Abstracts of Papers

LONGITUDINAL CONTROL SYSTEM FOR DUAL-MODE TRANSIT SYSTEM OF GENERAL MOTORS

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This paper discusses the longitudinal control system currently being developed by General Motors for use in the dual-mode transit system development program sponsored by the U.S. Department of Transportation. The longitudinal control system is considered in two functional areas: vehicle management and vehicle control. Synchronous and asynchronous vehicle management systems are evaluated, and the advantages and disadvantages associated with each technique are compared with their impact on management computer requirements, trip time, and system use. A synchronous slot concept was chosen as a logical first step in the development process because of its relative ease of implementation. Advantages associated with the adaptability of asynchronous vehicle management are outweighed by the complexity of asynchronous merge requirements.

The vehicle longitudinal control system being developed is a point follower; that is, each vehicle is constrained to remain in an assigned, moving, synchronous slot determined by the vehicle management system. A dual-mode vehicle was modeled and incorporated into a digital simulation containing a number of candidate guidance schemes controlling both throttle and brake actuators. With the aid of simulation results, guidance options are evaluated on the basis of on-board versus off-board equipment requirements, spacing and type of guideway benchmarks, and accuracy and response in the presence of abnormal operating conditions. Several options appear attractive.

Further effort in this area should consider controller refinements that allow more precise influence over parameters related to passenger comfort. Another area for future effort might be to determine a method of optimally selecting velocity command profiles based on known vehicle dynamics.

REFERENCE SIGNAL FOR SYNCHRONOUS LONGITUDINAL CONTROL

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One method of continuous reference signal generation for synchronous longitudinal control was previously investigated, its feasibility established, and several difficulties associated with its practical implementation defined. These difficulties, encountered with signals at 3.75 MHz, were excessive attenuation and variable propagation characteristics. The former limits operation to short distances, while the latter results in unexpected and undesired changes in slot length.

These difficulties can be partially alleviated by operating at a lower frequency (e.g., 450 KHz), according to the results of tests reported in the paper. The attenuation was greatly reduced, 0.25 versus 2.3 db/30.5 m (100 ft), but essentially no improvement in the variability of the propagation characteristics was noted. Operation under wet road conditions produced a significant increase in the attenuation—1.4 versus 0.25/30.5 m (100 ft)—and resulted in nearly a 50 percent change in the slot length.

This method of reference signal generation would be most practical for those dual-mode systems that use environmentally protected guiding structures. However, localized use (e.g., in merging operations) would readily be accomplished without the use of protected structures provided that environmental sensing were used to allow for compensating adjustments in the signal parameters.

BRAKING SYSTEM INTEGRATION IN DUAL-MODE SYSTEMS

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There are many interrelations of significance for properly integrating a braking function into a dual-mode transportation system. Factors shaping the characteristics of the braking system are its interfaces with other vehicle systems. The braking system must be compatible with power and propulsion systems and with command and control functions. The operational parameters of motion—headway, velocity, deceleration, and jerk limits—constitute, of course, another set of determining factors.

A dual-mode transportation system involves, in general, both an on-guideway and an off-guideway operation. The on-guideway portion offers essentially personal rapid transit amenities. The requirements in the vehicle in reference to braking capabilities on the guideway are then similar to those of PRT vehicles. The off-guideway braking system requirements are similar to those of buses, trucks, or automobiles. The integration of a braking function into a dual-mode system must be basically a compromise among on-guideway and off-guideway braking operations. In general, the compromise may be accomplished by use of either different braking systems (on different vehicles, as in a pallet-pod operation, or in the same vehicle) or by use of the same braking system suitable for on- and off-guideway operations.

Criteria against which braking systems may be measured are those of safety, economics, energy management, and environmental impact. By considering these criteria and the limitations set by the braking system's interfaces, an organized set or matrix of interrelations is developed from which desirable and undesirable aspects of integration of braking functions into a dual-mode system can be determined.

The significance of the interfaces is such that these become the controlling factors. The actual braking hardware now available, with proper design and application, is adequate for the tasks of stopping dual-mode vehicles. The braking function of necessity includes its controls, especially as headway is lowered to tenths of seconds on guideway where the limitations are the more restrictive. Off guideway, service braking is more restrictive, and emergency braking can be considered as back-up braking. Fail-safe braking is possible only when all interrelations are properly evaluated. Fail-safe, in the paper and in general, can mean only that under a failed mode the function is put into a back-up mode and probability of failure is reduced. A safety analysis such as fault-tree analysis is preferable to reliance on fail-safe concepts.

AUTOMATIC LONGITUDINAL CONTROL OF A MERGING VEHICLE

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Various facets of merging a vehicle into an automated high-speed stream of traffic are considered: a merging system structure, a set of typical requirements for an individual merging maneuver, the geometric and time constraints on that manuever, and a simple on-board vehicle controller for accomplishing it.

Since a means of providing continuous position reference information to a merging vehicle is now available, a position controller was selected for detailed study. This effort consisted of two parts. The first involves a simulation study of various controller designs and their response to large disturbance conditions [3 percent grade and 13.4-m/s (44-ft/s) wind force]. The second was a quasi, full-scale effort in which the behavior of a specially instrumented dual-mode vehicle was evaluated in various merging situations in which the terminal speed was 26.8 m/s (88 ft/s).

The findings to date from this ongoing study are as follows: (a) the details of the trade-off between the minimum required ramp length and the terminal merging error; (b) the development and validation of a model that resulted in data that closely correlated with those from full-scale tests; (c) the parameter range over which this model is valid; and (d) the conditions under which control of a merging vehicle, a corresponding comfortable ride, and excellent disturbance suppression can be obtained. A potential difficulty with the controller studied is the peak tracking error, which could cause difficulty if closely spaced merging vehicles were being simultaneously controlled.

Data were also collected for terminal speeds of 30.5 m/s (100 ft/s). The conclusions drawn are the same in both cases.

This controller will also provide good tracking both in steady-state constant speed operation and in organizing situations (e.g., position move-up and move-back commands). In effect, it could be used for all phases of longitudinal control, except perhaps emergency braking.

The major shortcoming is the somewhat large peak error incurred in merging operations. This error could be greatly reduced by using a more complex controller. One promising choice is currently being evaluated by analog simulation and will be subsequently tested under the partial full-scale approach described in the paper. Beyond that, plans are to conduct corresponding "complete" full-scale tests in which an externally generated reference trajectory is used.