Tutorial on Intelligent Vehicles

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Abstract

This tutorial focuses on an application in which the words 'Intelligent Autonomous Systems' represent not only an important research topic, but also a strategic solution to the mobility problem of the next years. Vehicles able to move autonomously and navigate in everyday traffic, in both highway and urban scenarios, will become a reality in the next decades. Besides the obvious advantages of increasing road safety and improving the quality and efficiency of people and goods mobility, the integration of intelligent features and autonomous functionalities on vehicles will lead to major economical benefits such as reduction of fuel consumption, efficient exploitation of the road network, reduction of personnel. Furthermore, not only the automotive field (public transportation, trucks, and passengers cars) is interested in these new technologies, but other sectors as well, each with its own target (industrial vehicles, military systems, mission critical and unmanned rescue robots).

Introduction

With the term "*Intelligent Vehicle*" we generally intend a vehicle that is able to automate some of its tasks. In case of *road* vehicles, these tasks may be the movement along a predefined path, the following of a specific vehicle, the planning of the best route; in case of *off-road* vehicles, the tasks that they should be able to perform range from the movement in unknown environments, to the accomplishment of some mission critical operations. Examples of the last case are rescue operations, military operations, and also traditional industrial robotics applications.

In this tutorial we will mainly refer to *road* vehicles capable of driving autonomously, namely able to automate –entirely or in part– one or more driving tasks. The automation of these tasks carries a large number of benefits, such as: a higher exploitation of the road network, lower fuel and energy consumption, and –of course– improved safety conditions compared to the current scenario.

The tasks that automatically driven vehicles are able to perform range from the following: the possibility to follow the road and keep within the right lane, maintaining a safe distance between vehicles, regulating the vehicle's speed according to traffic conditions and road characteristics, moving across lanes in order to overtake vehicles and avoid obstacles, helping to find the correct and shortest route to a destination, and the movement and parking within urban environments.

Besides the obvious advantages linked to increasing safety and reducing road accidents –thus saving human lives– the possibility of having vehicles riding in a much closer proximity than they do today, produces an increment of road capacity, and, together with the intelligent modulation of vehicles' speed, also causes an appreciable reduction of fuel consumption. In other words, Automatic Vehicle Driving tends to achieve optimal use of current infrastructures, improve mobility, and minimize risks, travel times, and energy consumption. Moreover, commercial and industrial vehicles which repeatedly move along a given path, benefit from a stronger control of their routes and require less personnel to manage their moves. Co-operative driving and dynamic fleet management can therefore play a fundamental role for the reduction of industrial costs.

Two main cooperative solutions are possible to achieve automatic driving functionalities: they require to act on

- infrastructures or
- vehicles.

Both scenarios have their own pros and cons, depending on the specific application. As a general rule, public transportation and industrial robotics applications –based on repetitive and prescheduled routes– can generally benefit from a specific and fixed road infrastructure. Instead, for private vehicles, moving along extremely large and extended road networks, the organization, set-up, and maintenance of nation-wide road infrastructures becomes cumbersome and extremely expensive.

Conversely, the establishment of a structured environment specifically designed for this purpose can be possibly considered for a reduced subset of the road network, for example for building a fully automated highway on which only automatic vehicles –public or private– can drive.

Moreover, infrastructure-based systems generally require a more extensive preparation time. For this reason, systems that are expected to be achieved on a short-term basis can only be vehicle-autonomous or at the most, simple versions of infrastructure-based systems. Such systems do not require a dedicated complex infrastructure or fit into already existing traffic infrastructure (RDS, GSM, beacons for automatic toll systems and traffic data banks).

Furthermore, Automatic Vehicle Driving hides another extremely important benefit, that first triggered the interest in this new field of application. The on-board equipment and technology that allows a vehicle to drive autonomously can also be exploited as a safety enhancement in a more general meaning. The autopilot can be switched to the more static task of monitoring the driver's activities. In case of dangerous situations –such as driver's illness or drowsiness–, the equipment understands the risk and warns the driver or even takes control of the vehicle, starting an emergency maneuver and stopping the vehicle on the emergency lane, or keeping the vehicle on the driving lane at a constant speed until the driver resumes control. The autopilot, considered in this second function, behaves like an *active* security system able to prevent accidents, like the Anti Breaking System, ABS.

In the last decade, a large number of research institutes worldwide have been involved in national and international projects related to the analysis of the *Intelligent Transportation Systems* problem, and a number of prototypes of intelligent vehicles have been designed, implemented, and tested on the road. The design of these prototypes was preceded by the analysis of solutions deriving from similar and close fields of research, and exploded with a great flourishing of new ideas, innovative approaches, and novel ad-hoc solutions. robotics, artificial intelligence, computer science, computer architecture, telecommunications, control and automation, signal processing are just some of the principal research areas from which the main ideas and solutions were first derived.

These vehicles are currently undergoing extensive tests both on structured environments, such as closed roads or private tracks, and on public roads in real traffic conditions. The first preliminary results of these tests demonstrated that full automation of traffic (at least on motorways or sufficiently structured roads) is technically feasible. Nevertheless, not all problems related to automatic vehicle driving that still remain to be solved are of technical nature: there are some aspects that must be considered and carefully evaluated in the design of such systems. First of all, prior to having an automatic driving system sold and installed on a commercial vehicle, all the legal aspects related to the responsibility in case of faults and incorrect behavior of the system must be solved. Secondly, in case no specific roads are built and dedicated to automatic vehicles only, the possibility of driving on a motorway along with automatic vehicles must be considered and its impact on human drivers evaluated. Although technical aspects seem to have a higher importance, these problems must be dealt with and solved as well, since they represent the basics and prerequisites on which future automatic highways will rely.

Tutorial Structure

The talk is divided in 4 parts:

1. Introduction,
2. Presentation of requirements and techniques,
3. Description of examples and discussion of current prototypes,
4. Results of main projects.

Target Audience

The talk is a practical overview designed for technical professionals working in any field of robotics such as indoor, outdoor, mission critical, since the solutions (signal processing and control techniques, as well as architectural issues) can be used for different applications.

History and Background of the Tutorial

This tutorial derives from surveys published on journals (such as "Vision-based Intelligent Vehicles: state of the art and perspectives," by Massimo Bertozzi, Alberto Broggi, and Alessandra Fascioli, *Journal of Robotics and Autonomous Systems*, 32(1):1–16, June 2000, and "Architectural Issues on Vision-based Automatic Vehicle Guidance: the Experience of the ARGO Project," *Real-Time Imaging Journal,* by Alberto Broggi, Massimo Bertozzi, and Alessasndra Fascioli, in press) and from the experience gained in the last few years as coordinator of special sessions within Intelligent Transportation Systems (ITS) and robotics conferences (IEEE Intelligent Transportation Systems Conference, IEEE Intelligent Vehicles Symposium, ISATA, SPIE Aerosense) as well as Departments and Special Issues of international journals (such as *IEEE Transactions on ITS, IEEE Intelligent Systems, Image and Vision Computing Journal, International Journal on Engineering Applications of Artificial Intelligence*).

A survey including comparisons among different projects worldwide and the main results of the ARGO project is published in the following book:

- *Automatic Vehicle Guidance: the Experience of the ARGO Autonomous Vehicle*, by A. Broggi, M. Bertozzi, A. Fascioli, and G. Conte, World Scientific Co. Publisher, Singapore, April 1999, ISBN 981-02-3720-0.

Alberto Broggi received both the Dr. Ing. (Master) degree in Electronic Engineering and the PhD degree in Information Technology from the University of Parma. From 1994 to 1998 he was Assistant Professor at the Dipartimento di Ingegneria dell'Informazione of the University of Parma, and from November 1998 he is Associate Professor of Artificial Intelligence at the Dipartimento di Informatica e Sistemistica (Vision Laboratory) of the University of Pavia, Italy.

He is the coordinator of the ARGO Project, aimed at developing a system for the automatic driving of vehicles on highways and freeways. His research interests include real-time computer vision algorithms for automated vehicle navigation, the development of low-cost architectures to be integrated on unmanned vehicles. He is the author of more than 100 publications on international scientific journals, book chapters, refereed conference proceedings, and a book covering the whole ARGO Project.

Actively involved in the organization of scientific events, Prof. Broggi is on the Editorial Board and Program Committee of many international journals and conferences and has been invited to act as guest-editor of journals and magazines theme issues on topics related to Intelligent Vehicles, Computer Vision Application, and Computer Architectures for Real-Time Image Processing.

Prof. Broggi is the Editor of a regular Department on ITS on IEEE Intelligent Systems Magazine and Associate Editor of IEEE Transactions on Intelligent Transportation Systems; he is the Newsletter Editor and Member of the Conference and Publication Committees of the IEEE Intelligent Transportation Systems Council. He is the Program Chair of the IEEE Intelligent Vehicles Symposium, Detroit, 2000.