Preface

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Biographical notes: Lotfi Beji received the Dipl.-Ing. Degree in Electromechanical Engineering from Ecole Nationale d'Ingénieur de Tunis, Tunisia, in 1992, Research Master Degree in Automatic and Applied Informatic Technology from Ecole Centrale de Nantes, France, in 1993, Dr.-Ing. Degree in Robotics from University of Evry Val d'Essonne, France, in 1997, and the Habilitation Degree in Robotics from University of Evry Val d'Essonne, France, in 2009. He is an Associate Professor in the STI Engineering Department (UFRST) and the Laboratory of Informatics, Biology and complex Systems (IBISC-CNRS). His current research interest is in modelling and feedback control of multi-vehicle formations, pattern transformation, and swarm systems.

Azgal Abichou received the MS Degree in 1990 from university Paris-Sud (Orsay), France, and PhD Degree in 1993 from Ecole des Mines de Paris, France, in Mathematics and Control theory. He is currently Professor of Mathematics at *ESSAI*, Tunisia. His research interests include nonlinear control of mechanical systems, robotics (hydraulic and parallel), control system analysis, and multi-vehicle formations.

Research in the field of modelling and control of multi-vehicle formations has made tremendous strides during the past few decades. Interest in multi-vehicle formations and their control has increased because of the many possible applications in military as well as civil fields. The study of robot formation control, inspired from swarm evolution in nature, began from the industry and military worlds with the idea of using multiple small vehicles instead of one big one. Teams of inexpensive robots, performing cooperative tasks, may prove to be more cost- and energy-effective than a single one. They are, in addition, capable of achieving a mission more efficiently. Using formations of robots includes other advantages such as increased feasibility, accuracy, robustness, flexibility and probability of success. Many studies have focused on the subject, based on different approaches and using different strategies, such as flexible/rigid virtual structure, behavioural approach, leader-following approach, consensus algorithms and swarm intelligence. Each approach has its advantages and disadvantages, and is used to achieve a specific goal: the rendezvous problem and alignment for wheeled mobile robot formation, the cooperative monitoring/surveillance for multiple UAVs formation, the delivery time for vehicles in an industrial environment. Generally, the consensus is designed so that the vehicles update the value of their information states based on those of their neighbours, and the control law is designed so that the information states of all of the vehicles in the formation converge to common value. The consensus algorithms are designed to be distributed, assuming only neighbour-to-neighbour interaction between vehicles.

This special issue aims to highlight recent advances in modelling, parameter identification, and minimisation of multi-vehicle formation, self-organised task allocation strategies for multi-vehicle systems and formation control. In sharing modelling approaches and control algorithms, the presented results permit to coordinate industrial Automatic Guided Vehicles (AGVs), generate formations of groups of non-holonomic mobile robots, organise inter-space vehicles in platoons, success pattern transformations in swarm systems, recover Micro Air Vehicles (MAVs) in flight (which is a challenging problem in multi-vehicle dynamics and control), move flexible virtual structure shape based on co-leaders, and render automatic the short distance in a platoon of vehicles.

We believe that the selected papers present rigorous techniques for developing tools that can be applied with good effect to reason about practical problems. Many of these papers have associated theoretical tools and real implementations.

We now summarise the contents of the papers.

Automatic Guided Vehicles (AGVs) are used more and more in industrial plants and warehouses. The companies working in this growing market are thus spurred to develop new technologies to improve the performances of their systems. In their paper ‘Coordination of industrial AGVs’, Roberto Olmi, Cristian Secchi and Cesare Fantuzzi present a methodology for coordinating a group of mobile robots that go through predefined paths in a dynamic industrial environment. The coordinated navigation issue permits minimisation of the delivery time while avoiding collisions between vehicles, including unexpected events that can occur in an industrial environment. Simulation tests considering real scenarios have been executed to compare the performance of the proposed technique.

Formation based on non-holonomic behaviour of mobile robots is an interesting problem that gives rise to some challenges in multi-vehicle cooperative control. The paper titled ‘Formation vector control of non holonomic mobile robot groups and its experimental verification’, by Hiroaki Yamaguchi, Yoichi Kanbo and Atsushi Kawakami, introduces a new control method for generating formations of groups of non-holonomic mobile robots with two independently driven wheels. Specifically, this paper proposes that the mobile robots try to match their translation velocities with desired velocities, while avoiding zigzag motions that have occurred before. This paper also confirms the effectiveness of the new control method by demonstrating an enclosing behaviour in which the mobile robot group generates an arc-shaped formation around a target in a monitored area. The mobile robots are controlled via a Bluetooth wireless network, incorporating visual feedback with a CCD camera measuring the positions and orientations of the mobile robots. The experimental verification supports the proposed formation vector control algorithm.

Traffic automation has emerged as a promising solution to the highway congestion problem in urban areas. One of the forward-looking traffic automation designs involves a fully automated highway system that supports platooning of vehicles. The platooning concept assumes that traffic on the highway is organised into groups of tightly spaced vehicles (platoons). In the paper 'Platooning over packet-dropping link', written by Seshadhri Srinivasan and Ramakalyan Ayyagari, the authors introduce an estimation-based platooning algorithm for vehicles connected over a communication link that is known to drop packets. The presence of packet dropout makes platooning difficult, as it tends to affect the rigidity of the platoon and hence may cause vehicles in a platoon to separate. The data that is needed to be transmitted for optimal estimation, given that a packet dropout has occurred, is explored.

The paper 'Towards a unifying mathematical framework for pattern transformation in swarm systems', by Blesson Varghese and Gerard McKee, identifies the major challenges in the area of pattern formation. This work is also motivated by the need for development of a single framework to surmount these challenges. A framework based on the control of macroscopic parameters is proposed. A definition for transformation and four special cases, namely elementary and geometrical transformations by repositioning all or some robots in the pattern are provided, and where a macroscopic parameter method and a mathematical tool – Moebius transformation – are introduced. Simulation of the latter method is reported in the paper.

Aerial recovery of MAVs presents a challenging problem in multi-vehicle dynamics and control. The paper 'Multi-vehicle dynamics and control for aerial recovery of micro air vehicles', by Mark B. Colton, Liang Sun, Daniel C. Carlson and Randal W. Beard, treats the recovery of MAVs in flight using a mothership and a towed drogue; the mothership executes an orbit that places the drogue in a stable, slower orbit that can be tracked by a MAV. A method for modelling the dynamics of the mothership-cable-drogue system, based on Gauss's principle, is presented. The differential fatness property of the system is exploited to calculate the mothership trajectories from the desired drogue orbits, and a backstepping controller is proposed that enables accurate mothership trajectory tracking. Further, a drag-based controller for the drogue is also described. Methods to enable the MAV to estimate and track the drogue orbit are discussed. The modelling and control results are illustrated through simulation and flight results.

In the literature, the motion control of multi-robots in formation through a Flexible Virtual Structure Approach (FVSA) is an active area in multi-vehicle modelling and control. The main result in the paper 'Co-leaders and a flexible virtual structure based formation motion control', by Asma Essghaier, Lotfi Beji, Mohamed Anouar El Kamel, Azgal Abichou and Jean Lerbet, consists in the dynamic model of n agents in formation as a single flexible body. It determines the shape of the formation with co-leaders belonging to the boarder and forming a convex hull around the remaining agents. Inspired from a shepherd who supervises his troop by controlling the elements being on the boarder, thus, he is able to control all the remainder of the troop. The authors show that the formation shape is preserved at the equilibrium under the control laws implemented into co-leaders. This work is supported by simulations.

Written by William Travis, Scott Martin and David M. Bevly, the paper 'Automated short distance vehicle following using a dynamic base RTK system' shows real-time applications from a close distance vehicle platoon in which the lead vehicle was man driven and the following vehicle was automated. A Dynamic base RTK (DRTK) algorithm was used to determine a precise relative position vector between the vehicles.

The vector was used as a means of controlling the following vehicle to the lead vehicle's path of travel. Results show the accuracy of the DRTK algorithm to be centimetre level and demonstrate the feasibility of the control concept. The standard deviation of path tracking error when driving straight was 0.24 m. The error while turning is a function of turning radius and baseline length. An expression for the theoretical error is provided, and the error from real-time tests is shown for different separation distances.

This special issue would not have become possible with the encouragement, foresight and continuous guidance at each moment of preparation given by Dr. Kevin Deng, Executive Editor, and of IJVAS. Cordial gratitude to him by the guest editors!

We also thank heartily the referees for their expertise and their commitment to the quality of the special issue. At this point, we hope that these brief accounts have convinced you to plunge into this special issue and we wish you a fruitful reading.