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THE DRIVING ROBOT OF THE ACC AUTONOMOUS CAR

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ABSTRACT
The aim of this paper is to present a general view about the autonomous driving researches made in the University of Applied Science Heilbronn, Germany. More exactly we will present aspects about our autonomous car design and construction and we will focus on the driving robot mechanical and electrical design.
Keywords: autonomous car; driving robot; control system architecture, trajectory tracking

1. INTRODUCTION
The autonomous can be defined like a car which is able to drive itself. So this means that we deal with a car which copies a human driver's performances. Is this a mobile robot? The answer is yes, if we consider only the navigation performance, but no, if we have in mind that it is necessary to add specific interfaces that are not needed in the mobile robots case. The present work has ignored this difference and has focused on the driving (navigation) performance that means that our autonomous car is in fact a mobile robot.
Scientific literature proves that the autonomous car subject is studied by many research teams. Spectacular results have been obtained by Volkswagen and by Stanford University. Joining together these two success stories is important, because it highlights the convergence of two direction of development: the automotive industry, which increases permanently the automation in the cars and the universities, which try to increase the navigation performances of the autonomous cars.
In order to exemplify the automotive industry projects, we will mention the "Autonomous Driving" project which was managed by Volkswagen. The purpose of the project was to develop an autonomous vehicle with the options of accidents avoidance and automatic driving. The project partners were the Brunswick Technical University, Robert Bosch GmbH, Kasprich-IBEO GmbH and Sondermachinen GmbH. Accordingly, up to ten vehicles were simultaneously driven automatically by robot-drives. To transform a VW in mobile robot a driving robot was implemented in the car. This driving robot has three "legs" (which allows it to manipulate the gas, clutch and brake pedals) and two "arms" (which manipulates the steer and the gearbox lever). The environment recognition was possible by: radar sensors, laser scanner, and two video cameras. All these systems allow the vehicle guidance, most precisely, computation of the desired trajectory; vehicle regulation, sensors functions etc.
In the universities, several projects on autonomous cars have been made as well. The Stanford University's Stanley mobile robot won the 2005 DARPA Grand Challenge. From [1,2] we know that Stanley was developed for high-speed desert driving and was controlled through artificial intelligence methods.
Based on these remarks, we briefly sum up our conclusions concerning the developments of autonomous cars:

- The results of these projects are summarized by the sentence: “It can be done, but it is too expensive”. Moreover, much knowledge from these projects have been used in the development of new automated systems;
- The autonomous car construction implies a mechanical and electrical design. There are two solutions: transform a real car into an autonomous car [1] or design a new vehicle [3].
- The mobile robots’ navigation has been defined from mathematical point of view [6], this means that we have the axiomatic background for mathematical solutions;
- Each mentioned work try to solve the navigation problem or a part of this problem in a particular way. There are used classical robust control techniques, fuzzy logic or neural network strategies [4] or solution based on Bayesian theory of probability [3, 5, 6];
- One drawback of the mentioned solutions is the time consuming computation, needed in solving complex situations [6,7,8].

This paper presents aspects about the ACC autonomous car that we have constructed in the University of Applied Science in Heilbronn, Germany. The presentation will include aspects from project management, mechanical and electrical design of the driving robot.

2. THE DRIVING ROBOT CONSTRUCTION

The mobile robot is a system composed of the following subsystems: the car, the driving robot, the control system and the extra sensory system. In order to accomplish our goals, we have organized our project using the well-know functional design concept presented in figure 1. There are three major levels in this procedure: construct, implement and test the driving robot in the car (an AKlasse Mercedes), construct the control system, integrate the sensors needed for the environment recognition and finally test the autonomous car.

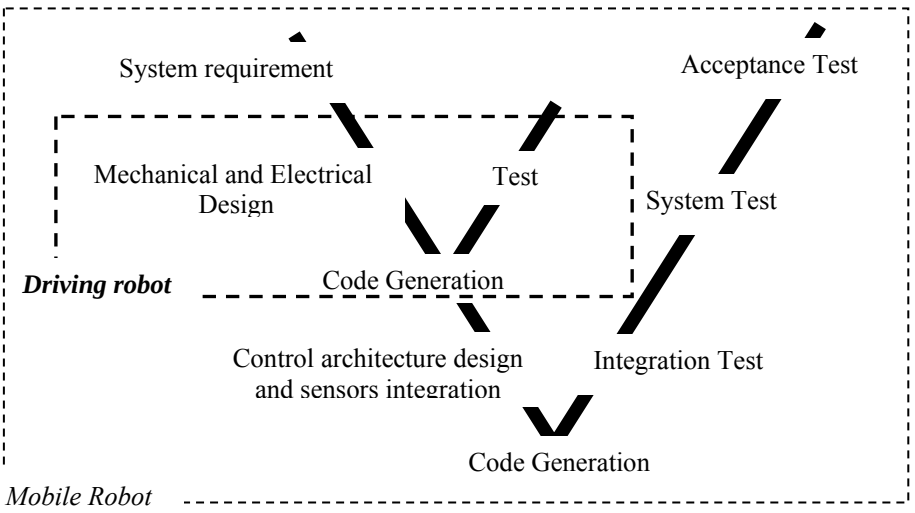


Figure 1. The functional design concept used in project management

The driving robots replace the human driver in the car and are usually made for car testing. These robots are produced by several firms. We will mention here the Stahle and Antony Best driving robots. Unfortunately these systems have not been suitable for our project, and we have constructed our on driving robot. This effort is motivated by the following reasons: the driving robots are made for indoor testing; the control programs, which run on these robots, are designed to perform cyclical operations and data acquisition and it is difficult to develop them in order to obtain artificial intelligent systems.

The electrical and data transfer block diagram of the constructed driving robot is presented in figure 2. It can be seen that the driving robot is composed of five subsystems, each one needed to copy a certain action of the human driver: steering, acceleration, turning the ignition key, turning the gearbox lever and braking the car.

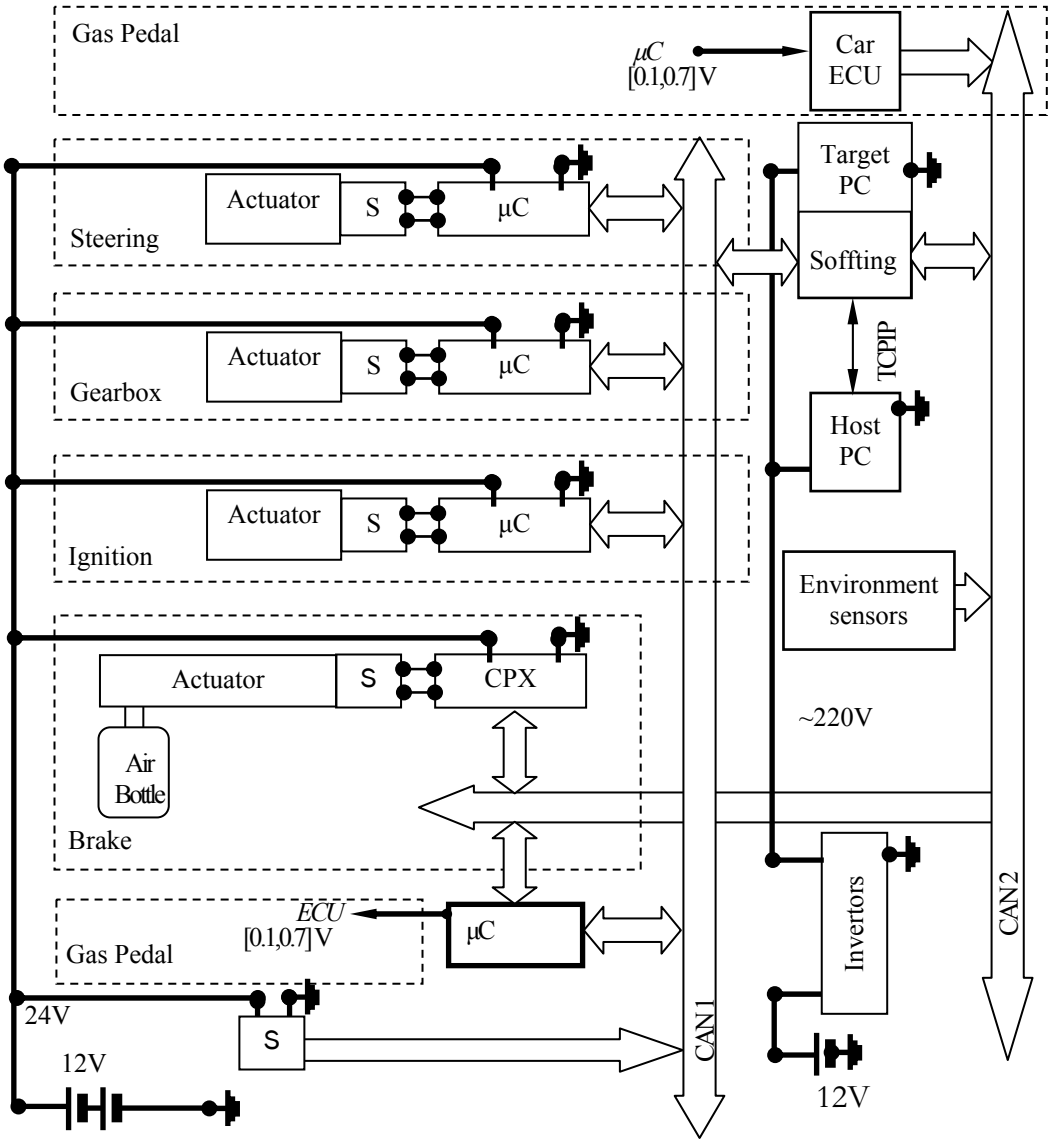
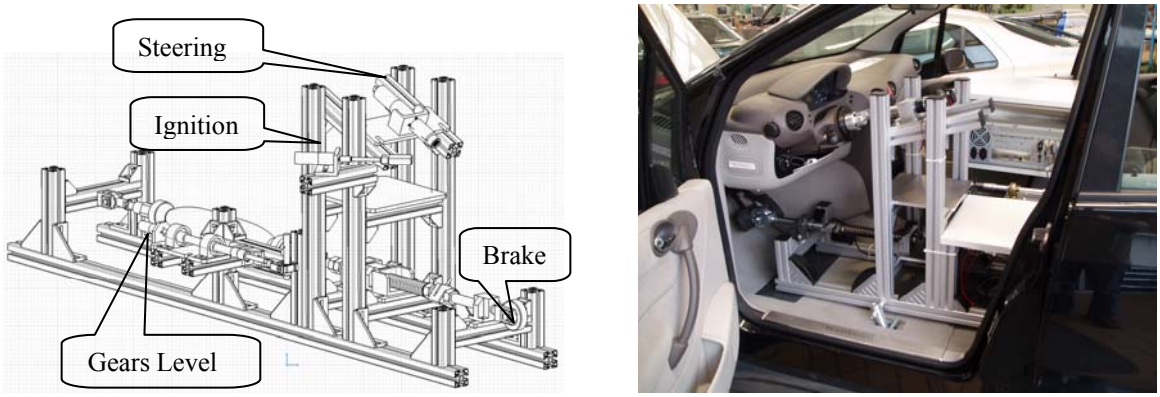


Figure 2. The Driving Robot electrical block diagram

Each subsystem consists of actuators (we have chosen MAXON DC motors and FESTO Muscle) sensors and microcontrollers which solve the local control problems.



a), b)

Figure 3. a) The Mechanical design of the driving robot, b) Integration of the robot in the car

Over these five local feedback loops, a main feedback loop is design. The hard of this loop consists of the environment sensors, the target PC (real time machine) and the CAN data transfer network. The program which runs on the target computer is the control system that we will present in the next section. In figure 3.a we have illustrated the CAD drawing of the robot, where for a better understanding we have identified the mentioned subsystems. In order to illustrate the integration of the driving robot in the car, in figure 3.b we have presented a picture of the autonomous car. For integration, test programs have been made in Matlab (using xPC toolbox) on the host computer (see figure 2) and have been downloaded on the target computer.

a), b)

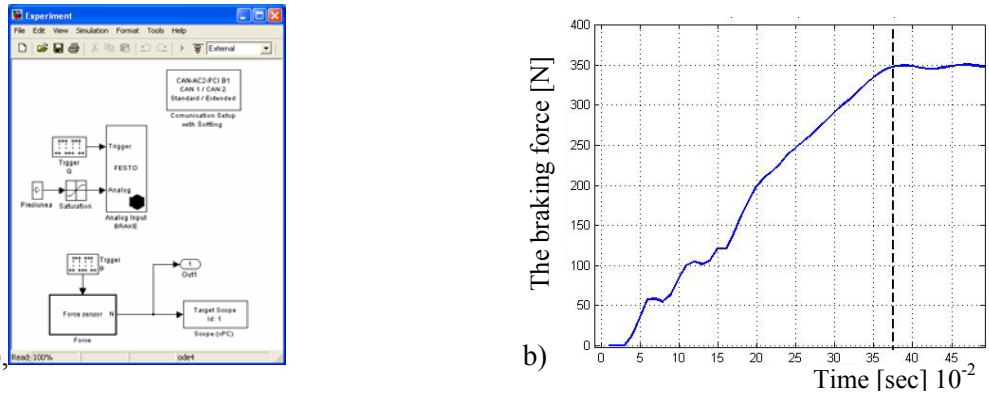


Figure 4. a) The test program for braking, b) Test result

To exemplify these tests, we have chosen the braking subsystem. More precisely, one of the braking tests programs is presented in figure 4.a, and the result of this test is presented in figure 4.b.

3. CONCLUSIONS

In the present paper we have focus on the driving robot designed for the ACC Autonomous car. For describing this robot we have start by discussing about the mobile robot which is the system which includes the driving robot. This is a highly integrated system and is composed from several subsystems. Each these subsystems (steering, ignition etc) has the purpose to replace a specific action of the human driver. The main benefit of our achievement has been a cheep robot which admits a intelligent control system implementation. This design has been followed by the control program structure and implementation. Based on the mentioned control program at present the autonomous car is running on the a priori defined trajectory.

4. REFERENCES

[1] http://robots,stanford.edu/papers/thurn. S. Thrun, aa, P. Mahoney. Stanley, the robot that won the DARPA Grand Challenge. Journal of Field Robotics, *forthcoming*

[2] B.P. Gerkey, S.Thrun, and G. Gordon. Visibility-based pursuit-evasion with limited field of view. International Journal on Robotics Research, 25(4) pp. 299-316, 2006

[3] Coué, C., Pradalier, C., Laugier, T., Bessiere, P., Bayesian Occupancy Filtering for Multitarget Tracking: An Automotive Application. The International Journal of Robotics Research Vol. 25, No. 1, January 2006, pp. 19-30, 2006

[4] Pomerleau, D: Neural Network Based Autonomous Navigation. Vision and Navigation: The CMU Navlab, C. Thorpe (Ed.), Kluwer Academic Publishers, Boston ,1990.

[5] C. Pradalier,C., Hermosillo, J., C.Koike, C., Braillon, C., Bessihre, P., Laugier, C., An Autonomous Car-Like Robot Navigating Safely Among Pedestrians Preceding of the 2004 IEEE 1ntermational Conference on Robotics& Automation New Orleans - April 2004

[6] Braillon., C., Kane Usher, K., Pradalier, C.,, Crowley, J., Laugier, C., Fusion of stereo and optical flow data using occupancy grids Proc. of the IEEE Int. Conf. on Intelligent Transportation Systems - Toronto (CA) - September 2006

[7] Chagas, C.,M., Koike, C., Bayesian Approach to Action Selection and Attention Focusing An Application in Autonomous Robot Programming. Doctoral Thesis l'École Doctorale Mathématiques, Sciences et Technologies de l'Information, Informatique , 2005

[8] Pradalier, C., Navigation intentionnelle d'un robot mobile. Doctoral thesis, l'École Doctorale Mathématiques, Sciences et Technologies de l'Information, Informatique , 2004