COBEM2015

ABCM Associação Brasileira de Engenharia e Ciências Mecânicas

23rd ABCM International Congress of Mechanical Engineering
December 6-11, 2015, Rio de Janeiro, RJ, Brazil

USING FUZZY INFERENCE SYSTEMS FOR BLENDING HUMAN'S AND AUTOMATIC CONTROL ON COMBAT GROUND VEHICLES

Hebert Azevedo Sá
Mauro Speranza Neto
Marco Antonio Meggiolaro
Pontifícia Universidade Católica do Rio de Janeiro (PUC-Rio) - Dept. Eng. Mecânica
Rua Marquês de São Vicente, 225 - Gávea, Rio de Janeiro - RJ, 22453-900
(azevedo@df.eb.br, msn@puc-rio.br and meggi@puc-rio.br)

Armando Morado Ferreira
Escola de Comando e Estado-Maior do Exército (ECEME)
Praça General Tibúrcio, 125 - Urca, Rio de Janeiro - RJ, 22290-270
(armando@ime.eb.br)

Abstract. *Human operators' and robots' shared control techniques are encouraging the research and development of Advanced Driver Assistance Systems (ADAS) and semi-autonomous control for automotive applications. In semi-autonomous control, the main feature is the blending of control signals generated by an automatic controller with the control from a human operator. In recent research, various techniques have been proposed to achieve this mixture of control signals. However, the use of Artificial Intelligence for that purpose is still scarce. The purpose of this work is to use Fuzzy Inference Systems to design an appropriate semi-autonomous control system for military vehicles, from which the choice of the automatic controller intervention level would be achieved. The results from simulations of the military vehicle are presented, while operated in dangerous situations, where the intervention is made necessary, e.g. in the presence of hostile enemy threats or in highly destabilizing maneuvers. The behavior of the controller's intervention variable is presented through its evolution curves and indicates its increase accordingly to the growth of the threat level for which the vehicle is exposed to. The results are critically analyzed, and it is concluded that the use of the proposed system will result in a qualitative increase in vehicle's safety, making it a more efficient military system, with greater operational capacity and enhancing the skills of its driver.*

Keywords: *Fuzzy Systems, Semi-autonomous Control, Military Vehicles*

1. INTRODUCTION

Automobiles are complex dynamic systems susceptible to the occurrence of various types of accidents, mostly caused by their own human operators. Studies by the World Health Organization (2013) and other statistics (National Highway Traffic Safety Administration, 2012) show that there are serious difficulties in solving the problem of safety on roads. In the specific context of military operations with the use of Ground Combat Vehicles (GCV), the risk of accident occurrence tend to amplify due to inherent causes of this scenario: the use of vehicles in unstructured terrain, presence of hostile enemy threats, low visibility for the drivers and etc.

In an attempt to mitigate the risks of motor vehicle accidents, recent trends have shown joint efforts between the academic community and the industry to promote the developments of Advanced Driver Assistance Systems (ADAS), able to improve the safety for both drivers and passengers (Chen and Li, 2014). An important class of ADAS are the semi-autonomous control systems, in which the control of the vehicle is exercised jointly between the human operator and an automatic controller, opening up possibilities for a synergistic combination that can increase the safety level of car traffic or military operations with the use of GCVs. Although it has already been addressed by researchers (Anderson, 2009), (Gray *et al.*, 2013), reports of the application of these types of systems remain scarce, and therefore this is an area to be further explored.

The purpose of this work is to present the development of a semi-autonomous control system for military vehicles, in which the main tool for blending the controls are the Fuzzy Inference Systems (FIS). Another important feature is the use of Model Predictive Controllers (MPCs) to the sub-controller's (the device that will share the authority over the vehicle with the driver) design. All modeling and design of the proposed system is presented, including the development of its two major subsystems: the Fuzzy Ponderer and the MPC-based Sub-Controller. In addition we present the mathematical development of a dynamic model used for the system simulations, which allowed us to obtain the results to be shown.

This paper is organized as follows: Section 2 generally discusses the design of the semi-autonomous controller, bringing details about the latest work undertaken in this area and the basic architecture proposed for the system to be developed. Section 3 deals specifically with the Fuzzy Ponderer and its project, with the input and output variables for the FISs that comprise it. Section 4 is dedicated to the design of the MPC-based sub-controller, the device that generates the signals to be pondered with the human driver's control. Section 5 reports the obtention of the vehicle's mathematical model, which is essential for the simulation and for the test results shown in Section 6. Section 7 finishes this work by presenting its main conclusions and suggestions for the future of this research project.

2. SEMI-AUTONOMOUS CONTROLLER'S DEVELOPMENT OVERVIEW

The development process of the semi-autonomous controller proposed in this paper begins with a literature review to provide the necessary theoretical framework and to identify the state-of-the-art on this theme. Thereafter we propose an original approach to the subject, with the use of Fuzzy Artificial Intelligence techniques, as described below.

2.1 Recent Work

Intelligent vehicles have served as the main theme in several research surveys. In this context, ADAS have played an important role, allowing a gradual transition from purely manual vehicles to autonomous ones. In their works, Nilsson (2011) and Chen and Duan (2014) divided the ADAS in the categories shown in Table 1.

Table 1: ADAS Categories and main characteristics.

CATEGORY	CHARACTERISTICS
Information/Warning Systems	Systems that provide information through different modalities and by different emergency levels, warning the driver of potential hazards.
Active assistance/semi-automation Systems	Systems designed to assist drivers in their driving tasks (acceleration, braking, steering, etc.).
Full/high automation Systems	Systems designed to take over the control of the vehicles and act automatically during driving.

Active assistance or semi-automation systems can be developed through the dynamic systems' control sharing between man and machine. Areas of knowledge such as Telerobotics and Supervisory control have been developed with the aim of integrating the skills of human operators with computer's speed and processing power (Sheridan, 1992). Prospecting the applications of these systems in robotic wheelchairs, Miller (1999) raised important questions about the problems that could occur when the two control signals diverge, which could compromise the safety and the controllability of the system. However, in a seminal work on the control of robotic assistance devices, Yu et al (2003) proposed the weighting of control signals provided by human operators and the automatic controller by adjusting an intervention level variable $k \in [0, 1]$, so that

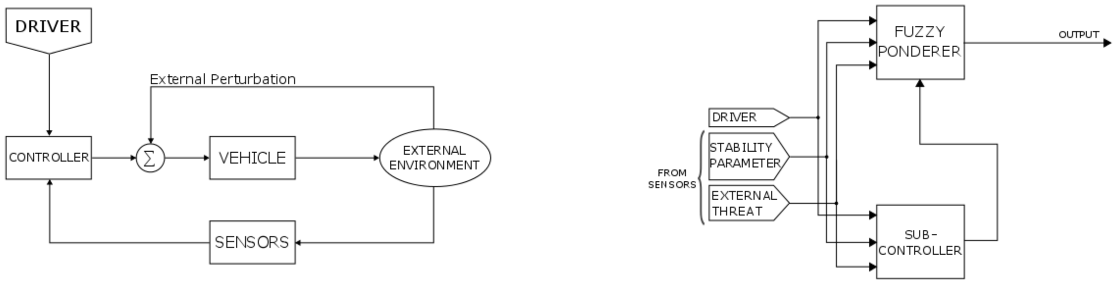
$$u = ku_c + (1 - k)u_h. \tag{1}$$

In that case, u_c and u_h were the values of the inputs provided by the automatic controller and the human operator while u was the final value of the input to be applied to the dynamic system. This work provided the basis for research on the application of similar systems in vehicles with greater speed and greater dynamic complexity, as reported by Anderson (2009). However, because of this increased complexity, the choice of techniques for designing controllers for such systems is a research challenge.

A suitable alternative to vehicular controllers' design is the use of MPCs. The MPCs make up a class of controllers that was initially used in industrial processes (Camacho and Bordons, 2007). Recently, however, these controllers have been applied in other types of systems, especially in autonomous vehicles, as in (Borrelli *et al.*, 2005), (Keviczky *et al.*, 2006), (Falcone *et al.*, 2007) and (Gray *et al.*, 2013).

Anderson and Iagnemma contributed significantly to the semi-autonomous control of vehicles when they developed a mathematical framework for that (Anderson, 2009). Their later work (Anderson *et al.*, 2010a), (Anderson *et al.*, 2010b), (Anderson *et al.*, 2011) and (Anderson, 2013) consolidated these techniques and influenced Storms and Tilbury, who applied MPCs techniques for the semi-autonomous control of high speed mobile robots (Storms and Tilbury, 2014).

Despite these development efforts, the use of Artificial Intelligence techniques in semi-autonomous control systems can be considered rare. Garus and Szymak (2008) used Fuzzy control to implement a two-layer controller to guide a submarine military vehicle while Sarimveis and Bafas (2003) integrated genetic algorithms to a Fuzzy MPC for nonlinear processes.



(a) Control Loop. (b) Proposed Controller.

Figure 1: Architectures of the Control Loop and Proposed Controller.

In a more recent work, the authors proposed the preliminary concepts of a semi-autonomous control system with applications in military ground vehicles, integrating Fuzzy Artificial Intelligence techniques to the system and limiting itself to presenting its general architecture and that of one of its sub-elements (Azevedo Sá *et al.*, 2015). This paper shows the evolution of the research project since then.

2.2 Proposed Approach

The main difference between the previous approaches and the proposed one is the use of Artificial Intelligence techniques, particularly fuzzy logic techniques. Figure 1a illustrates the proposed architecture for the system's control loop.

In this architecture, the controller is the main element of the control loop. The development of this controller is the primary objective of this research project. The proposal to its architecture is shown in Figure 1b.

There are two major sub-elements in the proposed architecture, i.e., the Fuzzy Ponderer and the Sub-Controller. The development of these sub-elements is presented in Sections 3and 4.

3. FUZZY PONDERER'S DESIGN

The Fuzzy Ponderer was designed to generate the intervention variable k mentioned in the equation 1, from the processing of inputs that represent the vehicle's stability and the threat level it is exposed to, in addition to the driver's own commands. Its main features are presented below.

3.1 General Architecture

Figure 2 illustrates the architecture of the Fuzzy Ponderer. It is an arrangement of low complexity Fuzzy Inference Systems (FIS) interconnected. The input variables of those FIS are: Δu - difference between the input provided by the driver and the automatic controller; $|R_{SM}|$ - absolute value of the stability metric defined in (2); $D_{a,i}$ - relative distance between the vehicle and the i^{th} shooter's line of sight; $V_{a,i}$ - relative velocity between the vehicle and the i^{th} shooter's line of sight; $D_{e,i}$ - relative distance between the vehicle and the i^{th} IED; and, $V_{e,i}$ - relative velocity between the vehicle and the i^{th} IED.

Besides these, there may be mentioned the following intermediate variables: $A_{e,i}$ - external threat posed by the i^{th} IED; $A_{a,i}$ - external threat posed by the i^{th} shooter; A_t - total external threat; and, B_{Motr} - driver's behavior;

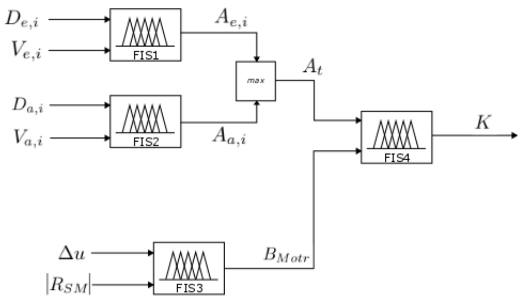


Figure 2: Fuzzy Ponderer's Inference Systems.

The input variables are direct information from sensors that are assumed existent and perfect, with the exception of the stability parameter, which is obtained through a complex processing of sensors' informations.

3.2 Stability Parameter

The stability parameter chosen for this project is used to quantify the tendency of a vehicle to evolve into a rollover condition. This parameter should be calculated from the measurement of Stability Moments SM_i, a physical quantity defined by Peters and Iagnemma in (Peters and Iagnemma, 2009). Then, there is used the parameter $R_{SM} \in [-1, 1]$, similar to the "load transfer", such that

$$R_{SM} = \frac{SM_l - SM_r}{SM_l + SM_r}. \tag{2}$$

Considering the definition of the Stability Moment, it is obvious to note that if $R_{SM} \to -1$ or $R_{SM} \to 1$, the vehicle is tending to a rollover about the right or left tipover axes. If $R_{SM} \to 0$, the vehicle tends to keep itself stable, with roll angle near zero.

3.3 Fuzzy Inference Systems

The Fuzzy Inference Systems that compose the Fuzzy Ponderer were designed according to the universes of discourse, fuzzy sets and fuzzy rules presented by the authors in previous works, and can be found with more details in (Azevedo Sá *et al.*, 2015).

4. MODEL PREDICTIVE SUBCONTROLLER

The sub-controller is the system element whose function is to generate control signals to be blended with the controls of the driver. An MPC is designed to implement it. As mentioned, the MPCs are suitable for the design of vehicular controllers. Its design basically depends on a mathematical model of the plant to be controlled and an optimization problem statement, with an objective function that represents a quantity to be minimized, mathematical constraints and an optimization algorithm to be periodically executed.

4.1 Kinematic Model

A kinematic model for six-wheels vehicle was conceived for the purpose of designing the Model Predictive Sub-Controller proposed. This low-complexity approach has been chosen because it demands less time for running the optimization algorithm, avoiding overload and controller's ineffectiveness. Although it is unable to represent some dynamic characteristics of the system, it is important to note that this model is considered sufficient to implement the MPC.

The development of the model was similar to that found in (Rajamani, 2012), where a kinematic model of lateral vehicle motion is presented. Considering Figure 3, it can be seen that there are two different possibilities for the development of the model: based on the front axle steering (and the instantaneous rolling center O_f), or based on the intermediate axle steering (and the instantaneous rolling center O_m). Actually, the true instantaneous rolling center is a point inside the triangle $O_iO_mO_f$. Considering the worst case as the one in which the curve performed by the center of gravity is the most open, we chose the far rolling center (in this case O_m), and thus we took the intermediate axle steering as basis.

Therefore, the continuous time model can be represented by

$$\begin{cases} \dot{x} = V cos(\psi + \beta) \\ \dot{y} = V sin(\psi + \beta) \\ \dot{\psi} = \dfrac{V cos\beta}{x_m + x_r}\, tan\ \delta_m \end{cases}, \tag{3}$$

where,

$$\beta = arctan\left(\frac{x_r\ tan\ \delta_m}{x_m + x_r}\right). \tag{4}$$

The inputs of this nonlinear model are V and $\delta_m = \delta_f / k_\delta$. However, for simplicity and to not consider the effects of longitudinal dynamics, in this work V is set constant. The steering angle δ_f (or δ_m), in turn, is discretized with a period T, assuming the input form shown in Figure 2.

In order to discretize the model, it can be observed that $\dot{\psi}$ is constant over time intervals of length T, and if its not zero,

$$\psi(kT + T) - \psi(kT) = \dot{\psi}_k T. \tag{5}$$

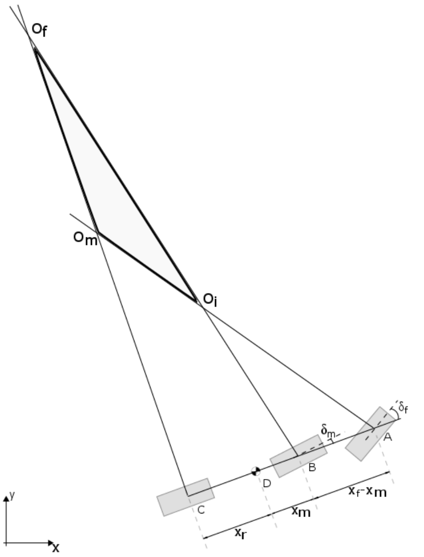


Figure 3: Three-axle vehicle's bicycle model

For the longitudinal position we have,

$$x(kT+T) - x(kT) = \int_{kT}^{kT+T} V cos(\psi+\beta)dt = \frac{V}{\dot{\psi}_k}[sin(\dot{\psi}_k T + \psi_k + \beta_k) - sin(\psi_k + \beta_k)], \tag{6}$$

and additionally, for the lateral position,

$$y(kT+T) - y(kT) = \int_{kT}^{kT+T} V sin(\psi+\beta)dt = -\frac{V}{\dot{\psi}_k}[cos(\dot{\psi}_k T + \psi_k + \beta_k) - cos(\psi_k + \beta_k)]. \tag{7}$$

If $\dot{\psi} = 0$, the model is simpler, becoming

$$\begin{cases} x(kT+T) = V cos(\psi+\beta)T + x(kT) \\ y(kT+T) = V sin(\psi+\beta)T + y(kT) \\ \psi(kT+T) = \psi(kT) \end{cases} . \tag{8}$$

Using this discrete-time nonlinear model for the vehicle, it is possible to predict the vehicle's positions with calculations and to optimize the objective function, considering the constraints that the problem is subjected to.

4.2 Objective Function

In the MPC, the objective function is used to predict and identify undesired behaviors of the dynamic system, and then to correct them by generating the adequate control signals. In general, this function incorporates a reference to the output signal as well as penalties for the input efforts and their variation between two consecutive control periods, or even for any inconvenient measurement or state. Assuming the sensors' ability to map the position of threats within the vehicle's combat zone, the distance between the vehicle and those threats can be easily calculated, making it possible to define an instantaneous potential threat ϕ such that

$$\phi = \sum_{i=1}^{N_T} \frac{\tau_i}{d_i^2}, \tag{9}$$

where N_T is the number of identified threats, τ_i is the constant that quantify the level of danger associated to the i^{th} threat and d_i is its distance to the vehicle. This potential threat serves as the output to the system, and the reference signal to be followed is simply $\phi_R = 0$.

Additionally, penalties were considered for input efforts and also for the lateral position of the vehicle, as we tried to define lateral boundaries to the movement. Therefore, the objective function at the instant time t was defined as [1]

---

[1] Here, the general standard notation $\hat{w}(t + kT \mid t)$ means "the predicted value of $w(t + kT)$ at the time instant t".

$$J(t) = R_\phi \sum_{k=1}^{N_p} \hat{\phi}^2(t + kT \mid t) + R_\delta \sum_{k=1}^{N_c} \delta_f^2(t + kT) + R_y \sum_{k=1}^{N_p} [\hat{y}^2(t + kT \mid t) - \Lambda^2]. \tag{10}$$

The definitions of the mentioned parameters are: N_p - the prediction horizon of the MPC; N_c - the control horizon; R_ϕ - the potential threat penalty weight on the objective function; R_δ - the input efforts penalty weight; and, R_y - the lateral distance (to the boundary) penalty weight.

On Figure 4, a general situation for a given time instant t is shown.

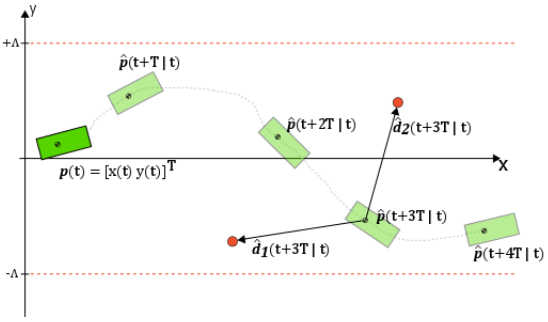


Figure 4: Predicted positions and orientations at instant t.

4.3 Constraint Setup

The stated optimization problem may be subjected to several constraints. In this case, we considered only constraints (equality and inequality) on the input signals of the kinematic model in order to restrict them according to the physical feasibility of the vehicle. The constraints are represented by

$$V(t + kT) = V_0, \tag{11}$$

and

$$\delta_f^2(t + kT) \leq \delta_{f,max}^2, \tag{12}$$

for $k = 1, 2, ..., N_p$ and the values: $V_0 = 25m/s$; $\delta_{f,max} = \pi/18rad = 20^o$. The time instant t represents the instant when the optimizations begins.

5. DYNAMIC MODEL FOR SIMULATION

The system presented in this work was proposed to be applied in special military vehicles, such as the Armored Personnel Carriers (APC), Armored Reconnaissance Vehicles (ARV) or Infantry Fighting Vehicles (IFV). Because they are high-value military systems for the Armed Forces, the conduction of experimental tests of the semi-autonomous controller being used in these vehicles is particularly difficult, due to government regulations and the protection of defense classified information.

To avoid the need to carry out experimental tests, a twelve Degrees Of Freedom (DOF) dynamical model of the GUARANI vehicle was developed and implemented in simulation environment. The informations needed to develop this model were obtained in the technical report (MULTICORPOS ENGENHARIA, 2008), provided by the Brazilian Army's Department of Science and Technology (DCT).

The nonlinear mathematical model was then developed from equations of motion and of the parameters in the report, taking the form

$$\begin{cases} \dot{\mathbf{x}} = \mathbf{f}(\mathbf{x}, \mathbf{u}) \\ \mathbf{y} = \mathbf{g}(\mathbf{x}) \end{cases}, \tag{13}$$

where $\mathbf{x}$ is the state vector of the system, $\mathbf{u}$ and $\mathbf{y}$ are input and output vectors, and $\mathbf{f}$ and $\mathbf{g}$ are nonlinear transformations. The development of this model will not be presented here, but is analyzed with further details in (Azevedo Sá *et al.*, 2015).

6. SIMULATIONS AND RESULTS

Subsequently to the development of the proposed control system and the implementation of the dynamic model mentioned in the previous section, simulations were performed in order to verify the effectiveness of the solution. The tests consisted in simulating the use of a vehicle in dangerous situations, where the control system's action was necessary to keep it safe. The system was further compared with a PID controller, as described below.

6.1 Test Configuration

The tests were configured to present a risk to the vehicle, where IEDs were employed within its theater of operations.

6.2 Results

The most appropriate way to present the results obtained in the simulated tests is the presentation of the Trajectory described by the vehicle under the control of the proposed system and the evolution curve of the Intervention Level. Moreover, it presents a comparison of these results with the results of a semiautonomous PID controller. Figure 5 shows these results.

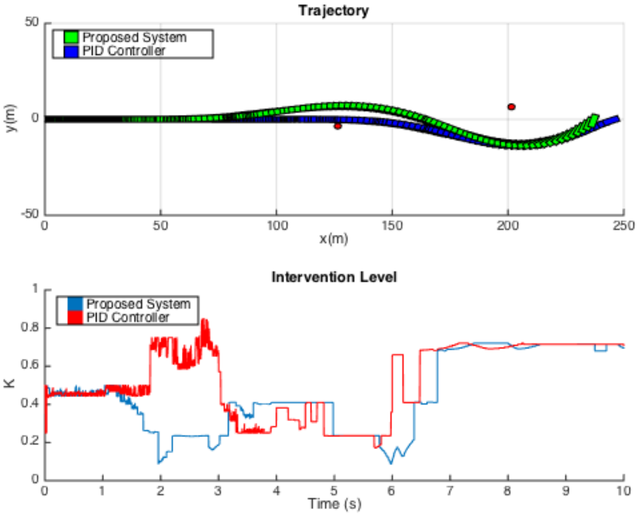


Figure 5: Trajectory and Intervention Level for the Proposed Control System and a PID controller.

The results show that the proposed system has a better performance on maneuvers to avoid the high risk of accidents involving the vehicle than the system using a PID controller. Furthermore, by observing the Intervention Level of both systems, it can be considered that the proposed system is less intrusive, as it maintained the lower level for most of the test time.

All tests were performed with the values of the objective function parameters calibrated as follows: $R_\phi = 1$; $R_\delta = 1000$; and $R_y = 0.00005$.

7. CONCLUSIONS

A new approach to the design of semi-autonomous control systems applied to military vehicles has been proposed in this work. A system was developed from the use of Fuzzy Artificial Intelligence techniques and of Model Predictive Controllers, represented by the design of its main components, called Fuzzy Ponderer and Model Predictive Sub-Controller. Simulation and testing of the proposed system were conducted from a dynamic model, obtained by the processing of technical information about APC GUARANI vehicle. The test results demonstrated the effectiveness of the proposed system, because its control intervention proved to be essential for the vehicle to be kept in a safe area of the terrain occupied by hostile enemy threats, if the driver is not aware of them.

We intend to continue this work seeking to improve the proposed system modifying some features of its sub-elements, such as the Fuzzy Poderer's Inference Systems or the Objective Function of the Model Predictive Subcontroller. It is also necessary to compare the proposed system with others available in the literature, as well as establishing a method to minimize the system's intervention levels, making it less intrusive for the driver.

8. REFERENCES

Anderson, S., Peters, S., Iagnemma, K. and Overholt, J., 2010a. "Semi-Autonomous Stability Control and Hazard Avoidance for Manned and Unmanned Ground Vehicles". In *Proceedings of the 27th Army Science Conference*. pp. 1–8.

Anderson, S., Peters, S.C. and Iagnemma, K., 2010b. "Semi-autonomous avoidance of moving hazards for passenger vehicles." In *Proceedings of the ASME 2010 Dynamic Systems and Control Conference*.

Anderson, S.J., 2009. *A unified framework for trajectory planning, threat assessment, and semi-autonomous control of passenger vehicles*. Thesis, Massachusetts Institute of Technology.

Anderson, S.J., 2013. *Constraint-based navigation for safe, shared control of ground vehicles*. Thesis, Massachusetts Institute of Technology.

Anderson, S.J., Peters, S.C., Pilutti, T.E. and Iagnemma, K., 2011. "Design and Development of an Optimal-Control-Based Framework for Trajectory Planning, Threat Assessment, and Semi-autonomous Control of Passenger Vehicles in Hazard Avoidance Scenarios". In *Robotics Research*, Springer Berlin Heidelberg, number 70 in Springer Tracts in Advanced Robotics, pp. 39–54. ISBN 978-3-642-19456-6, 978-3-642-19457-3.

Azevedo Sá, H., Neto, M. and Meggiolaro, M., 2015. "Artificial Intelligence based semi-autonomous control system for military vehicle." In *5o Colloquium SAE BRASIL de Eletroeletrônica Embarcada e Mostra de Engenharia*. SAE BRASIL, Rio de Janeiro.

Borrelli, F., Falcone, P., Keviczky, T., Asgari, J. and Hrovat, D., 2005. "MPC-based approach to active steering for autonomous vehicle systems". In *International Journal on Vehicle Autonomous Systems*, Vol. 3:2/3/4, s. 265.

Camacho, E. and Bordons, C., 2007. *Model Predictive Control*. Advanced Textbooks in Control and Signal Processing. Springer, 2nd edition.

Chen, F., M.W. and Duan, L., 2014. *Letting drivers know what is going on in traffic*. In Advances in Intelligent Vehicles, Elsevier, 1st edition.

Chen, Y. and Li, L., 2014. *Advances in Intelligent Vehicles*. Elsevier, 1st edition.

Falcone, P., Borrelli, F., Asgari, J., Tseng, H. and Hrovat, D., 2007. "Predictive Active Steering Control for Autonomous Vehicle Systems". *IEEE Transactions on Control Systems Technology*, Vol. 15, No. 3, pp. 566–580. ISSN 1063-6536. doi:10.1109/TCST.2007.894653.

Garus, J. and Szymak, P., 2008. "Application of fuzzy control to steering of semiautonomous underwater vehicle".

Gray, A., Gao, Y., Hedrick, J. and Borrelli, F., 2013. "Robust Predictive Control for semi-autonomous vehicles with an uncertain driver model". In *2013 IEEE Intelligent Vehicles Symposium (IV)*. pp. 208–213. doi: 10.1109/IVS.2013.6629472.

Keviczky, T., Falcone, P., Borrelli, F., Asgari, J. and Hrovat, D., 2006. "Predictive control approach to autonomous vehicle steering". In *American Control Conference, 2006*. pp. 6 pp.–. doi:10.1109/ACC.2006.1657458.

Miller, D., 1999. "Semi-Autonomous Mobility Versus Semi-Mobile Autonomy". American Association for Artificial Intelligence Technical Report SS-99-06.

MULTICORPOS ENGENHARIA, 2008. "Modelagem e análises da Viatura Blindada para Transporte de Pessoal (VBTP)". Technical Report.

National Highway Traffic Safety Administration, N., 2012. "TRAFFIC SAFETY FACTS 2012". Technical report, NHTSA National Center for Statistics and Analysis,.

Nilsson, J., 2011. "On the Interaction Between Driver Assistance Systems and Drivers in Situations of System Failure." Chalmers University of Technology.

Peters, S.C. and Iagnemma, K., 2009. "Stability measurement of high-speed vehicles". *Vehicle System Dynamics*, Vol. 47, No. 6, pp. 701–720. ISSN 0042-3114. doi:10.1080/00423110802344636.

Rajamani, R., 2012. *Vehicle Dynamics and Control*. Springer, 2nd edition.

Sarimveis, H. and Bafas, G., 2003. "Fuzzy model predictive control of non-linear processes using genetic algorithms". *Fuzzy Sets and Systems*, Vol. 139, No. 1, pp. 59–80. ISSN 0165-0114. doi:10.1016/S0165-0114(02)00506-7.

Sheridan, T.B., 1992. *Telerobotics, Automation and Human Supervisory Control*. The MIT Press, Cambridge, Massachussets.

Storms, J. and Tilbury, D., 2014. "Blending of human and obstacle avoidance control for a high speed mobile robot". In *American Control Conference (ACC), 2014*. pp. 3488–3493. doi:10.1109/ACC.2014.6859352.

World Health Organization, 2013. "Global status report on road safety 2013: supporting a decade of action." Technical report.

9. RESPONSIBILITY NOTICE

The authors are the only responsible for the printed material included in this paper.