Preface

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IMAV 2022

13th International Micro Air Vehicle Conference

September 12-16, 2022

Delft, the Netherlands

www.imavs.org

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FLAPPER DRONES

Contents

Preface

On behalf of the Local Organizing Committee, it is our pleasure to present the proceedings of the 13^{th} International Micro Air Vehicle Conference, which was held in Delft, the Netherlands from September 12-16, 2022. For the fourth time, the IMAV was organized by the Micro Air Vehicle Lab of the Delft University of Technology in the Netherlands.

These proceedings are available to the public as open-access publications, seeking to promote and contribute to the advancement of the state-of-the-art in the area of small flying robots and their applications for the benefit of society.

The IMAV is a pioneering scientific-technological event in the field of aerial robotics and has been established as the primary event for the communities of researchers dedicated to the study, development and research of Micro Air Vehicles. This year of 2022, was very special as it forms the first real-life event since the COVID19 pandemic. While, very unfortunately, several restrictions still prohibited several teams to participate, we are delighted to see over 140 full participants and over 100 visitors from industry. In particular, the greenhouse challenge attracted a lot of visitors from industry and students in the agricultural domain, which is a measure for the expected value of drones' added value to this field.

These proceedings contain twenty-five peer-reviewed scientific papers by sixty-seven authors organized in six sessions presented at the IMAV in 2022. The topics of these papers contain a nice mix ranging from aerial vehicle design and energy sources to control, navigation and perception. Together, the papers give an overview of the current state-of-the-art in the field of Micro Air Vehicles. Five articles were nominated for the best paper award, out of which one was granted the "Best Paper Award" at the award ceremony. Based on the quality of the scientific and technical contribution, ten papers were selected to be published in two scientific journals: the International Journal of Micro Air Vehicles (Sage), and Unmanned Systems (World Scientific).

We would like to express our sincere gratitude for the guidance and support of the members of the thirteen members of the International Committee from nine institutes who guide IMAV overall, and the seventeen reviewers from nine institutes, who played an important role in assuring the quality of all the papers. In addition to the presentation of the scientific papers, four keynote talks were delivered by experts in the field whom we want to thank for their valuable contributions. We also want to thank all members of the Local Organizing Committee for their invaluable support in the organization of this IMAV-2022. Last but not least, we are particularly grateful for the sponsorship provided by our wide range of sponsors: Gemeente Westland, RoboCrops, Bitcraze AB, Unmanned Valley, Office of Naval Research, US Army, Dronisos - Drone Light Shows, Flapper Drones, TU Delft Robotics Institute, and TU Delft AgTech Institute.

Delft, the Netherlands. September 2022

G. de Croon and C. De Wagter
MAVLab, TUDelft

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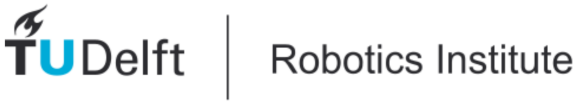

Websites

- https://www.dronisos.com/
- https://www.bitcraze.io/
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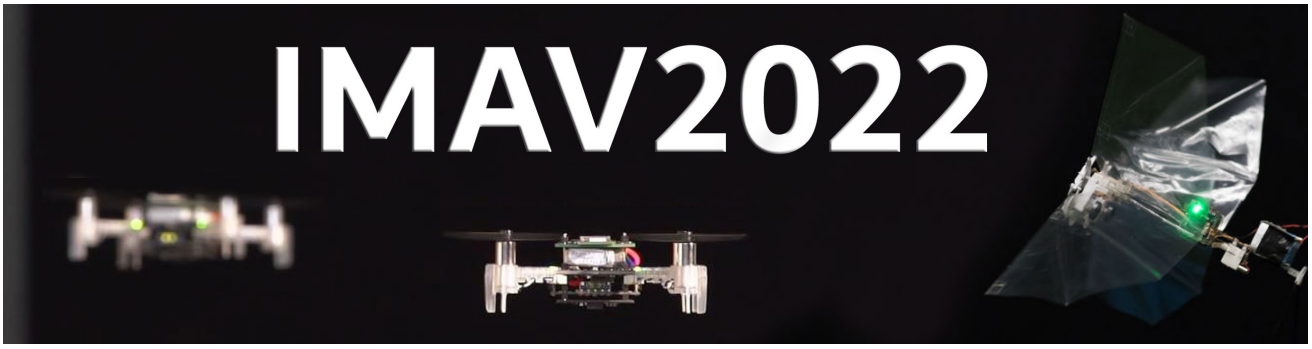
Call for Papers



The IMAV conference focuses on all scientific studies related to Micro Air Vehicles (MAVs), ranging from aerodynamics and design of small drones to their control and artificial intelligence. The conference is always combined with real-world competitions that aim to bring theory into practice and advance the state of the art. IMAV 2022 will be organized by TU Delft.

Submission Guidelines

Articles will be fully peer-reviewed and published open access. A selection of best-reviewed articles will be invited to special issues in the International Journal of Micro Air Vehicles and in the Unmanned Systems.

All papers must be original and not simultaneously submitted to another journal or conference. They must follow the template and be about 6 pages in length. File sizes should be minimized (max 5MB) while graphical quality should be maximized by using vector graphics whenever possible.

List of Topics

We solicit scientific articles in all areas related to Micro Air Vehicles, for example on the following (non-exhaustive) list of topics:

- (Unsteady) aerodynamics at low Reynolds numbers
- Agile/fast autonomous flight (autonomous drone racing
- Hybrid drones (combining fixed wings and rotors)
- Design of novel drone types (flapping-wing drones / silent drones)
- Biomimetic/bio-inspired drones for outdoors and indoors
- AI-capable drones - running (spiking) deep nets
- Drones that interact robustly with their environment (aerial manipulation)
- New control methods for drones
- Swarming (e.g., collaborative carrying, exploration
- Autonomous navigation in GPS-denied environments
- Integration of drones in airspace (sense-and-avoid, UTM, ...)
- Drone applications (search-and-rescue, greenhouse, package delivery)

Venue

- Location: Delft, the Netherlands (+ online)
- Event dates: September 12 -16, 2022. Web site: http://www.imavs.org/2022
- Article submission deadline: May 15, 2022

Contact

All questions about submissions should be emailed to imavsdotorg@gmail.com

Competitions

Nanocopter Challenge

Greenhouse Challenge

Package Delivery Challenge

Conference Oral Presentations

Guidance and Control

Perception

Deep Learning

Control of Transitioning MAV

MAV Design

Design and Control

Keynote Speakers

Hyper-dimensional Active Perception: a journey into the mind of a robotic bee

Yiannis Aloimonos, Computer Vision Laboratory – University of Maryland, College Park

Abstract

Action and perception are often kept in separated spaces, which is a consequence of traditional vision being frame-based and only existing in the moment and motion being a continuous entity. This bridge is crossed by the dynamic vision sensor (DVS), a neuromorphic camera that can see the motion. We propose a method of encoding actions and perceptions together into a single space that is meaningful, semantically informed, and consistent by using hyper-dimensional binary vectors (HBVs). We show that the visual component can be bound with the system velocity to enable dynamic world perception, which creates an opportunity for real-time navigation and obstacle avoidance with active perception. Actions performed by an agent are directly bound to the perceptions experienced to form its own "memory." Furthermore, because HBVs can encode entire histories of actions and perceptions—from atomic to arbitrary sequences—as constant-sized vectors, auto-associative memory was combined with deep learning paradigms for controls. Using this methodology we can implement, for manoquadrotors with all processing on board, a hierarchy of sensorimotor loops providing a set of competences (egomotion, moving object detection, obstacle avoidance, homing and landing) which can be interfaced with episodic, procedural and semantic memory, giving rising to a minimal cognitive system. The talk will conclude with a journey into the mind of a robotic bee using a variety of experimental results.

Biography

Yiannis Aloimonos is a Professor of Computational Vision and Intelligence at the Department of Computer Science, University of Maryland, College Park, and the Director of the Computer Vision Laboratory at the Institute for Advanced Computer Studies (UMIACS). He is also affiliated with the Institute for Systems Research, the Neural and Cognitive Science Program and the Maryland Robotics Center. He was born in Sparta, Greece and studied Mathematics in Athens and Computer Science at the University of Rochester, NY (PhD 1990). He is interested in Active Perception and the modeling of vision as an active, dynamic process for real-time robotic systems. For the past five years he has been working on bridging signals and symbols, specifically on the relationship of vision to control, and the relationship of action and language using Hyper-dimensional Computing.

Bio-inspired aerodynamics, actuation, sensing and control

Richard Bomphrey – Professor of Comparative Biomechanics – Royal Veterinary College

Abstract

How can the observation of animal aerodynamics inform bio-inspired aircraft? I will discuss how fundamental bioscience research can reach outside animal ecology and physiology to offer solutions to engineering challenges.

Flying animals must perceive and avoid obstacles, often in environments deprived of visual sensory cues. In my first example, I will show how collision-avoidance in nocturnal mosquitoes can be mediated by mechanosensory feedback, based on modulations of their own induced aerodynamic and acoustic fields as they enter ground- or wall-effect. Our computational fluid dynamics and aeroacoustic simulations are derived from detailed wing kinematics extracted from high-speed recordings of freely flying Culex quinquefasciatus mosquitoes. Based on Culex data, we have built palm-sized prototypes carrying a suite of bio-inspired sensor packages. I will discuss how aerodynamic and aeroacoustic cues that are associated with close proximity to the ground and wall planes could provide useful information to the flight controller (a mechanism we term 'aerodynamic imaging') and how mosquitoes perceive and interact with others using acoustic interactions.

In my second example, I will present our work based on measuring the changing shape of birds in flight. I will show how they minimise drag in a different way from conventional aircraft design on account of their smaller size, and how they remain unperturbed by strong gusts. Our detailed three-dimensional reconstructions of surface geometries show how wing elevation around the shoulder joint acts as an initially passive suspension system that rejects gusts, steadying the payload. The mechanism works most effectively when the aerodynamic centre of pressure is aligned with the mechanical centre of percussion, and therefore can be tuned either by changing wing shape or by the distribution of mass within the wing. Together, these topics give a small glimpse into the potential that continues to exist within the natural world for the improvement of small aircraft.

Biography

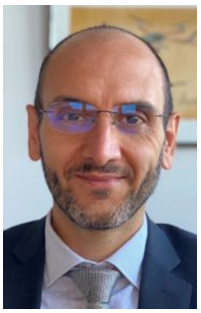
Richard's research blends biology and engineering. He uses biomechanics as a tool to investigate evolutionary biology and how the physical environment determines the morphology and control systems of flying animals. He has worked on the sensory mechanisms of insects and birds, including flow-sensing, load-sensing, and optic flow. Richard's work uses advanced equipment to investigate animal flight and understand their aerodynamic footprints by observing the motion of smoke or bubbles floating in the air. He has applied insights from biology to aerial robots inspired by birds and insects. Richard joined the Structure and Motion Laboratory at the Royal Veterinary College, University of London, in 2013 after reading Biological Sciences at Exeter, undertaking a DPhil (PhD) in Oxford, postdoctoral positions in Oxford and Bath, and an EPSRC Fellowship. He is currently Professor of Comparative Biomechanics at the Royal Veterinary College and Interim Vice Principal for Research.

Is control a solved problem in robotics MAV research?

Antonio Franchi – Professor in Aerial Robotics Control – Twente University

Abstract

In these days MAV and robotics research in general are dominated by data-driven approaches that are mainly focused on scientific problems related to perception and other AI-related problems. The design, modeling, and control problems, which have been the backbone of MAV research in the past decades seem to suffer a period of decline in terms of popularity. There are many possible explanations for this phenomenon. Perhaps there are no more relevant open control problems for UAVs; or maybe still unsolved problems are now perceived as solved because of some sort of 'mass hallucination'; or perhaps the attention is now distracted by other problems which have been neglected in the past because too hard to solve and now seem/are finally within reach thanks to the new AI wave; or another explanation could be that the problems still open in control are so difficult that everybody pretend to ignore them, like the 'Fox and the Grapes'. Or the motivation could be a different one of course. Or perhaps there is no decline in popularity at all and this research field is actually in very good shape but just not advertised enough to emerge.



In this keynote I will give my historical and technical point of view on the question whether there are still significant open scientific problems in UAV research on the design and control side and, in case the answer is yes, I will try to critically rank such open problems in terms of difficulty and provide possible technical directions to explore the paths toward their solutions.

Biography

Antonio Franchi (https://homepages.laas.fr/afranchi/robotics/) is a Full Professor in Aerial Robotics Control at the University of Twente, The Netherlands, in the Robotics and Mechatronics department, and an associated researcher at LAAS-CNRS (RIS team), Toulouse, France. He is a IEEE Senior Member.

From 2014 to 2019 he was a Permanent Researcher at CNRS and the leader of the aerial robotics activities at LAAS-CNRS. From 2010 to 2013 he was a Research Scientist and then a Senior Research Scientist at the Max Planck Institute for Biological Cybernetics in Germany, and the scientific leader of the group "Autonomous Robotics and Human Machine Systems". He received the Laurea (M.Sc.) degree (summa cum laude) in Electronic Engineering and the Ph.D. degree in System Engineering (Feb. 2010) from Sapienza University of Rome, Italy. In 2009 he was a visiting student at the University of California at Santa Barbara.

His main research interests lie in the robotics area, with a special regard to control and estimation problems and applications ranging across motion and physical interaction control, decentralized control/estimation/coordination, haptics, and hardware/software architectures. His main areas of expertise are aerial robotics and multiple-robot systems.

He published more than 150 papers in international journals, books, and conferences and gave more than 90 invited talks in international venues since 2010. In 2010 he was awarded with the "IEEE RAS ICYA Best Paper Award" for one of his works on Multi-robot Exploration. In 2018 he was a recipient of the 2018 IEEE RAS Most Active Technical Committee Award.

He was Associate Editor of the IEEE Transactions on Robotics from 2016 until 2021 and he is Senior Editor for IEEE ICRA since 2020. He has been associate editor of the IEEE Robotics & Autom. Mag. (2013 to 2016), IEEE ICRA (2014 to 2019), IEEE/RSJ IROS (2014 to 2017) and the IEEE Aerospace and Electric Systems Magazine (2015).

He is the project coordinator of JCJC ANR MuRoPhen, co-coordinator of the FlyCrane project, and a was a contributor to PRO-ACT H2020, all focused on multi-robot coordination/manipulation. He is the local coordinator of the EU H2020 Aerial-CORE project, he has been local coordinator in the EU H2020 AEROARMS project, the creator of the ANR PRC 'The Flying Co-worker' project, and he contributed to the EU FP7 ARCAS project, all focused on aerial robotic manipulation.

He is the co-founder and co-chair of the IEEE RAS Technical Committee on Multiple Robot Systems (>450 members).

He co-funded and was the program co-chair of the IEEE-sponsored International Symposium on Multi-robot and Multi-agent Systems (MRS 2017, 2019, and 2021). He co-organized the IEEE-RAS-sponsored 2019 and 2016 Summer Schools on Multiple Robot Systems at NUS, Singapore and CTU, Prague, and more than 15 workshops on Multi-robot Systems, Aerial Robots and Teleoperation at IEEE ICRA, IEEE/RSJ IROS, and RSS, among others.

Since 2010, he has been the mentor of 11 graduated PhD student and he is currently mentoring 8 PhD candidates. One the PhD theses he mentored won the Best Robotics Thesis French National Award in 2019.

Storytelling with drone swarms

Laurent PERCHAIS, CEO – Rémi POTET & Corentin GIRAUD, Drone Engineers at DRONISOS

Abstract

Dronisos, with its unrivalled technology developed completely in-house, has turned the sky into the world's biggest 3-dimensional screen using thousands of drones as animated pixels.

Major Events, Global Brands and world-renowned Theme Parks have all adopted this new medium of communication and entertainment, making Dronisos a worldwide leader in drone entertainment with over 15,000 performances to date.

Dronisos has invented a new medium for storytellers to bring their stories to life on the world's biggest stage – the sky.

However, for this keynote, we want to tell you OUR story. The story of a 5-year journey a team of engineers passionate about drones took on, inventing a new medium of expression while tackling technical and scientific challenges of autonomous drone swarms along the way.

Biography

Laurent PERCHAIS is the CEO of Dronisos. He is a graduate of the Ecole Polytechnique (Paris, France) and HEC Business School (Paris, France). Following his first role at Canal+ (French TV player), he held various positions at Orange (French Telco) both as an Engineer and as a Business manager, where he ended as Head of Strategy for Orange Content (TV, Music, Gaming. . . .) before becoming Dronisos CEO in 2017.

Remi POTET is a former IMAV participant and now a Dronisos expert in drone engineering. He holds an MSc from ISAE SUPAERO(Toulouse, France) and has been part of Dronisos' journey from almost the beginning (2018).

Corentin GIRAUD is a drone industry veteran. After a successful experience at Azur Drones, he joined Dronisos in 2020 to lead the development of Dronisos in the Defense & Safety sector. He graduated from ISAE-SUPAERO (Toulouse, France).

Papers

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Release

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