Control Design of an Automated Highway System

This paper describes the control design of an automated highway system (AHS). The main advantages of AHS can be summarized into two aspects: First, by arrange vehicles in the form of platoons, the mean inter-vehicle distance is decreased. Capacity of highway achieves 8000 vehicles per hour per lane compared to 2000 in today’s highways with manually controlled vehicles. Second, the tightly spaced vehicles make aerodynamic drag smaller, which means the reduction in fuel consumption and pollutant emission. AHS’s development involves advances in many fields of technology such as communication, computer, sensor, actuator, and large-scale control system design.

AHS has a five-layer architecture, which consists of network layer, link layer, coordination layer, regulation layer and physical layer. The physical layer contains all the on-board vehicle controllers of the physical components of a vehicle. The regulation layer manages the longitudinal and lateral guidance of the vehicle, and receivers orders from the coordinate layer. The coordination layer selects the activity the vehicle should execute and also communicates and coordinates with its peers. It is also responsible for commanding the regulation layer. For link layer, in each 0.5-5 km long segment of the highway, there is a link layer controller, i.e. a link. It is used to control the traffic flow and receive command from the network layer. The network layer is to control entering traffic and route traffic flow within the network of highway links. AHS also has developed an enhanced architecture that enable functions in faults and adverse environmental conditions.

The overall structure of AHS can be divided into two parts: on-board vehicle control system and road side control system. The on-board vehicle system (i.e. the coordination layer) is a hybrid system, i.e. a discrete event dynamic system which need to send and receive continuous-time dynamical signal coming from or to the regulation layer and physical layer. This paper shows details on how to design these three layers that could achieve the safety and efficiency goals of the on-board vehicle system.

The roadside system is to optimize the capacity and traffic flow of the overall AHS. The link layer function can be divided into two tasks: first is to determine a desired flow field that optimizes traffic flow on the link; second is to design decentralized feedback laws that stabilize the actual flow field at the desired flow field.

The most important part of AHS is the separation of various control functions that AHS must carry out into different layers with well-defined interfaces. The impact of architecture is profound. Because a good architecture simplifies design and testing and well-defined interfaces simplify software design and code development.

This paper presented safety and performance results of the hybrid system formed by coordination and regulation layer. The control of hierarchical system formed by the link, coordination, and regulation layers is discussed.

AHS control is a fairly large literature, so there are still some aspects not covered in this paper. Although the road has turns and twisted, the future of full automation is bright and research of AHS will keep on.