7 AUTOMATED VEHICLE CONTROL*

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7.1 Introduction

Mankind’s love for automobiles dates back more than one hundred years to when they were first introduced. The major functions performed while driving an automobile are lateral and longitudinal control of the vehicle. While the former is necessary to ensure that the vehicle does not lose track of the desired path, the latter is used to keep the vehicle at a safe speed dependent on the surrounding conditions and at a safe distance from the preceding vehicle (if any). This function is carried out by humans whose senses detect changes in the environment and act as stimuli. The human driver then reacts to these stimuli by applying either the brakes or the gas pedal. This reaction defines the driving behavior of an individual driver.

It is a well-known fact that the driving habits differ from person to person. The behavior of the human driver also has randomness associated with it that adversely affects safety and traffic flow characteristics. In the last decade considerable research has been done to automate the vehicle-highway system in an effort to improve safety, capacity and traffic flow characteristics. It has been envisioned that removing the human from the vehicle-driver control loop will eliminate the randomness associated with today’s manual traffic and satisfy the above requirements (Stevens, 1997). This motivates the concept of automated vehicle control.

The degree of automation in a vehicle determines the involvement of the human driver in the driving loop. While the use of partial automation as driver aids guarantees improved traffic flow characteristics, the same cannot be said of safety and throughput (Bose and Ioannou, 1998). However, full automation in the longitudinal direction is expected to benefit safety, capacity and traffic flow

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characteristics. Likewise, completely replacing the human driver in the driving loop with longitudinal and lateral automation, as in a fully automated vehicle, is expected to further improve safety. The use of actuators and sensors is deemed to improve safety, capacity and traffic flow characteristics for the following reasons: firstly, electronic sensors do not get fatigued, tired or distracted and are therefore more reliable (Ward, 1997). Secondly, the actuators react much faster than the average alert human driver, who has a time delay of about 1.0s to 1.5s (Milestone 2 Report, Appendix J, 1996). This implies that vehicles can travel closer, which translates into higher capacity/throughput (Bose and Ioannou, 1998). Thirdly, the deterministic response of the controllers in comparison to the random behavior of human drivers smoothes traffic flow (Bose and Ioannou, 1999). Different system configurations for automated vehicle deployment have been outlined in Hall (1997).

The lateral and longitudinal functions of an automated vehicle are performed with the use of lateral and longitudinal controllers that work in conjunction with on-board sensors (Walker and Harris, 1993). The longitudinal controller comprises two subsystems, namely throttle and brake controllers that do not work simultaneously (Ioannou and Xu, 1994). A switching logic dictates the switching from one controller to the other. The lateral controller uses a lateral control system (Peng and Tomizuka, 1990) that uses a road referencing/sensing system that measures the position and orientation of the vehicle relative to the road (Hessburg et al., 1991).

Chapter 7 deals with vehicle automation, how it is achieved and the subsequent benefits. We begin with vehicle longitudinal and lateral dynamics models in section 7.2 that are used to design automated controllers. Different manual vehicle models that provide a better understanding of the human-driver interface are overviewed in section 7.3. This is useful when designing an automated controller to mimic the behavior of the human driver and partially/completely replacing him/her in the driving loop. A design of an automated longitudinal controller is briefly outlined in section 7.4. This is followed by discussions on longitudinal controllers for heavy-duty vehicles, vehicle-to-vehicle communication designs and sensor requirements that are needed to ensure safe and proper operation of automated vehicles. Next the intervehicle spacing of an automated vehicle that is dictated by the longitudinal controller and the expected safety level due to its use are highlighted.

The lateral control of light and heavy-duty vehicles using automated controllers are briefly outlined in the next section, 7.5, followed by necessary lateral/side sensor requirements. Different sensor technologies available today are evaluated for their applicability as both longitudinal and lateral sensors. Increased level of safety due to the use of an automated lateral controller in addition to an automated longitudinal controller is discussed next.

A beneficial effect of automation, namely automated lane changing, is investigated in section 7.6 using different acceleration profiles of the lane changing vehicle. String stability in vehicle following is evaluated for manual and automated traffic in section 7.7 using the models presented in the previous sections. Lastly, mixed manual/automated driving is discussed and benefits are evaluated as a