Prediction Capabilities for Cyber Physical Vehicles

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ABSTRACT

Cyber physical systems open new ground in the automotive domain. Autonomous vehicles will try to adapt to the changing environment, and decentralized adaptation is a new type of issue that needs to be studied. This article investigates the effects of adaptive route planning when real-time online traffic information is exploited. Simulation results show that if the agents selfishly optimize their actions, then in some situations, the cyber physical system may fluctuate and sometimes the agents may be worse off with real-time data than without real-time data. The proposed solution to this problem is to use anticipatory techniques, where the future state of the environment is predicted from the intentions of the agents. This article concludes with this conjecture: if simultaneous decision-making is prevented, then intention-aware prediction can limit the fluctuation and help the cyber physical system converge to the Nash equilibrium, assuming that the incoming traffic can be predicted.

KEYWORDS

Benefit of Online Real-time Data, Braess Paradox, Connected Car, Intention-Aware Prediction, Navigation, Online Routing Game, Online Routing Problem, Price of Anarchy, Routing Game, Routing Problem

INTRODUCTION

Ubiquity and interconnection are important in information systems, and they are behind many concepts like pervasive computing, ubiquitous computing, ambient intelligence, internet of things, and cyber physical systems. A cyber-physical system is a system of real-world objects that are controlled or monitored by computer-based algorithms, usually through the Internet. Cyber physical systems open new ground in the automotive domain by introducing entirely new services to the traditional concept of a car. The connected, smart car provides a way to stay in touch with the world during drive time. There is a possibility for new kind of infotainment services and connected car applications to provide better services for drivers and the automotive industry as well. The novel applications include fleet management based on data collection via embedded software, data management in the cloud, and data analytics. The predictive maintenance can be based on the monitoring of the state of the vehicle, and the analytics can be based on cloud-enabled platforms to provide new services to car manufacturers, maintenance and service companies, insurance companies, and entertainment providers.

Automotive manufacturers and suppliers can utilize these cyber physical systems to diagnose vehicle malfunctions on the road. This direct and immediate information can be used to avoid costly recalls by understanding product quality and rapidly assessing safety issues in order to optimize production. Telecommunication companies can develop new connected applications and services, which may be consumed either in vehicles or remotely through smartphone apps. Better driving experience can be delivered by exploiting information about the location, movement, and status

DOI: 10.4018/IJCPS.2019010104

of vehicles by analyzing map context and driver behavior. Non-traditional automotive industry participants may provide many of these novel services.

The above-mentioned services are mainly centralized services, in the sense that there is a single organization that collects data from the cyber physical system, analyses it, and then takes actions. Because there is only one actor that senses the environment and takes actions, this is centralized adaptation. This model suits well the traditional automotive industry.

Cyber physical systems help the development of self-driving cars as well. Autonomous vehicles can detect their environment, using different sensors like radar, LIDAR, GPS, computer vision and data from the Internet. The planning unit of the autonomous vehicle merges and interprets the collected information to determine the necessary control actions to navigate the car and avoid obstacles. Autonomous vehicle technology is expected to provide several benefits like those shown in Table 1. In order to achieve these benefits, the autonomous vehicles have to act collectively. Because there are several actors that sense the environment and take actions, this is decentralized adaptation.

With the advent of autonomous vehicles, decentralized adaptation will be a new type of issue that needs to be investigated. Humans and software agents are working together in such decentralized autonomous vehicle environments. The critical challenge (Çolak et al. 2016) is using the generated big amount of real-time data in a way that the overall decentralized adaptive human-agent collective benefits from the instant availability of information. The availability of real-time data changes the behavior of the active entities (agents) of the system as well, because they try to adapt to the observed situation. Classical autonomous vehicle research focuses on how to control a single vehicle to get to its destination. The control of a single vehicle needs adaptation to the environment. If there are several active entities in the environment and all of them try to adapt to the observed and predicted changes, then the overall system may demonstrate strange behavior. Just imagine two people going in the opposite direction on a corridor, and then they try to avoid a possible collision by trying to bypass in the same direction at the same time. Sometimes there is a hesitation until they finally settle who goes in which direction to avoid the collision. In order to foster the development of practical cyber physical applications in the automotive domain for decentralized adaptation, researchers have to prove that autonomous adaptation is better off with real-time data than without.

This article will discuss different models, methods and challenges, which are investigated in a decentralized autonomous vehicle environment where things have embedded intelligence and they have real-time sensor capabilities. In these environments, autonomous adaptive entities play an important role.

Next section will overview the models of decentralized adaptation, the simulation of the game theory model of adaptation will be presented, and the challenge posed by the instant availability of real-time data in cyber physical systems will be discussed. The second next section will present decentralized adaptation with intention-aware prediction as a solution to the problem posed by the instant availability of real-time data in cyber physical systems. The third next section will demonstrate in a scenario the limits of intention-aware prediction. Finally, future research direction will be projected in the form of a conjecture and the article will be concluded.

Table 1. There are several application scenarios for autonomous vehicles to exploit cyber physical capabilities

Cyber Physical Autonomous Vehicle Capabilities	Benefits of Autonomous Vehicles
• Environment Sensing (Perception) • Radar, Ultrasonic, Video camera, Laser Scanner (LIDAR) • Floating Car Data, Mobile Phones or GPS • Vehicle to Vehicle interactions (V2V) • Vehicle to Infrastructure interaction (V2I) • Vehicle to Environment interactions (V2E)	• The mobility of the elderly and disabled people can be increased • Traffic flow can be more efficient and congestions might be avoided • Finding urban parking places can be faster • Fuel efficiency can be increased • The travel time can be used for other activities