INTELLIGENT TRANSPORT SYSTEMS

TECHNOLOGIES AND APPLICATIONS

EDITED BY

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The editors would like to express their heartfelt condolences to the family and friends of Dr Rus Leelaratne, who passed away unexpectedly on 16 April 2015. He is survived by his amazing wife Sharon and their two beautiful daughters, Ruchi and Ishani. His experience and reputation in the field of automotive antennas makes his contribution to this book of great importance, and his untimely death is a significant loss to the scientific world. May his heart and soul find peace and comfort.

About the Editors

Dr Asier Perallos holds a PhD, MSc and BSc in Computer Engineering from the University of Deusto (Spain). Since 1999 he has been working as a lecturer in the Faculty of Engineering at the University of Deusto, being now accredited by Spanish Government as Associate Professor. His teaching focuses on software design and distributed systems, having taught several BSc, MSc and PhD courses. He is currently the Head of the Computer Engineering Department and in the past has been the director of several MSc in Software Engineering. He is also Head Researcher at the DeustoTech Mobility Unit at the Deusto Institute of Technology (DeustoTech), where he coordinates the research activities of around 25 researchers. This research unit promotes the application of ICT to address smarter transport and mobility. In particular, Perallos' research background is focused on telematic systems, vehicular communication middleware and intelligent transportation systems. He has over a decade of experience in R&D management, has led around 50 projects and technology transfer actions, has published more than 20 JCR indexed publications, made more than 50 other contributions in the area of intelligent transport systems, and has supervised two PhD dissertations.

Dr Unai Hernandez-Jayo holds a PhD in Telecommunications from the University of Deusto. Since 2004 he has been working as a lecturer in the Faculty of Engineering at the University of Deusto. He teaches both undergraduate and graduate degrees in the area of acoustics, electronics and analogue and digital communication systems. He also works as researcher and project manager at the Deusto Institute of Technology (DeustoTech), where he is responsible for the work area on the development of wireless communications solutions in the field of vehicular communications. Moreover, he is part of the WebLab-Deusto (www.weblab.deusto.es) research team, leading the design and development of remote laboratories focused on analogue electronics. He has an extensive experience in R&D management, working in projects and technology transfer actions. As part of them, he has more than 70 publications in relevant international conferences and journals on vehicular communications, Intelligent Transport Systems, VANETs, remote laboratories, advanced learning technologies, including indexed journal articles.

Dr Enrique Onieva received a BE degree in Computer Science Engineering, an ME degree in Soft Computing and Intelligent Systems and a PhD degree in Computer Science from the University of Granada, Spain, in 2006, 2008 and 2011, respectively. From 2007 to 2012, he has been with the AUTOPIA Program at the Centre of Automation and Robotics, Consejo Superior de Investigaciones Científicas, Madrid, Spain. During 2012 he has been with the Models of Decision and Optimization group, at the University of Granada. Since the beginning of 2013, he has been with the Mobility Unit at the Deusto Institute of Technology (DeustoTech), where he carries out cutting-edge research in the application of soft computing techniques to the field of intelligent transportation systems. He has participated in more than 15 research projects and authored more than 80 scientific articles. From them, more than 25 are published in journals of the highest level. His research has been recognized and awarded several times in international conferences. Currently, he is one of the most prolific researchers in his area. His research interest is based on the application of Soft Computing Techniques to Intelligent Transportation Systems, including fuzzy-logic based decision and control and evolutionary optimization.

Dr Ignacio Julio García-Zuazola completed a PhD in Electronics (Antennas) part-time program in 2008; viva in 2010, University of Kent, Canterbury, UK, and received a BEng (with honours) in Telecommunications Engineering, Queen Mary University of London in 2003, an HND degree in Telecommunications Engineering, College of North West London in 2000, and an FPII degree in Industrial Electronics, School of Chemistry & Electronics of Indautxu, Spain in 1995. He has been employed as a Research Associate, University of Kent (2004), Research Engineer, Grade 9/9, University of Wales, Swansea, UK (2006), Research Associate, University of Kent (2008), Senior Research Fellow, University of Deusto, Bilbao, Spain (2011) and Visiting Senior Research Fellow at the I3S, University of Leeds, UK (2011). He holds educational awards in Electrical Wiring, Pneumatic and Hydraulic Systems, and Robotics and possesses relevant industrial experience, having been hired for Babcok & Wilcox (1993), Iberdrola (1995), Telefonica (1997), Thyssen Elevators (1998), and Cell Communications (2000). He engaged in an SME in electrical wiring in 1996, is currently a Research Associate at Loughborough University, UK (2014) and combines his full-time job with part-time EMBA studies. He led the antennas research line, supervised and mentored students at Deusto and currently bids for EU grants and contributes to the scientific and technological development of Loughborough by promoting and increasing research and innovation. He was included in the *Marquis Who's Who in the World* 2010 edition and has published work in international journals such as *IEEE Transactions*, *IET Proceedings*, and *Electronics Letters*. Current research interests include single-band and multiband miniature antennas, and the use of Electromagnetic-Band Gap (EBG) structures and Frequency-Selective Surfaces (FSS). He is an active member of the IET and IEEE.

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Foreword

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Introduction

Computers, electronics, satellites and sensors are playing an increasingly important role in our transport systems, as instruments used for different purposes under different conditions. Intelligent Transportation Systems (ITS) apply information and communication technologies to every transport mode (road, rail, air, water) and provide services which can be used by both passenger and freight transport. Nowadays, the main challenge lies in the integration of existing technologies with the aim of making transport more sustainable, which involves a compromise between efficiency, eco-friendship and safety.

This book presents a holistic approach to ITS, combining academic and industrial contributions. It attempts to merge some of the most effective contributions and technical approaches in ITS, which are currently under development in referenced research institutions and universities. Also, the present book reflects on how these works can be deployed in real scenarios thanks to the experiences of collaboration.

The book is divided into five parts and 16 chapters. Each part and chapter delimits its own field in order to provide a well-connected and correlated narrative thread, in which the reader observes a workflow from research to deployment of ITS. First, it includes an overview of reference architectures developed within the main European and American research projects. Then, it enquires into each of the layers presented in architectures, from physical to application layer, describing the technological challenges which are currently faced by some of the most important ITS research groups. Some of these technological issues are related to areas such as wireless communications in vehicular environments, sensors networks and surveillance, or data processing techniques. It contributes to provide the desired holistic vision in this area. The book concludes with some end applications and services for users and traffic managers deployed by industrial partners.

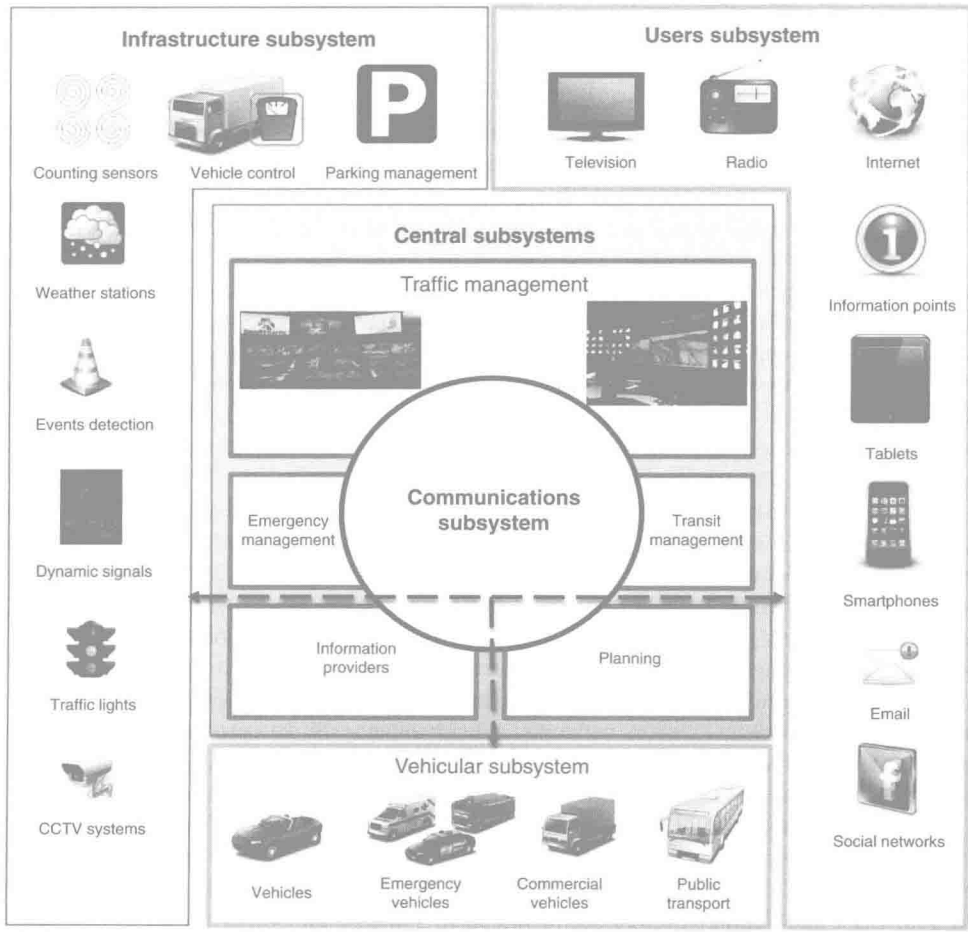
Around 50 highly qualified authors have contributed to this book. Their studies provide a widespread, heterogeneous and international vision of ITS. They are from three continents, representing nine countries: United Kingdom, Spain, Portugal, Italy, France, Finland, Croatia, USA and China. Authors are affiliated to some of the world's leading institutions and companies in the ITS area. In total, 13 different affiliations are represented, with a fair balance between industrial and academic contributions.

Intelligent Transportation Systems

The term ITS encompasses the set of applications that make use of information and communication technologies in the field of transport with the aim of obtaining economic, social and energy benefits. ITS can be applied to any means of transport and considers any of the involved agents: vehicle, infrastructure and user (driver or passenger).

As mentioned above, the main function of ITS is to improve the performance of transport systems, as well as to help, on the one hand, the management of the infrastructure by means of its exploitation and decision-making systems and, on the other hand, the users, in order to obtain an overall satisfaction with the transport system.

For this reason, ITS consist of systems responsible for collecting information concerning the state of the scenario, systems in charge of processing and integrating the information and, finally, systems that are responsible for providing results to end users, as shown in the below figure. In this way, the information collected in real time by ITS may be used to



Intelligent Transportation Systems conceptual model.

determine the state of the communications network, to plan a trip, to manage dynamically the traffic in a certain area, to report data from a logistics operator to the customer or to show traffic events in Geographic Information Systems (GIS). In summary, all the actors have access to more information and more tools that help them to process it in order to carry out a more coordinated and intelligent operation of a transport system, whether it be on road, rail, water or air.

If a definition should be given, it can be said that ITS are a set of solutions based on the combination of telecommunications and computer technologies designed and developed to improve the management, maintenance, monitoring, control and safety of transport. At the same time, an intelligent system can be defined as optimizing processes or resources for obtaining a desired product, providing this information in real time, for its follow-up, evaluation and control, and allowing introduced variations during the course of their management.

For this reason, in addition to the main objectives listed above, ITS provide a number of benefits derived from the improvement in the operational efficiency and reliability of offered services, production improvement in the management of transport infrastructure, as well as increased safety, reduction of environmental impact and a variety of information services provided to the users of the transport. Therefore, ITS include different tools and services resulting from the application of telematics concepts in the area of transport; among many others, the following can be mentioned:

- automatic traffic management systems;
- public transport information services;
- traveller information systems;
- fleet management and location systems;
- emergency management;
- electronic payment systems;
- cooperative vehicular systems.

As can be seen, the types of applications and services are very varied, mainly because ITS continuously evolve, and increasingly more efforts and resources are being devoted to their development and implementation.

On the other hand, public (and private) institutions play a crucial role in fostering policies that help and encourage the development and deployment of applications that improve the current ITS. An example is found in the European Union; the current programme of aid (called research Horizon 2020) includes work oriented towards 'Smart, green and integrated transport'[1], which encourages projects and ideas related to 'Mobility for Growth' or 'Green Vehicles'.

In recent years, a large number of projects, research and innovations have been focused on the issues mentioned here, all of them grouped under the ITS topic. In the following table some research projects and initiatives in this area are listed.

[1] Further information can be found at http://ec.europa.eu/programmes/horizon2020/en/h2020-section/smart-green-and-integrated-transport

Some international ITS research projects.

Project	Description
PREVENT Preventive and active safety applications contribute to the road safety goals on European roads	It aims to promote the development, deployment and use of Intelligent Integrated Safety Systems in Europe, helping drivers to avoid accidents. The key concepts are that depending on the significance and timing of the danger, the systems alert the drivers as early as possible, warn them and, if they do not react, actively assist or ultimately intervene. It addresses services such as Safe Speed and Safe Following, Lateral Support and Driver Monitoring, Intersection Safety and Vulnerable Road Users and Collision Mitigation.
AIDE Adaptive Integrated Driver-vehicle Interface	The objective is to generate the knowledge and to develop methodologies and human-machine interface technologies required for safe and efficient integration of Advanced Driver Assistance Systems (ADAS), In-Vehicle Information Systems (IVIS) and nomad devices into the driving environment. It tests innovative concepts and technologies to maximize the efficiency of ADAS, minimize the level of workload and distraction imposed by IVIS and nomad devices and enable the potential benefits of new in-vehicle technologies and nomad devices in terms of mobility and comfort, without compromising safety.
SAFESPOT Cooperative systems for road safety 'Smart Vehicles on Smart Roads'	The project aims to prevent road accidents by developing a 'Safety Margin Assistant' that detects in advance potentially dangerous situations and that extends in space and time drivers´ awareness of the surrounding environment. This is done by using both the infrastructure and vehicles as sources (and destinations) of safety-related information, defining an open, flexible and modular communications architecture, developing the key enabling technologies and infrastructure-based sensing techniques and testing scenario-based applications to evaluate the impacts and end-user acceptability.
COOPERS Co-operative networks for intelligent road safety	This project is focused on the long-term development of innovative applications for traffic management, by coordinating between vehicle and infrastructure. It provides vehicles and drivers with real-time local situation-based information and safety-related status information, distributed via dedicated infrastructure-to-vehicle communication links. It follows a three-step approach for implementation of I2V communication: improvement of road sensor infrastructure and traffic control applications for more precise situation based traffic information and driver advice, development of a communication concept and applications able to cope with the I2V requirements (reliability, real time capability and robustness) and demonstration of results on important sections of European motorways.

Project	Description
CVIS Co-operative Vehicle-Infrastructure Systems	It develops and integrates the essential basic and enabling technologies such as a multichannel communications and network platform readily adaptable for both vehicle and roadside, a highly accurate positioning and local map module and an open software environment for applications. These components allow a vehicle to share urgent information with nearby vehicles, and to dialogue with both the immediate roadside infrastructure and infrastructure operators and service providers.
SAFETRIP Satellite application for emergency handling, traffic alerts, road safety and incident prevention	This project provides an integrated system platform that allows any third party company to develop applications for the road market, promotes innovative satellite technologies and communication features and integrates in vehicles a device called 'Greenbox' offering a universal two-way communication system. In the project the following applications were tested: provision of real-time traffic information and warnings generated by the collection of data coming from other vehicles, emergency call system and tracking in real-time of vulnerable passenger transports.
PRE-DRIVE	Based on the overall description of a common European architecture for an inter-vehicle and vehicle-to-infrastructure communication system, this projects aims to develop a detailed system specification and a functionally verified prototype to be used in future field operational tests. Furthermore, it develops an integrated simulation model for cooperative systems to estimate the expected benefits of Car-2-X communication in terms of safety, efficiency and environment. Finally, all tools and methods necessary for functional verification and testing of cooperative systems under real traffic conditions are realized.
DRIVE C2X DRIVing implementation and Evaluation of C2X communication technology in Europe	Its objective is to carry out comprehensive assessment of cooperative systems through field operational tests in various places in Europe in order to verify their benefits and to pave the way for market implementation. This proposal builds strongly on previous and on-going work on cooperative systems, which are now considered to be mature enough for large-scale field operational tests. Essential activities in this project are the testing methodology and evaluation of the impact of cooperative driving functions on users, environment and society.

(*Continued*)