rethink if it really makes sense to use a fuel wasting truck for commuting, in particular with confirmed car occupancy rates (in Europe and US) of 1–1.5 persons/car (European Environment Agency (EEA), 2010). Moreover, the relationship drivers currently have with their cars has to be reconsidered, as in the long term they will most likely have to give up to reflect their status symbol by their car due to economical, ecological, or other reasons.

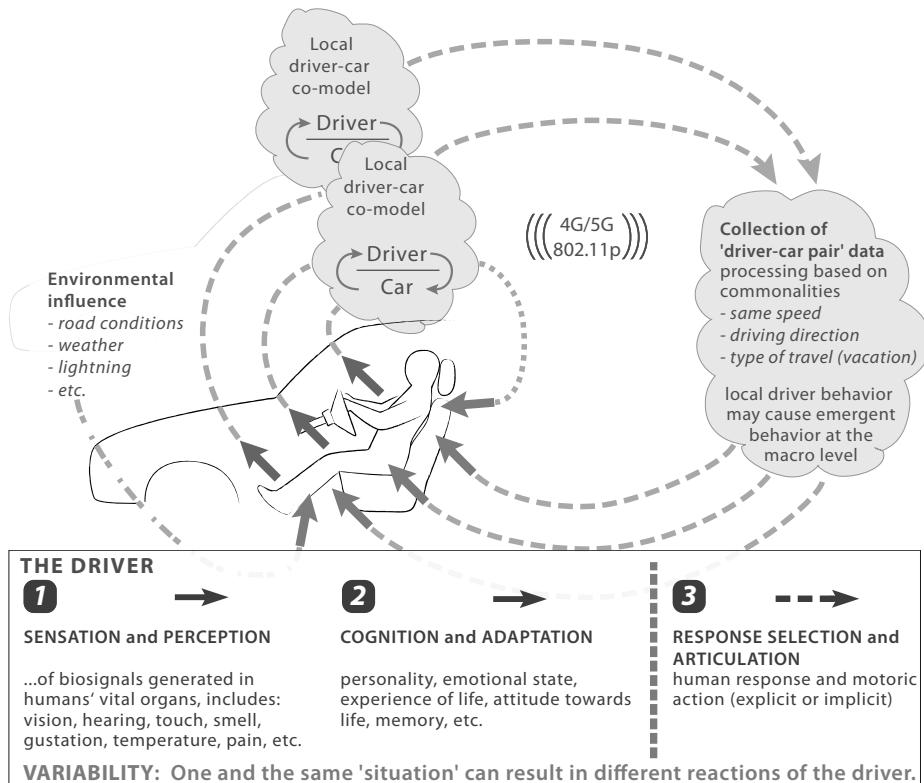
Two trends are foreseeable. First, self-driving vehicles will emerge on the road and in that case fewer people will (have to) own a private car. However, according to a recent study by the carmaker Ford (Falk & Mundolf, 2013), 7 out of 10 people aged 35

or below would like to use technology and social services to adopt the car to their life style and 58% of the same group would like to precisely configure the “look & feel” of their car – customization will be the success criteria. Second, rural depopulation will result in more and more people living in the cities, and as a consequence most of the trips will be short distance. Nowadays, about 40% of British people already state that they can use the bike, bus, or walk for many journeys instead of riding a car (Gatersleben, 2012).

Fortunately, a turnaround in vehicle use and value are noticeable today. A series of studies still confirm that a considerable number of young drivers insist that their own cars express their personality (plus Marktforschung, 2011), but recent statistics show that lot of people from this group do not have an emotional relationship with their car any more. Asked about what personal things are the most important ones, the Smarthpone, an own apartment and a (mountain) bike are top-ranked while the former ‘status symbol’ car has in the past 10 years lost much ground (Schulz-Braunschmidt, 2012). In addition, more and more young people do not even own a driving license – between 2000 and 2008 the rate of German driving license holders (age group 18 to 26) decreased from 90.5% to 75.5%, and further decreased between 2007 and 2010 by more than 10 percent (Grass, 2011). (E-)bikes and public transport are the preferred way of travelling around (Bratzel, 2011). This could be seen as an ideal prerequisite to improve the future of mobility using “connected technology” to provide sustainable car-rental, -sharing, -pooling services and optimization services for inter-modal transport.

### 17.2.2 Intelligent Services to Support the Next Generation Traffic

Self-owning and individual use of vehicles will likely be increasingly replaced by intelligently organized mobility services that are easy to use and provide intuitive user interfaces. The shift in values requires sophisticated cooperation strategies between all traffic participants, communication technologies, and road infrastructure to fulfil all the diverse transportation requirements with a different means of transportation. Therefore, the next generation of Intelligent Transportation Systems (ITS) is challenged by the complex interactions of technological advancements and the social nature of individuals using these technologies. Traffic in the future will not be determined by individual drivers’ selfish desires and intentions, but by the negotiation between the collection of cars and utilization requests of drivers (Figure 17.1). According to a recent study (Kalmbach, Bernhart, Kleimann, & Hoffmann, 2011, p. 63), if used interurban, one shared vehicle could replace up to 38 cars! – a strong motivation toward the development of novel vehicular services and self-driving mechanisms.



**Figure 17.1:** Overview of the Human-Car confluence concept (based on (Ferscha & Riener, 2009))

Research in the field has shown considerations and issues related to driver behavior models or the information/knowledge flow in such a highly connected setting. To illustrate, (Lee, Lee, & Salvucci, 2012) showed computational models of driver behavior and (Schroeter, Rakotonirainy, & Foth, 2012) discussed the challenges and opportunities that place- and time-specific digital information may offer to road users. The concept of driver-vehicle confluence discussed by (Riener, 2012) goes one step further, by aiming at understanding the symbiosis between drivers, cars, and (road) infrastructure by including reasoning about driver states and social or emotional interaction. Also the calls of national and international funding agencies further reflect that both researchers and practitioners have serious interests in developing the research field of socially-inspired cars.

## 17.3 Human-Car Entanglement: Driver-Centered Technology and Interaction

Researchers and practitioners have realized that efforts should be put on ‘drivers’ to improve driver-vehicle interaction and thus, drivers can be released from subsidiary activities and can concentrate on the primary task. To this end, it is necessary to understand human capability and limitation and apply those principles to system design.

### 17.3.1 Intelligent Transportation Systems (ITS)

To design human-centered driver assistance systems, a number of research groups have explored ITS based on a multidisciplinary approach, e.g., (Doshi, Tran, Wilder, Mozer, & Trivedi, 2012). For example, to capture the “complete vehicle context”, researchers at the University of California, San Diego (UCSD) have used a combination of computer vision and behavioral data analysis. Further, they have tried to forecast the trajectory of the vehicle in real-time, by predicting a driver’s behaviors (Doshi & Trivedi, 2011). Such a system can allow the ITS to compensate for risky circumstances, such as lane change departures (Salvucci, 2004) or rear end collisions. Researchers have also applied a vision-based approach to analyze the foot movement before, during, and after the pedal operation to gather information about driver behaviors, states, and styles (Tran, Doshi, & Trivedi, 2012). This is similar to the prediction of steering behavior based on body posture and movement (Riener, Ferscha, & Matscheko, 2008). In addition, the possibility of using haptic feedback has been tested to support the driver in reallocating his or her attention to critical situations and thereby, enhance their situation awareness (Mulder, Abbink, & van Paassen, 2011). The HumanFIRST Program in Minnesota employs psychology and human factors engineering to investigate the distraction potential associated with in-vehicle signing information and analyze drivers’ opinions about mileage-based road usage fees (Creaser & Manser, 2012). The National Advanced Driving Simulator (NADS) Center in Iowa has worked on data reduction and safety systems to detect where the driver looks at (e.g., instrument panel or mirrors) (Schwarz, He, & Veit, 2011). In addition, they have contributed to the development of systems that take over the vehicle control and safety policies (e.g., by studying alcohol impairment sensitivity (Brown, Fiorentino, Salisbury, Lee, & Moeckli, 2009)). The University of Michigan Transportation Research Institute (UMTRI) has addressed the problem of older drivers on the road and suggested launching separate vehicles for older drivers (Eby & Molnar, 2012). Nowadays, they also conduct research on connected vehicles on the road. Even though many more researchers are working on ITS, there remains a research gap between research settings and actual settings that needs to be further

bridged. Our conceptualization also includes the individual driver's states and their connection to external information streams (e.g., car to backbone).

#### Emotional Transportation Systems (ETS)

Given that humans have affective, cognitive, and behavioral elements, driver-centered technology should consider all of the three elements to be truly intelligent. Whereas driver cognition and behavior have been continuously addressed, emotions and affect have not been focused on in driving research until recently. In a dynamic driving context, information processing might interact with a driver's emotional state in a more complicated way. From this background, to achieve more natural and social interactions between a driver and a car, a car needs to detect a driver's affective states and appropriately respond to the driver and this necessity of research on driver emotions has appeared fairly recently, e.g., (Eyben et al., 2010). Research has shown that not just the driver arousal level, but also specific emotional states influence driving performance differently (e.g., anger (Dula, Martin, Fox, & Leonard, 2011), nervousness (Li & Ji, 2005), sadness (Jeon & Zhang, 2013), frustration (Y. Lee, 2010), etc.). Diverse emotion detection methods for the driving context have been suggested including physiological sensors (e.g., (Riener, 2009, Ferscha, & Aly, 2009)), speech recognition systems (e.g., (Eyben et al., 2010)), or the combinations of more than two methods (e.g., facial detection + speech detection (Jeon & Walker, 2011)). However, all of these attempts are still in an early stage and research is still needed to develop a more robust, but unobtrusive means to detect a driver's emotional states. A more critical issue is how the emotional transportation systems can intervene in a driver's emotional context after detecting it. Harris (e.g., cognitive reappraisal (Harris & Nass, 2011)) and Jeon (e.g., attention deployment (Jeon, 2012)) have tried to apply a psychological emotion regulation model (Gross, 2002) to driving situations using speech-based systems. Further, other modalities/methods could also be explored and developed such as a type of emotional gauge (just like a speedometer), a certain piece of music, or specific haptic feedback.

### 17.3.2 Recommendations

Time has come to change the long tradition of system-centered design, and to move over to systems, applications, and devices that focus on new forms of sensing, perceiving, interpreting, and reacting in the junction of 'man and machine'. To implement this in a car, new forms of interaction and communication emerging at the confluence between human and systems need to be incorporated by integrating real world contexts, socio-cultural aspects, and multi-faceted functions. Interaction concepts have to take care of the facts that (i) driving is almost a pure visual task with viewing direction toward the street, (ii) a driver has limited cognitive abilities and attentional resources, (iii) configuring an instrument cluster and displays in the car compete with limited attentional resources of the driver, and (iv) a full range of apps and cloud

computing services can enable the driver to work in the car in a similar way than to those in the office or at home. The adoption of human factors for the next-generation (dynamic and ubiquitous) vehicular environment raises crucial challenges within the field of ITS/automotive ICT. Those challenges include (i) implementing sensors, actuators, and communication interfaces for drivers, (ii) analyzing driver behavior data from those embedded sensors, (iii) reacting proactively based on those data, (iv) predicting collective system behaviors, and (v) solving ethical issues regarding all of these processes.

Dealing with all these issues calls for a novel driver state model, including full-fledged knowledge of the state transitions and the relationship between diverse emotions and cognitive processes. Drivers' cognitive and affective mental states alter dynamically and have a deep impact on how to perceive a task or an interface. Thus, these should be considered critically in future vehicular user interfaces. In addition to detecting drivers' state, the system should infer their intention and accordingly react in problematic situations. Here, we also need to identify a means to inform or stimulate the driver in an unobtrusive way. Note that this approach should be carefully taken, given that user freedom and controllability is generally a critical issue in HCI (Molich & Nielsen, 1990).

Many drivers still think that cars are a vehicle of personal freedom, and they do not want to relinquish vehicle control (O'Dell, 2012). More precisely, at least two kinds of driving need to be differentiated: (i) if drivers enjoy driving (“driving per se is fun”), they will insist on manual control and (ii) if drivers only want to commute efficiently, then they will use an autonomous car and enjoy reading the paper or relaxing. All these aspects are directly influential for human-centered intelligent driver assistance systems research, but so far research has been only focusing on improvements of the individual driver (driver-car pair). Thinking one step further, to achieve improvements in road throughput, avoid traffic jams, or reduce CO<sub>2</sub> emissions on a larger scale, driver-vehicle pairs should be connected to a sort of vehicular backbone, and information from this network should be used to optimize traffic on the macro scale. For example, intentions/reservations of all the individual drivers within a certain area or with a common goal could be collected and forwarded to a cloud service featuring data aggregation, common decision making, etc. to finally attain global changes in traffic behavior. We will have a look into this “collective driving” paradigm in the next section.

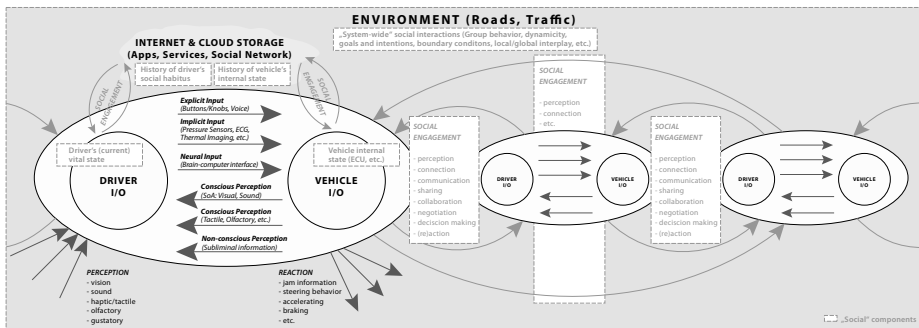
## 17.4 Socially-Inspired Traffic and Collective-Aware Systems

The Safe Intelligent Mobility – Test Field Germany (simTD) project gives a foretaste of possibilities of collective approaches in future traffic. It aims to help drivers select the best routes, detect obstacles before they see them, or reduce emissions through energy-efficient driving. To achieve these goals, a fleet of 120 networked cars using



car-to-car and car-to-x communication is running on highways, country roads, and city streets. (Results from the large-scale field operational trial are expected to appear in 2014). While innovative, this project also focuses on the ‘traditional’ problems, and does not really bring up novel ideas in the field of collective adaptive or socially-inspired systems. In the end, it is not provocative enough to force the required paradigm change.

Successful applications of socially-inspired driving mechanisms (Figure 17.2) require to understand how the driver-vehicle pairs could make use of their (i.e., the drivers) social habitus, composed from (past and present) driving and mobility behaviors, social interactions with passengers, pedestrians, bicyclists, other vehicles, infrastructure, and last but not least, drivers’ vital states when exposed to other road participants in live traffic. It further requires to define what social behavior in this context is. We agree on the definition of the US National Center for Biotechnology Information (NCBI), which states that social behavior is “any behavior caused by or affecting another individual, usually of the same species” (National Center for Biotechnology Information (NCBI), 2014). In addition, social behavior refers to interaction and communication (e.g., provoke a response, or change in behavior, without acting directly on the receiver) and includes terms, such as aggression, altruism, (self-)deception, mass (or collective) behavior, and social adjustment. Social behavior, as used in sociology, is followed by social actions directed at other people and designed to induce a response. Transferring this definition into the automotive domain, social behavior could be understood as the behavior of drivers, vehicles, pedestrians, and other road participants affecting each other.



**Figure 17.2:** Social engagement in a collective traffic system. Successful application requires a) reliable and accurate data sources (driver, vehicle), b) authentic models to predict driver behavior and vehicle state, c) intelligent cloud services, d) non-distracting (driver) notification channels

### 17.4.1 The Driver: Unpredictable Behavior

Each and every driver has his/her own personality and the internal state of the driver may change by different reasons from one moment to the next. This is, of course, a source of unpredictable and unsafe behavior. Legislative regulations and traffic control can prevent danger caused by alcohol, drugs, fatigue, but there are other sources that (temporarily) influence the normal competence of a driver (for example, stress, anger, or rage). In the meantime, advances in sensor technology have enabled the detection of drivers' mental/physiological or emotional states, but the detection accuracy and reliability is still far from being applied in widespread networks of self-organizing cars to influence decision making and negotiation processes.

Another factor that plays a significant role in the dynamicity of traffic is social forgivingness (Aarts, 2012). Traffic is a social system in which road users interact with each other and it is important in terms of safety that drivers steer their cars with anticipation. That is, drivers prepare themselves to detect another driver's potentially unsafe action early enough so that they can react appropriately and prevent, or at least, minimize negative consequences (Houtenbos, 2010). In addition, more competent road users could allow, for example, the less competent road users to commit errors without any serious consequences (Aarts, 2010). In order for a (willing) driver to be capable of acting with social forgivingness he/she must (i) have the correct expectations of the situations he/she is in, (ii) be capable of assessing the intentions of other road users correctly, and (iii) have the capacity to adapt his/her own behavior. The willingness to act in a socially forgiving manner is often influenced by external factors. For example, if the traffic light on a busy junction turns green for only a short time, the willingness of a particular driver to act with social forgivingness (i.e., yield) would most probably be low.

Advances in communication and in-car technology, together with the growing complexity and interdependence (Giannotti et al., 2012) of modern societies and economies, have been the main motivation for the emergence of approaches such as collective awareness, collective judgment, and collective action or behavior change (Mulgan & Leadbeater, 2013). Based on virtual communities for social change linked to environmental monitoring systems to enhance their awareness, collective systems can be used to effectively guide drivers in their everyday decisions (travelled route, departure time, etc.) and optimize traffic behavior based on efficiency (road throughput) and ecological (CO<sub>2</sub> emission) impacts (Sestini, 2012). Trust in technology (e.g., in semi-autonomous vehicles) or information presented on a display serves as a substantial success factor for services operating in large (self-organizing) systems. There is evidence that people in this human-technology intermix have a “fundamental bias to trust one's own abilities over those of the system” (de Vries, Midden, & Bouwhuis, 2003). It is also important to understand to what extent a person is willing to get out of his/her fundamental bias by adopting (and trusting) an ICT system. However, there already exist networks of people helping each other (e.g., forums), and people

joining these networks and empowering each other on their own. According to a recent survey, more than two thirds of people (68%) say that they trust what (other people in) the network tells them more than what companies or the state says; just 5 percent disagrees (Perrin, 2013), which indicates a high possibility of the successful application of collective services.

#### 17.4.2 The Car: Socially Ignorant

Cars have recently become “smart” and they have nowadays an increasing perception of what is going on on the road and in the environment (e.g., road and weather condition, traffic density and flow, emerging jams, accidents, etc.), but, as of now, they are mindless and need to be controlled by an individual. The first step toward social intelligence in traffic was made by equipping all (newly sold) cars with wireless Internet, and the next step toward socially-inspired behavior was enabled by social services, already available in the car and used there to share sort of social driving information (experience, traffic situation) amongst other vehicles via social networking services (SNS) such as Facebook or Twitter. An online survey recently conducted in three different countries (Jeon, Riener, Lee, Schuett, & Walker, 2012) revealed that about 70% of people are active social network service users (61.9% Austrians, 84.6% US citizens, 85% Koreans), and about 20% of them are using these services while in the car. More interesting is that drivers not only track (44%) the status of a friend or a driver with the same commuting pattern, but also comment on the statuses of others (27%) or tweet traffic updates (26%) while operating the car.

However, still neither vehicles nor all the embedded (assistance) systems integrated into vehicles can act socially. Instead, it is drivers that socially act based on emotions or mood, situation, experience, or learned behavior. For instance, they stop their car on the curbside, wave their hand, let another car back out, and use the headlight flasher to inform upcoming traffic about dangerous situations. However, with the emergence of self driving or (semi-) autonomous vehicles, the communications between computer-controlled and manually-controlled vehicles (c.f., social driver-vehicle units or “the driver-car” (Dant, 2004)) and other road participants (pedestrians and bicyclists) need to be improved to allow efficient coexistence without severe danger of the involved parties. The next generation ITS has to include the essence of social intelligence to improve efficiency and safety by enabling cars to interact in a similar way humans communicate and interact one with another. The car should, for example, relieve drivers by taking over their tasks and accomplishing them as efficiently as the human driver by applying sort of social intelligence. Socially behaving cars should create true value (Riener, 2012) for the road participants, and not just post the social status or feelings of a driver or provide status information of the car (and collect “Like’s”) as Facebook does. This requires to embed social skills to

consider social interaction, collective negotiation, and concerted (re)action between all the entities.

### 17.4.3 Networks of Drivers and Cars: Socially-Aware?

Social interaction in the car was previously offered only on an individual level, i.e., between one driver and another or between a driver and his or her vehicle. However, recent technological advances have led to a stronger interrelationship between the entities (Riener & Ferscha, 2013) and allowed for spontaneous formation of cooperative car crowds. Going one step further, social awareness has to deal with both individual and group behaviors and goals (Serbedzja, 2010), and such a system is basically comprised of many local actors (driver-car pairs) with (i) individual information (habits, customs, character, daily routine, personality, emotions, cognitions, physical states, intrinsic and extrinsic behaviors, restricted perception of their environment, and a limited capacity of action, etc.) as well as (ii) collective information (social grouping, long and short term social behaviors, social practice, both prejudices and tolerance, fashion, tradition, social etiquette, etc.).

With regard to individual information, (social) criteria characterizing human behavior and/or reputation need to be validated. Attributes to be considered include the ability to communicate and interact, willingness to negotiate, cognitive abilities, self-managing behavior history, reputation, ability to assert oneself, forget/forgive, rapid assessment and decision making, and learning/adaptation capabilities. For collective information, cars are socializing to achieve a global optimum goal based on a cost (fitness) function that concerns the environment of the problem in its totality. The difficulties in traffic include (i) that different time scales are evident (driving action: seconds, emergence of a jam: minutes to hours; change of weather: hours to days; legal regulations: month to years), (ii) that driving is a highly dynamic task (negotiation, re-distribution of the decision to local actors, or behavior adaption, etc. is often not possible by the due time), (iii) that there are many (local) actors with individual behavior, restricted perception of their environment, and a limited capacity of action involved, and (iv) that the context and its boundary conditions are continuously changing (traffic situation, jams/accidents, driver state (e.g., sleepy driver), infrastructure failures (e.g., no traffic lights), weather conditions (dry to snow storm), etc.) (Bersini, 2010; Bersini & Philemotte, 2007). Furthermore, to provide more stable solutions (interplay of individual and collective levels), it is required to perfectly understand the reality to be faced, i.e., the contexts and its boundary conditions in which the scenario is embedded into. Last but not least, the aspect of ethics needs to be integrated in solutions to provide ethical sensitivity to each of the above aspects.

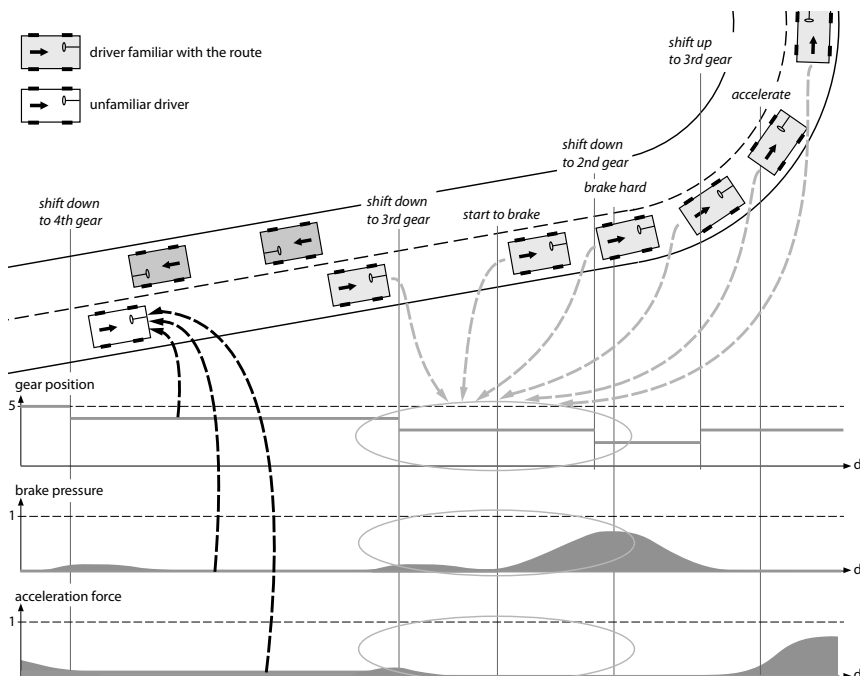
#### 17.4.4 Recommendations

Traffic density and likelihood/duration of jams have considerably increased in the past decades and with it more and more drivers feel increased stress and anger from traffic; finally a number of people cancel or postpone planned trips due to anticipated high traffic. These problems cannot be solved by just adding another lane to the highway, building new roads, or pushing public transportation. A sustainable solution requires a holistic approach including new ways of traveling (platooning, car- and bike-sharing, active mobility), concerted coordination, and proactive traffic management. This can be already achieved by the current technology, and by further applying concepts such as incentivization, driver behaviors can be changed specifically. Moreover, a socially-enabled car requires a social environment (for example, intelligent roads with dynamically changing lanes; road signs adapting to the driver, etc.) and social cars should have social capabilities, such as (i) “learning” (a car automatically recommends alternative routes if having learned that there is a traffic jam every workday in that region at a certain time; such a behavior would be relevant for drivers using a rental car in an unknown area), (ii) “remembering” (a vehicle remembers from one winter to the next, that driving at or near the speed limit is not wise on temperatures below zero degrees or snow coverage on the road), or (iii) “forgetting” (a car moves more carefully after having been involved in an accident; however, the incident is forgotten after some time and avoids that the car is fearful and drives too slow in the long term), etc. To give a concrete example to force safety, ITS could take over the control of a car moving inappropriately in convoy (e.g., a driver ignoring a road situation or reacting too slowly) by applying the brakes, changing the steering angle, or accelerating the vehicle. It needs to be argued, however, whether drivers are able to prohibit a broad application of this auto pilot-like safety system as they would not be willing to accept restrictions in their personal liberty. Traffic fully under control of computer systems and network communications also poses potential for criminal activities (central control can be (mis)used to induce mass collisions or to generate gridlocks from everywhere).

By merging all the information from drivers, cars, and infrastructure into a common database, the basis for an improved interaction between the involved parties could be established. This implies more than developing new interfaces or driving assistance systems. To implement it, looking into similarities in biology can be a good starting point. For example, driving is in some aspects similar to ants moving on a trail, and they use pheromones to share information about the environment (e.g., food sources (Karlson & Lüscher, 1959)). Likewise, other drivers’ signal can cause short-term changes in the driving behavior (i. e., hormones (Huber & Gregor, 2005) or neurotransmitters). Other examples from biology include stigmergy (a concept to store states in the environment that can be easily retrieved by specialized sensors) or superorganisms (in our sense a collection of agents which can act in orchestration to produce phenomena governed by the collective (Kelly, 1994)).

### 17.4.5 Experience Sharing: A Steering Recommender System

One example scenario accentuating the potential of the symbiosis between drivers with different knowledge is the steering recommender system. The idea behind is, that drivers familiar with a certain route (e.g. daily commuting on that road, living in the area for a long time, etc.) have detailed, intuitive, and implicit knowledge about how to drive as efficient as possible. They know the optimum points of braking before and accelerating in/after a curve, they know the sections where overtaking is possible, and they know potential points of danger (bus stop, cars backing out, blind head, sharp turn, etc.). Collecting and processing the information from all experienced drivers (using CAN bus information and GPS data to keep track of parameters, such as steering (wheel) angle, when (and how often) the brake pedal is pushed, which gear is engaged, and when the gear is changed up/down, etc.) could be used in a service providing steering recommendations to other, unfamiliar drivers (new drivers and/or on holiday trip). By using this service (Figure 17.3), traffic flow should be more homogeneous as vehicles would then drive with similar optimal conditions where appropriate. Further, this system could be used as a warning service to notify vehicles about upcoming hazards detected implicitly by many drivers ahead. Based on it, road safety will increase and also the average fuel consumption should be minimized.



**Figure 17.3:** Driving advice from expert drivers would help nonlocals to optimize their driving behavior and, thus, to drive more efficient and safe

## 17.5 Conclusion

In this chapter we have discussed the potential that a collective understanding of the traffic situation together with a concerted behavior modification by socially-acting vehicles have for future traffic. We expect that this allows to automatically resolve conflicts in mass traffic, negotiate with each other, behave as a collective to optimize characteristics such as driving time or efficiency, address the topic of environmental protection, raise safety on the road by monitoring other cars' behavior in the vicinity, and enhancing driving experience, satisfaction, and pleasure.

Based on an analogy with biology, such a system could be implemented as a type of a “collective brain” gathering neural inputs from all the drivers in a common area of interest and featuring common decision making and negotiation on the route or lane taken by each individual driver within the collective, by adopting paradigms known as pheromones, stigmergy, or superorganisms.

Our concept should be understood as a specific instantiation of human-computer confluence working towards the goal of full understanding of the symbiosis between drivers, cars, and infrastructure. It covers not only sharing of information about an oil spill on the road, but also reasoning about driver states and social/emotional interaction. This ultimate goal can be achieved by modeling driver behaviors, conducting simulations and empirical driving studies, investigating distributed negotiation processes, and relating these results to observations in real world.

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