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Driver-Vehicle Confluence or How to Control your Car in Future?

Andreas Riener
Johannes Kepler University Linz
Institute for Pervasive Computing
riener@pervasive.jku.at

ABSTRACT

Human-computer confluence (HCC) aims at investigating how the emerging symbiotic relation between humans and computing devices can enable new forms of sensing, perception, interaction, and comprehension. Latest advancements in information and communication technology have been the key enabler that this vision actually became reality. The concept of driver-vehicle confluence is understood as a specific instantiation of HCC, and its main objective is to understand the symbiosis between drivers, cars, and the infrastructure within an arbitrarily large region of interest. This covers not only information sharing within a collective of cars, for example about an oil spill on the road – more important is to reason about driver states, learn about social connections and emotional influences, and forecast driver action or vehicle movement. All these can be achieved by modeling driver behavior, studying distributed negotiation processes, performing driving studies and simulations, and relating the results back to observations made in reality.

In this visionary paper we identify some of the most crucial problems and present some possible solutions to establish driver-vehicle confluence in the automotive domain. By introducing this concept we are dealing with complex traffic situations, many distributed vehicles (i. e., driver-car pairs) that can act in orchestration, or drivers represented as emoting individuals. The success of any objective to achieve is mainly determined by wide user acceptance. For this reason, advantages and positive effects should superficially be generated for the individual driver. Some examples are reduced traveling time, lower fuel consumption/CO_2 emission, or a more relaxed style of driving (improved driving experience and pleasure). Due to the close coupling and interconnectedness of involved entities, effects on the local level would directly induce changes such as increased road safety, traffic flow optimization or enhanced economy of driving, also on the global scale. Two concrete scenarios are outlined in the back of this paper to accentuate the potential and beneficial effects the application of driver-vehicle confluence might have on future traffic.

Categories and Subject Descriptors

H.1.2 [**Models and Principles**]: User/Machine Systems—driver-vehicle models; H.5.2 [**Information Interfaces and Presentation**]: User Interfaces—social interaction

Keywords

Driver-vehicle confluence; socializing individuals; traffic optimization; emotional state modeling; collective driving

1. FROM TECHNOLOGY TO HUMANITY

Vehicle drivers today are concerned with many concurrent information streams that need to be processed, reviewed, and reacted on immediately. Lot of information is related to driving, for instance

- internal vehicle status, e. g., oil/air pressure, temperature values or engine parameters,
- movement characteristics such as speed, friction, steering angle,
- road infrastructure information (electronic billboards, overhead traffic signs, but also data from induction loop sensors or traffic cameras), and
- parameters from the environment like tarmac surface temperature, wind speed, or weather situation,

another part belongs to driving unrelated information such as news/music from the car stereo, remote communication with the (smart)phone, direct conversation with co-passengers, and data retrieved from the Internet. This is problematic as more information in the car usually coincides with greater capabilities and more functions, which finally results in higher visual load (for the observation) and requires higher manual demands (for the operation) [27]. As if this high information load weren't enough, the latest boost in information quantity is provoked by social network services whose information is permanently emerging at the driver. A online user survey conducted by us 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 (Figure 1). More interesting is, that not only the status of a friend or a driver with same commuting pattern, etc. is tracked (44%), it is rather that drivers comment on the statuses of others (27%) or *tweet* traffic updates (26%) while operating the car. These examples clearly emphasize that driving today is likely to cause high visual and/or manual demands on a driver's resources (as predicted already 20 years back by Wierwille in his seminal paper [27]), and minimizing the visual/manual demand of in-car tasks should be

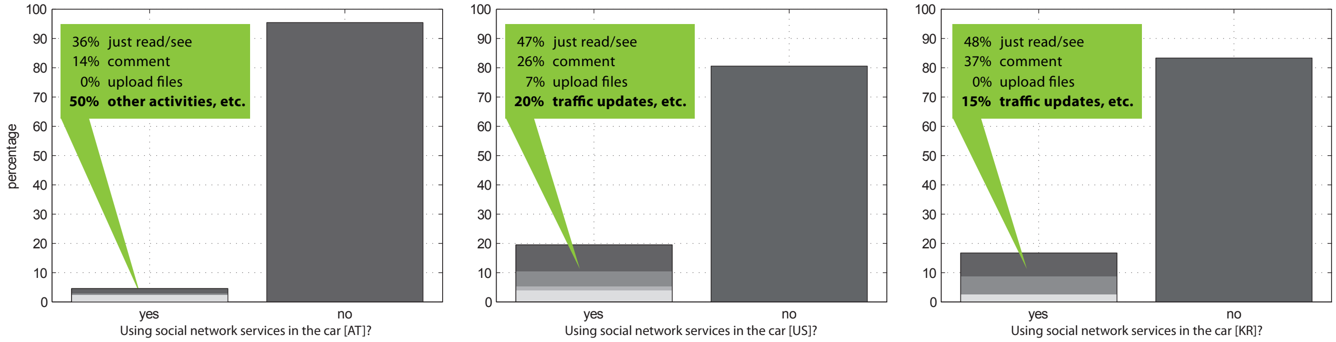

Figure 1: About 20% of people who use social services (AT: 61.9%, US: 84.6%, KR: 85%) use them also while in the car (Austria lags behind). [Basis: car usage survey May 2012, 225 participants, [11]].

one of the main objectives of future automotive interface research. Beside that, the high dynamicity of driving coupled with plethora of information around all the time and spontaneous decisions to be taken by the driver are likely to cause additional mental load, elicit (negative) emotional stress (often referred to as *anger*), and –as a consequence– alters the internal mental state of the driver. Last but not least, it should be emphasized that information received by the driver through the visual (or other channels) is judged based on the current emotional state, assessed based on the character of the person (e. g., choleric/apathetic), and finally enriched with desires or specifications (e. g., how to reach a destination in time, without road charge or jam, etc.). All these factors might have an impact on the action taken by the driver and need to be considered in a model representing the driver in order to provide efficient and, above all, proper feedback and assistance.

To recapitulate, the most crucial issues in driver-vehicle interaction today are (i) to get the **excessive information** under control with focus on minimizing visual, manual, and cognitive demands and (ii) to create a **appropriate emotional driver model** to 'understand' why a certain driving action is carried out, what the driver is feeling, or what he/she is expected to do next.

1.1 Technology: Growth of information

To better understand which types of information are available in the car, and where to apply possible solutions, we start with a historical overview of information processing in the car. In the early days vehicles were controlled by mechanical and pneumatic means with almost no possibility of intervention by the driver. With technological advances, electrical sensors/actuators and first information systems emerged in the car. The first solution to cope with the rising complexity of vehicle operation was to establish simple point-to-point in-vehicle networks to interconnect the different sensors and actuators in a car with controls in the dashboard, later extended with a simple engine control unit (ECU) acting as central "server". In the 1980s the increasing number of distributed sensors, actuators, as well as the information/assistance systems in and around the dashboard disallowed the further usage of discrete wiring to connect one element to another. Efficient in-vehicle networks based on serial protocols (such as CAN, MOST, FlexRay) were developed to further afford sharing of more and more information and to manage all the resources as effectively as possible. In the 1990s, several service and assistance systems were integrated into vehicles, as for instance powertrain control modules (PCM) together with on-board diagnostics (OBD), electronic brake force distribution (EBD) system, the electronic stability program (ESP) [16], etc. At about the same time cell phones and car navigation systems found their way into the car (the first GPS-based navigation systems were offered by Pioneer and Mitsubishi Electric in 1990). Later, the whole class of heterogeneous pervasive and ubiquitous technology driven devices/interfaces (gaze control, speech interaction, haptic I/O, etc.) popped up in the car. The last ten years were finally dominated by the broad emergence of wireless communication (IEEE 802.11p/WAVE) and everywhere Internet connectivity, connecting formerly independently acting drivers and cars to 'the rest of the planet'. These days more than 1 billion of cars are running worldwide (2009: 965 millions), more than the social network Facebook has active users (March 2012: 901 millions), which offers huge potential for services based on interconnected, socializing cars, but might also be the source for additional distraction. What we discover in vehicular interfaces today is a still increasing number of sensors and actuators, more and larger displays, and –enabled by Internet availability and content stored in the *cloud*– feature-rich applications that have found their way into the car (Audi, for example, supply customers with *Apps* via their own App Center [8]); the dashboard progressively "*mutates to a sink of condensed information*" and the driver is more and more challenged and unable to cope with all the information.

1.2 Humanity: Drivers as emoting individual

While the focus of car manufacturer is still on 'increasing the number of services or assistance functions' (to stand competition with other manufacturer), researcher have already realized that effort should be 'put on the human driver' to simplify interaction by utilizing novel interaction concepts, incorporating cognitive abilities of the individual driver or factors such as interrelationship/trust/belief in groups of drivers. In the following we give an overview of research projects following this way of thinking.

Related work: Focus on driver rather than technology

The concept of driver-vehicle confluence puts the human driver forward and its aim is to create human-centered driver assistance system that improves vehicle handling, driving safety, or releases the driver from subsidiary activities to concentrate on the primary task. *Intelligent driver support* or *human centered driver assistance* systems have been explored and pursued for a while by a number of research groups. The University of California at San Diego (UCSD), for example, follows a multidisciplinary research approach to achieve the before addressed goals. In particular they examine the link between the driver and the automobile to see what modifications can be made to the automobile in order to support the driver. To capture the vehicle context and to research driver assistance systems that put the driver first, they use a combination of computer vision, behavioral analysis studies, driver intent studies, and psychological studies. Recently they are focusing on driver behavior prediction to forecast the trajectory of the vehicle prior in real-time [5]. Such a system could improve road safety a lot by allowing a driver assistance system to compensate for dangerous or uncomfortable circumstances such as lane change departures [23] or rear end collisions. A concrete example with good prospects is to monitor and predict driver foot behavior. In [26], the authors have applied a vision based approach to analyze the foot movement not only during pedal operation, but before and after a pedal press to gather additional information about driver behavior, state, and driving style. By building a HMM model to learn the temporal foot behavior they are able to predict a brake or acceleration press before it actually happens. This is an important step toward human-centric intelligent driver assistance systems. The University of Iowa, more precisely its National Advanced Driving Simulator (NADS) center, is a long-standing expert in testing advanced driver assistance systems using simulators of varying levels of fidelity and driving realism. They have worked on data reduction systems [24] and safety systems detecting where the driver looks at (e. g., instrument panel or mirrors). In addition, they have contributed to the development of safety policies, e. g., by studying alcohol impairment sensitivity [2] and on systems that take over control. However, even if operating the world's most advanced ground vehicle simulator, there remains in the end a gap between simulation and reality (caused by inertia of masses, danger, etc.) that needs to be considered and tested. The Control & Simulation division of Delft University investigates the possibilities of using haptic feedback to provide the driver with tactile cues of the environment to support him/her in reallocating attention in critical situations [20]. Aim of the project, initiated by the Nissan Vehicle and Transportation Research Laboratory, is to conduct research in intelligent driver support systems to help drivers to enhance their awareness of the environment and supporting them in properly allocating their attentional resources. The mission of the Sustainable Worldwide Transportation initiative of UMTRI is to address major safety, environmental, economic, and social issues of road transportation. For example, a recent report discusses the problem of older drivers on the road and suggest to launch separate vehicles for older drivers (similar, for example, to cell phones with less functions and larger knobs) [6]. The HumanFIRST program of the University of Minnesota employs the tools and methods of psychology and human factors engineering to improve scientific understanding of driver performance and cognitive functions. To give an example, they investigate the distraction potential associated with in-vehicle signing information or analyze drivers' opinions about mileage-based road usage fees [4].

These initiatives give only a short glimpse of research going on these days, but substantiates that the attention of a driver required to interact with the car should be brought down to a low level. All the aspects addressed are directly influential for human-centric intelligent driver assistance systems research. Nevertheless, so far most of the research groups have looked on improvements for the individual driver (*driver-car pair*); with almost complete interconnectedness the next level should be the investigation in a greater, if not global, context by connecting driver-vehicle pairs to a sort of *vehicular backbone*, and to use information from individuals to optimize traffic on the macro scale. To this end, a very ambitious project was started just recently in Germany [3]. The "simTD" (Safe Intelligent Mobility - Test Field Germany) project aims to help drivers select the best routes, detect obstacles before they see them, or cut 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 driving on highways, country roads, and city streets. (Results from the large-scale field operational trial are expected for 2013). While innovative, this project also focuses on "traditional" problems, and does not really bring up novel ideas or forces a paradigm change.

1.3 Disappearing technology

We are heading towards a change in emphasis supported by the statement "*[..] today we have some connections between the physical world (in which we live) and the digital world (which we use for everyday tasks), but when we can truly blend them together, we get something completely new [..] We still work with computers. But we should get to the point where we are unaware that we are dealing with computers...*" [18]. Time has come to change for the long tradition of system-centered design, and to move over to systems, applications, and devices that focuses on new forms of sensing, perception, interpretation, and reaction in the junction of 'man and machine'. To actually implement this in the car domain, new forms of interaction and communication emerging at the confluence between human and technical systems needs to be incorporated by building and integrating real world (context, social)-aware, multi-functional systems according to those requirements. The integration of human factors and individual behavior into today's dynamic and ubiquitous vehicular environment raises crucial challenges within the field of automotive ICT, involving not only sensors/actuators and communication interfaces, but including topics such as human behavior analysis from embedded sensors, sensing and interpretation of physiological measures, activity monitoring and proactive reaction using integrated actuators, collective system behavior, and last but not least also ethical issues. The simple facts that persons emote all the time (i. e., mental states alter dynamically) and that a certain cognitive state might have a deep impact on how an interface is perceived or a task is processed can be used as underpinning for the importance of emotion or social awareness in future vehicular interaction and UI design.

2. THE VISION

Starting to design the future of driver-vehicle interaction and vehicle control, we have to identify the major issues responsible for driver distraction, such as information overload or disruptive technology. General conditions to consider in driving today are that (i) the human driver has limited cognitive abilities and attention resources, (ii) driving is (still) a almost pure visual task where the viewing direction should be focused on the street all the time, (iii) more and more displays and services in the car compete with limited attention resources at the driver, and (iv) broad Internet availability and cloud computing enables the driver to access data and applications as like in the office. In considering these factors, concrete solutions have focused in the past primarily on technological aspects. Now (as already pointed out) time

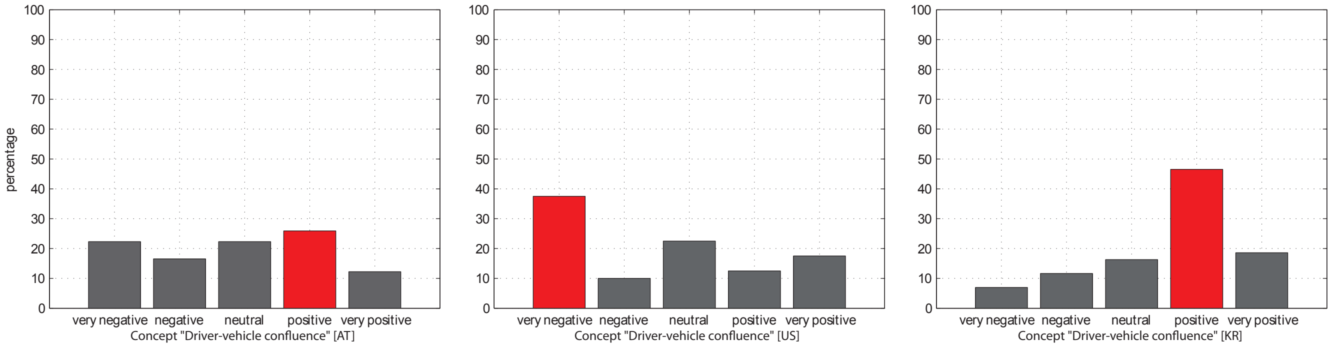

Figure 2: User assessment of the proposed driver-vehicle confluence concept [11].

has come for improvements related to human factors (*the driver*) by employing new forms of driver-vehicle interaction at the individual level and that allow for improvements in driving efficiency, experience, pleasure, etc.

To achieve this, improvements should be considered in the following lines (non-exhaustive enumeration):

- **V1. Focused attention is required from the driver:** A driver being in charge of supervising all the control instruments and information / assistance systems might have reduced resources to maintain *situation awareness* [7] all the time. It should be clear that possible solutions have to put focus on improvements in the perception of elements in the dashboard or environment. Information that is presented to the driver needs to be preselected and/or filtered to preserve attention resources at the driver and devote them to driving related tasks. A second issue is that future UIs need to be more natural to experience and intuitive to use in order to avoid reasoning about how to use a control to execute a certain function. (This is actually evident for instance in complex multi-stage controls such as BMW iDrive or Audi MMI).
- **V2. Driver emotions need to be detected (and controlled?)** as emotions in driving exhibit a serious distraction level (similar to those experienced by the classical distraction sources). The emergence of negative emotional stress, most likely caused by operation complexity, need to be compensated but also the effect of (*too*) positive emotional experience need to be discovered as (over-)happiness and high spirits might result in incautious driving. Last but not least emotions and their relationship to culture, ethic heritage, etc. have to be investigated and accounted.
- **V3. Future cars have to 'understand' what the driver wants**, i. e., the vehicle has to detect the current mental/emotional state of the driver, infer his/her intention, and react in problematic situations. This calls for an appropriate emotional state model for driving and includes full-fledged knowledge of state transitions and the relationship between emotions but also ways and means to inform or stimulate the driver in an unobtrusive way. Of course, this approach should be considered critical as it is known that user freedom (number 3 of Nielsen's ten usability heuristics [19]) is one of the most important guidelines in HCI. When it comes to cars, drivers often don't want the car to 'know' what he/she want and react accordingly (as some examples have previously shown).
- **V4. Collective rather than individual behavior:** To achieve improvements in road throughput or traffic jam avoidance, but also in a reduction of CO_2 emissions or other economic optimizations, intentions/reservations of all the individual drivers within a certain area or with common goal should be forwarded to a 'collective (artificial) brain' featuring common decision making and attaining traffic optimization.

2.1 Assessment of driver-vehicle confluence

To gain deeper insights whether or not drivers actually like (and trust) the concept of driver-vehicle confluence as proposed before, a great many of persons were asked in the car usage survey [11] about their opinion on this issue. The results between the 3 sites Austria (AT), North America (US), and Korea (KR) are quite different. These disparities further motivate to incorporate cultural or ethical factors in interface design and parameterization. On a 5-level Likert scale, Austrian and Korean drivers responded positive to very positive (AT: 2.90 ± 1.35, KR: 3.58 ± 1.14) while respondents from the US strongly dislike the concept (US: 2.63 ± 1.53) (Figure 2). At this time we do not have detailed information for the reason of this divergence, but we assume that part of the problem stems from the formulation/translation of questions to Korean/German.

3. GENERAL APPROACH OF DVC

To realize the 'vision' as stated before, that is for example ultimate, sporty driving experience coupled with high road safety, "driver-vehicle confluence" is the proposed solution. Merging all the information coming from drivers, vehicles, and the environment into a collective foundation should allow for improved interaction between the involved parties. In particular, the following points should trigger active discussions and drive future research.

3.1 Input modalities

The main weak point of vehicle control (i. e., 'chain of sensory perception/reaction') is addicted to the cognitive-motoric task of the driver. To disburden this link in the cycle chain, **implicit input** is the preferred solution today, with some potential for further improvements (e. g., driver state estimation from pressure sensors integrated into the seat, thermal imagery to assess cognitive overload or driving stress, physiological sensors). Even higher capabilities are expected from the application of **neural techniques** (e. g., brain-computer interface (BCI)) to gather and process input

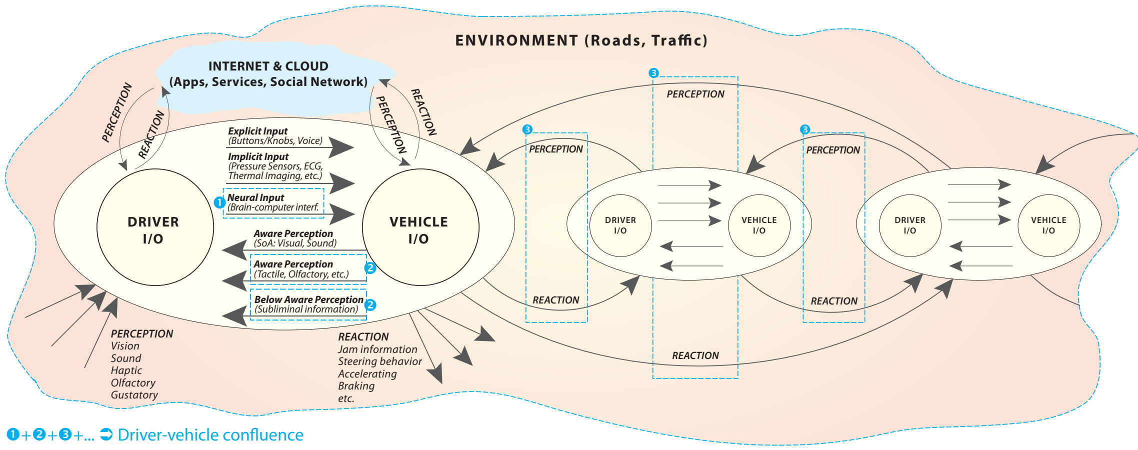

Figure 3: Driver-vehicle confluence: Channels of information exchange.

from the driver in a fully implicit, inattentive, embodied, distraction- and workload-free manner.

3.1.1 Showcase: Brain-computer interface

The application of (one way 'driver-to-vehicle') **brain-computer interfaces** is a challenging research task to control (preferable driving unrelated) devices such as the air conditioning system, car stereo, and maybe the route guidance system. Todays BCI's are almost exclusively used in the gaming domain and it is very hard, if not impossible, to generate and transfer high reliable and accurate commands also while driving as there have to be many concurrent information channels monitored and served. Another issue is the impact of vibrations induced by the vehicle's engine or passed from the roadbed on the head mounted EEG sensors or eyetracker (EOG).

3.2 Output channels

Despite the fact that the visual channel is highly overloaded while operating the car, driving is (still) a more or less pure visual task and the supervision of all the information items in and around the dashboard requires significant eyes-off-the-road times, known as critical to affect road safety. Glances totaling more than 2 seconds increase, for example, crash risk by at least two times [15]. This is one of the major reasons for the rapid emergence of head-up displays (HUD) projecting driving related information directly in the field of view of the driver. The HUD technology solves the problem of looking off-the-road; unfortunately, another problem appears in place of. The overlay of two different kinds of visual information increases the risk of *inattentional blindness* [9] (that is related to the problem that shifting the attention between information sources might result in a loss of part of the information; even more problematic is, that the driver might be not at all aware of this loss). To solve this problem for good and all, new information channels such as **tactile feedback** and **olfactory stimuli** or modalities of perception like **subliminal feedback** (i. e., information transmission below aware perception) need to be established on broader scale as before.

3.2.1 Showcase: Odors – high risk research

Still underrepresented in commercial products, much potential can be indicated to the application of olfactory interfaces, for example by "displaying" scent of burning oil in the passenger compartment to warn the driver in case of motor defects, or to systematically employ odors to calm down or refresh the driver to increase driving safety or avoid a driver to fall asleep (this type of stimulus would fall under the mental processing state of subliminal unattended because of the absence of top-down attention and the weak strength of the stimulus). The motivation for using scents as perception channel is motivated by the fact that specific odors elicits sedative/relaxant or revitalizing effects [13]. Further studies have found out that the olfactory channel was less effective, had a less disruptive effect on a driver's primary task as compared to visual or auditory stimuli, and has therefore the potential to improve vehicle control. The use of olfactory information still remains a great challenge as its perception is subtle and imprecise and particular fragrances won't 'work' for everyone [1], [21]. Even more important, it was revealed that the emotional state of healthy subjects has a clear effect on olfaction – a negative state reduces olfactory sensitivity. As emotional states are likely to change quickly and uncontrolled during vehicle operation, e. g., in congested situations or on vehicles cutting in, a change in the emotional state would directly affect olfactory sensitivity. Other problems to deal with are olfactory adaptation and that olfactory information cannot be (easily) restricted to a certain space.

3.3 Behavior adaptation

In addition to "classical" interface extensions, also the intrinsic fundamentals of driving (e. g., driver intention, behavior adaption) carries lot of potential for improvements. Inspiration could be borrowed from biology by identifying similarities that can be adopted to driving or driver behavior modeling. Examples include the application of **pheromones** (substances which are secreted to the outside by an individual and received by a second individual of the same species, in which they release a specific reaction [..] [12]) , **stigmergy** (i. e., to store states in the environment that can be easily retrieved by specialized sensors) or **superorganisms** (an organism consisting of many organisms or more technical a collection of agents which can act in orchestration to produce phenomena governed by the collective [14]).

3.3.1 Showcase: Pheromones and Neurotransmitters

One concrete example might be movements of ants on a trail – which is in some concerns similar to (motorway) traf-

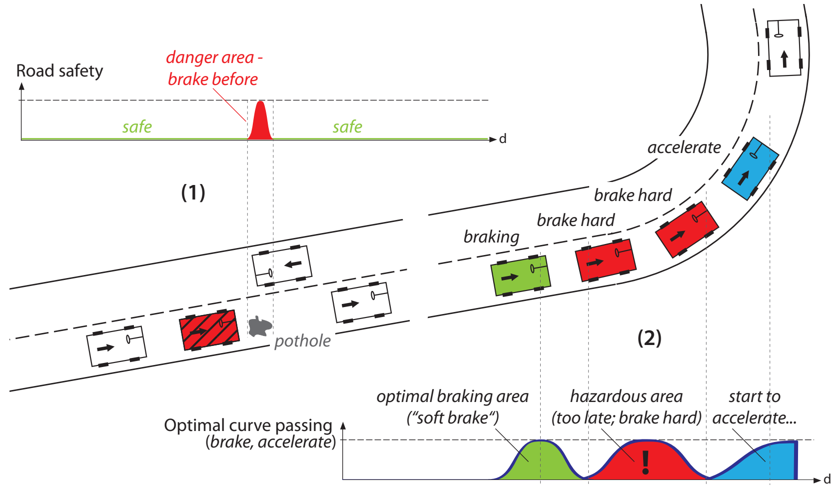

Figure 4: Frequency of braking on a certain point can be used to warn drivers (1); driving advices from familiar drivers would help non-locals to optimize their individual driving behavior and thus to optimize fuel consumption/CO2 emissions (2). Both concepts might help drivers to feel an increased pleasure of driving.

fic. Using pheromones, ants, bees, etc. share not only information about the environment (food sources, traffic jam ahead), but also **changes the behavior and/or physiology of pheromone receivers** [12]. A similar approach could be also used in the car to change a driver's condition or behavior by application of a signal pheromone to cause short-term changes in the driving behavior (or, in case of human beings, of hormones [10] or neurotransmitters).

Summary

By considering individual potentials for improvements (brain-computer interfaces, implicit interaction, messaging below aware perception, stigmergy, etc.), "driver-vehicle confluence" as outlined in Figure 3 would finally define an environment where the **car implicitly recognizes the behavior and condition of the driver** (e. g., movement, stress levels, fatigue, communication behavior, stored history), **infers what the driver wants**, **informs the driver** (tactile/olfactory/etc. feedback; subliminal stimulation) or **reacts accordingly** (adjust AC, control car stereo, volume +/-, turn off the phone, switch lights off, etc.). Another basic property of such a system would be that all the **adaptation is done automatically**, maybe even proactively, but in any case without involving the driver (meaning that it is operating fully autonomously in the background). Finally, on **detection of deviations** (e. g., in the driven route) the **vehicle would warn the involved drivers** or would even **intervene** by applying brakes, changing the lane, etc.

4. EXAMPLE SCENARIOS

A traffic light (jumping to red on one street, and to green on the orthogonal route) might be a simple trigger for the emergence of collective driver behavior. All the drivers approaching the road crossing would immediately know what this activity means and reply with a corresponding (re)action. The one facing the red light would apply the brakes and stop in a way to avoid rear-end collisions and other hazards, drivers on the other street would accelerate and pass the crossing safely. The conflict resolution/negotiation is (usually) working even in extraordinary situations, for instance when an emergency vehicle is going straight over the crossroad. With the concept of driver-vehicle confluence, similar behavior should be rendered possible in future driving considering more complex situations, involving more distributed vehicles, and with social behavior of humans transfered to their cars to achieve objectives on global as well as local levels. In the following, two concrete example scenarios are outlined to better accentuate the potential the application of driver-vehicle confluence might have on future traffic.

4.1 Economic Driving

Events from the CAN bus or from other in-car buses can be aggregated and extended with information coming from the environment to finally obtain deeper knowledge about driving behavior. This information can then be used to advise the driver or to warn other drivers nearby. More concrete, the CAN bus, for instance, delivers information when (and how often) a driver is pushing the brake pedal. Considering GPS information is available, this information could be mapped to a geolocation. Collecting this information for all cars (*car-driver pairs*), a distributed "danger map" could be built up for a certain region (Figure 4, (1)). This map would indicate regions as 'hazardous' where all the drivers apply the brake (hard), whereas in regions specified as 'safe' not a single driver (or only very few of them) would push the brake pedal (e. g., on a straight motorway section). This sort of information cannot only be used to detect hazardous situations in certain areas and to initiate appropriate actions, but also for improvements in operating the vehicle under normal (safe) driving condition.

To give a more tangible example, it is well known that cycles of braking/accelerating significantly contributes to the overall fuel consumption. According to the US Department of Energy[1] could anticipative driving (i. e., avoidance of speeding/rapid acceleration/unnecessary braking) lower average gas mileage by about 33 percent at highway speeds and by 5% intra-urban. A simple yet effective application would be a "braking/accelerating recommender system" operating based on the fact that drivers familiar with a place or region knows best how to drive on the route while non-locals

[1] `http://www.fueleconomy.gov/feg/driveHabits.shtml`, last retrieved August 23rd, 2012.

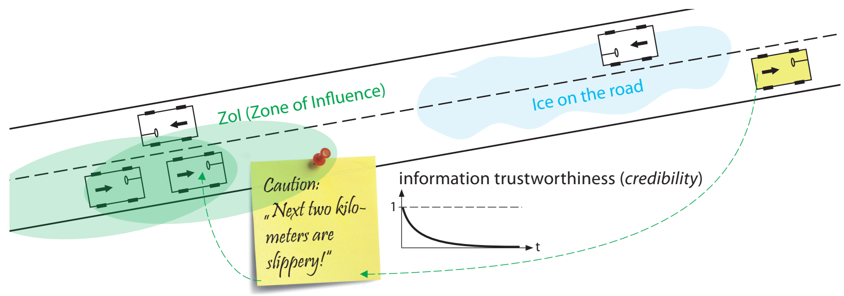

Figure 5: Stigmergy applied to the automotive domain. A car could post a digital note (pheromone) so that other cars would be warned ahead the hazardous area. Its credibility is removed over time (i. e., evaporating in the comprehension of pheromones and fragrances) in order to provide only relevant, up-to-date information.

would never have this anticipative behavior/knowledge and would most likely brake too late or start to accelerate at the wrong point. Furthermore, the former group would be aware of curves and their characteristics (curve radius, optimum point of braking before and acceleration in the curve, etc.), they would know the sections where overtaking is possible, and they would know all the dangerous areas (e. g., regions susceptible to wind or bridges exposed to black ice). A new assistance system could take advantage of this knowledge by providing non-locals with in time information on how to pass through a route under optimum conditions, e. g., when and how strong to apply the brake, when start again to accelerate, where to overtake, which gear to engage, etc. (Figure 4, (2)). With these advices we can achieve, beside safer and more relaxed driving, a reduction in fuel consumption or optimize carbon dioxide emissions. The variance in gathered data (directly influencing the accuracy of advices) could be further narrowed by using data only from highly experienced drivers (e. g., with more than 15 years driving experience, more than 30,000 miles driven per year, or a minimum usage of the specific route of once a week), and skip data sets of novice drivers.

4.2 Stigmergy

Stigmergy (Greek: *stigma*=mark, sign, *ergon*=work, action) is a coordination concept based on indirect communication derived from social insects (ants moving on a trail, bees collecting honey or living in a beeyard, termites building a nest) and was introduced by the French biologist *Grasse* in 1959 to refer to termite behavior. A fundamental characteristic of stigmergy that could be applied to the automotive context as well is, that communication takes place by means of environment modifications, e. g., by leaving traces (messages, signs, notes) in the surrounding that are sensed by other entities, and that are affecting their subsequent behavior or eliciting a response (action). Coming back to the 'ant example', stigmergy (or emergent behavior) can be discovered in insects moving on a trail. Signs left along the trail can be easily detected by passing ants and mapped to their geolocation. By following the 'markers', ants could be guided to the destination point (i. e., food source). The signs (fragrances, or more specific 'pheromones'), if not "renewed", evaporate over time to avoid leaving outdated information in the environment. [22] has demonstrated the power of stigmergy as a tool for coordination in a loosely coupled system and as vehicles moving on a road are at least by now and from a ICT point-of-view (with regard to communication and connectivity) considered a loosely coupled system, this paradigm could (and should!) be also transferred into the automotive domain [25]. The information exchange between the "virtual, electronic container" and the agents (cars) can be interpreted as kind of social interaction. This way (and as shown in Figure 5) a car could 'drop' information or experience while passing a section (e. g., limited sight due to fog, slippery road, etc.) and other cars reaching or coming close to the spot can read and interpret the note and thus being proactively warned ahead a hazardous region or situation.

5. EXPECTED IMPACT

By putting the driver rather than technology in the center of efforts with regard to complexity reduction in vehicle operation, we see great potential to revolutionize traffic in Europe and to achieve the long term visions and road safety goals of the European countries (e. g., "Vision Zero" [17]). In particular, we expect that drivers have a more relaxed driving experience and feel pleasure while controlling their cars. This 'individual behavior enhancing' add-on of vehicles offers huge chances on the market for (European) automobile manufacturer (with expected much higher impact than yet another assistance or driver information system). A further expected impact is that sort of collective understanding of the traffic situation together with a concerted behavior modification of drivers should have the potential to enable improvements such as reducing global fuel consumption or CO_2 emission. This could be achieved by a kind of "collective brain" gathering neural input 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. Of course, this includes also the control of traffic lights, speed limits, and traffic signs to optimize the traffic flow. (This is rather different to how collective driving behavior is practiced/understood today: On a detected traffic jam the navigation system automatically calculates and proposes a alternative route; the problem is, however, that the rerouting algorithm works equally in all navigation systems of a certain manufacturer, which finally leads to the emergence of a "new jam" on the diversion route while the main route is getting free... Much better would be a common decision making/negotiation who goes where, maybe based on rewards, to establish sort of 'load balancing' on the roads.)

6. CONCLUSION

In this paper we have identified some of the most crucial problems in vehicle operation today and have come up with a number of possible solutions to establish human-computer confluence in the automotive domain. This concept should be understood as a specific instantiation of human-computer confluence working towards the goal of understanding the symbiosis between drivers, cars, and infrastructure within a region of interest and from a global point of view. This covers not only sharing of information about an oil spill on the road, in particular it includes reasoning about driver states and social or emotional interaction, and can be achieved, for example, by modeling driver behavior, studying distributed negotiation processes, performing driving studies and simulations, and relating their results to observations made in reality. With "economic driving" and "stigmergy" two concrete example scenarios were outlined to better accentuate the potential and beneficial effects the application of driver-vehicle confluence might have on future traffic. These are, for example, reduced traveling times, lower fuel consumption/CO_2 emissions, or a more relaxed style of driving (i. e., improved driving experience and pleasure).

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