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Model based investigations of an integrated control system for automatic lane change in critical conditions.

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Abstract: The article presents the concept of an automatic, integrated control system for a two-axle truck activated at the time of a critical road situation, consisting in the need to bypass a suddenly appearing obstacle. In earlier works, the authors used only the controller coupled to the steering system for sudden lane changes. Currently, the operation of the steering system controller has been integrated with the ESC (Electronic Stability Control) system, which causes temporary braking of selected wheels of the vehicle to stabilize its movements. Simulation tests of the functioning of the integrated control system during sudden lane change were carried out for an unladen and fully loaded vehicle driven with a high speed on a wet road - in conditions close to critical. The test results were compared with the results obtained during this maneuver only with the use of the steering system controller. They show undoubted advantages of such integration of both systems.

Keywords: automatic lane change, critical conditions, integrated control system

1. Introduction

The dynamic development of controllers, actuators, sensors, monitoring devices, networks and telecommunications technologies favor the emergence of more and more effective systems supporting the driver's actions related to driving a vehicle. In recent years, a significant effort has been placed on the development of assistance systems that are activated automatically when a critical road situation occurs and replace the driver in the selection and implementation of an effective or at least the most beneficial defensive maneuver. Advanced research on such systems is carried out in many research centers, eg [1,2] and in the near future they will be used in mass-produced cars.

In previous publications, eg. [3,4], the authors presented design and research works on a steering system controller that automates the lane change process of a car when an obstacle suddenly appears. This controller generates a "bang-bang" reference steering signal and then corrects it through two regulators that minimize the deviations between the reference and actual waveforms describing the vehicle movement. The developed control algorithm was based on simplified (and therefore effective in on-line calculations) reference models. Simulation tests of the sensitivity of the developed controller were carried out in a wide range of changes in road and operating conditions, in relation to a "difficult" object such as a truck. The maneuver of avoiding the obstacle in the vast majority of attempts was successful without the need to change the previously adopted assumptions and the established values of the controller parameters. However, in a few cases of steering an unladen car at high speed and on a slippery surface, the directional stability was lost.

There is a statement in the professional literature, eg [5] that the steering system provides good driving properties only when the lateral acceleration is low, the vehicle drift angle is low, and the tire sideslip characteristics are linear. However, in emergency situations, accompanied by high lateral acceleration (such as occur during sudden lane changes), the characteristics of the tires become non-linear and the desired effect of controlling the car's movement cannot be achieved by steering the steering wheel alone. In this case, the additional inclusion of the braking system in the vehicle motion control may prove very beneficial. In connection with the above, research was undertaken on the integration of the developed steering system controller with the ESC (Electronic Stability Control) system, which causes temporary braking of selected vehicle wheels when destabilization threatens.

The article will present the concept of an integrated control system, models as well as analytical and simulation tests.

2. Results and Discussion

The integrated assistant system consists of an active steering system that triggers the given steering angles of the front wheels and the electronic control of the track (ESC), which causes temporary braking of selected vehicle wheels.

The two systems that make up the assistant system use as a reference model a flat, single-track "bicycle model" of a car known from numerous publications, but modified by performing simple transformations to express the vehicle's motion in a global system and by linearization of the equations of motion. The assistant system initiates a sudden lane change maneuver, initially carried out only by appropriate steering of the front wheels, so that the car is shifted to the adjacent lane in the shortest possible time and on the shortest possible road. In practice, the implementation of such a maneuver requires very fast turning of the steering wheel from one side to the other (“bang-bang” steering). The ESC system is superior to the steering system controller and when the vehicle approaches the limit of adhesion, it brakes the appropriate wheels, increasing the radius of the path and reducing the speed of the car, which additionally secures the vehicle's stable movement.

The integration of these systems allows for simultaneous control of these subsystems and enables the mutual exchange of information from individual sensors and actuators. Coordination, on the other hand, ensures the harmonious functioning of the systems and the synchronization of partial activities of individual systems, enabling the correct implementation of the main goal, i.e. a sudden lane change.

3. Concluding Remarks

The use of an integrated system controlling the sudden lane change maneuver effectively eliminated the loss of directional stability of an unloaded car on a slippery road.

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