Resolving Multiplexed Automotive Communications

Applied Agency and the Social Car

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Early streets contained a thriving social structure, without automobiles.

When automobiles were introduced, there was not a friendly integration of the vehicles to city streets and country roads. Instead, early automobiles were rather anti-social to street life, often causing great divides between the public, who felt they had a right to streets, and drivers, whose automobiles' speed and power quickly dominated them. This phenomenon was illustrated in a montage of clips in Harold Lloyd's 1928 film, "Speedy" [26].

The sociability of humans around automobiles was initially that of conflict. People had opinions and fights with regard to accessing public streets, and many attempted to introduce legislation to protect the public against automobiles [1].

Recently, this phenomenon has been echoed in attempts to regulate automobile/mobile phone use, where cars on the street play the part of the norm that is being taken over and made more dangerous by those using mobile phones while driving. Now people are designing embedded telecommunications technologies into cars, and in the process, making cars, in their entirety, communications devices. Historical debates related to the automobile have been resurrected, and perceived threats to the public are being challenged as they were in the past.

Mobile technology supports both asynchronous and synchronous communication without much of a noticeable time delay, resulting in multiple multiplexed communications scenarios. These can be described as layers of partially overlapping messaging networks. We call the dynamic structure comprising the flow of messages, transactions, and information within and between these networks PolySocial Reality (PoSR) [2]. In this article, we explore the impact of discontinuities within PoSR as we examine the next layer of integration of the automobile as a communications device in society. In particular, we explore the need to develop software for the social automobile that encapsulates a concept of agency on the part of drivers and other automobiles.

The idea of a "socially inspired" car is not new. Indeed, early on in the introduction of automobiles, as depicted by photos and in films, cars were often set within highly social contexts: groups of people were called upon to right cars that had driven off the road, or that stalled in traffic and needed a crank to restart [27]. Automobiles with running boards along their sides invited young people to hitch rides down city streets [28]. Not everyone had a car and people often helped each other by offering rides or by running errands for those who were not as fortunate. Many early depictions had vehicles with open tops that encouraged driver-to-driver communication or communication with others on the city streets and sidewalks.

What really happened was much less idyllic: people fought automobile owners and drivers for control over the public streets and subsequently lost. It was a highly social process, but not social in the way that the streets were used before automobiles were present. The situation was social in terms of conflict, opinion, discussion, and politics, and was not necessarily polite, cooperative, or peaceful.

> By the turn of the nineteenth century, streets were already shared by several sociotechnical systems. Private, horse-drawn vehicles and city services depended on the roadways. Pedestrians, pushcart vendors, and children at play used the streets as well. The balance was always delicate and sometimes unstable, and crowds of automobiles soon disrupted it. During the 1910s and 1920s competitors fought to retain, or establish, legitimate title to the streets. Of the many street rivalries, the feud between pedestrians and motorists was the most relentless — and the deadliest. Blood on the pavement often marked the clashing perspectives. Success or failure on the streets reflected not only the opinions but the fortunes of those who used them. Pedestrians forced from the street by aggressive motorists blamed the problem on spoiled "joy riders," and were in turn dismissed as boorish "jay walkers" by irritated drivers [3, p. 332].

Although at times unpleasant or even deadly, the historical social communication over use of the streets shared a common trait: it was synchronous – people were interacting with each other within the same timeframe. As cars were able to move at higher speeds and have a more robust architecture, they became enclosed, creating an environment that was even less socially integrated with the community outside their exteriors.

Eventually, telecommunications devices became robust enough to be mobile. Radio phones, then Citizens Band (CB) radios, were used for in-car communications, followed somewhat later by mobile phones. These devices entered the car environment and reconnected those inside vehicles to others outside their cars, who may or may not have been either on the road (as with CB radios and mobiles) or on landlines. In particular, the early days of CB radio exhibited many parallels to issues today as people attempt to create a "socially inspired car." According to Dannefer and Poushniky [4], CB radio usage created an anonymous, private (by anonymity) and extended social network that gave people confidence that they could get access to help, traffic information, weather, police activities, etc., through communications with other members of the network. Anyone could purchase and use a CB radio, and while there was always the potential for criminal activity or betrayal of trust, it did not inhibit people from using the network. Trust was implicit by both having a CB and being a "Good Buddy" [4].

> The CB technology facilitates the expression of closeness, but prevents its natural concomitant of commitment. This is so because the constraints placed upon behavior in repeated face-to-face interaction situations are absent. The overall impact of the technology has been to create a facade of strong social ties. Unfortunately, the social network thus produced is fragile [4, p.616].

While CB radio communication was tenuous, due to its anonymous nature and lack of face-to-face interaction, it also happened only in synchronous time. The addition of mobile devices to the car enabled both synchronous and asynchronous communications, as well as documentation of where a call originated from, duration, and so on. Thus, the tracking implicit in mobile records and connections thwarted the privacy found in anonymity. However, simultaneously, the robustness of trust increased as people were able to track and learn each other's identities. As phones became message enabled, communication between people via mobile or telephony technologies became more asynchronous. This enabled people to communicate in a way that was time shifted, sending messages out with no knowledge of when they would be received or replied to, and/or to retrieve messages sent to them at their leisure.

Social Automobiles

The Socially Inspired Car

The "Transition to the Socially Inspired Car" might be titled the "Return to the Socially Inspired Car" as we revisit and reinvent sociability through technologically assisted transportation. Sociability has different forms and at its foundation extends beyond our ability to communicate with one another to be social. Sociability is part of our survival strategy as humans. To survive, humans must remember (or at least be consonant with) their dependence on each other for existence. Edward T. Hall wrote, "Man and his extensions constitute one interrelated system" [5]. As much as we'd like to separate that which is "social" from that which is in the environment, we cannot, for these are interdependent [6].

Cars and people are already part of a highly complex interrelated social system that includes the infrastructure that they are dependent upon. This interactive social system creates and maintains the systems that enable cars to function: streets and road repair, fuel, rubber for tires, oil, glass, metal, paint, and other industries combine to make the idea of a running car possible. When one is isolated in a comfortable car moving down a beautiful road, it is unlikely that the social system required to make the drive possible is even considered by the driver. If we add the potential for synchronous or asynchronous message communication to that driving experience, we can see that the interrelated social systems become even more complex.

PolySocial Reality

We have used PolySocial Reality as a conceptual model to describe the global interaction context within which people (and other connected agents) experience the social mobile web and other forms of communication [2], [7] (see Fig. 1).

One of the applications of PoSR is to represent multiple agents and the composite of their respective individual points-of-view (POV) with respect to the multiple networks within which they are connected to other agents. This helps us to understand how the local circumstances of agents relate to circumstances in other locales they are interacting with (directly or indirectly) over networks. A property of even simple networks is that each "node" has a different "experience" with respect to the rest of the network – no two nodes see exactly the same data. With multiple networks (e.g., corresponding to meta- and multi-graphs (Fig. 2)), the contrasts in POV become even greater. There is no direct way for a node to be aware a priori of what additional networks connected nodes or other agents might be a part of [8]. PoSR is the aggregate of information across networks. This information is not generally known or inferable by individual agents contained within the networks. PoSR is based upon the core concept that dynamic relational structures emerge from the aggregate of multiplexed asynchronous or synchronous data creations of all individuals within the domain of networked, non-networked, and/or local experiences [7].

As an interaction context, PoSR represents outcomes with respect to cohesive sociability. Frequently there will be an expanded social network, but parts of these expanded social networks will be connected by weak, single dimension attributes, leading to fragmentation. Fragmentation within PoSR encourages individuation, which makes it more difficult for humans to be social (and cooperative) with one another, even as they effectively have a larger social network. While implementations continue to focus on individuated orientations, this problem will be further compounded.

Fig 1:

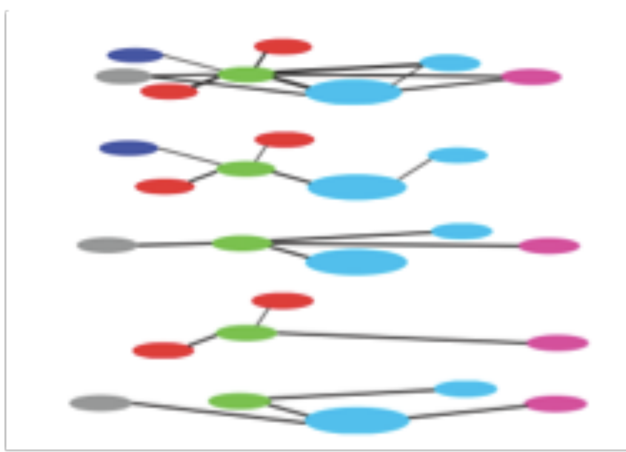

Fig. 1. An "exploded view" of a fragment of a PoSR network. Each layer represents a different social network of the same individuals, each based on a communication channel.

The more that people share common sources of information while interacting with each other, the greater their capacity to effectively collaborate becomes. If they share too few channels relevant to a common goal, there may be too little mutual information about a transaction to interact and communicate well collaboratively. Poor collaborative interaction can lead to further relational fragmentation with the potential to promote individuation on a broader scale [9]. By changing the means that humans use to manage space and time in their daily routines, developers can shift our experience from individuated user experiences to enhanced sociability within a multi-user, multiple application, multiplexed messaging PoSR environment.

Fig 2:

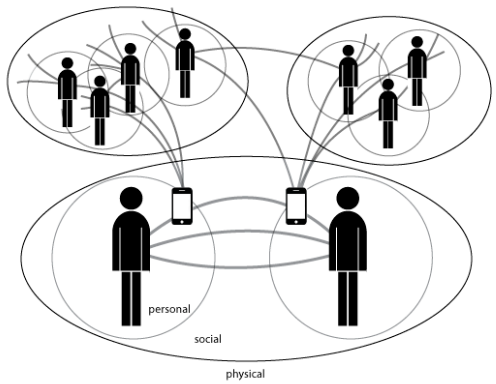

Fig. 2. Meta-multigraph with individual nodes situated in contextual sets.

In an automobile we have multiple channels supporting multiple networks, sending and receiving communications – which may or may not be multiplexed, and may or may not be synchronous – all while moving. This activity can quickly add up and become overwhelming, evidenced by the issues that have been the subject of legislation around the world regarding behavior relating to phones and driving, texting, and in some cases even holding, a mobile device [10], [11].

The Connected Car

Imagine someone driving on the road in a "connected car." They are being assisted by various on-screen windshield Augmented Reality (AR) applications that guide them through traffic, map their route, and suggest places to stop along the way that they might want to visit. They still have the capability to make and answer calls and instruct an agent how to respond to email, etc., all while in motion. A driver might also be drinking a coffee, or having a snack [12]. They may even be wearing a head mounted display device in addition to what is installed in the vehicle.

In addition to balancing these instruments, tasks, and activities, there are even more challenges that will face drivers in the near future.

The battle for the territory of the car and its digital interior has just begun. In "Connected cAR: Becoming the Cyborg Chauffeur," Applin [12] suggests that one way to automate cars might be to use human behavior to train the Artificial Intelligence (AI) of the car. At present, while a human is still needed for nearly all automobiles, humans may be starting to train automobile systems as to the parameters of driving behavior.

The car is apparently one of the next battlefields for ownership of our personal data and privacy. It is an intimate environment and there will soon be enough sensors to document every human habit and behavior within it. While cars will become the panoptic reporter to our every move, people will also be burdened with an overwhelming amount of data ostensibly aimed at "aiding" them in the driving task. There will be touch activated windshields, Augmented Reality (AR) navigation lines projected onto the windshield that guide drivers on a track of navigation, and the blending of both scenarios with the addition of ads showing up on screen. Audio feedback based on sensor activity is currently available as a service in certain commercial vehicles. Installed sensors monitor driver behavior and provide immediate audio feedback if a driver suddenly changes lanes, is speeding, or engages in other unsafe behaviors [12].

While an audio warning to remind people that their cars are weaving is useful, it does not fully address the issues that are required to keep cars safe with a multiple menu of digital, technological, and social options soon at their command. If nothing else, cars will have to provide tools that simplify the decisions that both people and their car algorithms need to make to keep the car safe.

Sharing, or making a car more "social" is certainly a double-edged idea. In one way, it can be similar to what happened in the later days of the automobile (after the turf wars for the streets had subsided), where "social" behaviors (such as sharing) led to cooperation that helped the driver and, in turn, helped those that became passengers or were part of the community. In another sense, too much sharing does not benefit drivers or their communities, but instead that of advertisers, manufacturers, governments and so on. This is a less egalitarian view of sharing and sociability. If information is going to be exchanged between cars – authority, accountability, and the audit trail for when information is viewed and who gets to review it, will also need to be considered. An environment of sharing information and coordinating vehicles enters people and their cars into a different kind of social relationship on the road. This environment also creates new opportunities for criminality, as car hijackers/hackers find ways to control vehicles to overtake, steal, or utilize to aid them in their various schemes of either overt theft or overtaking control of information systems to cause accidents…or worse [13].

Multiplexed Attention, Agency, and Software Development

At present, humans use mobile devices to extend their capabilities, often while they do more than one thing at once. "Divided attention," describes the state when humans focus their attention on more than one thing at a time. Research on divided attention suggests that people using mobile devices, are not generally able to concentrate on other things in their vicinity when walking or driving whilst having a conversation that requires them to process information [14], [15]. Communications across PoSR networks exacerbate the impact of divided attention to greater extremes as attention is greatly multiplexed and the complexity of the messaging environment goes well beyond the capabilities of physiological systems that enable people to do critical things required for their safety and the safety of others. This can be controlled if people are able to make the right choices for their attention, but making the right choices is difficult in a divided attention context. Safety strategies take time to develop, and the results of poor decisions can be critical. Thus, the interaction environment described by PoSR poses great challenges to using upcoming technologies to improve the social integration of people and their vehicles. The high entropy of driving conditions in conjunction with the PoSR environment poses a complexity problem that requires a particular kind of artificial intelligence (AI) agency to help solve. When cars have the potential to be "social" (even between themselves as machine-to-machine) there exists a high likelihood for fragmentation due to PoSR-related multiplexing. In hardware terms, the ability to parse multiple messages in an automobile is certainly possible. Sensors could be added to handle needed functionality and a processor could be dedicated to each subsystem promoting undivided attention other than a few input settings. Software is another matter entirely.

Agency is the capacity to make nondeterministic choices from a set of options as events unfold. For example, humans exercise agency in a car when deciding to run a red light, or not, or to turn left and visit friends on the way to the store. Since options are known possible contingencies, the capacity to exercise these as choices depends on having the sufficient skills and knowledge to do so. People generally can foresee more options than they have ability or confidence to exercise in any given situation. A potential benefit of technology is that it can create more options, and by extension, make it easier for people to exercise those options. However, as technology changes, so do its benefits and the options that are created within them.

Technology expands agency in particular directions, but can lead to loss of earlier enactable options if the earlier options depend on prior knowledge, skills, and technology that may be replaced by newer options.

The foundation of a social relationship requires the presumption of agency on the part of the other. Otherwise, it is not a social relationship, but instead a technical relationship where the right knowledge and action will result in a given behavior. Social relations require that each party understand that the other can exercise agency. The nature of the relationship will impact, but not determine, how each party's agency is enacted. The effectiveness of social relationships is based more on trust and reciprocity than specific actions. In return people gain access to the knowledge and skills of others, increasing their exercisable options and thus expanding their agency beyond the capacity of their own knowledge and skill, as well as increasing their capacity to contribute to simultaneous tasks.

Presently cars do not have agency. Anti-lock brakes, airbags, and other seemingly automatic features mimic agency in cars, but those are based on decision trees, fuzzy logic, or local rules, and will not scale to the multiplexed environment of a truly social car that can take over aspects of driving which presently require human agency to perform.

The capacity for both human and machine to make genuine choices from a rich set of options adaptively as events unfold is the ideal outcome for a driving environment where events can be unpredictable. In other words, in the case of people within cars, the combination of humans/cars needs to have relatively successful outcomes in order to avoid accidents. The discussion of agency applied to PoSR and the social car comes into the fray not so much because we are concerned with the specific agency of an individual person or car, but because to exercise agency in a social context, understanding that others have agency and a context for that agency is essential to an individual applying their own agency. We are suggesting that to be successful, the social car will require an AI that has operational agency in the sense that its own decisions are in part based on the presumption of agency in other vehicles (human or mechanical), and thus that the AI has the capacity to make judgments based on trust and reciprocity rather than relying on behavioral extrapolations alone. Bojic et al. [16] highlight some of the issues and problems relating to integrating machines into social networks [16, p. 89]. However, although they include agency in their argument, they assume this is imposed from outside the social network, whose purpose is to realize this external agency, which is driving the global process as a series of distributed local processes. Manzalini et al. anticipate the need for distributed agency-driven context awareness [17]. We argue that if there is more than one agency at play, necessarily these local processes must include a presumption of agency on the part of all interacting systems in order to resolve the often conflicting goals of different agencies.

Problems can emerge from having to manage any loss of information that comes about by distributing messages across too many non-intersecting networks (an outcome of PoSR). When people do not know enough of the context relating to the people they are communicating with, there is a greater likelihood of creating unwarranted inferences. When communicating in person, people infer things based on many inputs, including observations, content of the communication, past experiences with the other party, and context, which enable them to understand how the other person is situated. When the other person in a communications transaction is situated doing different things that the observer is not aware of, due to being in another location, the observer needs to learn to make more conservative estimates from their inferences, or they will be at risk of making judgments that will not achieve desired outcomes. As a rule, more general inferences are less tailored to specific individuals (and situations) and are not necessarily the most accurate or the most efficient. Generalized inferences do not work as well as more tuned coordinated social interchanges. This kind of impact of fragmentation in PoSR could easily happen in an engineering sense: messages, the foundation of sociability, require observations and other data to produce accurate inferences and judgments for successful communication and in turn, successful cooperation.

When observational cues are absent, more conservative general estimates must be made. It is not a hardware problem; the hardware can process whatever it needs to in a vehicle in terms of data. But software is difficult to write because, unless there is some type of corrective for contextual interpretation, more conservative judgments will need to be made, which in turn means less efficient/accurate/appropriate judgments, which in turn reduces the scope of what can be accomplished. In a car that is monitoring many different sensor inputs plus potential multiple, multiplexed, social messages that contribute to interpretations of PoSR context, plus its own agency, the event of one message interpreted poorly could have disastrous results. This problem also makes it difficult to certify such a system because in order to certify it, nearly all of the local inferences will need to be as close to 100% reliable as possible. Due to variability of interpretations in PoSR with respect to multiplexed messaging from a hypothetically huge number of vehicles on the roads, this becomes nearly impossible.

This complexity problem emerges from a combination of agency, volume of messages, and the context of the messages that are both coming in and being sent out to other people and vehicles. Not all messages are available to all segments at all times. An incomplete distribution of the messages creates more confusion, as it is impractical to send everyone every message and expect them to process the data.

Because there only needs to be one message that is not properly contextually transmitted or interpreted for a disastrous result, particularly in an automobile, accounting for a broader range of activities that are happening at any given time will have to be designed into the system. In other words, PoSR contexts might be alleviated somewhat – if each network member knew something about the other networks of each other member. Solutions might include agents that summarize different things for different parts of the communications in order to create more accurate interpretations of messages or to design less efficient systems. A possible solution, in part, may be to produce some kind of subsystem that manages context within PoSR. A system of contextual "tokens" could accumulate for each context and be transmitted with messages as a kind of summary of the other's originating and interpretive context. These could be collected as they flow across more and more networks. This would produce a contextual history that is attached to the communications, allowing for the development of more agency on the part of the system.

Thing Theory and the Connected Car

The realization of the connected car might be possible, or at least improved, by incorporating internal systemic decision making with reference to agency and bi-directional interaction.

Thing Theory [18] is an agent-based network model that conforms knowledge of the local context of each participating Thing-agent to a common understanding by all Thing-agents, thus granting agents within a network a shared contextual understanding. Local knowledge for each Thing-agent is gained through its relationship to people and other agents in the environment, as well as system-subagents and meta-agents in other systems. A Thing-agent is informed of the local knowledge, which is then fit to the objectives and circumstances of all participating agents.

Thing Theory was inspired by the notion of the character "Thing" from "The Addams Family," a 1960s television show based on a comic of the same name created by Charles Addams. Thing is characterized as a disembodied hand (and forearm) that has been with the family for many years and is described as both a "family retainer" and "friend." Thing inhabits a series of tabletop boxes in different rooms of the house [19] that could be compared to a type of roughly cobbled physical network. Thing communicates with the family by gestures, sign language, writing out notes, or tapping out messages in Morse code. Thing serves the family by accessing a portal in contextual proximity to what is needed or desired at the precise moment it is required, in the precise room or context needed. Thing is not only a ubiquitous agent, but also an anticipatory one that migrates within the environment. The sensing, response, and location-awareness of Thing is a useful aspirational model for a network agent in a static or moving location-aware smart environment.

Thing functions as a communal agent. It develops relationships and shapes knowledge and responses for different actors within the system that it serves. The Thing-agent collects information on all systems. While this presents issues with protecting the privacy and security of all parties in different connected cars, the development of partial identity brokers (so we are sure who we are transacting with) and the validity of the information (so that auto-spoofers cannot easily "hack" traffic) can ameliorate privacy and security concerns. A Thing-agent can serve a real need to revise and design processes so that they are not so brittle, fragile, or unidirectional.

In [18] we discuss possible approaches for implementing Thing theory in location-aware environments. A Thing-agent at a minimum is a means to inform agents (people and car sub-systems) of the information about processes within a smart environment in pragmatic terms that make sense to those agents. These conditions promote good decision making (understanding options and agency), ideally utilizing a high-level interactive interface that adapts to the POV of each agent to each other to the extent required.

A Thing-agent includes a representation of the pragmatic contexts in which processes are expressed. This is done such that the Thing-agent facilitates choices by agents, and makes more choices available to agents, rather than forcing them into specific choices.

In such a situation there are many complex contingencies that can arise. A Thing-agent might employ non-monotonic multi-agent simulations incorporating specifications for each process and that relates sensor-based information to present scenarios of possible ways processes and users might interact with each other. On this basis a Thing-agent can indicate available options to each of the other agents in different contexts, and provide feedback in terms of what is likely to occur should an agent make a given choice (and how other agents are likely to view this choice and respond), thus a basis for "fine-tuning" how they proceed.

There exist logic and associated software architectures for developing such multi-agent simulations in a manner to support decision-making. Deontic logic is a good candidate for a useful semantics that supports constructing simulations of the type needed [20], [21]. Castro and Maibaum [22] present a deontic logic suitable for representing the interrelations of users with agency, and Horty [23] discusses at length representing and reasoning with agency in deontic logic.

A Thing-agent mediated multi-agent simulation can be useful for designing software to promote cooperation and knowledge exchange needed to coordinate cars on the road. Such an exchange could leverage "simulation services" provided by a Thing-agent to support their decision-making, and possibly improve the joint understanding of dynamic production environments. These simulation services would direct attention once again to outcomes rather than processes, since all parties could see different possibilities emerging from their actions in interaction with others. They could then alter course as needed to improve probabilities of a good outcome dynamically.

This approach to process control would be far more adaptive and would favor outcomes over processes while leaving room for drivers to deploy their individual skills towards achieving these outcomes. Exploiting a Thing-agent to ensure that the information that needs to be shared to support agency in the network of drivers and cars is available to maximize the capacity for cooperation, and avoid the problems that can arise from PoSR networks such as missed or misunderstood messages, or connected individuation [24]. Thing-agents could be employed within a system of restricted privacy based on tasks, rather than tracking agent's behavior.

Not everyone in the social environment of the road fully knows the objectives, roles, and responsibilities of what the other is up to, nor should unnecessary information be available for privacy and security reasons.

Trusted Agents May Help Restore "Order"

Highly heterogeneous messaging environments that enable individuals and their cars, and/or individuals in cars and their passengers, to connect and communicate with each other and others, can lead to a complex situation that currently has little overlap for cooperation [9]. This will be especially challenging as the hardware form factor migrates to a head-mounted glasses option, or possibly even "in-head" mounting. Software development that enlists the use of Agents for certain processes and tasks may help to restore "order" in the car.

It has been documented that having connection in the car (via the CB radio research [4], and as evidenced by the overwhelming usage of mobile phones and texting while driving [4], [11]) to systems outside the car, is important and valuable for humans. It is worth further exploration to determine if social needs within vehicles remain the same from the CB radio days, or have changed with the times. Furthermore, as the car becomes a fully automated form with Artificial Intelligence eventually replacing the human driver, planning for how it will handle the complex multiplexed environment of communications that emerges as PoSR, along with its own newfound agency, within its environment is critical.

Thing Theory is one possible approach to resolving some of these problems while improving security and maintaining privacy. Resolution can be achieved with two approaches. The first, using either a virtual or emergent Thing-agent, (where the systems comprising each car are constructed from a constantly aggregating information feed) to create a plausible POV for other cars on the road. Alternatively, a series of literal Thing-agents belonging to the road would effectively direct traffic, replacing or augmenting current "Things" such as traffic signals, roundabouts, and road markers.

A useful means of representing PoSR contexts might include creating some form of dynamic commentary regarding an agent's context that is constructed from any combination of visual, aural, or language-based elements that can be modified, rescaled, and browsed by end users to find information they require from the present or past about others they are interacting with, directly or indirectly, in a compact form [6].

Appropriate descriptions of PoSR contexts may offer location aware applications a tractable means of traversing the complexity of single and multiple user experiences while maintaining the complexity required by users (and cars) to construct further applications of the technologies they employ [6].

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