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Challenges in Unmanned Aircraft Systems

From Controller Design to Integration into the National Airspace

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ABSTRACT

Unmanned systems in general and unmanned Aircraft Systems (UAS) in particular, have seen unprecedented levels of growth during the last decade even though their 'utilization' has been the subject of criticism at times. However, it has been argued that UAS applications in civilian and public domains will be dominant in the future, focusing on fire detection, forest protection, crime prevention, power line inspection, environmental monitoring, emergency response and traffic monitoring, to name just a few application domains. Rotary wing UAS, unmanned helicopters, because of their ability to hover, take off from, and land almost anywhere, offer the best and a very viable solution to the 'eye-in-the-sky' alternative. Therefore:

Focusing on unmanned helicopters, and putting emphasis on controller/navigation system design, a series of controllers, from simple PID, fuzzy-PID, to multivariable LQG, H_{∞} , robust and Model Predictive Control (MPC), as well as a novel discrete backstepping controller are presented and tested for several different flying profiles. In addition, a novel nonlinear MPC augmented with a recurrent Neural Network for learning is proposed for autonomous vertical autorotation of unmanned helicopters post main/tail rotor failures, with extensions to manned helicopters, too.

Recommendations for deriving equivalent levels of safety for UAS leading to their potential integration into the National Airspace System are discussed based on improved reliability and fault tolerance requirements.

Comprehensive studies and experimentation support the proposed approaches. Video clips will be shown.

Dr. Valavanis received the Diploma in Electrical and Electronic Engineering (5 years of study) from the National Technical University of Athens (<http://www.ntua.gr>), Greece, in June 1981, and he completed the Professional Engineer (PE) exams in Electrical and Mechanical Engineering in February 1982. He received the M.Sc. degree in Electrical Engineering and the PhD degree in Computer and Systems Engineering from Rensselaer Polytechnic Institute (RPI) (<http://www.renselaer.edu>) in 1984 and 1986, respectively.

From 1987 to 1990 he held the Analog Devices Career Development Chair for Assistant Professors at the Department of Electrical and Computer Engineering, Northeastern University (<http://www.northeastern.edu>), Boston, where he was also Director of the Robotics Laboratory. From 1991 to 1999 he was with The Center for Advanced Computer Studies (CACS), University of Louisiana at Lafayette (<http://www.cacs.louisiana.edu>) where he served as Associate Professor (1991-1995) and Professor (since 1995) of Computer Engineering, as Associate Director for Research at the A-CIM Center (1993-1999) and as Director of the Robotics and Automation Laboratory. He also held the A-CIM/[TC]²/Regents Professorship in Manufacturing.

From 1999-2003, he was Professor in the Department of Production Engineering and Management, Technical University of Crete (<http://www.tuc.gr>), Greece, Director of the Laboratory of Intelligent Systems and Robotics, Director of the Graduate Program and Chair of the University Industrial Advisory Board.

From 2003-August 2008 he was Professor at the University of South Florida Department of Computer Science and Engineering (<http://www.cse.usf.edu>), where he also served as Deputy Director at the Center for Robot-Assisted Search and Rescue (CRASAR) until the summer of 2005. In 2006, he created the Unmanned Systems Laboratory in the College of Engineering, in which he served as Director. He was also the Managing Director of the National Institute for Applied Computational Intelligence (NIACI) and a Faculty Associate at Center for Urban Transportation Research (CUTR).

He joined the University of Denver on September 1, as Professor and Chair of the Electrical and Computer Engineering Department.

He is also Guest Professor in the Faculty of Electrical Engineering and Computing, Department of Telecommunications, University of Zagreb (<http://www.fer.hr>), Croatia.

Dr. Valavanis' research interests are focused in the areas of Unmanned Systems, Distributed Intelligence Systems, Robotics and Automation. He has published over 300 book chapters, technical journal / transaction and conference papers. He is the co-author of the book (with Dr. G. N. Saridis) Intelligent Robotic Systems: Theory, Design and Applications, Kluwer Academic Publishers, 1992, he co-edited (with B. Siciliano) the book Control Problems in Robotics and Automation, Lecture Notes in Control and Information Sciences, Vol. 230, Springer-Verlag, 1998. He also co-authored (with J. Balic, N. Tsourveloudis and S. Ioannidis) the book Intelligent Manufacturing Systems: Programming and Control, University of Maribor Publications, 2003. He is also the Editor (and co-author of nine chapters) of the book Advances in Unmanned Aerial Vehicles: State of the art and the road to autonomy, published by Springer in June of 2007. He also co-edited the book (with P. Oh and L. A. Piegl) Unmanned Aircraft Systems - International Symposium on Unmanned Aerial Vehicles, UAV'08, and he co-authored the book (with K. Dalamagkidis and L. A. Piegl) On Integrating Unmanned Aircraft Systems in to the National Airspace System: Issues, Challenges, Operational Restrictions, Certification, and Recommendations, both published by Springer. Most recently, he edited the book Intelligent Control Applications to Engineering Systems, also published by Springer. He also completed (with G. Atsalakis and K. Zopounidis) the book Stock Market Forecasting Techniques (in Greek), published by Klidarithmos (ISBN 978-960-461-121-8) in 2008.

He has organized two International Advanced Robotics Programme (IARP) meetings in Lisbon, Portugal, and Lafayette, LA, he has taught Tutorial Workshops at the IEEE CDC, ACC, and ICRA, Conference on Telecommunications (ConTel) and the Mediterranean Conference in Control and Automation. He served as Associate Editor of the IEEE Transactions in Robotics and Automation from 2/1996-2/1999, as the Robotics and Automation Society "Discrete Event Dynamic Systems Technical Committee" co-Chair for two years, and as an Associate Editor of the IEEE Robotics and Automation Society Magazine from 1994 to 1995. He was Editor-in-chief of the Magazine for ten years (1996-2005). He was the Book Review Editor of the Journal of Intelligent and Robotic Systems until 2006 and he serves on the Editorial Advisory Board of the International Series on Microprocessor Based and Intelligent Systems Engineering Series published by Springer. He also served as a member of the IEEE Robotics and Automation Society Awards Committee for three years, and currently as chair of the Aerial Robotics and Unmanned Aerial Vehicles Technical Committee.

Dr. Valavanis has been on the organizing committee of many IEEE conferences, serving as General, Program, Registration and Local Arrangements Chair. He was the General Chair (with F. Lewis) of the 11th Mediterranean Conference on Control and Automation, June 2003, and the Program Chair of the 2004 IEEE ICRA. He was the General Chair (with P. Anstaklis) of the 15th Mediterranean Conference on Control and Automation, June 2007, and the General Chair (with W. Gruver) of the IEEE SMC International Conference on Distributed Human-Machine Systems, March 2008. He is also the General Chair of the 2011 IEEE Multi-Conference on Systems and Control. In 1998, he was elected as Vice President – Administration of the IEEE Mediterranean Control Association (MCA). He was a Distinguished Speaker in the IEEE Robotics and Automation Society (- 2003) and he is a senior member of IEEE.