Cognition in Connected Vehicles

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***Abstract*—In this paper,**

***Index Terms*—cognition, connected vehicles ...**

I. Introduction

Intelligent transportation systems (ITS) will form an integral part of society's transportation infrastructure within few years

A. Roads as Social Environments

A social environment refers to an individual's physical surroundings, resources and social relationships. A social relationship includes the interaction between two or more individuals in the environment. A social relationship is the most dynamic part of a social environment. Hence, developing and maintaining positive social relationships is crucial for a social environment and is influenced by the individuals' quality of interaction. Roads are social environments in which individual vehicles interact with each other through their "nonverbal" behaviors obeying the same traffic law. However, there are many violations of the laws on the roads all over the world in daily basis which consequently leads to expensive and sorrowful failures. What causes these failures is mostly the failure of the drivers to effectively interpret their driving environment and make an appropriate decision with respect to their constraints such as lack of time, lack of perception, and plethora of cognitive load. Therefore, it is crucial to involve awareness in the vehicles to share the meaning of what they dynamically perceive rather than broadcasting the data coming from their sensory system. For example, any sensory information leading to an alert on a particular vehicle does not necessarily have the same meaning both for the occupants and the neighbors of that vehicle. The alert warns the occupants of the vehicle to be aware of an internal failure (e.g., malfunction in the transmission system), or an external adversary (e.g., an unexpected leaping of an animal into the road). The same alert has a different meaning for the close vehicle approaching from behind; no matter what caused the alert in the leading vehicle, the posterior vehicle should slow down effective immidiately. However, the same alert can be interpreted in a totally different way for a neighbor in front of the originally alerted vehicle. In fact, this vehicle can ignore the received alert and continue the safe drive. Ultimately, these type of improvements leads to a higher quality of vehicles' interaction which consequently increases the safety of the roads.

B. Driving Needs Pareto Optimal Decisions

Cognitive architectures are used to solve high-dimensional multi-objective tasks and to make proper decisions with respect to the dynamics of such environments. Most of the time the real world problems possess a high level of complexity due to the dynamism involved in the environment. A social environment is an example of such complex environments. A social environment includes humans as variety of sources making decisions independently but interrelated to each other. Roads are social environments and driving is the social act of drivers' behavior. It is clear that driving involves many decisions in which a driver needs to maintain its own objectives while recognizing objectives of the others.

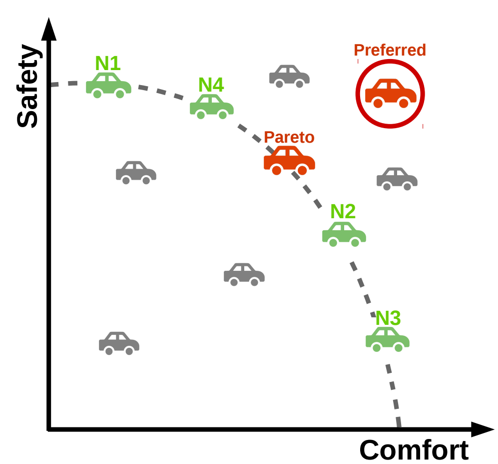

Figure 1: Pareto optimal decisions for the neighbors.

Let's consider two general objectives, *Safety* and *Comfort*, for any driver while driving between the source and the destination. Indeed, all the drivers would like to maximize both of these objectives while driving. However, while they need to obey the traffic law, they need to take into account their neighbors' driving behaviors.

C. Cognition Systems

Integration of cogniton into connected vehicles needs us to understand the building blocks of cognition, how do they relate to each other, and what functional operations they provide. We choose Newell's general theory of cognitive control, PEACTIDM [1], to describle the underlying abstract processes of a cognitive system. PEACTIDM is a theory of cognitive control where cognition is decomposed into a set of eight abstract functional operations [1] all of which are hypothesized as the building blocks of one's immediate behavior. Figure 2 shows the sequence of PEACTIDM's building blocks.

Perceive is the reception of raw sensory data. For instance, connected vehicles receive data from both their own local sensory system (e.g., GPS) and their neighbor vehicles (e.g., an abrupt change in their velocities). *Encode* is the transformation of the sensory data into features that the cognitive system can process. In the cognitive architectures using Bratman's BDI paradigm [2] each sensory data will be tranformed into a new *belief*. The cognitive architecture will be able to use these beliefs in different processes. For example, in connected vehicles there will be a belief about the current accelaration value of the vehicle which corresponds to the sensory data indicating this value. *Attend* is the act of shifting or maintaining the focus of attention on an event. For instance, an alert raised because of a sudden speed reduction of multiple leading neighbor vehicles needs to be attended immediately while the same alert does not need the same level of attention if the leading vehicles are a few miles apart. *Comprehend* is the act of trnasforming an event into a goal or task-spcific representation and inferring the curent status of the world. For instance, a vehicle receiving an alert requiring an immediate reaction needs to identify the cause of the problem even though the alert has raised and received from another vehicle. Thus, the receiver of the alert can apply replanning if necessary.

Tasking is the process of recognizing a goal based on the new state of the world. For example, a vehicle can recognize a goal in the plan to exit the highway with respect to the new beliefs about an accident a few miles ahead and the current state of the highway which causes constant speed reduction. *Intend* initiates a future action based on the current goal as response to the current event. For instance, if the current goal of the vehicle is to leave the highway, the vehicle begins to change the lane to the right most to be able to take the next exit. *Decode* translates the response based on the given *intention* into a series of motor actions. For instance, if the intention is changing the lane to the right, The vehicle applies a series of actions including using the right blinker, checking the occupancy status of the right lane, and turning the steering wheel to the right whenever it is appropriate. *Motor* executes the actions decoded based on the given intention. For example, in case of a lane change, the blinker starts to blink and the wheels turn to the right respective to the amount of change on the steering wheel.

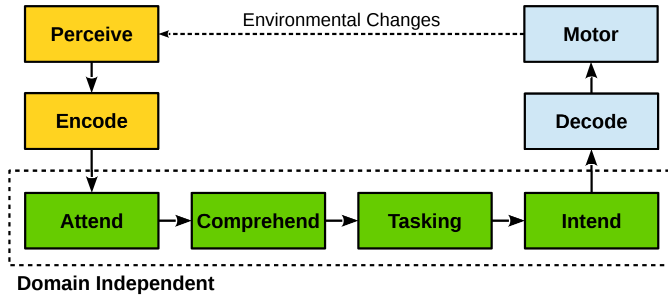

Figure 2: PEACTIDM

II. Affective Motivational Collaboration Theory

Affective Motivational Collaboration Theory is about the interpretation and prediction of observable behaviors in a dyadic collaborative interaction. This theory is built on the foundations of the *SharedPlans* theory of collaboration [3] and the *cognitive appraisal* theory of emotions [4]. The theory focuses on the processes regulated by emotional states. The observable behaviors represent the outcome of reactive and deliberative processes related to the interpretation of the self's relationship to the collaborative environment. Affective Motivational Collaboration Theory aims to explain both rapid emotional reactions to events as well as slower, more deliberative responses. The reactive and deliberative processes are triggered by two types of events: *external* events, such as the other's *utterances* and *primitive actions*, and *internal* events, comprising changes in the self's mental states, such as belief formation and emotional changes. Affective Motivational Collaboration Theory explains how emotions regulate the underlying processes when these events occur during collaboration. This theory elucidates the role of motives as goal-driven affect-regulated constructs with which an agent can form new intentions to cope with internal and external events. The focus of underlying mechanisms is on the ones depicted as mental processes in Figure 3 along with the mental states.

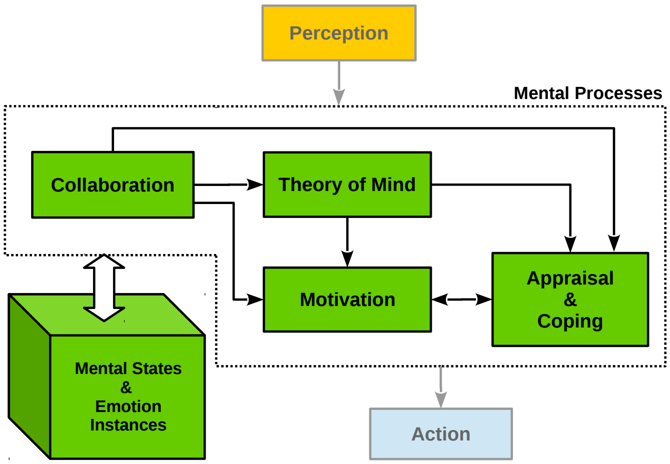

Figure 3: Computational framework based on Affective Motivational Collaboration Theory (arrows indicate primary influences between mechanisms).

The *Mental States* includes self's (robot's) beliefs, intentions, motives, goals and emotion instances as well as the anticipated Mental States of the other (human). The *Collaboration* mechanism maintains constraints on actions, including task states and the ordering of tasks. The *Collaboration* mechanism also provides processes to update and monitor the shared plan. The *Appraisal* mechanism is responsible for evaluating changes in the self's Mental States, the anticipated Mental States of the other, and the state of the collaboration environment. The *Coping* mechanism provides the self with different coping strategies associated with changes in the self's mental states with respect to the state of the collaboration. The *Motivation* mechanism operates whenever the self a) requires a new motive to overcome an internal impasse in an ongoing task, or b) wants to provide an external motive to the other when the other faces a problem in a task. The *Theory of Mind* mechanism is the mechanism that infers a model of the other's anticipated mental state. The self progressively updates this model during the collaboration.

III. Proposed Cognition Mechanism in Connected Vehicles

IV. Case Study

V. Future Works

VI. Conclusion

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