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INTELLIGENT VEHICLE DEVELOPMENT PLATFORM

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Abstract: *Electronic stability control (ESC) has been developed particularly during the present century. The first purpose of this study is to offer software engineering students the opportunity to familiarize themselves with state-of-the-art technology. Line followers are used in multiple applications in the industry. The second purpose of this study is to offer a basis for developing line follower-like technologies. These may, for example, include camera-based navigation and inter-vehicle communication. A remote controlled miniature vehicle was modified to act as the physical basis for the development platform. The modification included the addition of a motor to each wheel allowing them to be controlled individually. A servo motor handled the steering. An on-board computer was installed that ran the ESC program and combined it with the wireless signal from the user. Results of the study prove that ESC technology is scalable and the development platform meets the requirement of an optional control method.*

Keywords: esc, car, miniature, interface

1. INTRODUCTION

Intelligent transportation systems employ advanced communication, information and electronics technologies in order to create more intelligent roads, vehicles and users.[1] These systems can be divided into six categories: Advanced Traffic Management Systems, Advanced Travellers Information Systems, Commercial Vehicles Operation Systems, Advanced Public Transportation Systems, Advanced Vehicles Control Systems and Advanced Rural Transportation Systems.

A line follower is a device that can follow a path. The path can be visible, like a black line on a white background, or invisible, such as an embedded magnetic strip. Line followers are commonly used in the industry for tasks like delivering mail or medications within a building. Other applications include warehouse operations, like product retrieval. The technology also aids in the automatization of busses and other means of transport.[2] During the period of 1980-1995 a sedan-type car was, for the first time, equipped with two forward-facing tv cameras in a development project in order to enable road- and lane-following capabilities.[1]

According to numerous studies, electronic stability control systems are highly effective in helping the driver maintain control of the vehicle, thereby reducing the severity of crashes and saving lives.[3] Electronic stability control is especially effective both in keeping the vehicle on the road and eliminating rollover accidents which account for over 1/3 of all fatalities in single vehicle accidents.[4] The popularity of vehicle stability control systems is increasing rapidly and they are becoming standard equipment with many manufacturers.[5]

Drivers generally perform poorly when action is suddenly required to maintain vehicle stability. [5]

The reason behind this is physics-based and is related to low counter-torque capabilities by means of steering in sideslip situations. Most vehicle stability control systems on the market are brake-based. Torque-biasing systems can be utilized on four-wheel drive vehicles for improved vehicle stability and handling performance. In contrast to brake-based stability control systems, torque biasing has the capability to provide stability control without slowing down the longitudinal response of the vehicle.

Electronic stability control is currently underutilized in many areas.[6] In particular, hybrid vehicles which are structurally compatible with torque biasing, could gain a commercial edge if the technology was adopted instead of basic, brake-based stabilization. The benefit of electric motors is that they are capable of providing rapid deceleration and acceleration, unlike an internal combustion engine.

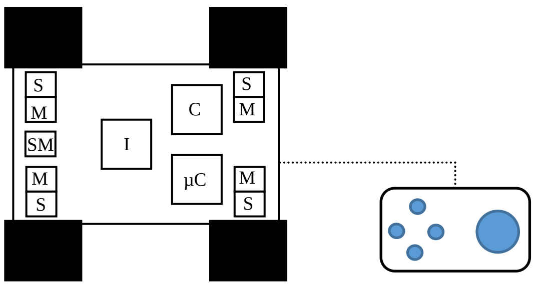
Lightweight, coreless flux motors, enable vehicles to utilize individually driven wheels using an in-wheel motor mount topology or similar technology.[7] With the ability to define individual drive characteristics to each wheel i.e. ”torque vectoring”, vehicles exhibit excellent handling characteristics, as they can generate counter moments by regulating the torque at each wheel.

This paper focuses on Advanced Vehicles Control Systems and in particular Electronic Stability Control and an interface for user-defined means of control. The aim is to develop a platform that integrates both technologies. The research was divided into three parts based on the original goals set: the ESC program, the mechanical construction of the vehicle and the wireless, user-defined control interface. Each part was developed separately, though in accordance with the final objective of full compatibility.

The motivation for this study is to offer future practitioners a platform to work with state-of-the-art vehicle technology. On the other hand, the system acts as a development platform for wireless control methods for vehicles. These methods may include further iterations of line following technology, image recognition utilization and so forth.

2. VEHICLE PLATFORM

The system in whole comprises a customized radio controlled car chassis fitted with an electric motor to each of the four wheels, a servo motor connected to the drag link that relays power to steer the front wheels, an on-board computer and two power supplies. One of them runs the motors and the other powers the computer. The on-board computer runs the ESC code and communicates wirelessly with an external, stationary computer that receives user inputs from a gamepad attached to it. The system is illustrated in Fig. 1 and the main system components used are listed in Table 1.



S = Hall-sensor
M = Motor (drive)
SM = Servo motor (steering)
I = Inertial measurement unit
C = Computer
μC = Microcontroller
..... = Wireless connection

Fig. 1. The development platform

2.1 Mechanical Construction

The first step of the mechanical construction process was to remove all parts that restricted individual control of the wheels. The main components removed where the rear and front differential gears and their connecting parts. Also the single DC motor was removed. Mounts for rear and front gears were 3D printed and installed. One DC motor was installed on each wheel. Finally, an upper frame was also added to the vehicle in order to allow

	Specifications	Function
MECHANICAL		
Car chassis	Customized radio controlled 1/8 scale vehicle	Physical platform for components
ELECTRONICS		
Inertial measurement unit	Adafruit BN0055 9-DOF	Car rotation and acceleration
Speed measurement	Hall sensor	Wheel rotation speed
Manual control	Microsoft Xbox game pad	Input for control signal
Drive motors	Turnigy 2209 1050kv Brushless Motor	Wheel torque production
On-board computer	Raspberry Pi 2 B	Signal processing
On-board microcont-roller	Arduino MEGA	ESC program execution
SOFTWARE		
Simulation software	MATLAB SIMULINK	ESC and control program construction

for the attachment of all components and their connectors.

Table 1. Main components of the system

2.2 User-Defined Wireless Control

A relatively simple computer program was constructed and ran on a stationary computer. The program relayed inputs, given by the user with a gamepad, wirelessly to the on-board computer. There the Input signals where automatically scaled to match the input requirements of all DC motors. Also the data type was automatically converted. This approach allowed for numerous types of control device to be used. The input parameters included acceleration, deceleration, steering and ESC on/off.

2.3 Electronic Stability Control

The electronic stability control was based on the principle of torque-vectoring. The ESC program was designed with simulation software and compiled into C language to be run on the on-board microcontroller. The removed mechanical front and back differentials were also implemented as part of the ESC program. The basic principle of the ESC is that it receives inputs from various sensors, including the speeds of the motors, combines them with the user input and controls the motors according to its algorithm. The principle of the program is shown in Fig. 2.

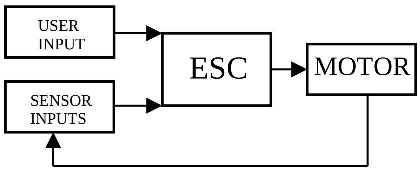


Fig. 2. ESC system

2.4 Testing

Testing of the ESC code was initially carried out virtually, within the simulation program by feeding arbitrary inputs to the ESC loop. These inputs simulated real life occurrences, such as wheel slip and chassis rotation. The wireless control system was initially tested by running a hardware-in-the-loop simulation. This was done to allow for system analysis using the simulation program. Motor response was tested on a test bench. Final system testing was performed in real life on various surfaces including both slippery and nonslippery materials. During the final testing the ESC code was run by the on-board microcontroller.

3. RESULTS

The platform was fully functional consisting of a customized miniature vehicle chassis, 3D printed support structures for the mechanics and an on-board computer and microcontroller for handling signals and running the ESC program respectively. Additionally, program included as part of the platform on the stationary computer, relayed input signals to the on-board computer. The signals could be sent and received in a near real-time manner. The program processing the control signal, was able to convert the incoming signal type to that required by the ESC system. The increase in stability was visually noticeable when driving around corners with the ESC system turned on. The effect was particularly clear on slippery surfaces.

4. CONCLUSIONS

The ESC intercepted whenever it was turned on and had a visible effect on the stability of the vehicle. This demonstrates that ESC technology, in its essence, is possible to implement with relatively simple measures. It also proves that the technology is scalable. Taking these results into account, it seems like such an addition to relevant engineering curriculums, as ESC designing, could be added to offer students experience in state-of-the-art vehicle technology. This project only explored basic ESC functionality with no adjustment options, for example, but the task could be made more realistic by adding wheel slip control resembling the ABS brakes and traction control of conventional vehicles. Based on the approach described in the paper, such functionality would, perhaps, be possible with only slight alterations to the code.

One of the major design questions at the beginning of the project was whether to opt for a combination of motors and friction brakes or whether to utilize the braking capability of the electric motors. Based on available literature on the topic and the trend in full-scale vehicle development, the decision was taken to attempt the latter. The choice set torque requirements to the motors in relation to the mass of the car which were not fully fulfilled by the chosen motors. Another fact that weighed in the decision making in favour of motor braking, was the simplicity of the mechanics that the option enabled.

Since the mechanical starting point for the project was a basic remote controlled car chassis and the project required fully independent control of each wheel, the overall task also proved to be an exercise in precise measuring and 3D printing. After several iterations of printed parts, the right settings were found and the resulting components met the requirements. The 3D printed parts withstood the testing and performed as expected. The Hall sensors that were used to gauge the speed of each wheel, turned out to be a practical choice since the shape of a Hall sensor lends itself well to structures with limited installation space.

Real-time response turned out to be a critical factor of performance in all parts of the control chain. Hence, it dominated the decision-making regarding computer type, file type and the general architecture. Another reason that real-time performance was chosen as a leading principle in the design process, was to allow future users of the platform to avail of a realistic development environment. The slight lag in the control signal mentioned in the results section was not visible when a laptop was used instead of the single-board computer on-board the vehicle. Therefore it can be concluded that the lag was solely due to a slow piece of hardware and not the architecture as such.

All desired technical functionality in the platform was achieved and it is a functional platform for use in developing real-life vehicle technologies, such as inter-vehicle communication and camera assisted navigation.

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