


International Conference on Unmanned Aircraft Systems ICUAS 2023

June 6-9
Lazarski University, Warsaw, Poland

Technical Program and Book of Abstracts

ICUAS

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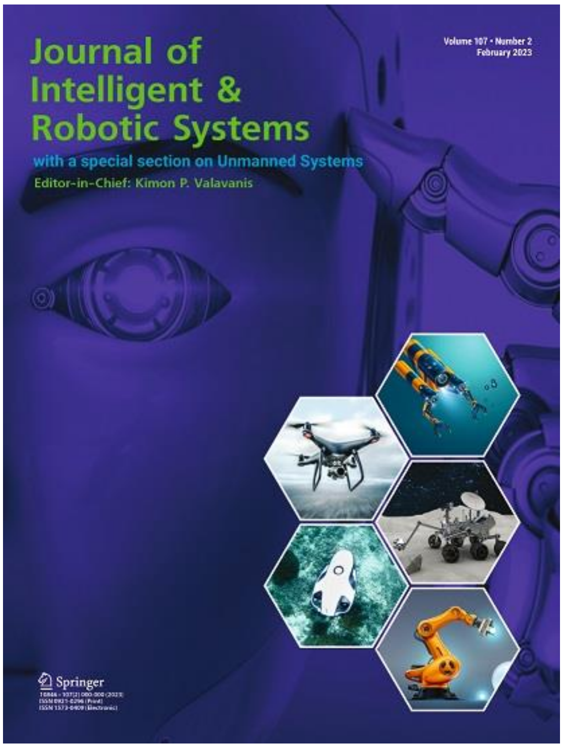

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Welcome Message from the ICUAS Association

Dear participants and attendees:

On behalf of the ICUAS Association Inc., and in my capacity as the President of the Association, it is a privilege, a great pleasure and an honor to welcome you to the *2023 International Conference on Unmanned Aircraft Systems* (ICUAS'23). ICUAS'23 takes place for the first time on a university campus, on the campus of Lazarski University, in Warsaw, Poland. Lazarski University was chosen because it is home of the Lazarski Aviation Academy, which is a research center that offers studies combining the aviation industry with law and business, and, because of its Aviation Law program.

ICUAS'23 is, again, a hybrid conference that allows for physical and virtual paper presentations, physical and virtual attendance. We certainly hope that a year from now, in 2024, we will go back to the 'physical presence only' model that gives conferences momentum stimulating live discussions and interactions.

I also take the opportunity to inform you that the ICUAS Association Newsletter has transitioned to an ***eMagazine***, which will be published quarterly – the 2nd Issue, the Spring 2023 issue, will be published in early May, it will be emailed to you and it will be available to download and print at www.icuas.com.

We look forward to your active involvement in the Association and in the conference, and to your contributions and feedback. We welcome your participation, and we are open to your ideas and suggestions. Please note that, this year, Dr. Nikos Vitzilaios has prepared a more detailed and enhanced questionnaire and survey, compared to the one sent to you last year, and we kindly request that you complete and submit it; we are eager to review your comments with the aim of improving the annual technical conference and to better serve you.

I offer my best wishes for a successful and productive event, I look forward to seeing all of you in Warsaw, and I also look forward to continuing working with you.

Kimon P. Valavanis

Welcome Message from the ICUAS'23 General Chairs

Dear participants and attendees:

On behalf of the 2023 ICUAS Organizing Committee, it is a privilege and a great pleasure to welcome you to this year's conference. ICUAS'23 is organized on the campus of Lazarski University, in Warsaw, Poland. The three-day technical conference is preceded by a one-day Workshops/Tutorials program, which is composed of three (3) Tutorials / Workshops. Being on a university campus makes us feel at home and helps bring us closer to each other, stimulating discussions and possible collaboration.

Conference participants represent academia, industry, government agencies, lawyers, policy makers, manufacturers, students, and end-users, all having deep interest in the state-of-the-art and future directions in UAS/RPAS. In response to the Call for Papers, we received a healthy number of 250 contributed, invited session, and poster papers. Following a very thorough and in-depth peer review process, the committee accepted for presentation and inclusion in the conference proceedings 189 contributed, invited session and poster papers. All papers were also checked following the *iThenticate Document Viewer Guide* before the final decision was made. We have assembled a full three-day top-quality Technical Program. We also have three Plenary Lectures in which the keynote speakers address pressing, and important issues related to several aspects of unmanned aviation. ICUAS'23 also includes the UAV Competition, which is student focused, offering unique opportunities for students to test and compare their skills with those of their peers, worldwide.

The Organizing Committee members, the Associate Editors and the reviewers have devoted an enormous amount of time and effort to assemble an exciting, informative, and educational conference. We are thankful to all for their dedication and professionalism.

The peer review process is coordinated by the Program Chairs and Vice Chairs, who assign groups of papers to the Associate Editors. We thank all of them for their extremely valuable contributions and dedication. All papers are submitted through the PaperCept Conference Management System; Dr. Pradeep Misra is the 'glue' who keeps all conference components together. We would not have been able to complete the paper review process without his help, and for this, we thank him wholeheartedly.

We thank all the authors for your participation and contributions. We hope you enjoy the conference, as well as Warsaw.

With our warmest regards,

Anna Konert, YangQuan Chen, and Andrea Monteriu

Welcome Message from the ICUAS'23 Program Chairs/Vice Chairs

Dear participants and attendees:

Welcome to ICUAS'23. This year we received 250 contributed, invited session, and poster papers. The paper review process has been extremely thorough and rigorous. All papers were also checked for originality using the *iThenticate Document Viewer Guide*. Our goal was for each paper to have at least three (total) reviews, counting the reviews of the Program Chairs and Vice Chairs and that of the Associate Editors. We met and exceeded this goal; the aim was simply to make just and informed decisions.

The review process resulted in accepting 189 contributed, invited and poster session peer reviewed papers as shown below.

COUNTRY	SUBMITTED	ACCEPTED
Algeria	3	2
Argentina	3	2
Australia	2	1
Austria	2	1
Brasil	19	13
Canada	12	8
China	14	12
Colombia	1	1
Croatia	3	3
Cyprus	6	6
Czech Republic	5	2
Denmark	6	3
Finland	2	1
France	9	7
Germany	9	7
Greece	4	3
Hungary	3	2
India	15	9
Ireland	1	1
Israel	2	2
Italy	17	15
Japan	3	1
Kazakhstan	1	1
Kenya	2	1
Korea, South	5	5
Luxembourg	3	3
Malta	1	0
Mexico	6	6
Netherlands	7	7
New Zealand	3	0
Norway	2	1
Poland	10	7
Portugal	1	1
Russia	1	0
Singapore	5	4
Spain	13	13
Sweden	4	4
Switzerland	4	4
Turkey	3	3
United Kingdom	4	4
USA	34	23
TOTAL	**250**	**189**

The technical program spans three days, during which all accepted (and uploaded) papers are presented, physically or virtually – four (4) accepted papers have not been uploaded in final form.

We would like to thank all the authors for their contributions. The rigorous review process would not have been possible if we did not have such a strong community of expert reviewers. We thank all reviewers for their professional service. Dr. Pradeep Misra helped us in working and effectively using the online paper submission and review system. This system is very sophisticated and yet very practical to use for both small- and large- scale conferences. It is very hard to imagine how things would have been done without this excellent tool!

We hope you enjoy not only the technical aspects of the conference but also the historic city of Warsaw.

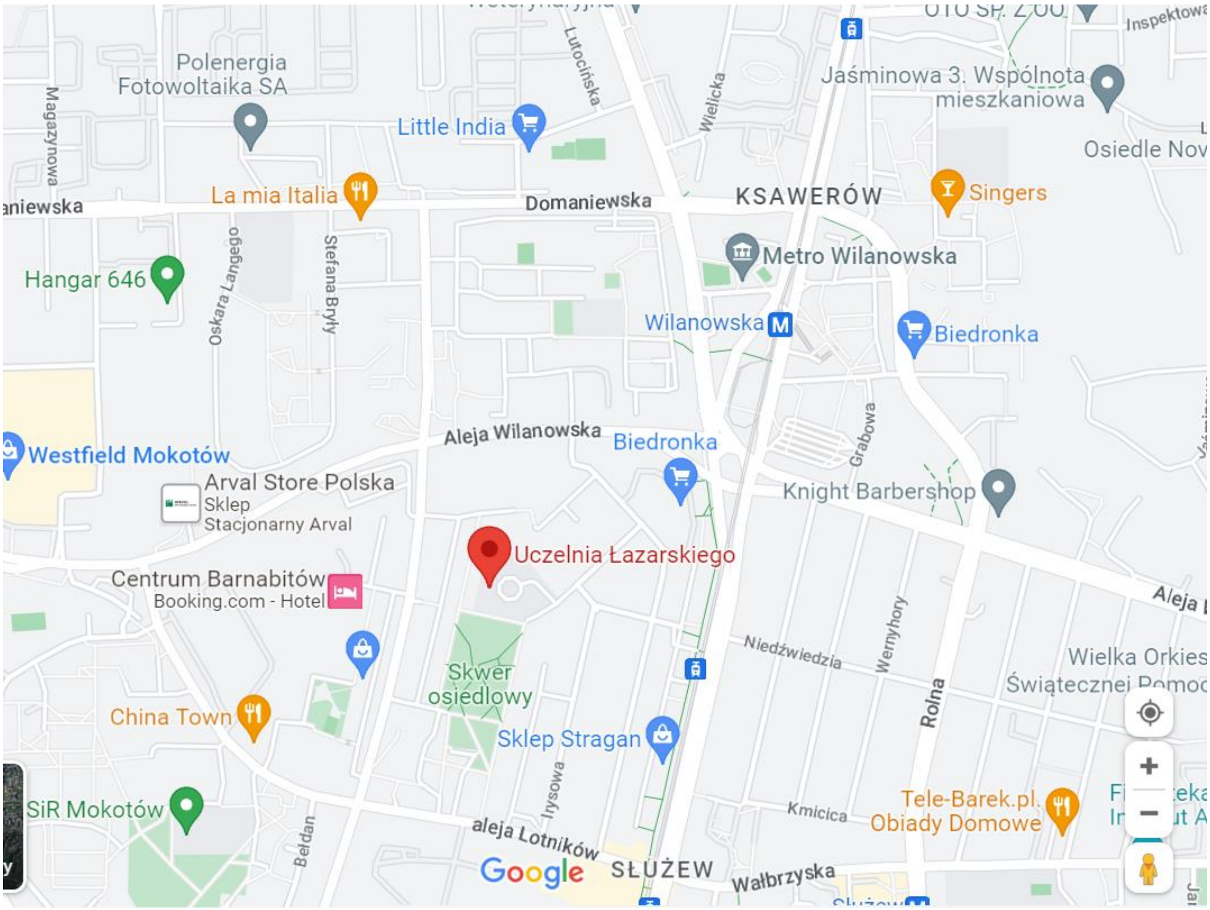
George Nikolakopoulos, Benjamyn Scott, Nikos Vitzilaios and Xiang Yu

ICUAS'23 General Information

The Venue

ICUAS'23 will take place on the campus of Lazarski University, https://www.lazarski.pl/en/, in Warsaw, Poland. Lazarski is a private university that comprises the Faculty of Law and Administration, the Faculty of Economics and Management and the Faculty of Medicine. The Faculty of Law and Administration also offers a Bachelor of Aviation Law and Professional Pilot Licence program.

The ***campus location*** is at the address: Świeradowska 43, 02-662 Warsaw, Poland. The campus is in the Mokotów district, close to a public transport hub, close to the Wilanowska underground station, as well as a bus and tram terminal. One may reach the university from practically any corner of Warsaw.



Traveling to Warsaw

This information has been sourced from the official Warsaw Tourism website, which provides all the details. Click on https://warsawtour.pl/en/getting-to-warsaw/ for information.

By Plane – Option 1: Chopin Airport

The Chopin Airport, www.lotnisko-chopina.pl, is located about 10 km from the city center. The city center may be reached by public transportation as follows:

- **Bus** number 175 runs to the center and around the Old Town (Stare Miasto).
- **Bus** number 148 and 188 runs to the other side of the river, to Praga, Grochów and Gocław.
- **Night bus** number N32 runs to the city center.
- **Suburban train** line S2 and S3 or RL go to the city center.

Transport tickets are required on all lines.

Moreover, there are several reliable taxi companies in front of the Terminal that one may use. It is advisable to avoid people in the Arrivals Hall, encouraging you to use random taxis. They are often unlicensed, and their fees are several times higher than registered and legal taxis. Note that Warsaw is very Uber- /Bolt- /FREE NOW- friendly. Rates are cheaper than traditional taxis.

By Plane – Option 2: Warsaw Modlin Airport

The Warsaw Modlin Airport, modlinairport.pl, is located around 35 km North-West from the city center, which may be reached by train. Koleje Mazowieckie trains depart from Modlin railway station, which can be reached by a special airport bus, which leaves from the airport terminal at times coordinated with the train timetable. A special airport ticket that costs 19 PLN can be purchased in the airport terminal. The estimated travel time to the city center is 1 hour and 15 minutes.

Taxis offer another option for transportation. The airport recommends one taxi company: Taxi Modlin. Transfer to the center of Warsaw costs from 100 to 250 PLN (depending on the district). Again, avoid people in the Arrivals Hall, encouraging you to use random taxis.

By Bus

The bus station Dworzec PKS Warszawa Zachodnia at Aleje Jerozolimskie 144 offers international and national connections. Tickets for national and international routes can be purchased at ticket offices at the station and on the website E-Podróżnik, www.e-podroznik.pl.

By Train

Warsaw has three large railway stations with international and domestic long-distance connections.

- **Warszaw Centralna**, Aleje Jerozolimskie 54, is in the heart of the city, and it is reachable from all districts of Warsaw.
- **Warszawa Zachodnia**, Aleje Jerozolimskie 144, is right next to the international bus station. It is convenient for people taking long-distance (both national and international) buses.
- **Warszawa Wschodnia**, ul. Lubelska 1, is located on the Praga side of the river.

Train tickets may be purchased at the ticket windows (kasa) in the stations, on the internet, or at selected travel agencies. One may also purchase tickets on the train from the conductor, whom you must seek out immediately upon boarding the train. Tickets sold on the train are subject to an additional fee.

Reaching Lazarski University from Warsaw and the Conference Hotels

Bus transportation will be provided to all registered participants from the five selected hotels to the Lazarski University campus. The departure time is 8:00 AM from the first hotel (for all three days of the conference). Return to the hotels will be at 7:00 PM on Wednesday, and 4:00 PM on Friday. Transportation on Thursday afternoon will be arranged based on what time the UAV Competition will finish. Details will be provided as we get closer to the conference dates.

However, to better assist conference participants, the instructions provided below should be followed to reach the conference venue and/or the hotels. Note that all bus and train timetables are available on Google Maps. Tickets may be purchased from ticket machines that are conveniently located at the bus/tram stops or metro stations, as well as inside the trams and buses (card payments only).

From Regent Warsaw Hotel

- Walk around 10 mins to the tram station DWORKOWA 06
- Take tram number 75 in the direction WYŚCIGI (every 8-10 minutes)

- Ride 7 stops (around 12 minutes)
- Gett of the tram at the tram stop NIEDŹWIEDZIA 03
- Walk around 7 mins to Lazarski University.

<u>From Hotel Bristol</u>

Option 1:

- At the bus stop HOTEL BRISTOL 02 take bus number 222 (in the direction BIELAŃSKA, every 20 minutes)
- Ride for 3 stops (around 5 minutes)
- Gett of the bus at the bus stop PL. BANKOWY 02
- Walk around 130 m to the nearest Metro entrance (station RATUSZ ARSENAŁ)
- Take M1 in the direction KABATY (every 2-3 minutes)
- Ride for 7 stops (around 13 minutes)
- Get out at the metro station WILANOWSKA
- Walk around 12 minutes to Lazarski University.

Alternatively, take tram number 4 or 75 (both in the direction WYŚCIGI, every 5 minutes), ride one stop, get of at NIEDŹWIEDZIA 03 and walk around 7 minutes to Lazarski University.

Option 2:

- At the bus stop HOTEL BRISTOL 01 take bus number 175 (in the direction TERMINAL AUTOKAROWY) OR bus number 128 (in the direction SZCZĘŚLIWICE) – every 5 minutes
- Ride for 5 stops (around 10 minutes)
- Get of at the bus stop CENTRUM 06
- Walk around 150 m to the nearest Metro entrance (station CENTRUM)
- Take M1 in the direction KABATY (every 2-3 minutes)
- Ride for 5 stops (around 10 minutes)
- Get of at at the metro station WILANOWSKA
- Walk around 12 minutes to Lazarski University.

Alternatively, take tram number 4 or 75 (both in the direction WYŚCIGI, every 5 minutes), ride one stop, get of at NIEDŹWIEDZIA 03 and walk around 7 minutes to Lazarski University.

<u>From Hotel Raffles Europejski</u>

- The hotel is just opposite the Bristol Hotel. Follow the previously stated instructions.

<u>From Sheraton Grand Warsaw</u>

- Walk around 4 mins to the bus station PL. TRZECH KRZYŻY 03
- Take bus number 118 in the direction METRO POLITECHNIKA (every 15 minutes)
- Ride 4 stops (around 8 minutes)
- Get of at the bus stop METRO POLITECHNIKA 09
- Walk around 10 m to the nearest entrance to Metro (station POLITECHNIKA)
- Take M1 in the direction KABATY (every 2-3 minutes)
- Ride for 4 stops (around 7 minutes)
- Get of at the metro station WILANOWSKA
- Walk around 12 mins to Lazarski University.

Alternatively, take tram number 4 OR 75 (both in the direction WYŚCIGI, every 5 minutes), ride one stop, leave at NIEDŹWIEDZIA 03 and walk around 7 mins to Lazarski University.

<u>From Novotel</u>

- Walk around 3 minutes to the nearest entrance to Metro (station CENTRUM)
- Take M1 in the direction KABATY (every 2-3 minutes)
- Ride for 5 stops (around 9 minutes)
- Get of at the metro station WILANOWSKA
- Walk around 12 mins to Lazarski University.

Alternatively, take tram number 4 OR 75 (both in the direction WYŚCIGI, every 5 minutes), ride one stop, get of at NIEDŹWIEDZIA 03 and walk around 7 mins to Lazarski University.

From Lazarski University to the UAV Competition Site

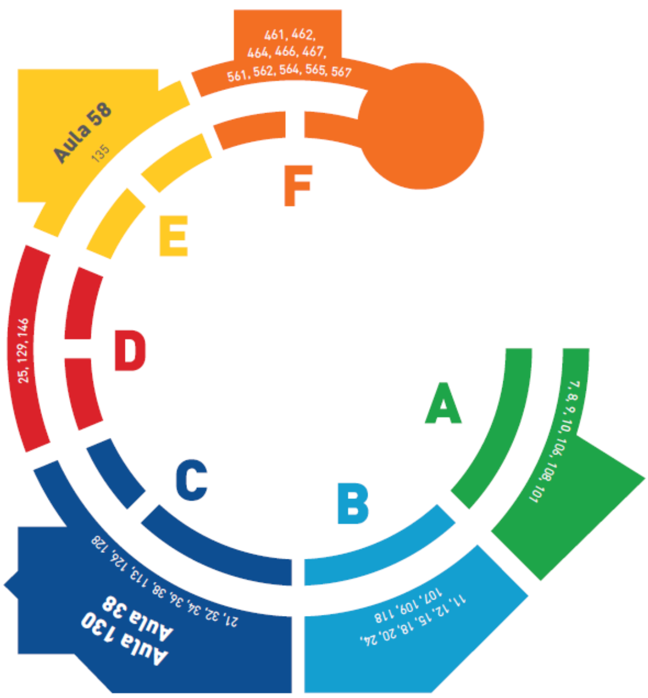
The UAV Competition will take place in a near by High School. Bus transportation will be provided on Thursday afternoon for registered conference participants. However, one may follow the below instructions to reach the High School, which is about 2 Km from Lazarski University (about 20 – 25 minutes walk).

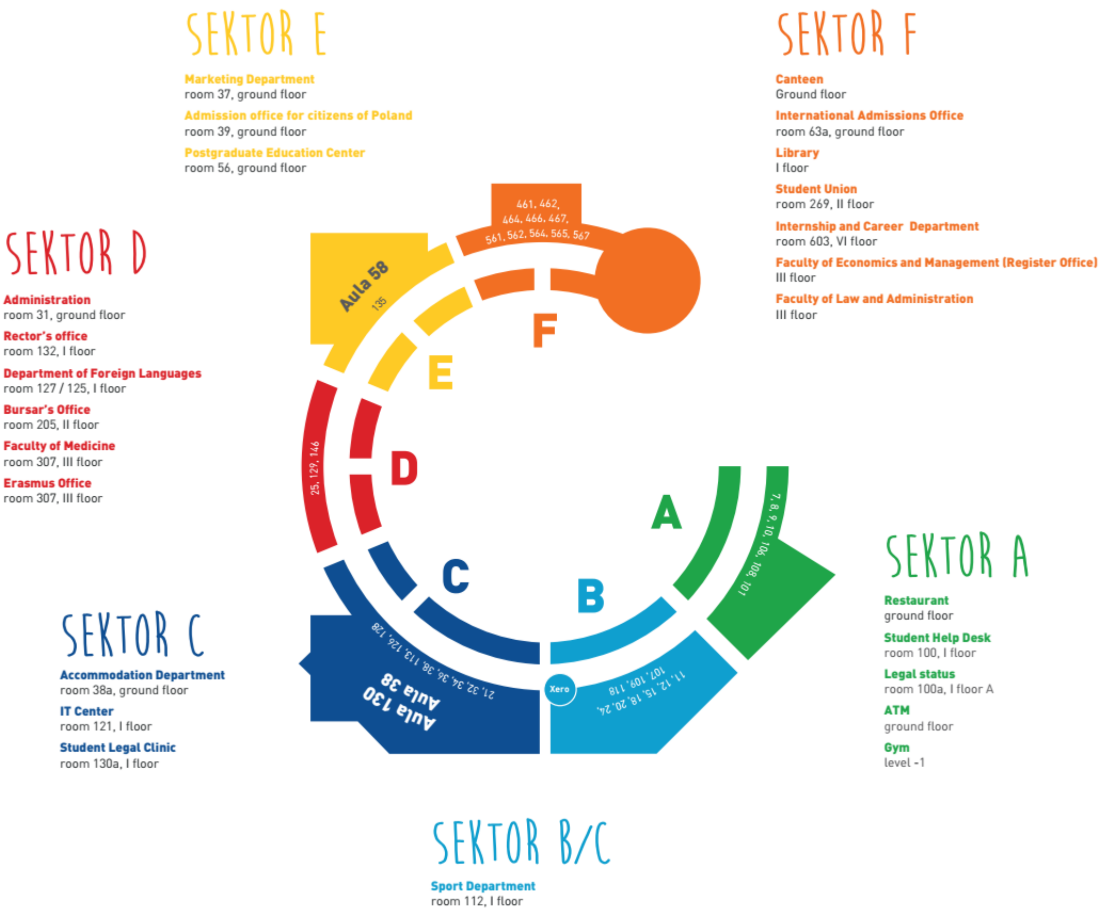
- Walk around 9 minutes to the bus station BEŁDAN 02
- Take bus number 402 (in the direction WYNALAZEK), or bus number 401 (in the direction URSUS-NIEDŹWIADEK), or bus number 189 (in the direction OS. GÓRCZEWSKA) – the bus schedule is every 5 minutes
- Ride for 2 stops (around 4 minutes)
- Get of at the bus stop POSTĘPU 02
- Walk around 270 m to *LXV Liceum Ogólnokształcące z Oddziałami Integracyjnymi im. gen. J. Bema* (Marynarska 2/6, 02-674 Warszawa).

Recommended Taxi Companies: However, should you prefer to use traditional taxi services, the following companies are recommended: EKO TAXI – +48 22 644 22 22; ELE TAXI – +48 22 811 11 11; SAWA TAXI – +48 19 123 / +48 22 644 44 44.

CONFERENCE LOGISTICS

ICUAS’23 is a four-day event, starting with workshops and tutorials on Tuesday, June 6, followed by a three-day technical conference on June 7-9. The conference includes three Keynote Lectures. The meeting rooms in which all technical sessions will take place, shown in the figure (see next page), are Room 58 (Aula 58) for the three Keynote Lectures, and Rooms 118, 130, 464, 465 and 466 for the five parallel sessions. The three workshops / tutorials will be in Rooms 464, 465 and 466. The registration area and exhibit booths will be on the main floor, which will serve as the focal point for the duration of the conference. Poster papers will be on display, as needed, and they will include physical or video-recorded presentations.





Conference Registration

All conference attendees <u>must register</u> by using the online registration when they upload the final version of their papers. This is the preferred option. Late and onsite registration is also available for non-authors who want to attend the conference. It is not required to present a paper in the conference program to register and to attend the conference. All registered participants must check in at the Registration Desk to pick up their registration packages. Personal badges will be provided to all registered participants. Attendees must always wear their badges when attending any ICUAS'23 event (workshops, tutorials, technical sessions, and social functions). Conference details will be posted and updated daily in the registration area. To register, follow the steps:

- ✓ Go to https://controls.papercept.net
- ✓ Scroll down the list until you find ICUAS 2023 - Choose ICUAS 2023 (from the list of conferences)
- ✓ Click on Register for ICUAS'23
- ✓ Login with your PIN and Password. *First time users must create a 'profile', to get a PIN and Password.*
- ✓ After you Log in, choose **Registree**.
- ✓ Follow the self-explained screens to register.

Alternatively, and especially if you have not authored a paper, you may register through www.icuas.com.

The registration desk will be open during the following hours:

TUESDAY, JUNE 6:	***<u>Workshop/Tutorial Registration only</u>*** Note that morning registration is for Workshops and Tutorials only.	8:30 AM – 10:00 AM

Conference Registration 3:00 PM – 5:00 PM

WEDNESDAY, JUNE 7: 8:00 AM – 4:00 PM
THURSDAY, JUNE 8: 8:00 AM – 2:00 PM
FRIDAY, JUNE 9: 8:00 AM – 10:00 AM

Onsite conference registration policy & fees

Attendees can register for the Conference under the following registration categories/rates:

Attendee Status	**Registration Fee**
	Late/Onsite
Full Regular Registration - Physical Presence	$660
Full Regular Registration – Virtual Presence	$480
Student Registration (Physical Presence)	$360
Student Registration (Virtual Presence)	$325
Guest Registration (social events)	$200
T1: New Developments on Sense and Avoid, Distributed Fault Detection and Diagnosis, Fault-tolerant Control and Fault-tolerant Cooperative control Techniques for Unmanned Systems (Physical Presence)	$240
T1: New Developments on Sense and Avoid, Distributed Fault Detection and Diagnosis, Fault-tolerant Control and Fault-tolerant Cooperative control Techniques for Unmanned Systems (Virtual Presence)	$120
T2: Review of State-of-the-Art Deep Learning Approaches for Visual Object Recognition and Tracking: Applications to UAS (Physical Presence)	$160
T2: Review of State-of-the-Art Deep Learning Approaches for Visual Object Recognition and Tracking: Applications to UAS (Virtual Presence)	$85
T3: Current and Future Surveillance Technologies for Airspace Integration of UAS in Controlled and Uncontrolled Airspace (Physical Presence)	$160
T3: Current and Future Surveillance Technologies for Airspace Integration of UAS in Controlled and Uncontrolled Airspace (Virtual Presence)	$85
Extra Welcome Reception Ticket	$50
Extra Farewell Reception Ticket	$50
Extra Banquet Ticket	$100

Internet Access
All registered attendees will have complementary internet access.

Lunch for participants
Lunch will be served to registered conference participants. Lunch tickets will be provided for Wednesday, Thursday and Friday, June 7 to 9.

Coffee Breaks with snacks
There will be two coffee breaks per day for all registered participants, one in the morning and one in the afternoon.

Events and Receptions
The ICUAS'23 social agenda includes a *Welcome Reception* on Tuesday, June 6; *Banquet*, on Thursday, June 8 and a short *Farewell* on Friday, June 9.

ICUAS'23 Tutorials and Workshops

ICUAS'23 offers three pre-conference Workshops/Tutorials addressing current and future topics in unmanned aircraft systems from experts in academia, national laboratories, and industry. Interested participants may find details on www.uasconferences.com, and they may use the online system for registration. Tutorials/Workshops will take place on Tuesday, June 6. Duration is either *Full-Day* (09:00 - 17:00) or *Half-Day* (09:00 - 13:00, or 14:00 – 18:00).

TUTORIALS / WORKSHOPS - Tuesday, June 6, 2023		
Location	**Time**	**Title**
Room 464	Full-Day 9:00-18:00	*New Developments on Sense-And-Avoid (S&A), Distributed Fault Detection and Diagnosis (DFDD), Fault-Tolerant Control (FTC) and Fault-Tolerant Cooperative Control (FTCC) Techniques Unmanned Systems*
Room 465	Half-Day 9:00-13:00	*Review of State-Of-The-Art Deep Learning Approaches for Visual Object Recognition and Tracking: Applications to Unmanned Aircraft Systems*
Room 466	Half-Day 9:00-13:00	*Current and Future Surveillance Technologies for Airspace Integration of UAS in Controlled and Uncontrolled Airspace*

ICUAS'23 Plenary Lectures

ICUAS'23 includes three Keynote Lectures given by leading authorities in their fields. We are proud to include them in the Technical Program. Plenary Lectures will be in Aula 58. The schedule for the lectures is shown next.

KEYNOTE / PLENARY TALKS		
Day	**Time**	**Aula 58**
Wednesday June 7	09:30 – 10:30	**Increasingly Autonomous Perception and Decision Systems for Advanced Air Mobility**, Prof. Ella Atkins, Virginia Tech, USA
	14:00 – 15:00	**Soft Aerial Robots**, Prof. Begoña Chiquinquira Arrue Ullés, University of Seville, Spain
Friday June 9	09:00 - 10:00	**From Competition to U-Space Certification and Implementation — a Story about "What If….?** Panel Korzec, Droneradar Sp. Z. O. O., Poland

UAV Competition

Results and details may be found at: https://github.com/larics/icuas23_competition/discussions/52. The finalist teams are from India, Korea, Hong Kong, Canada, and Spain, reflecting geographical diversity. The final competition is on Thursday, June 8, 4:00 – 7:00 PM.

ICUAS' 23 TECHNICAL PROGRAM AT A GLANCE

Tutorials / Workshops – Tuesday, June 6

TW1	TW2	TW3
09:00-18:00 TuATW1 **Room 464**	**09:00-13:00 TuATW2** **Room 465**	**09:00-13:00 TuATW3** **Room 466**
New Developments on Sense-And-Avoid (S&A), Distributed Fault Detection and Diagnosis (DFDD), Fault-Tolerant Control (FTC) and Fault-Tolerant Cooperative Control (FTCC) Techniques Unmanned Systems	*Review of State-Of-The-Art Deep Learning Approaches for Visual Object Recognition and Tracking: Applications to Unmanned Aircraft Systems*	*Current and Future Surveillance Technologies for Airspace Integration of UAS in Controlled and Uncontrolled Airspace*

Technical Program – Wednesday, June 7

Track 1	Track 2	Track 3	Track 4	Track 5
09:00-09:30 WeOO **Room 58** **ICUAS 2023 Opening**				
09:30-10:30 WePL1 **Room 58** **Increasingly Autonomous Perception and Decision Systems for Advanced Air Mobility** ***(Prof. Ella Atkins, Virginia Tech, USA)***				
11:00-12:40 WeA1 **Room 118** Fail-Safe Systems	**11:00-12:40 WeA2** **Room 130** Manned/Unmanned Aviation I	**11:00-12:40 WeA3** **Room 464** Path Planning I	**11:00-12:40 WeA4** **Room 465** Simulation I	**11:00-12:40 WeA5** **Room 466** UAS Applications I
14:00-15:00 WePL2 **Room 58** **Soft Aerial Robots** ***(Prof. Begoña Chiquinquira Arrue Ullés, University of Seville, SPAIN)***				
16:00-17:20 WeB1 **Room 118** Risk Analysis	**16:00-17:20 WeB2** **Room 130** Manned/Unmanned Aviation II	**16:00-17:20 WeB3** **Room 464** Path Planning II	**16:00-17:20 WeB4** **Room 465** Simulation II	**16:00-17:20 WeB5** **Room 466** UAS Applications II
17:30-19:00 WeC1 **Foyer Area** **Poster Paper Session**				

Technical Program – Thursday, June 8

Track 1	Track 2	Track 3	Track 4	Track 5
09:00-10:40 ThA1 **Room 118** Sensor Fusion	**09:00-10:40 ThA2** **Room 130** UAS Testbeds	**09:00-10:40 ThA3** **Room 464** Path Planning III	**09:00-10:40 ThA4** **Room 465** Swarms	**09:00-10:40 ThA5** **Room 466** UAS Applications III
11:00-12:40 ThB1 **Room 118** Current Advances in UAS – Best Paper Finalists	**11:00-12:40 ThB2** **Room 130** Energy Efficient UAS	**11:00-12:40 ThB3** **Room 464** Path Planning IV	**11:00-12:40 ThB4** **Room 465** Networked Swarms	**11:00-12:40 ThB5** **Room 466** UAS Applications IV
14:00-15:20 ThC1 **Room 118** Security	**14:00-15:20 ThC2** **Room 130** Micro and Mini UAS	**14:00-15:20 ThC3** **Room 464** Air Vehicle Operations	**14:00-15:20 ThC4** **Room 465** Regulations	**14:00-15:20 ThC5** **Room 466** UAS Applications V
16:00-19:00 ThD1 **UAV Competition**				

Technical Program – Friday, June 9

Track 1	Track 2	Track 3	Track 4	Track 5
09:00-10:00 FrPL1 **Room 58** **From Competition to U-Space Certification and Implementation — a Story about "What If….?** **(*Panel Korzec, Droneradar Sp. Z. O. O., POLAND*)**				
10:30-12:30 FrA1 **Room 118** Aerial Robotic Manipulation	**10:30-12:30 FrA2** **Room 130** Reliability of UAS	**10:30-12:30 FrA3** **Room 464** Autonomy	**10:30-12:30 FrA4** **Room 465** Control Architectures I	**10:30-12:30 FrA5** **Room 466** Multirotor Design and Control I
14:00-16:00 FrB1 **Room 118** Aerial Manipulation: Design, Control and Applications	**14:00-16:00 FrB2** **Room 130** Perception and Cognition	**14:00-16:00 FrB3** **Room 464** Navigation	**14:00-16:00 FrB4** **Room 465** Control Architectures II	**14:00-16:00 FrB5** **Room 466** Multirotor Design and Control II

ICUAS ’23 Technical Sessions and Content List

Wednesday June 7, 2023

Enhancing Situation Awareness in Beyond Visual Range Air Combat with Reinforcement Learning-Based Decision Support, pp. 56-62.

Scukins, Edvards	SAAB Aeronautics
Klein, Markus	SAAB Aeronautics
Ögren, Petter	KTH Royal Institute of Technology

12:00-12:20 WeA2.4

Pilots in the Evolving Urban Air Mobility: From Manned to Unmanned Aviation, pp. 63-70.

Shi, Yuran	Leiden University

12:20-12:40 WeA2.5

A Framework for Operational Volume Generation for Urban Air Mobility Strategic Deconfliction, pp. 71-78.

Thompson, Ellis Lee	George Washington University
Wei, Peng	George Washington University
Xu, Yan	Cranfield University

WeA3 Room 464

Path Planning I (Regular Session)

Chair: Dharmadhikari, Mihir Rahul	Norwegian University of Science and Technology
Co-Chair: Zhang, Xinyu	Tsinghua University

11:00-11:20 WeA3.1

An Integrated Real-Time UAV Trajectory Optimization and Potential Field Approach for Dynamic Collision Avoidance, pp. 79-86.

Dasari, Mohan	University of Luxembourg
Habibi, Hamed	University of Luxembourg
Sanchez-Lopez, Jose-Luis	University of Luxembourg
Voos, Holger	University of Luxembourg

11:20-11:40 WeA3.2

Path Planning for Air-Ground Amphibious Robot Considering Modal Switching Point Optimization, pp. 87-94.

Wang, Xiaoyu	Tsinghua University
Huang, Kangyao	Tsinghua University
Zhang, Xinyu	Tsinghua University
Sun, Honglin	Tsinghua University
Liu, Wenzhuo	Tsinghua University
Liu, Huaping	Tsinghua University
Li, Jun	Tsinghua University
Lu, Pingping	University of Michigan

11:40-12:00 WeA3.3

Solving Vehicle Routing Problem for Unmanned Heterogeneous Vehicle Systems Using Asynchronous Multi-Agent Architecture (A-Teams), pp. 95-102.

Ramasamy, Subramanian	University of Illinois at Chicago
Bhounsule, Pranav	University of Illinois at Chicago
Mondal, Mohammad Safwan	University of Illinois at Chicago
Humann, James D.	DEVCOM Army Research Laboratory
Reddinger, Jean-Paul	DEVCOM Army Research Laboratory
Dotterweich, James	DEVCOM Army Research Laboratory
Childers, Marshal	DEVCOM Army Research Laboratory

12:00-12:20 WeA3.4

Manhole Detection and Traversal for Exploration of Ballast Water Tanks Using Micro Aerial Vehicles, pp. 103-109.

Dharmadhikari, Mihir Rahul	Norwegian University of Science and Technology
De Petris, Paolo	Norwegian University of Science and Technology
Nguyen, Huan	Norwegian University of Science and Technology
Kulkarni, Mihir Vinay	Norwegian University of Science and Technology
Khedekar, Nikhil Vijay	Norwegian University of Science and Technology
Alexis, Kostas	Norwegian University of Science and Technology

12:20-12:40 WeA3.5

Overview of UAV Trajectory Planning for High-Speed Flight, pp. 110-117.

Rocha, Lidia	Federal University of Sao Carlos
Saska, Martin	Czech Technical University in Prague
Teixeira Vivaldini, Kelen Cristiane	Czech Technical University in Prague

WeA4	Room 465
Simulation I (Regular Session)	
Chair: De la Rosa Rosero, Fernando	Universidad De Los Andes
Co-Chair: Obidowski, Damian	Lodz University of Technology
11:00-11:20	WeA4.1
Variable Pitch Propeller - Blade Pitch Moment Computational Analysis, pp. 118-122.	
Podsedkowski, Maciej	Lodz University of Technology
Lipian, Michal	Lodz University of Technology
Obidowski, Damian	Lodz University of Technology
11:20-11:40	WeA4.2
Preliminary Aerodynamic Simulation of a Flying Car Concept, pp. 123-128.	
Zhang, TingRui	Huazhong University of Science and Technology
Liu, Ying	Huazhong University of Science and Technology
Wu, Zhuoran	Huazhong University of Science and Technology
Li, Zidong	Huazhong University of Science and Technology
Ran, Shuo	Huazhong University of Science and Technology
Tian, Fengnian	Huazhong University of Science and Technology
11:40-12:00	WeA4.3
Analysis of Aircraft Simulation Validity in Different Flight Conditions, pp. 129-136.	
Benyamen, Hady	University of Kansas
Mays, Benjamin	University of Kansas
Chowdhury, Mozammal	University of Kansas
Keshmiri, Shawn	University of Kansas
Ewing, Mark	University of Kansas
12:00-12:20	WeA4.4
Indoor Vehicle-In-The-Loop Simulation of Unmanned Micro Aerial Vehicle with Artificial Companion, pp. 137-143.	
Hiba, Antal	SZTAKI Institute for Computer Science and Control
Körtvélyesi, Viktor	SZTAKI Institute for Computer Science and Control
Kiskaroly, Albert	SZTAKI Institute for Computer Science and Control
Bhoite, Omkar	SZTAKI Institute for Computer Science and Control
Dávid, Patrik	SZTAKI Institute for Computer Science and Control
Majdik, András L.	SZTAKI Institute for Computer Science and Control
12:20-12:40	WeA4.5
Virtual Reality and Human-Drone Interaction Applied to the Construction and Execution of Flight Paths, pp. 144-151.	
Sanchez Otalora, Nelson Andres	Universidad De Los Andes
Munera Davila, Santiago Felipe	Universidad De Los Andes
De la Rosa Rosero, Fernando	Universidad De Los Andes

WeA5	Room 466
UAS Applications I (Regular Session)	
Chair: O'Brien, Richard	United States Naval Academy
Co-Chair: Dhami, Harnaik	University of Maryland
11:00-11:20	WeA5.1
Dynamic Graph Propagation for Performance-Based Tactical Conflict Resolution in Urban Air Mobility, pp. 152-158.	
Huang, Cheng	Cranfield University
Petrunin, Ivan	Cranfield University
Tsourdos, Antonios	Cranfield University
11:20-11:40	WeA5.2
Unmanned Aerial Vehicles and Livestock Management: An Application in Western Crete, pp. 159-166.	
Sarantinoudis, Nikolaos	Technical University of Crete
Arampatzis, George	Technical University of Crete
Valavanis, Kimon P.	University of Denver
Tsourveloudis, Nikos	Technical University of Crete
11:40-12:00	WeA5.3
How High Can You Detect? Improved Accuracy and Efficiency at Varying Altitudes for Aerial Vehicle Detection, pp. 167-174.	
Makrigiorgis, Rafael	University of Cyprus

Kyrkou, Christos	University of Cyprus
Kolios, Panayiotis	University of Cyprus

12:00-12:20	WeA5.4

Proportional Navigation-Based Guidance for an Autonomous Interdiction Mission against a Stationary Target, pp. 175-182.

Choudhary, Aman	Indian Institute of Technology Madras
A, Vivek	Indian Institute of Technology Madras
Ghosh, Satadal	Indian Institute of Technology Madras

12:20-12:40	WeA5.5

State-Aware Path-Following with Humans through Force-Based Communication Via Tethered Physical Aerial Human-Robot Interaction, pp. 183-190.

Hallworth, Ben W.	ETH Zürich
Allenspach, Mike	ETH Zürich
Siegwart, Roland Y.	ETH Zürich
Tognon, Marco	Inria

WeB1 Room 118

Risk Analysis (Regular Session)

Chair: Bertrand, Sylvain	ONERA
Co-Chair: Dasari, Mohan	University of Luxembourg

16:00-16:20	WeB1.1

Handling Uncertainties in Ground Risk Buffer Computation for Risk Assessment and Preparation of UAV Operations, pp. 191-198.

Bertrand, Sylvain	ONERA
Lala, Stephanie	ONERA
Raballand, Nicolas	ONERA

16:20-16:40	WeB1.2

Acquisition and Formalization of Knowledge to Ensure Safe Behavior of Heterogenous Unmanned Autonomous Systems - an Interdisciplinary Approach, pp. 199-206.

Sieber, Christoph	Helmut Schmidt University Hamburg
Worpenberg, Christian	Helmut Schmidt University Hamburg
Vieira da Silva, Luis Miguel	Helmut Schmidt University Hamburg
Schuler-Harms, Margarete	Helmut Schmidt University Hamburg
Fay, Alexander	Helmut Schmidt University Hamburg

16:40-17:00	WeB1.3

Towards Requirements for Third-Party Assessments in the Specific Operations Risk Assessment Process, pp. 207-212.

Heikkilä, Eetu	VTT Technical Research Centre of Finland Ltd
Tiusanen, Risto	VTT Technical Research Centre of Finland Ltd
Öz, Emrehan	VTT Technical Research Centre of Finland Ltd

17:00-17:20	WeB1.4

On SORA for High-Risk UAV Operations under New EU Regulations: Perspectives for Automated Approach, pp. 213-220.

Habibi, Hamed	University of Luxembourg
Dasari, Mohan	University of Luxembourg
Sanchez-Lopez, Jose-Luis	University of Luxembourg
Voos, Holger	University of Luxembourg

WeB2 Room 130

Manned/Unmanned Aviation II (Regular Session)

Chair: Inoue, Roberto Santos	Universidade Federal De São Carlos
Co-Chair: Valavanis, Kimon P.	University of Denver

16:00-16:20	WeB2.1

Technological Certainties and Regulatory Doubts: An Overlook at Unmanned Aviation and Urban Air Mobility in Europe, pp. 221-228.

Trimarchi, Andrea	Università Di Verona

16:20-16:40	WeB2.2

Enhanced Nonlinear Adaptive Control of a Novel Over-Actuated Reconfigurable Quadcopter, pp. 229-234.

Derrouaoui, Saddam Hocine	Ecole Supérieure Ali Chabati
Bouzid, Yasser	Ecole Militaire Polytechnique

Belmouhoub, Amina	University Mohamed El Bachir El Ibrahimi
Guiatni, Mohamed	Ecole Militaire Polytechnique
16:40-17:00	WeB2.3

Preliminary Design and Prototype Development of an Air-Ground Carrier Platform, pp. 235-240.

Chen, Tianlang	Huazhong University of Science and Technology
Han, Jiaxue	Huazhong University of Science and Technology
Wang, Jinglan	Huazhong University of Science and Technology
Yan, Sitan	Huazhong University of Science and Technology
Wan, Chieh	Huazhong University of Science and Technology
Tian, Fengnian	Huazhong University of Science and Technology
17:00-17:20	WeB2.4

Incremental Nonlinear Dynamic Inversion Controller for a Variable Skew Quad Plane, pp. 241-248.

De Ponti, Tomaso Maria Luigi	Delft University of Technology
Smeur, Ewoud	Delft University of Technology
Remes, Bart	Delft University of Technology

WeB3 Room 464

Path Planning II (Regular Session)

Chair: Kim, Youngjoo	Nearthlab Inc
Co-Chair: Zhang, Youmin	Concordia University
16:00-16:20	WeB3.1

Wind-Aware Path Optimization for an Aerobot in the Atmosphere of Venus Using Genetic Algorithms, pp. 249-256.

Puigvert I Juan, Anna	West Virginia University
Martinez Rocamora Junior, Bernardo	West Virginia University
Pereira, Guilherme	West Virginia University
16:20-16:40	WeB3.2

A Multi-Objective Approach for Unmanned Aerial Vehicle Mapping, pp. 257-264.

Moltajaei Farid, Ali	University of Regina
Mouhoub, Malek	University of Regina
16:40-17:00	WeB3.3

Coordinated Multi-Robot Exploration Using Reinforcement Learning, pp. 265-272.

Mete, Atharva	University of Regina
Mouhoub, Malek	University of Regina
Moltajaei Farid, Ali	University of Regina
17:00-17:20	WeB3.4

Urban Air Mobility Trajectory Planning, pp. 273-280.

Exadaktylos, Stylianos	University of Cyprus
Vitale, Christian	University of Cyprus
Kolios, Panayiotis	University of Cyprus
Ellinas, Georgios	University of Cyprus

WeB4 Room 465

Simulation II (Regular Session)

Chair: Rafee Nekoo, Saeed	Universidad De Sevilla
Co-Chair: Manoharan, Amith	University of Tartu
16:00-16:20	WeB4.1

Constrained Design Optimization of a Long-Reach Dual-Arm Aerial Manipulator for Maintenance Tasks, pp. 281-288.

Rafee Nekoo, Saeed	Universidad De Sevilla
Suarez, Alejandro	Universidad De Sevilla
Acosta, Jose Angel	Universidad De Sevilla
Heredia, Guillermo	Universidad De Sevilla
Ollero, Anibal	Universidad De Sevilla
16:20-16:40	WeB4.2

Improved Path Planning Algorithm of an Informed RRT Algorithm in 3D Space, pp. 289-296.

Tian, Haowen	National University of Singapore
Huang, Sunan	National Universtiy of Singapore
Wang, Pengfei	National University of Singapore

Xiang, Cheng	National University of Singapore
Cao, Jiawei	National University of Singapore
Teo, Rodney	National University of Singapore
16:40-17:00	WeB4.3

Multi-Agent Target Defense Game with Learned Defender to Attacker Assignment, pp. 297-304.

Manoharan, Amith	University of Tartu
Thakur, Prajwal	University of Tartu
Singh, Arun	University of Tartu
17:00-17:20	WeB4.4

Path Gain and Channel Capacity for HAP-To-HAP Communications, pp. 305-312.

Yılmaz, Atakan	Hacettepe University
Yılmaz, Nihan	Hacettepe University
Kalem, Gokhan	Turkcell Technology
Durmaz, Mehmet Akif	Turkcell Technology

WeB5	Room 466
UAS Applications II (Regular Session)	
Chair: Gonzalez, Luis Felipe	Queensland University of Technology
Co-Chair: Kandath, Harikumar	International Institute of Information Technology Hyderabad
16:00-16:20	WeB5.1

Efficient UAS Sensor Mounting Using Contact Force Feedback, pp. 313-319.

Kalaitzakis, Michail	University of South Carolina
Kosaraju, Bhanuprakash	University of South Carolina
Vitzilaios, Nikolaos	University of South Carolina
16:20-16:40	WeB5.2

Drones Practicing Mechanics, pp. 320-327.

Uppaluru, Harshvardhan	University of Arizona
Rastgoftar, Hossein	University of Arizona
El Asslouj, Aymane	University of Arizona
Ghufran, Mohammad	University of Arizona
16:40-17:00	WeB5.3

A Signal Temporal Logic Planner for Ergonomic Human–Robot Collaboration, pp. 328-335.

Silano, Giuseppe	Czech Technical University in Prague
Afifi, Amr	University of Twente
Saska, Martin	Czech Technical University in Prague
Franchi, Antonio	University of Twente
17:00-17:20	WeB5.4

Towards Safe Operations in Urban Environments with UAVs, pp. 336-342.

Caballero González, Rafael	Center for Advanced Aerospace Technologies
Jiménez Cámara, Pablo	Center for Advanced Aerospace Technologies
Perez-Grau, Francisco Javier	Center for Advanced Aerospace Technologies
Viguria, Antidio	Center for Advanced Aerospace Technologies
Ollero, Anibal	Universidad De Sevilla

WeC1	Foyer Area
Poster Paper Session (Poster Session)	
Chair: Nascimento, Tiago	Czech Technical University in Prague
Co-Chair: Teixeira Vivaldini, Kelen Cristiane	Czech Technical University in Prague
17:30-19:00	WeC1.1

Assessing the Impact of Soil Contamination on Maize Plant Development Using UAV-Based Multispectral Indices, pp. 343-348.

Gargiulo, Massimiliano	Italian Aerospace Research Centre
Savarese, Claudia	Italian Aerospace Research Centre
Tufano, Francesco	Italian Aerospace Research Centre
Parrilli, Sara	Italian Aerospace Research Center
Verrillo, Mariavittoria	Università Di Napoli Federico II
Cozzolino, Vincenza	Università Di Napoli Federico II
Piccolo, Alessandro	Università Di Napoli Federico II

De Mizio, Marco	Italian Aerospace Research Centre

17:30-19:00	WeC1.2

Autonomous Control of UAV for Proximity Tracking of Ground Vehicles with AprilTag and Feedforward Control, pp. 349-353.

Yi, JunHak	Chung-Ang University
Lee, Donghee	Chung-Ang University
Park, Wooryong	Chung-Ang University
Byun, Woohyun	Chung-Ang University
Huh, Soobin	Chung-Ang University
Nam, Woochul	Chung-Ang University

17:30-19:00	WeC1.3

Autonomous Soaring Simulation and Glider System Development, pp. 354-359.

Jacobs, Stephen	West Virginia University
Gu, Yu	West Virginia University

17:30-19:00	WeC1.4

Bandwidth-Aware Coverage Path Planning for Swarm of UAVs with Aerial Base Station, pp. 360-365.

Choi, Uihwan	Electronics and Telecommunications Research Institute
Lee, Soojeon	Electronics and Telecommunications Research Institute

17:30-19:00	WeC1.5

Communications-Aware Robotics: Challenges and Opportunities, pp. 366-371.

Bonilla Licea, Daniel	Czech Technical University in Prague
Silano, Giuseppe	Czech Technical University in Prague
Ghogho, Mounir	Czech Technical University in Prague
Saska, Martin	Czech Technical University in Prague

17:30-19:00	WeC1.6

Comparing DNN Performance to Justify Using Transference of Training for the Autonomous Aerial Refueling Task, pp. 372-376.

Miller, Dillon	United States Naval Academy
Mwaffo, Violet	United States Naval Academy
Costello, Donald	United States Naval Academy

17:30-19:00	WeC1.7

Development of a Control Framework to Autonomously Install Clip Bird Diverters on High-Voltage Lines, pp. 377-382.

D'Angelo, Simone	Università Di Napoli Federico II
Pagano, Francesca	Università Di Napoli Federico II
Ruggiero, Fabio	Università Di Napoli Federico II
Lippiello, Vincenzo	Università Di Napoli Federico II

17:30-19:00	WeC1.8

Ensuring Accuracy in Auto-Bounding Box Generation for the Autonomous Aerial Refueling Mission, pp. 383-388.

Doherty, Charles	United States Naval Academy
Costello, Donald	United States Naval Academy
Kutzer, Michael	United States Naval Academy

17:30-19:00	WeC1.9

Heterogeneous Multi-Robot Systems Approach for Warehouse Inventory Management, pp. 389-394.

Sales, Augusto Vinicius	Universidade Federal Da Paraíba
Mira, Pedro	Universidade Federal Da Paraíba
Nascimento, Ana Maria P.S.	Universidade Federal Da Paraíba
Brandao, Alexandre Santos	Universidade Federal De Viçosa
Saska, Martin	Czech Technical University in Prague
Nascimento, Tiago	Czech Technical University in Prague

17:30-19:00	WeC1.10

Mixed Reality Human-Robot Interface to Generate and Visualize 6DoF Trajectories: Application to Omnidirectional Aerial Vehicles, pp. 395-400.

Allenspach, Mike	ETH Zürich
Laasch, Severin	ETH Zürich
Lawrance, Nicholas	ETH Zürich
Tognon, Marco	ETH Zürich
Siegwart, Roland Y.	ETH Zürich

17:30-19:00	WeC1.11

Multirotor Motion Enhancement Using Propeller Speed Measurements, pp. 401-406.

Awad, Heba Abdelnasser	Imperial College London
Heggo, Mohammad	Imperial College London
Pang, Oscar	Imperial College London
Kovac, Mirko	Imperial College London
McCann, Julie	Imperial College London

17:30-19:00	WeC1.12

Quadcopter Capable of Autonomously Chasing Micro-Aircraft with Real-Time Visual Tracker, pp. 407-412.

Lee, Donghee	Chung-Ang University
Park, Wooryong	Chung-Ang University
Yi, JunHak	Chung-Ang University
Byun, Woohyun	Chung-Ang University
Huh, Soobin	Chung-Ang University
Nam, Woochul	Chung-Ang University

17:30-19:00	WeC1.13

Spatial Mapping of Light Aircraft with Stereo Vision Camera for Use on Unmanned Aircraft System for Defect Localisation, pp. 413-418.

Connolly, Luke	South East Technological University
O'Gorman, Diarmuid	South East Technological University
Garland, James	South East Technological University
Tobin, Edmond	South East Technological University

17:30-19:00	WeC1.14

The Gannet Solar-VTOL: An Amphibious Migratory UAV for Long-Term Autonomous Missions, pp. 419-424.

Carlson, Stephen	University of Nevada – Reno
Moore, Brandon	University of Nevada – Reno
Karakurt, Tolga	University of Nevada – Reno
Arora, Prateek	University of Nevada – Reno
Cooper, Tyler	University of Nevada – Reno
Papachristos, Christos	University of Nevada – Reno

Thursday, June 8, 2023

ThA1	Room 118
Sensor Fusion (Regular Session)	
Chair: Inoue, Roberto Santos	Universidade Federal De São Carlos
Co-Chair: Hamanaka, Masatoshi	RIKEN Center for Advanced Intelligence Project

09:00-09:20	ThA1.1

Systolic Array for Parallel Solution of the Robust Kalman Filter Used for Attitude and Position Estimations in UAVs, pp. 425-432.

Campos, Leandro José Evilásio	Universidade Federal De São Carlos
Terra, Marco Henrique	Universidade Federal De São Carlos
Menotti, Ricardo	Universidade Federal De São Carlos
Inoue, Roberto Santos	Universidade Federal De São Carlos

09:20-09:40	ThA1.2

Improving Resolution in Deep Learning-Based Estimation of Drone Position and Direction Using 3D Maps, pp. 433-440.

Hamanaka, Masatoshi	RIKEN Center for Advanced Intelligence Project

09:40-10:00	ThA1.3

A Robust and Adaptive Sensor Fusion Approach for Indoor UAV Localization, pp. 441-447.

Sajjadi, Sina	Toronto Metropolitan University
Bittick, Jeremy	Toronto Metropolitan University
Janabi Sharifi, Farrokh	Toronto Metropolitan University
Mantegh, Iraj	National Research Council Canada

10:00-10:20	ThA1.4

Time-Varying Formation Tracking with Distributed Multi-Sensor Multi-Target Filtering, pp. 448-454.

Qi, Jialin	Beihang University
Zhang, Zheng	Beihang University

Dong, Xiwang	Beihang University
Yu, Jianglong	Beihang University
Li, Qingdong	Beihang University
Jiang, Hong	Beihang University
Ren, Zhang	Beihang University

10:20-10:40 ThA1.5

Experimental Analysis of Radar/Optical Track-To-Track Fusion for Non-Cooperative Sense and Avoid, pp. 455-462.

Vitiello, Federica	Università Di Napoli Federico II
Causa, Flavia	Università Di Napoli Federico II
Opromolla, Roberto	Università Di Napoli Federico II
Fasano, Giancarmine	Università Di Napoli Federico II

ThA2 Room 130

UAS Testbeds (Regular Session)

Chair: Valavanis, Kimon P.	University of Denver
Co-Chair: Koschlik, Ann-Kathrin	German Aerospace Center

09:00-09:20 ThA2.1

Towards an Integrated Vehicle Health Management for Maintenance of Unmanned Air Systems, pp. 463-470.

Koschlik, Ann-Kathrin	German Aerospace Center
Meyer, Hendrik	German Aerospace Center
Arts, Emy	German Aerospace Center
Conen, Philipp	German Aerospace Center
Jacob, Geo	German Aerospace Center
Soria Gomez, Maria	German Aerospace Center
Kamtsiuris, Alexander Athanasios	German Aerospace Center
Jilke, Lukas	German Aerospace Center
Aigner, Johanna	German Aerospace Center
Raddatz, Florian	German Aerospace Center
Wende, Gerko	German Aerospace Center

09:20-09:40 ThA2.2

A Benchmark Framework for Testing, Evaluation, and Comparison of Quadrotor Linear and Nonlinear Controllers, pp. 471-478.

Martini, Simone	University of Denver
Stefanovic, Margareta	University of Denver
Rizzo, Alessandro	Politecnico Di Torino
Rutherford, Matthew	University of Denver
Livreri, Patrizia	Università Di Palermo
Valavanis, Kimon P.	University of Denver

09:40-10:00 ThA2.3

UAV-Based Networked Airborne Computing Simulator and Testbed Design and Implementation, pp. 479-486.

Wang, Baoqian	San Diego State University
Xie, Junfei	San Diego State University
Ma, Ke	San Diego State University
Wan, Yan	University of Texas at Arlington

10:00-10:20 ThA2.4

Lowering the Entry Barrier to Aerial Robotics Competitions, pp. 487-492.

Perez-Grau, Francisco Javier	Center for Advanced Aerospace Technologies
Leon Barriga, Pablo	Center for Advanced Aerospace Technologies
Viguria, Antidio	Center for Advanced Aerospace Technologies

10:20-10:40 ThA2.5

Software Architecture for Controlling in Real Time Aerial Prototypes, pp. 493-498.

Offermann, Alexis	Université Grenoble Alpes
De Miras, Jérôme	Université De Technologie De Compiègne
Castillo, Pedro	Unviersité De Technologie De Compiègne

ThA3 Room 464

Path Planning III (Regular Session)

Chair: Chen, YangQuan	University of California - Merced

Co-Chair: Zhang, Youmin	Concordia University
09:00-09:20	ThA3.1

A Modified Artificial Potential Field for UAV Collision Avoidance, pp. 499-506.

Srivastava, Astik	Delhi Technological University
Vasudevan, V.R.	Delhi Technological University
Dalal, Harikesh	Delhi Technological University
Nallanthiga, Raghava	Delhi Technological University
Baliyarasimhuni, Sujit, P.	IISER Bhopal
09:20-09:40	ThA3.2

UAV Path Planning Employing MPC-Reinforcement Learning Method Considering Collision Avoidance, pp. 507-514.

Ramezani, Mahya	University of Luxembourg
Habibi, Hamed	University of Luxembourg
Sanchez-Lopez, Jose-Luis	University of Luxembourg
Voos, Holger	University of Luxembourg
09:40-10:00	ThA3.3

Nonlinear Model Predictive Control for Repetitive Area Reconnaissance with a Multirotor Drone, pp. 515-522.

Marcellini, Salvatore	Università Di Napoli Federico II
Ruggiero, Fabio	Università Di Napoli Federico II
Lippiello, Vincenzo	Università Di Napoli Federico II
10:00-10:20	ThA3.4

Battery-Health-Aware UAV Mission Planning Using a Cognitive Battery Management System, pp. 523-528.

An, Di	University of California - Merced
Krzysiak, Rafal	University of California - Merced
Hollenbeck, Derek	University of California - Merced
Chen, YangQuan	University of California - Merced
10:20-10:40	ThA3.5

Spatiotemporal VRP for Collision-Free Multi-UAV Inspection Planning, pp. 529-536.

Im, Jaehan	Nearthlab Inc
Kim, Youngjoo	Nearthlab Inc

ThA4	Room 465
Swarms (Regular Session)	
Chair: Zhang, Youmin	Concordia University
Co-Chair: Duan, Haibin	Beihang University
09:00-09:20	ThA4.1

Unmanned Aerial Vehicle Cargo Delivery Assignment Via Time-Varying Constriction Pigeon-Inspired Optimization with Memory Retrospection, pp. 537-542.

Liu, Xinghan	Beihang University
Zhang, Yan	Beihang University
Duan, Haibin	Beihang University
09:20-09:40	ThA4.2

Multi-UAV Cooperative Search Planning Algorithm Based on Dynamic Target Probability Model, pp. 543-548.

Ao, Zihang	China Satellite Maritime Measurement and Control Department
Zhang, Yulong	Xi'an University of Technology
Huang, Jing	Xi'an University of Technology
Lin, YiCheng	China Satellite Maritime Measurement and Control Department
Zhou, Xiaodeng	China Satellite Maritime Measurement and Control Department
Zhang, Youmin	Concordia University
09:40-10:00	ThA4.3

A General Framework for Multi-UAV Communication Connectivity Maintenance through Scalable Task Allocation, pp. 549-556.

Cao, Jiawei	National University of Singapore
Leong, Wai Lun	National University of Singapore
Teo, Rodney	National University of Singapore
Huang, Sunan	National Universtiy of Singapore
10:00-10:20	ThA4.4

SwarmGear: Heterogeneous Swarm of Drones with Morphogenetic Leader Drone and Virtual Impedance Links for Multi-Agent Inspection, pp. 557-563.

Darush, Zhanibek	Skolkovo Institute of Science and Technology
Martynov, Mikhail	Skolkovo Institute of Science and Technology
Fedoseev, Aleksey	Skolkovo Institute of Science and Technology
Shcherbak, Aleksei	Skolkovo Institute of Science and Technology
Tsetserukou, Dzmitry	Skolkovo Institute of Science and Technology

ThA5 Room 466

UAS Applications III (Regular Session)

Chair: Salinas, Lucio Rafael	University of Bristol
Co-Chair: da Silva, Leandro Marcos	University of São Paulo

09:00-09:20 ThA5.1

3D Maps of Vegetation Indices Generated Onboard a Precision Agriculture UAV, pp. 564-571.

Ramírez, Germán	Centro De Investigaciones En Óptica
Montes de Oca Rebolledo, Andres	Centro De Investigaciones En Óptica
Flores, Gerardo	Centro De Investigaciones En Óptica

09:20-09:40 ThA5.2

Unmanned Aircraft Systems and Urban Air Mobility at the Service of Public Administration for an Acceleration of Essential Services in the Smart Cities of the Future, pp. 572-579.

Di Guardo, Giuseppina Agata	Italian Ministry of Labour and Social Policy
Gaspari, Francesco	Università Guglielmo Marconi

09:40-10:00 ThA5.3

UAV Embedded Real-Time Object Detection by a DCNN Model Trained on Synthetic Dataset, pp. 580-585.

Maroquio Bernardo, Ricardo	Instituto Federal De Educação, Ciên Cia E Tecnologia Do Espírit
Silva, Luis	Centro Federal De Educação Tecnológica Celso Suckow Da Fonseca
Ferreira Rosa, Paulo Fernando Ferreira Rosa	Instituto Militar De Engenharia

10:00-10:20 ThA5.4

Digital Twin Technology for Wildfire Monitoring Using UAV Swarms, pp. 586-593.

Salinas, Lucio Rafael	University of Bristol
Tzoumas, Georgios	University of Bristol
Pitonakova, Lenka	Qubiq Interactive
Hauert, Sabine	University of Bristol

10:20-10:40 ThA5.5

A LiDAR-Based Method to Identify Vegetation Encroachment in Power Networks with UAVs, pp. 594-601.

Savva, Antonis	University of Cyprus
Papageorgiou, Manos	University of Cyprus
Kyrkou, Christos	University of Cyprus
Kolios, Panayiotis	University of Cyprus
Theocharides, Theocharis	University of Cyprus
Panayiotou, Christos	University of Cyprus

ThB1 Room 118

Current Advances in UAS – Best Paper Finalists (Regular Session)

Chair: Valavanis, Kimon P.	University of Denver
Co-Chair: Monteriù, Andrea	Università Politecnica Delle Marche

11:00-11:20 ThB1.1

Model-Free Control for Quadrotor Attitude Via Tent Map-Based Pigeon-Inspired Optimization, pp. 602-607.

Yuan, Yang	Beihang University
Duan, Haibin	Beihang University
Wei, Chen	Beihang University

11:20-11:40 ThB1.2

Design of PrisMAV: An Omnidirectional Aerial Manipulator Based on a 3-PUU Parallel Mechanism, pp. 608-615.

Rubio, Matthias	ETH Zürich
Naef, Joshua	ETH Zürich
Buehlmann, Franz	ETH Zürich
Brigger, Philippe	ETH Zürich
Huesser, Moritz	ETH Zürich
Inauen, Martin	ETH Zürich

Ospelt, Nicole	ETH Zürich
Gisler, Daniel	ETH Zürich
Tognon, Marco	Inria
Siegwart, Roland Y.	ETH Zürich

11:40-12:00 ThB1.3

Investigating the Applicability of LTE-M for Network Identification of Unmanned Aerial Systems in U-Space, pp. 616-625.

Jepsen, Jes Hundevadt	University of Southern Denmark
Mader, August Ravn	University of Southern Denmark
Andreasen, Troels Dupont	University of Southern Denmark
Singh, Radheshyam	Technical University of Denmark
Jensen, Kjeld	University of Southern Denmark

12:00-12:20 ThB1.4

Deep Learning-Based Reassembling of an Aerial & Legged Marsupial Robotic System-Of-Systems, pp. 626-633.

Arora, Prateek	University of Nevada - Reno
Karakurt, Tolga	University of Nevada - Reno
Avloniti, Eleni Spyridoula	University of Thessaly
Carlson, Stephen	University of Nevada - Reno
Moore, Brandon	University of Nevada - Reno
Feil-Seifer, David	University of Nevada - Reno
Papachristos, Christos	University of Nevada - Reno

12:20-12:40 ThB1.5

Real-Time Applicable Cooperative Aerial Manipulation: A Survey, pp. 634-643.

Barakou, Stamatina	National Technical University of Athens
Tzafestas, Costas	National Technical University of Athens
Valavanis, Kimon P.	University of Denver

ThB2 Room 130

Energy Efficient UAS (Regular Session)

Chair: Theilliol, Didier	Université De Lorraine
Co-Chair: Salinas, Lucio Rafael	University of Bristol

11:00-11:20 ThB2.1

Design and Management of a Hydrogen Fuel Cell Powered Quadrotor, pp. 644-651.

Zeng, Dan	Beihang University
Guo, Xiaoyu	The University of Manchester
Guo, Kexin	Beihang University
Dong, Zhen	University of Warwick
Yu, Xiang	Beihang University

11:20-11:40 ThB2.2

Design and Validation of a Wireless Drone Docking Station, pp. 652-657.

Stuhne, Dario	University of Zagreb
Vasiljevic, Goran	University of Zagreb
Bogdan, Stjepan	University of Zagreb
Kovacic, Zdenko	University of Zagreb

11:40-12:00 ThB2.3

Unmanned Aerial Vehicles Experimental Characterization in Controlled Extreme Environmental Conditions, pp. 658-662.

Parin, Riccardo	Eurac Research
Bojeri, Alex	MAVTech Srl
Benedetto, Fabio	MAVTech Srl
Ristorto, Gianluca	MAVTech Srl
Guglieri, Giorgio	Politecnico Di Torino

12:00-12:20 ThB2.4

Battery Health Based Remaining Mission Time Prediction of UAV in Closed Loop, pp. 663-670.

Kanso, Soha	Université De Lorraine
Jha, Mayank Shekhar	Université De Lorraine
Valavanis, Kimon P.	University of Denver
Ponsart, Jean-Christophe	Université De Lorraine

Theilliol, Didier — Université De Lorraine

12:20-12:40 — ThB2.5

Quadrotors with Slung Payloads: Energy Analysis and Experimental Validation, pp. 671-678.

Alkomy, Hassan — York University
Shan, Jinjun — York University

ThB3 — Room 464
Path Planning IV (Regular Session)

Chair: Givigi, Sidney — Queen's University
Co-Chair: Koschlik, Ann-Kathrin — German Aerospace Center

11:00-11:20 — ThB3.1

Spiral Coverage Path Planning for Multi-UAV Photovoltaic Panel Inspection Applications, pp. 679-686.

Luna, Marco Andrés — Universidad Politécnica De Madrid
Ale Isaac, Mohammad Sadeq — Universidad Politécnica De Madrid
Fernandez-Cortizas, Miguel — Universidad Politécnica De Madrid
Carlos, Santos — Universidad De Alcalá
Ragab, Ahmed — October 6 University
Molina, Martin — Universidad Politécnica De Madrid
Campoy, Pascual — Universidad Politécnica De Madrid

11:20-11:40 — ThB3.2

UAV Path Planning for the Delivery of Emergency Medical Supplies, pp. 687-694.

Aldao Pensado, Enrique — University of Vigo
Fontenla Carrera, Gabriel — University of Vigo
Gonzalez de Santos, Luis Miguel — University of Vigo
Gonzalez Jorge, Higinio — University of Vigo

11:40-12:00 — ThB3.3

Hierarchical Cooperative Assignment Algorithm (CAA) for Mission and Path Planning of Multiple Fixed-Wing UAVs Based on Maximum Independent Sets, pp. 695-702.

Cabral, Kleber — Queen's University
Silveira, Jefferson — Queen's University
Rabbath, Camille Alain — Defence Research and Development Canada
Givigi, Sidney — Queen's University

12:00-12:20 — ThB3.4

Unscented Optimal Control for 3D Coverage Planning with an Autonomous UAV Agent, pp. 703-712.

Papaioannou, Savvas — University of Cyprus
Kolios, Panayiotis — University of Cyprus
Theocharides, Theocharis — University of Cyprus
Panayiotou, Christos — University of Cyprus
Polycarpou, Marios M. — University of Cyprus

12:20-12:40 — ThB3.5

Intelligent Method for UAV Navigation and De-Confliction --Powered by Multi-Agent Reinforcement Learning, pp. 713-722.

Xia, Bingze — Concordia University
Mantegh, Iraj — National Research Council Canada
Xie, Wenfang — Concordia University

ThB4 — Room 465
Networked Swarms (Regular Session)

Chair: Rastgoftar, Hossein — University of Arizona
Co-Chair: Javidi da Costa, João Paulo — Hamm-Lippstadt University of Applied Sciences

11:00-11:20 — ThB4.1

H∞ Optimal Distributed Tracking Control Algorithm for Network Distributed Systems with an Application to UAV, pp. 723-730.

Kucuksayacigil, Gulnihal — Uskudar University

11:20-11:40 — ThB4.2

Resilient Leader-Following Formation Control for a Fleet of Unmanned Aerial Vehicles under Cyber-Attacks, pp. 731-737.

Vazquez Trejo, Juan Antonio — Université De Lorraine

Guenard, Adrien	Université De Lorraine
Adam-Medina, Manuel	Tecnológico Nacional De México
Ciarletta, Laurent	Université De Lorraine
Ponsart, Jean-Christophe	Université De Lorraine
Theilliol, Didier	Université De Lorraine

11:40-12:00 ThB4.3

Cloud-Based Control of Drone Swarm with Localization Via Ultra-Wideband, pp. 738-744.

Sharma, Deeshant	Indian Institute of Technology Hyderabad
Sahu, Annu	Indian Institute of Technology Hyderabad
Babu Mannam, Naga Praveen	Indian Institute of Technology Hyderabad
P, Rajalakshmi	Indian Institute of Technology Hyderabad

12:00-12:20 ThB4.4

Can a Laplace PDE Define Air Corridors through Low-Altitude Airspace?, pp. 745-752.

El Asslouj, Aymane	University of Arizona
Atkins, Ella	University of Michigan
Rastgoftar, Hossein	University of Arizona

12:20-12:40 ThB4.5

Design and Deployment of an Efficient Communication Service for Multi-UAV Systems, pp. 753-760.

Morgan Pereira, Pedro Henrique	Federal University of Rio Grande Do Sul
Pasandideh, Faezeh	Federal University of Rio Grande Do Sul
Basso, Maik	Federal University of Rio Grande Do Sul
Javidi da Costa, João Paulo	Hamm-Lippstadt University of Applied Sciences
Pignaton de Freitas, Edison	Federal University of Rio Grande Do Sul

ThB5 Room 466

UAS Applications IV (Regular Session)

Chair: Sarcinelli-Filho, Mário	Federal University of Espirito Santo
Co-Chair: Kandath, Harikumar	International Institute of Information Technology Hyderabad

11:00-11:20 ThB5.1

EAMOS: Execution of Aerial Multidrone Mission Operations and Specifications Framework, pp. 761-768.

Gutmann, Markus	Alpen-Adria Universität Klagenfurt
Rinner, Bernhard	Alpen-Adria Universität Klagenfurt

11:20-11:40 ThB5.2

Sliding Mode Control of Tethered Drone: Take-Off and Landing under Turbulent Wind Conditions, pp. 769-774.

Azaki, Zakeye	GIPSA-Lab
Dumon, Jonathan	GIPSA-Lab
Meslem, Nacim	GIPSA-Lab
Hably, Ahmad	GIPSA-Lab

11:40-12:00 ThB5.3

Package Delivery Based on the Leader-Follower Control Paradigm for Multirobot Systems, pp. 775-781.

Santos Cardoso, Emanuele	Universidade Federal Do Espírito Santo
Bacheti, Vinícius Pacheco	Universidade Federal Do Espírito Santo
Sarcinelli-Filho, Mário	Universidade Federal Do Espírito Santo

12:00-12:20 ThB5.4

Vision-Based Cooperative Moving Path Following for Fixed-Wing UAVs, pp. 782-789.

Félix, Miguel	Academia Da Força Aérea Portuguesa
Oliveira, Tiago	Academia Da Força Aérea Portuguesa
Cruz, Gonçalo	Academia Da Força Aérea Portuguesa
Silva, Diogo	Academia Da Força Aérea Portuguesa
Alves, João Filipe Gomes Moreira	Academia Da Força Aérea Portuguesa
Santos, Luis	Academia Da Força Aérea Portuguesa

12:20-12:40 ThB5.5

Multi-Auctioneer Market-Based Task Scheduling for Persistent Drone Delivery, pp. 790-797.

Rinaldi, Marco	Politecnico Di Torino
Primatesta, Stefano	Politecnico Di Torino
Guglieri, Giorgio	Politecnico Di Torino
Rizzo, Alessandro	Politecnico Di Torino

ThC1	Room 118
Security (Regular Session)	
Chair: Branco, Kalinka Regina Lucas Jaquie Castelo	University of São Paulo
Co-Chair: Monteriù, Andrea	Università Politecnica Delle Marche
14:00-14:20	ThC1.1
Human Factors in the Age of Autonomous UAVs: Impact of Artificial Intelligence on Operator Performance and Safety, pp. 798-805.	
Alharasees, Omar	Budapest University of Technology and Economics
Adali, Osama H.	Technical University of Košice
Kale, Utku	Budapest University of Technology and Economics
14:20-14:40	ThC1.2
Design of Stealthy Sparse Attacks for Uncertain Cyber Physical Systems, pp. 806-811.	
Du, Xinyang	Beihang University
Xi, Zhiyu	Beihang University
14:40-15:00	ThC1.3
Anomaly-Based Intrusion Detection System for In-Flight and Network Security in UAV Swarm, pp. 812-819.	
da Silva, Leandro Marcos	University of São Paulo
Ferrão, Isadora	University of São Paulo
Dezan, Catherine	Université De Bretagne Occidentale
Espes, David	Université De Bretagne Occidentale
Branco, Kalinka Regina Lucas Jaquie Castelo	University of São Paulo
15:00-15:20	ThC1.4
Onboard Passive Radar System Implementation for Detection and Tracking of Rogue UAVs, pp. 820-826.	
Souli, Nicolas	University of Cyprus
Kardaras, Panayiotis	University of Cyprus
Kolios, Panayiotis	University of Cyprus
Ellinas, Georgios	University of Cyprus

ThC2	Room 130
Micro and Mini UAS (Regular Session)	
Chair: Hamanaka, Masatoshi	RIKEN Center for Advanced Intelligence Project
Co-Chair: Ma, Ziqing	Delft University of Technology
14:00-14:20	ThC2.1
Deep Learning Approach to Drogue Detection for Fixed-Wing UAV Autonomous Aerial Refueling with Visual Camera, pp. 827-834.	
Liu, Yunxiao	Fudan University
Li, Han	Fudan University
Wang, Liangxiu	Fudan University
Ai, Jianliang	Fudan University
14:20-14:40	ThC2.2
Development and Calibration of Autopilot Hardware for Small Fixed-Wing Air Vehicles with Flight Test Validation of Linear Output Feedback Controller, pp. 835-841.	
Kandath, Harikumar	International Institute of Information Technology Hyderabad
Pushpangathan, Jinraj	International Institute of Information Technology Hyderabad
Bera, Titas	Indian Institute of Science
Dhall, Sidhant	Indian Institute of Science
Bhat, M. Seetharama	Indian Institute of Science
14:40-15:00	ThC2.3
Attitude Control of a Tilt Rotor Tailsitter Micro Air Vehicle Using Incremental Control, pp. 842-849.	
Lovell-Prescod, Gervase Hugo Ludovic Henry	Delft University of Technology
Ma, Ziqing	Delft University of Technology
Smeur, Ewoud	Delft University of Technology
15:00-15:20	ThC2.4
Implementation of Partial Observable Markov Decision Process (POMDP) Algorithm Using Bitcraze Crazyflie Drones, pp. 850-857.	
Graham, Conor John	Queensland University of Technology
Gonzalez, Luis Felipe	Queensland University of Technology
Sanoe, Abdullay	Queensland University of Technology

ThC3	Room 464
Air Vehicle Operations (Regular Session)	
Chair: Sarcinelli-Filho, Mário	Federal University of Espirito Santo
Co-Chair: Ferrão, Isadora	University of São Paulo
14:00-14:20	ThC3.1
Exploiting the Line Virtual Structure Formation for Cooperation of Two Mobile Robots, pp. 858-862.	
Villa, Daniel Khede Dourado	Federal University of Espírito Santo
Sarcinelli-Filho, Mário	Federal University of Espirito Santo
14:20-14:40	ThC3.2
RHFSafeUAV: Real-Time Heuristic Framework for Safe Landing of UAVs in Dynamic Scenarios, pp. 863-870.	
Singh, Jaskirat	University of Petroelum and Energy Studies
Adwani, Neel	University of Petroleum and Energy Studies
Kandath, Harikumar	International Institute of Information Technology Hyderabad
Krishna, Madhava	International Institute of Information Technology Hyderabad
14:40-15:00	ThC3.3
Intelligent Diagnosis of Engine Failure in Air Vehicles Using the Alpha Dataset, pp. 871-878.	
Ferrão, Isadora	University of São Paulo
da Silva, Leandro Marcos	University of São Paulo
Almeida da Silva, Sherlon	University of São Paulo
Dezan, Catherine	Université De Bretagne Occidentale
Espes, David	Université De Bretagne Occidentale
Branco, Kalinka Regina Lucas Jaquie Castelo	University of São Paulo

ThC4	Room 465
Regulations (Regular Session)	
Chair: Konert, Anna	Łazarski University
Co-Chair: Barbano, Mario	Università Di Genova
14:00-14:20	ThC4.1
Concept for an Automated Detection of Conflicts in UAS Traffic Management, pp. 879-886.	
von Roenn, Luca	Helmut-Schmidt-Universität
Grebner, Tobias Georg Gerhard	Helmut-Schmidt-Universität
Fay, Alexander	Helmut-Schmidt-Universität
14:20-14:40	ThC4.2
The Practical and Legal Aspects of Geographical Zones for Unmanned Aircraft Systems in Poland - Facilitation or Complication?, pp. 887-894.	
Fortońska, Agnieszka	University of Silesia
Berus, Matylda	Łazarski University
Fabisiak, Sylwia	Łazarski University
Ostrihansky, Magdalena	Polish Air Navigation Services Agency
14:40-15:00	ThC4.3
Implementing Urban Air Mobility in a Multi-Level Regulatory Framework: Perspectives from the EU, pp. 895-902.	
Barbano, Mario	Università Di Genova
Costa, Valentina	Università Di Genova
15:00-15:20	ThC4.4
Criminal Liability for Unlawful Usage of Unmanned Aircraft Vehicles in Selected Countries of the World, pp. 903-910.	
Osiecki, Mateusz	Łazarski University
Fortońska, Agnieszka	University of Silesia
Książek-Janik, Ewelina	Łazarski University

ThC5	Room 466
UAS Applications V (Regular Session)	
Chair: Givigi, Sidney	Queen's University
Co-Chair: Giernacki, Wojciech	Poznan University of Technology
14:00-14:20	ThC5.1
Deep Reinforcement Learning Solution of Reach-Avoid Games with Superior Evader in the Context of Unmanned Aerial Systems, pp. 911-918.	
Silveira, Jefferson	Queen's University
Cabral, Kleber	Queen's University

Rabbath, Camille Alain	Defence Research and Development Canada
Givigi, Sidney	Queen's University
14:20-14:40	ThC5.2

Toward Improving Tracking Precision in Motion Capture Systems, pp. 919-925.

Retinger, Marek	Poznan University of Technology
Michalski, Jacek	Poznan University of Technology
Kozierski, Piotr	Poznan University of Technology
Giernacki, Wojciech	Poznan University of Technology
14:40-15:00	ThC5.3

Design and Realization of a Cable-Drogue Aerial Recharging Device for Small Electric Fixed-Wing UAVs, pp. 926-932.

Wang, Liangxiu	Fudan University
Li, Han	Fudan University
Liu, Yunxiao	Fudan University
Ai, Jianliang	Fudan University

Friday, June 9, 2023

FrA1	Room 118
Aerial Robotic Manipulation (Regular Session)	
Chair: Gabellieri, Chiara	University of Twente
Co-Chair: Rafee Nekoo, Saeed	Universidad De Sevilla
10:30-10:50	FrA1.1

Online Trajectory Generation for Aerial Manipulator Subject to Multi-Tasks and Inequality Constraints, pp. 933-939.

Chen, Rui	Beihang University
Liu, Qianyuan	Beihang University
Chen, Zeshuai	Beihang University
Guo, Kexin	Beihang University
Yu, Xiang	Beihang University
Guo, Lei	Beihang University
10:50-11:10	FrA1.2

CLF-Based Control for Aerial Manipulation Using Multirotor UAVs, pp. 940-947.

Namigtle Jimenez, Alfredo	Instituto Nacional De Astrofísica, Óptica Y Electrónica
Alvarez Muñoz, Jonatan Uziel	Institut Polytechnique De Sciences Avancées
Diaz-Tellez, Juan	Instituto Tecnólogico De Puebla
Enriquez Caldera, Rogerio Adrian	Instituto Nacional De Astrofísica, Óptica Y Electrónica
Escareno Castro, Juan Antonio	University of Limoges
Durand, Sylvain	Strasbourg Univeristy
Marchand, Nicolas	GIPSA-Lab
Guerrero-Castellanos, J. Fermi	Benemérita Universidad Autónoma De Puebla
11:10-11:30	FrA1.3

Theoretical and Experimental Investigation on Body Control after Perching for Flapping-Wing Robots: Extending the Workspace for Manipulation, pp. 948-955.

Serrano Luque, Pablo	Universidad De Sevilla
Satué Crespo, Álvaro César	Universidad De Sevilla
Rafee Nekoo, Saeed	Universidad De Sevilla
Acosta, Jose Angel	Universidad De Sevilla
Ollero, Anibal	Universidad De Sevilla
11:30-11:50	FrA1.4

Physical Human-Aerial Robot Interaction and Collaboration: Exploratory Results and Lessons Learned, pp. 956-962.

Afifi, Amr	University of Twente
Corsini, Gianluca	Université De Toulouse
Sable, Quentin	University of Twente
Aboudorra, Youssef	University of Twente
Sidobre, Daniel	Université De Toulouse
Franchi, Antonio	University of Twente
11:50-12:10	FrA1.5

Differential Flatness and Manipulation of Elasto-Flexible Cables Carried by Aerial Robots in a Possibly Viscous Environment, pp. 963-968.

Gabellieri, Chiara — University of Twente
Franchi, Antonio — University of Twente

12:10-12:30 — FrA1.6

Nonlinear MPC for Full-Pose Manipulation of a Cable-Suspended Load Using Multiple UAVs, pp. 969-975.

Sun, Sihao — University of Twente
Franchi, Antonio — University of Twente

FrA2 — Room 130

Reliability of UAS (Regular Session)

Chair: Giernacki, Wojciech — Poznan University of Technology
Co-Chair: Monteriù, Andrea — Università Politecnica Delle Marche

10:30-10:50 — FrA2.1

Actuator Fault Detection in Centrally Powered Variable-Pitch Propeller Quadrotor Vehicles, pp. 976-981.

Chaturvedi, Sanjay — Indian Institute of Technology Kanpur
Sahoo, Soumya Ranjan — Indian Institute of Technology Kanpur

10:50-11:10 — FrA2.2

PADRE – Propeller Anomaly Data REpository for UAVs Various Rotor Fault Configurations, pp. 982-989.

Puchalski, Radosław — Poznan University of Technology
Kołodziejczak, Marek — Poznan University of Technology
Bondyra, Adam — Poznan University of Technology
Rao, Jinjun — Shanghai University
Giernacki, Wojciech — Poznan University of Technology

11:10-11:30 — FrA2.3

Toward Lightweight Acoustic Fault Detection and Identification of UAV Rotors, pp. 990-997.

Kołodziejczak, Marek — Poznan University of Technology
Puchalski, Radosław — Poznan University of Technology
Bondyra, Adam — Poznan University of Technology
Sladic, Sasa — University of Rijeka
Giernacki, Wojciech — Poznan University of Technology

11:30-11:50 — FrA2.4

UAV-FD: A Dataset for Actuator Fault Detection in Multirotor Drones, pp. 998-1004.

Baldini, Alessandro — Università Politecnica Delle Marche
D'Alleva, Lorenzo — Università Politecnica Delle Marche
Felicetti, Riccardo — Università Politecnica Delle Marche
Ferracuti, Francesco — Università Politecnica Delle Marche
Freddi, Alessandro — Università Politecnica Delle Marche
Monteriù, Andrea — Università Politecnica Delle Marche

11:50-12:10 — FrA2.5

Quantifying Weather Tolerance Criteria for Delivery Drones – a UK Case Study, pp. 1005-1012.

Oakey, Andy — University of Southampton
Cherrett, Tom — University of Southampton

12:10-12:30 — FrA2.6

A Reliability Framework for Safe Octorotor UAV Flight Operations, pp. 1013-1020.

T., Thanaraj — Nanyang Technological University
Govind, Siddesh — Air Traffic Management Research Institute
Roy, Anurag — Nanyang Technological University
Ng, Bing Feng — Nanyang Technological University
Low, Kin Huat — Nanyang Technological University

FrA3 — Room 464

Autonomy (Regular Session)

Chair: Branco, Kalinka Regina Lucas Jaquie Castelo — University of São Paulo
Co-Chair: Causa, Flavia — Università Di Napoli Federico II

10:30-10:50 — FrA3.1

BDP-UaiFly System: A Platform for the RoboCup Brazil Open Flying Robot Trial League, pp. 1021-1028.

Alves Fagundes Junior, Leonardo — Universidade Federal De Viçosa
Oliveira Barcelos, Celso — Universidade Federal De Viçosa

Gandolfo, Daniel Ceferino — National University of San Juan
Brandao, Alexandre Santos — Universidade Federal De Viçosa

10:50-11:10 — FrA3.2

Creating Trustworthy AI for UAS Using Labeled Backchained Behavior Trees, pp. 1029-1036.

Ögren, Petter — KTH Royal Institute of Technology
Alfredson, Jens — Saab Aeronautics

11:10-11:30 — FrA3.3

Multi-Agent Reinforcement Learning for Multiple Rogue Drone Interception, pp. 1037-1044.

Valianti, Panayiota — University of Cyprus
Malialis, Kleanthis — University of Cyprus
Kolios, Panayiotis — University of Cyprus
Ellinas, Georgios — University of Cyprus

11:30-11:50 — FrA3.4

Autonomous Navigation and Control of a Quadrotor Using Deep Reinforcement Learning, pp. 1045-1052.

Mansour, Mohamed — German University in Cairo
El-Badawy, Ayman — German University in Cairo

11:50-12:10 — FrA3.5

Multicopters Obstacle Avoidance by Learning Optical Flow with a Balance Strategy, pp. 1053-1058.

Gao, Wenhan — Beihang University
Jiang, Shuo — Beihang University
Quan, Quan — Beihang University

12:10-12:30 — FrA3.6

Online Reward Adaptation for MDP-Based Distributed Missions, pp. 1059-1066.

Hamadouche, Mohand — Université De Bretagne Occidentale
Dezan, Catherine — Université De Bretagne Occidentale
Espes, David — Université De Bretagne Occidentale
Branco, Kalinka Regina Lucas Jaquie Castelo — University of São Paulo

FrA4 — Room 465

Control Architectures I (Regular Session)

Chair: Bertolani, Giulia — Università Di Bologna
Co-Chair: Chen, YangQuan — University of California - Merced

10:30-10:50 — FrA4.1

State Dependent Regional Pole Assignment Controller Design for a 3-DOF Helicopter Model, pp. 1067-1072.

Arican, Ahmet Cagri — Gazi University
Copur, Engin Hasan — Necmettin Erbakan University
Inalhan, Gokhan — Cranfield University
Salamci, Metin U. — Gazi University

10:50-11:10 — FrA4.2

Dynamic Modelling and Robust Backstepping Control of Hybrid Unmanned Amphibious Multirotor Robot for Smooth Media Transition in the Presence of Uncertainty, pp. 1073-1080.

Khatri, Jay — Indian Institute of Technology Jodhpur
Gupta, Sandeep — Indian Institute of Technology Kanpur
Mohanta, Jayant Kumar — Indian Institute of Technology Jodhpur

11:10-11:30 — FrA4.3

L1 Adaptive Attitude Augmentation of a Small-Scale Unmanned Helicopter, pp. 1081-1088.

Ryals, Andrea Dan — Università Di Pisa
Bertolani, Giulia — Università Di Bologna
Pollini, Lorenzo — Università Di Pisa
Giulietti, Fabrizio — Università Di Bologna

11:30-11:50 — FrA4.4

A PX4 Integrated Framework for Modeling and Controlling Multicopters with Tiltable Rotors, pp. 1089-1096.

Marcellini, Salvatore — Università Di Napoli Federico II
Cacace, Jonathan — Università Di Napoli Federico II
Lippiello, Vincenzo — Università Di Napoli Federico II

11:50-12:10 — FrA4.5

Novel Cascaded Incremental Nonlinear Dynamic Inversion Controller Approach for a Tiltrotor VTOL, pp. 1097-1105.

Henkenjohann, Mark	Fraunhofer Institute for Mechatronic Systems Design IEM
Nolte, Udo	Fraunhofer Institute for Mechatronic Systems Design IEM
Henke, Christian	Fraunhofer Institute for Mechatronic Systems Design IEM
Traechtler, Ansgar	University of Paderborn
12:10-12:30	FrA4.6

Position Control of Crazyflie 2.1 Quadrotor UAV Based on Active Disturbance Rejection Control, pp. 1106-1113.

Michalski, Jacek	Poznan University of Technology
Retinger, Marek	Poznan University of Technology
Kozierski, Piotr	Poznan University of Technology
Giernacki, Wojciech	Poznan University of Technology

FrA5 Room 466

Multirotor Design and Control I (Regular Session)

Chair: Pierri, Francesco	Università Della Basilicata
Co-Chair: Arogeti, Shai	Ben-Gurion University of the Negev
10:30-10:50	FrA5.1

A Fully Actuated Drone with Rotating Seesaws, pp. 1114-1121.

Yecheskel, Dolev	Ben-Gurion University of the Negev
Arogeti, Shai	Ben-Gurion University of the Negev
10:50-11:10	FrA5.2

The ODQuad: Design and Experimental Validation of a Novel Fully Actuated Quadrotor, pp. 1122-1127.

Nigro, MIchelangelo	Università Della Basilicata
Pierri, Francesco	Università Della Basilicata
Caccavale, Fabrizio	Università Della Basilicata
Ryll, Markus	Technical University Munich
11:10-11:30	FrA5.3

Transition Control Planning and Optimization for a Boxed-Wing eVTOL Tiltrotor Vehicle Using Trim Analysis, pp. 1128-1135.

Hyun, Jeongseok	Konkuk University
Jang, Minseok	Konkuk University
Nguyen, Tuan Anh	Konkuk University
Lee, Jae-Woo	Konkuk University
11:30-11:50	FrA5.4

Finite Integral Terminal Synergetic Control of a Disturbed Quadcopter with Variable Geometry, pp. 1136-1141.

Belmouhoub, Amina	University Mohamed El Bachir El Ibrahimi of Bordj Bou Arreridj
Bouzid, Yasser	Ecole Militaire Polytechnique
Derrouaoui, Saddam Hocine	Ecole Supérieure Ali Chabati
Medjmadj, Slimane	University of Bordj Bou Arreridj
Guiatni, Mohamed	Ecole Militaire Polytechnique
11:50-12:10	FrA5.5

Wall Effect Evaluation of Small Quadcopters in Pressure-Controlled Environments, pp. 1142-1147.

David Du Mutel de Pierrepont Franzetti, Iris	Politecnico Di Torino
Parin, Riccardo	Eurac Research
Capello, Elisa	Politecnico Di Torino
12:10-12:30	FrA5.6

Adaptive Single-Gain Non-Singular Fast Terminal Sliding Mode Control for a Quad-Rotor UAV against Wind Perturbations, pp. 1148-1154.

Olivas, Gustavo	Tecnológico De Monterrey
Castaneda, Herman	Tecnologico De Monterrey

FrB1 Room 118

Aerial Manipulation: Design, Control and Applications (Invited Session)

Chair: Fumagalli, Matteo	Danish Technical University
Co-Chair: Im, Jaehan	Nearthlab Inc
Organizer: Fumagalli, Matteo	Danish Technical University
Organizer: Nikolakopoulos, George	Luleå University of Technology
Organizer: Tognon, Marco	Inria
14:00-14:20	FrB1.1

PACED-5G: Predictive Autonomous Control Using Edge for Drones Over 5G (I), pp. 1155-1161.

Sankaranarayanan, Viswa Narayanan	Luleå University of Technology
Damigos, Gerasimos	Luleå University of Technology
Seisa, Achilleas Santi	Luleå University of Technology
Satpute, Sumeet	Luleå University of Technology
Lindgren, Tore	Ericsson Research
Nikolakopoulos, George	Luleå University of Technology

14:20-14:40 FrB1.2

Enhancing Human-Drone Interaction with Human-Meaningful Visual Feedback and Shared-Control Strategies (I), pp. 1162-1167.

Franceschini, Riccardo	Eurecat
Fumagalli, Matteo	Danish Technical University
Cayero, Julian Cayero	Eurecat

14:40-15:00 FrB1.3

Design and Evaluation of a Mixed Reality-Based Human-Robot Interface for Teleoperation of Omnidirectional Aerial Vehicles (I), pp. 1168-1174.

Allenspach, Mike	ETH Zürich
Kötter, Till	ETH Zürich
Bähnemann, Rik	ETH Zürich
Tognon, Marco	Inria
Siegwart, Roland Y.	ETH Zürich

15:00-15:20 FrB1.4

AIRFRAME - Fast Prototyping Framework for UAVs Definition (I), pp. 1175-1182.

Berra, Andrea	Center for Advanced Aerospace Technologies
Sanchez-Cuevas, P. J.	Center for Advanced Aerospace Technologies
Trujillo, Miguel Ángel	Center for Advanced Aerospace Technologies
Heredia, Guillermo	Universidad De Sevilla
Viguria, Antidio	Center for Advanced Aerospace Technologies

15:20-15:40 FrB1.5

A Vision-Based Approach for Unmanned Aerial Vehicles to Track Industrial Pipes for Inspection Tasks (I), pp. 1183-1190.

Roos-Hoefgeest Toribio, Sara	Univesity of Oviedo
Cacace, Jonathan	Università Di Napoli Federico II
Scognamiglio, Vincenzo	Università Di Napoli Federico II
Alvarez, Ignacio	Universidad De Oviedo
González de los Reyes, Rafael Corsino	University of Oviedo
Ruggiero, Fabio	Università Di Napoli Federico II
Lippiello, Vincenzo	Università Di Napoli Federico II

15:40-16:00 FrB1.6

Fully Actuated, Corner Contact Aerial Robot for Inspection of Hard-To-Reach Bridge Areas (I), pp. 1191-1198.

Gonzalez-Morgado, Antonio	Universidad De Sevilla
Alvarez-Cia, Carlos	Universidad De Sevilla
Heredia, Guillermo	Universidad De Sevilla
Ollero, Anibal	Universidad De Sevilla

FrB2 Room 130

Perception and Cognition (Regular Session)

Chair: Ferrão, Isadora	University of São Paulo
Co-Chair: Bertolani, Giulia	Università Di Bologna

14:00-14:20 FrB2.1

GATSBI: An Online GTSP-Based Algorithm for Targeted Surface Bridge Inspection, pp. 1199-1206.

Dhami, Harnaik	University of Maryland
Yu, Kevin	Virginia Tech
Williams, Troi	University of Maryland
Vajipey, Vineeth	University of Maryland
Tokekar, Pratap	University of Minnesota

14:20-14:40 FrB2.2

Semi-Autonomous Search and Rescue System, pp. 1207-1212.

Walz, Eli	United States Naval Academy
Hammonds, Katie	United States Naval Academy
Rumbaugh, Megan	United States Naval Academy
O'Brien, Richard	United States Naval Academy

14:40-15:00	FrB2.3

Assessment of LiDAR Detection Capabilities for Urban Air Mobility Applications, pp. 1213-1220.

Aldao Pensado, Enrique	University of Vigo
Fontenla Carrera, Gabriel	University of Vigo
Gonzalez de Santos, Luis Miguel	University of Vigo
Gonzalez Jorge, Higinio	University of Vigo

15:00-15:20	FrB2.4

A System for Real-Time Display and Interactive Training of Predictive Structural Defect Models Deployed on UAV, pp. 1221-1225.

Heichel, Jack	University of North Dakota
Mitra, Rajrup	University of North Dakota
Jafari, Faezeh	University of North Dakota
Das, Amrita	University of North Dakota
Dorafshan, Sattar	University of North Dakota
Kaabouch, Naima	University of North Dakota

15:20-15:40	FrB2.5

H2AMI: Intuitive Human to Aerial Manipulator Interface, pp. 1226-1232.

Zoric, Filip	University of Zagreb
Orsag, Matko	University of Zagreb

FrB3	Room 464
Navigation (Regular Session)	
Chair: Nascimento, Tiago	Czech Technical University in Prague
Co-Chair: Shan, Jinjun	York University

14:00-14:20	FrB3.1

Open-Source Hardware/Software Architecture for Autonomous Powerline-Aware Drone Navigation and Recharging, pp. 1233-1240.

Nyboe, Frederik F	University of Southern Denmark
Malle, Nicolaj Haarhøj	University of Southern Denmark
Duong Hoang, Viet	University of Southern Denmark
Ebeid, Emad Samuel Malki	University of Southern Denmark

14:20-14:40	FrB3.2

Cooperative UAS Forest Navigation with Feature Based SLAM, pp. 1241-1248.

Martens, Mats	Technische Universität Berlin
Uijt de Haag, Maarten	Technische Universität Berlin

14:40-15:00	FrB3.3

UAV Navigation in 3D Urban Environments with Curriculum-Based Deep Reinforcement Learning, pp. 1249-1255.

de Oliveira, Iure Rosa Lima	Universidade Federal De Viçosa
de Carvalho, Kevin Braathen	Universidade Federal De Viçosa
Brandao, Alexandre Santos	Universidade Federal De Viçosa

15:00-15:20	FrB3.4

PredictiveSLAM - Robust Visual SLAM through Trajectory-Aware Object Masking, pp. 1256-1261.

Heiß, Micha	Aarhus University
Hansen, Jakob Grimm	Aarhus University
Li, Dengyun	Aarhus University
Kozlowski, Michal	Aarhus University
Kayacan, Erdal	Aarhus University

15:20-15:40	FrB3.5

Visual Navigation Based on Deep Semantic Cues for Real-Time Autonomous Power Line Inspection, pp. 1262-1269.

Alexiou, Dimitrios	Centre for Research and Technology Hellas
Zampokas, Georgios	Centre for Research and Technology Hellas
Skartados, Evangelos	Centre for Research and Technology Hellas
Tsiakas, Kosmas	Centre for Research and Technology Hellas
Kostavelis, Ioannis	Centre for Research and Technology Hellas

Giakoumis, Dimitrios — Centre for Research and Technology Hellas
Gasteratos, Antonios — Democritus University of Thrace
Tzovaras, Dimitrios — Centre for Research and Technology Hellas

15:40-16:00 FrB3.6

Vision-Aided Approach and Landing through AI-Based Vertiport Recognition, pp. 1270-1277.

Veneruso, Paolo — Università Di Napoli Federico II
Miccio, Enrico — Università Di Napoli Federico II
Opromolla, Roberto — Università Di Napoli Federico II
Fasano, Giancarmine — Università Di Napoli Federico II
Gentile, Giacomo — Collins Aerospace
Tiana, Carlo — Collins Aerospace

FrB4 Room 465

Control Architectures II (Regular Session)

Chair: Theilliol, Didier — Université De Lorraine
Co-Chair: Valavanis, Kimon P. — University of Denver

14:00-14:20 FrB4.1

Obstacle Avoidance Based on the Null Space Control Approach for a Formation of an Aerial and a Ground Robot, pp. 1278-1285.

Mafra Moreira, Mauro Sergio — Federal University of Espírito Santo
Sarcinelli-Filho, Mário — Federal University of Espirito Santo

14:20-14:40 FrB4.2

System Identification-Based Fault Detection and Dynamic Inversion Control of an Uncrewed Aerial Vehicle, pp. 1286-1293.

Bowes, Robert — University of Kansas
Benyamen, Hady — University of Kansas
Keshmiri, Shawn — University of Kansas

14:40-15:00 FrB4.3

A Proportional Closed-Loop Control for Equivalent Vertical Dynamics of Flapping-Wing Flying Robot, pp. 1294-1300.

Rafee Nekoo, Saeed — Universidad De Sevilla
Ollero, Anibal — Universidad De Sevilla

15:00-15:20 FrB4.4

Equivalent Vertical Dynamics of Flapping-Wing Flying Robot in Regulation Control: Displacement Transmissibility Ratio, pp. 1301-1307.

Rafee Nekoo, Saeed — Universidad De Sevilla
Ollero, Anibal — Universidad De Sevilla

15:20-15:40 FrB4.5

Anafi_ros: From Off-The-Shelf Drones to Research Platforms, pp. 1308-1315.

Sarabakha, Andriy — Nanyang Technological University
Suganthan, Ponnuthurai — Nanyang Technological University

15:40-16:00 FrB4.6

Distributed Observer-Based Leader-Following Consensus Control for LPV Multi-Agent Systems: Application to Multiple VTOL-UAVs Formation Control, pp. 1316-1323.

Vazquez Trejo, Jesus Avelino — Centro Nacional De Investigación Y Desarrollo Tecnológico
Ponsart, Jean-Christophe — Université De Lorraine
Adam-Medina, Manuel — Centro Nacional De Investigación Y Desarrollo Tecnológico
Valencia-Palomo, Guillermo — Tecnológico Nacional De México
Theilliol, Didier — Université De Lorraine

FrB5 Room 466

Multirotor Design and Control II (Regular Session)

Chair: Tzes, Anthony — New York University Abu Dhabi
Co-Chair: Zhang, Youmin — Concordia University

14:00-14:20 FrB5.1

Development, Model, Simulation, and Real Test of a New Fully Actuated Quadrotor, pp. 1324-1330.

Flores, Alejandro — Centro De Investigaciones En Óptica
Verdìn, Rodolfo Isaac — Centro De Investigaciones En Óptica
Moreno Jimenez, Hugo Alberto — Centro De Investigaciones En Óptica

Flores, Gerardo	Centro De Investigaciones En Óptica

14:20-14:40	FrB5.2

Design and Prototyping of a Ground-Aerial Robotic System, pp. 1331-1336.

Kotarski, Denis	Karlovac University of Applied Sciences
Šćuric, Alen	University of Zagreb
Piljek, Petar	University of Zagreb
Petrovic, Tamara	University of Zagreb

14:40-15:00	FrB5.3

Mechatronic Design and Control of a Hybrid Ground-Air-Water Autonomous Vehicle, pp. 1337-1342.

Chaikalis, Dimitris	New York University
Evangeliou, Nikolaos	New York University Abu Dhabi
Nabeel, Muhammed	New York University Abu Dhabi
Giakoumidis, Nikolaos	New York University Abu Dhabi
Tzes, Anthony	New York University Abu Dhabi

15:00-15:20	FrB5.4

A Load Compensation Controller for Off-The-Shelf Unmanned Aerial Vehicles, pp. 1343-1348.

Bacheti, Vinícius Pacheco	Federal University of Espirito Santo
Villa, Daniel Khede Dourado	Federal University of Espírito Santo
Brandao, Alexandre Santos	Universidade Federal De Viçosa
Sarcinelli-Filho, Mário	Federal University of Espirito Santo

15:20-15:40	FrB5.5

Adaptive Fault-Tolerant Trajectory Tracking and Attitude Control of a Quadrotor UAV Subject to Actuator Faults, pp. 1349-1355.

Hu, Xinyue	Northwestern Polytechnical University
Fu, Yifang	Northwestern Polytechnical University
Huang, Yulu	Northwestern Polytechnical University
Wang, Ban	Northwestern Polytechnical University
Li, Ni	Northwestern Polytechnical University
Zhang, Youmin	Concordia University

15:40-16:00	FrB5.6

Experimental Quadrotor Physical Parameters Estimation, pp. 1356-1362.

Rodríguez-Cortés, Hugo	Centro De Investigación Y De Estudios Avanzados Del IPN
Romero, Jose-Guadalupe	Instituto Tecnológico Autónomo De México
Tlatelpa-Osorio, Y. E.	Centro De Investigación Y De Estudios Avanzados Del IPN
Martinez-Ramirez, Marco A.	Centro De Investigación Y De Estudios Avanzados Del IPN
Corte´s-Benito, I.	Centro De Investigación Y De Estudios Avanzados Del IPN

ICUAS ’23 Paper Abstracts

WeA1	Room 118
Fail-Safe Systems (Regular Session)	
Chair: Sun, Sihao	University of Twente
Co-Chair: Valavanis, Kimon P.	University of Denver

11:00-11:20 WeA1.1

Fast Quadrotor Rotor Failure Detection and Identification Using Onboard Sensors and a Kalman Filter Approach, pp. 1-8

Strack van Schijndel, Bram Adriaan — Delft University of Technology
Sun, Sihao — University of Twente
de Visser, Cornelis C. — Delft University of Technology

This paper presents a novel method for fast and robust detection of actuator failures on quadrotors. The proposed algorithm has little model dependency. A Kalman estimator estimates a stochastic effectiveness factor for every actuator, using only onboard RPM, gyro, and accelerometer measurements. Then, a hypothesis test identifies the failed actuator. This algorithm is validated online in real-time, also as part of an active fault tolerant control system. Loss of actuator effectiveness is induced by ejecting the propellers from the motors. The robustness of this algorithm is further investigated offline over a range of parameter settings by replaying real flight data containing 26 propeller ejections. The detection delays are found to be in the 30～130 ms range, without missed detections or false alarms occurring.

11:20-11:40 WeA1.2

Multivariate Data Analysis for Motor Failure Detection and Isolation in a Multicopter UAV Using Real-Flight Attitude Signals, pp. 9-16

Ashe, Avijit — International Institute of Information Technology Hyderabad
Goli, Srikanth — International Institute of Information Technology Hyderabad
Kandath, Harikumar — International Institute of Information Technology Hyderabad
Gangadharan, Deepak — International Institute of Information Technology Hyderabad

Reconfigurable aerial platforms such as multicopter unmanned aerial vehicles (UAVs) allow the design of fail-safe systems because of inherent redundancy in actuators and sensors to maintain stability with a reduction in flight performance. The methods based on univariate and multivariate time series analysis of just the attitude signals can pave the way for model-free systems that can be generalized across a class of UAVs like multicopters. In this paper, we present a critical analysis of real-flight attitude time-series signals and investigate them for data-driven motor fault and failure detection and isolation (FDI), specifically for multicopters configurations like quadcopters and hexacopters. We analyze flight data for different scenarios of outdoor flights, healthy and faulty, hovering and cruising, loss of efficiency, and single-rotor failure of every motor. We evaluated it for small to medium-sized multi-copters. The failure detection and classification are performed without relying on analytical system modeling or the knowledge of the controller.
Thus, we perform three major assessments: vector auto-regression (VAR) using residual variance, time-frequency analysis, and dimensionality analysis of the recorded variables, to support the classification framework. To the author's best knowledge, it is an early attempt at laying the foundation for engineering features from streaming attitude data, instead of simulations, which works on existing open-source autopilot hardware and is agnostic to the firmware as well. This foundation allows us to implement various FDI frameworks in real-time directly using the above variables on multicopters, which drastically increases the levels of safety and scalability of unmanned flights in drone applications.

11:40-12:00 WeA1.3

Neural Network-Based Propeller Damage Detection for Multirotors, pp. 17-23

Pose, Claudio Daniel — Universidad De Buenos Aires
Giribet, Juan Ignacio — Universidad De San Andrés
Torre, Gabriel — Universidad De San Andrés
Marzik, Guillermo — Universidad De San Andrés

This work presents a method for detecting and identifying possible damages to propeller blades in multirotor vehicles, for a particular case study of a quadrotor. The detection method is based on a neural network, which takes as input the energy of several spectral bands of the inertial measurements and control variables, and outputs a measure of how damaged a propeller is. The ability of the network to correctly generalize from a limited dataset will be shown by training it using data gathered from an indoor, controlled environment, and evaluating it using data from outdoor flights.

12:00-12:20 WeA1.4

Safety Procedure Using Path Planning Methods for Tilt-Wing Unmanned Aerial Vehicles, pp. 24-31

König, Eva — RWTH Aachen University
Seitz, Sebastian — RWTH Aachen University
Voget, Nicolai — RWTH Aachen University
Danielmeier, Lennart — RWTH Aachen University
Moormann, Dieter — RWTH Aachen University

This paper presents a safety procedure for tilt-wing unmanned aerial vehicles (UAV) considering flight dynamic constraints, geofences, and static obstacles. The proposed safety procedure ensures that the UAV remains in a safe flight state or is transferred into such a state if the initial flight path cannot be flown as planned. This is accomplished by planning an emergency flight path to one of the predefined safety points periodically during normal operation using existing path planning algorithms. This emergency flight path is planned even before an error has occurred and is automatically activated in case of errors due to external influences, system failure, or defects. Once the safety point is reached, the flight system can remain in hover state or enter a transition to landing. Within this paper,

the procedure is implemented for a tilt-wing UAV and offers a safety feature that is executed at regular intervals during flight.

12:20-12:40 WeA1.5

Safety Net Detection by Optic Flow Processing, pp. 32-39

Daini, Xavier — Aix-Marseille Université
Coquet, Charles — Aix-Marseille Université
Raffin, Romain — Université De Bourgogne
Raharijaona, Thibaut — Université De Lorraine
Ruffier, Franck — Aix-Marseille Université

Drone navigation is an area of study that is receiving more and more attention. Obstacle detection techniques and autonomous guidance are continuously improving, but some types of obstacles are still very difficult to detect with current methods. Safety nets used to separate and secure 2 contiguous spaces are indeed very difficult to detect by Lidar and by image processing based on pattern recognition. The method we propose here separates the optical flow detections to identify the presence of a safety net: i) by using the norm of their vector, ii) by matching them to a regression defining a plane (safety net or wall). Our results show that the proposed method detects a net in front of a wall with very few false positives thanks to a small displacement. Moreover, important parameters such as the distance between the net and the wall as well as the distance between the net and the drone can be estimated with at most 20% error.

WeA2 Room 130

Manned/Unmanned Aviation I (Regular Session)

Chair: Arogeti, Shai — Ben-Gurion University of the Negev

Co-Chair: Parin, Riccardo — Eurac Research

11:00-11:20 WeA2.1

Control of a Multi-UAV System in String-Like Flight in 3D Space, pp. 40-47

Arogeti, Shai — Ben-Gurion University of the Negev
Ailon, Amit — Ben-Gurion University of the Negev

The paper suggests a control algorithm for trajectory tracking for a group of Unmanned Aerial Vehicles (UAVs) that flies in a string-like formation in 3D space. The proposed controller is based on hyperbolic functions and guarantees the string stability property of the group. We implement a control law under physical constraints and avoid singularities during the process. To illustrate the nature of the controller and its capabilities, numerical results and simulations are presented.

11:20-11:40 WeA2.2

Monte Carlo Tree Search and Convex Optimization for Decision Support in Beyond-Visual-Range Air Combat, pp. 48-55

Scukins, Edvards — SAAB Aeronautics
Klein, Markus — SAAB Aeronautics
Kroon, Lars — SAAB Aeronautics
Ögren, Petter — KTH Royal Institute of Technology

Air combat is a high-risk activity where pilots must be aware of the surrounding situation to outperform the opposing team. The chances of beating the opposing team improve when the pilots have superior situation awareness, thus allowing them to act before the opposing team can do counteractions. In a highly dynamic environment, such as air combat, it can be difficult for pilots to track all adversarial units and their capabilities. In this work, we propose a combination of Monte Carlo Tree Search (MCTS) and Convex optimization to help pilots analyze the situation and be aware of any potential risks associated with missile guidance in Beyond Visual Range air combat. Our process uses MCTS to assess the best action from an opposing aircraft perspective. At the same time, the convex optimization problem searches available aircraft trajectories that enable missile guidance in relation to the opponent's potential actions. The proposed system is intended to support human decisions made by a pilot inside the aircraft or by a remote pilot operating an unmanned aerial system (UAS).

11:40-12:00 WeA2.3

Enhancing Situation Awareness in Beyond Visual Range Air Combat with Reinforcement Learning-Based Decision Support, pp. 56-62

Scukins, Edvards — SAAB Aeronautics
Klein, Markus — SAAB Aeronautics
Ögren, Petter — KTH Royal Institute of Technology

Military aircraft pilots need to adjust to a constantly changing battlefield. A system that aids in understanding challenging combat circumstances and suggests appropriate responses can considerably improve the effectiveness of pilots. In this paper, we provide a Reinforcement Learning (RL) based system that acts as an aid in determining if an afterburner should be turned on to escape an incoming air-to-air missile. An afterburner is a component of a jet engine that increases thrust at the expense of exceptionally high fuel consumption. Thus, it provides a short-term advantage, at the cost of a long-term disadvantage, in terms of reduced mission time. Helping to choose when to use the afterburner may significantly lengthen the flight duration, allowing aircraft to support friendly aircraft for longer and suffer fewer friendly fatalities due to this extended ability to provide support. We propose an RL-based risk estimation approach to help determine whether additional thrust is required to escape an incoming missile and study the benefits of thrust-aided evasive maneuvers. The suggested technique gives pilots a risk estimate for the scenario and a recommended course of action. We create an environment in which a pilot must decide whether or not to activate additional thrust to achieve the intended aim at a potentially high fuel consumption cost. Additionally, we investigate various trade-offs of the generated evasive manoeuvre policies.

12:00-12:20 WeA2.4

Pilots in the Evolving Urban Air Mobility: From Manned to Unmanned Aviation, pp. 63-70

Shi, Yuran — Leiden University

In November 2022, the European Commission published the Drone Strategy 2.0, which includes a three-stage approach for Urban Air

Mobility. Similarly, as early as 2020, the United States Federal Aviation Administration, together with the National Aeronautics and Space Administration, and industrial partners, conducted research on concepts of Urban Air Mobility operations. These regulatory initiatives addressed the evolutionary approach in the advancement of Urban Air Mobility, including operations conducted by manned aircraft, remotely piloted aircraft and autonomous aircraft successively. Pilots are an important component in the three-stage approach to the socially embraced model of Urban Air Mobility. This article will analyse relevant technical rules and social protection issues relating to pilots, in order to show how the insufficient aviation labour rules would impact the deployment and advancement of Urban Air Mobility; and what regulatory solutions are for both on-board and remote pilots.

12:20-12:40 WeA2.5

A Framework for Operational Volume Generation for Urban Air Mobility Strategic Deconfliction, pp. 71-78

Thompson, Ellis Lee — George Washington University
Wei, Peng — George Washington University
Xu, Yan — Cranfield University

Strategic pre-flight functions focus on the planning and deconfliction of routes for aircraft systems. The urban air mobility concept calls for higher levels of autonomy with onboard and en route functions but also strategic and pre-flight systems. Existing endeavours into strategic pre-flight functions focus on improving the route generation and strategic deconfliction of these routes. Introduced with the urban air mobility concept is the premise of operational volumes. These 4D regions of airspace, describe the intended operational region for an aircraft for finite time. Chaining these together forms a contract of finite operational volumes over a given route. It is no longer enough to only deconflict routes within the airspace, but to now consider these 4D operational volumes. To provide an effective all-in-one approach, we propose a novel framework for generating routes and accompanying contracts of operational volumes, along with deconfliction focused around 4D operational volumes. Experimental results show efficiency of operational volume generation utilising reachability analysis and demonstrate sufficient success in deconfliction of operational volumes.

WeA3 Room 464

Path Planning I (Regular Session)

Chair: Dharmadhikari, Mihir Rahul — Norwegian University of Science and Technology

Co-Chair: Zhang, Xinyu — Tsinghua University

11:00-11:20 WeA3.1

An Integrated Real-Time UAV Trajectory Optimization and Potential Field Approach for Dynamic Collision Avoidance, pp. 79-86

Dasari, Mohan — University of Luxembourg
Habibi, Hamed — University of Luxembourg
Sanchez-Lopez, Jose-Luis — University of Luxembourg
Voos, Holger — University of Luxembourg

This paper presents an integrated approach that combines trajectory optimization and Artificial Potential Field (APF) method for real-time optimal Unmanned Aerial Vehicle (UAV) trajectory planning and dynamic collision avoidance. A minimum-time trajectory optimization problem is formulated with initial and final positions as boundary conditions and collision avoidance as constraints. It is transcribed into a nonlinear programming problem using Chebyshev pseudospectra method. The state and control histories are approximated by using Lagrange polynomials and the collocation points are used to satisfy constraints. A novel sigmoid-type collision avoidance constraint is proposed to overcome the drawbacks of Lagrange polynomial approximation in pseudospectra methods that only guarantees inequality constraint satisfaction only at nodal points. Automatic differentiation of cost function and constraints is used to quickly determine their gradient and Jacobian, respectively. An APF method is used to update the optimal control inputs for guaranteeing collision avoidance. The trajectory optimization and APF method are implemented in a closed-loop fashion continuously, but in parallel at moderate and high frequencies, respectively. The initial guess for the optimization is provided based on the previous solution. The proposed approach is tested and validated through indoor experiments.

11:20-11:40 WeA3.2

Path Planning for Air-Ground Amphibious Robot Considering Modal Switching Point Optimization, pp. 87-94

Wang, Xiaoyu — Tsinghua University
Huang, Kangyao — Tsinghua University
Zhang, Xinyu — Tsinghua University
Sun, Honglin — Tsinghua University
Liu, Wenzhuo — Tsinghua University
Liu, Huaping — Tsinghua University
Li, Jun — Tsinghua University
Lu, Pingping — University of Michigan

An innovative sort of mobility platform that can both drive and fly is the air-ground robot. The need for an agile flight cannot be satisfied by traditional path planning techniques for air-ground robots. Prior studies had mostly focused on improving the energy efficiency of paths, seldom taking the seeking speed and optimizing take-off and landing places into account. A robot for the field application environment was proposed, and a lightweight global spatial planning technique for the robot based on the graph-search algorithm taking mode switching point optimization into account, with an emphasis on energy efficiency, searching speed, and the viability of real deployment. The fundamental concept is to lower the computational burden by employing an interchangeable search approach that combines planar and spatial search. Furthermore, to safeguard the health of the power battery and the integrity of the mission execution, a trap escape approach was also provided. Simulations are run to test the effectiveness of the suggested model based on the field DEM map. The simulation results show that our technology is capable of producing finished, plausible 3D paths with a high degree of believability. Additionally, the mode-switching point optimization method efficiently identifies additional acceptable places for mode switching, and the improved paths use less time and energy.

11:40-12:00 WeA3.3

Solving Vehicle Routing Problem for Unmanned Heterogeneous Vehicle Systems Using Asynchronous Multi-Agent Architecture (A-Teams), pp. 95-102

Ramasamy, Subramanian	University of Illinois at Chicago
Bhounsule, Pranav	University of Illinois at Chicago
Mondal, Mohammad Safwan	University of Illinois at Chicago
Humann, James D.	DEVCOM Army Research Laboratory
Reddinger, Jean-Paul	DEVCOM Army Research Laboratory
Dotterweich, James	DEVCOM Army Research Laboratory
Childers, Marshal	DEVCOM Army Research Laboratory

Fast moving but power hungry unmanned aerial vehicles (UAVs) can recharge on slow-moving unmanned ground vehicles (UGVs) to cooperatively perform tasks over wide areas. Such a cooperation can be achieved efficiently by solving a path planning problem. On top of solving a path planning problem, the problem of routing a heterogeneous set of vehicles in an optimal fashion is quite challenging. To solve the computationally expensive path-planning problem in a reasonable time, we created a two-level optimization approach with heuristics. At the outer level, the UGV route is parameterized by considering which set of locations to visit in the scenario and the UGV wait times to recharge UAVs and at the inner level, the UAV route is solved by formulating and solving a vehicle routing problem with capacity constraints, time windows, and dropped visits. The UGV free parameters need to be optimized judiciously to create high quality solutions. We explore two methods for tuning the free UGV parameters: (1) a Genetic Algorithm (GA), and (2) Asynchronous Multi-agent architecture (A-teams). The A-teams uses multiple agents to create, improve, and destroy solutions. The parallel asynchronous architecture enables A-teams to quickly optimize the parameters. Our results on test cases show that the A-teams produces similar solutions as GA but is 2-3 times faster.

12:00-12:20 WeA3.4

Manhole Detection and Traversal for Exploration of Ballast Water Tanks Using Micro Aerial Vehicles, pp. 103-109

Dharmadhikari, Mihir Rahul	Norwegian University of Science and Technology
De Petris, Paolo	Norwegian University of Science and Technology
Nguyen, Huan	Norwegian University of Science and Technology
Kulkarni, Mihir Vinay	Norwegian University of Science and Technology
Khedekar, Nikhil Vijay	Norwegian University of Science and Technology
Alexis, Kostas	Norwegian University of Science and Technology

This paper presents a method for the autonomous exploration of multiple compartments of a Ballast Water Tank inside a vessel using Micro Aerial Vehicles. Navigation across the compartments of ballast tanks often requires the robot to pass through narrow cross-section ``manholes'' (e.g., 0.8x0.6m). Hence, this work presents an algorithm to explicitly detect and localize such manholes using 3D LiDAR data and a strategy to reliably navigate through them to enable autonomous exploration of multiple compartments of the tank. Two ablation studies are presented analyzing the effective 3D space with respect to the manhole in which reliable detection takes place. Furthermore, the method is evaluated onboard a collision-tolerant aerial robot in two autonomous exploration experiments in relevant mock-up scenarios.

12:20-12:40 WeA3.5

Overview of UAV Trajectory Planning for High-Speed Flight, pp. 110-117

Rocha, Lidia	Federal University of Sao Carlos
Saska, Martin	Czech Technical University in Prague
Teixeira Vivaldini, Kelen Cristiane	Czech Technical University in Prague

The use of autonomous unmanned aerial vehicles has increased for High-Speed flights, leading to the need for improved performance. Trajectory planning is the primary approach to achieving high speeds, as it is safer and more flexible than other planning types. Some approaches include polynomial trajectories, optimization-based, search-based, sampling-based, and artificial intelligence, mainly reinforcement learning. This paper provides an overview of the main techniques for high-speed trajectory planning in UAVs and the challenges associated with them. It also describes essential UAV dynamics, control, and perception to reach high speeds. These techniques are demonstrated in several missions and environments, describing their methodologies. Finally, we discuss the open problems and potential future research directions in this field.

WeA4 Room 465

Simulation I (Regular Session)

Chair: De la Rosa Rosero, Fernando	Universidad De Los Andes
Co-Chair: Obidowski, Damian	Lodz University of Technology

11:00-11:20 WeA4.1

Variable Pitch Propeller - Blade Pitch Moment Computational Analysis, pp. 118-122

Podsedkowski, Maciej	Lodz University of Technology
Lipian, Michal	Lodz University of Technology
Obidowski, Damian	Lodz University of Technology

The paper presents the methodology of pitching moment prediction in drone rotors equipped with a variable pitch propeller. The proposed study describes extension of the available software like QPROP to calculate the blade pitching moment. The simulation results are validated with experimental data from the wind tunnel test and shows an example use of the proposed method. The research highlights potential applications where this analysis is crucial and where challenges of variable pitch propeller design might be solved with the proposed method.

11:20-11:40 WeA4.2

Preliminary Aerodynamic Simulation of a Flying Car Concept, pp. 123-128

Zhang, TingRui	Huazhong University of Science and Technology
Liu, Ying	Huazhong University of Science and Technology
Wu, Zhuoran	Huazhong University of Science and Technology
Li, Zidong	Huazhong University of Science and Technology
Ran, Shuo	Huazhong University of Science and Technology
Tian, Fengnian	Huazhong University of Science and Technology

The pursuit of flight has never ceased, and flying cars are gradually becoming a reality. However, only a few designs can accommodate both ground travel and aerial flight. As a result, aerodynamic research on flying cars is relatively scarce. This paper presents a novel concept of a flying car. The concept transforms between flight mode and vehicle mode through the rotation and folding of rotors and wings. Using aerodynamic simulation methods, the aerodynamic characteristics of the flying car in four states, including ground travel, single body, vertical take-off and landing, and forward flight, under different incoming flow speeds are studied. The simulation results provide guidance for the design of the flying car concept.

11:40-12:00 WeA4.3

Analysis of Aircraft Simulation Validity in Different Flight Conditions, pp. 129-136

Benyamen, Hady	University of Kansas
Mays, Benjamin	University of Kansas
Chowdhury, Mozammal	University of Kansas
Keshmiri, Shawn	University of Kansas
Ewing, Mark	University of Kansas

Rapid growth in unmanned aircraft systems (UAS) applications has resulted in exponential increase in the number of new but inexpensive aircraft. Open-source or engineering-level analysis software supports most of these designs and their dynamic analyses. This work analyzes the validity of a perturbed non-linear six-degree-of-freedom simulation of a fixed-wing UAS under six flight conditions. The aircraft model is developed using a component build-up method. Simulations are compared to flight data under different flight conditions: straight flight, level turn, ascending and descending flight. We additionally assessed the dynamic model accuracy when the aircraft was forced into loss of control. In another flight test, the commanded flight speed was reduced to coerce the aircraft into a stall. Unsupervised learning algorithms are used to classify flight data into different flight phases and to select flight portions for analysis. Monte Carlo (MC) simulations are performed to assess dynamic model accuracy while taking simulation parameter uncertainties into account. Results qualify uncertainty levels in predicted states and show that the base dynamic model can only capture aircraft's body rotation rate trends within some errors. The MC simulations mostly capture the flight rotation rates, however, in several instances, the flight data is not captured despite considering simulation parameter uncertainties.

12:00-12:20 WeA4.4

Indoor Vehicle-In-The-Loop Simulation of Unmanned Micro Aerial Vehicle with Artificial Companion, pp. 137-143

Hiba, Antal	SZTAKI Institute for Computer Science and Control
Körtvélyesi, Viktor	SZTAKI Institute for Computer Science and Control
Kiskaroly, Albert	SZTAKI Institute for Computer Science and Control
Bhoite, Omkar	SZTAKI Institute for Computer Science and Control
Dávid, Patrik	SZTAKI Institute for Computer Science and Control
Majdik, András L.	SZTAKI Institute for Computer Science and Control

Vehicle-in-the-loop simulation is an extension of the well-known hardware-in-the-loop technique, where a vehicle moves in real space while a simulator generates input for on-board sensors real-time. VIL frameworks designed for unmanned aerial vehicles have many open challenges. This paper introduces an indoor VIL for micro aerial vehicles in a drone arena equipped with precise positioning system and reliable wireless communication. This indoor setup stands as a prototype and predecessor for other outdoor VIL simulators for large scale applications. The raw optical navigation performance is tested which is the building block for sensor fusion and on-board fast sensor consistency check. A use-case of a companion drone in cooperative navigation is also presented.

12:20-12:40 WeA4.5

Virtual Reality and Human-Drone Interaction Applied to the Construction and Execution of Flight Paths, pp. 144-151

Sanchez Otalora, Nelson Andres	Universidad De Los Andes
Munera Davila, Santiago Felipe	Universidad De Los Andes
De la Rosa Rosero, Fernando	Universidad De Los Andes

This article presents a system architecture that integrates the construction, execution, and monitoring of three-dimensional flight paths for drones using virtual reality (VR). In this work, we propose a system that allows the construction and execution of flight paths by people who lack experience in drone piloting. For this purpose, the integration of two computational modules is introduced into the system architecture. On the one hand, the VR module allows the user to define three-dimensional flight paths in a VR scenario by using Human-Drone interactive techniques, while on the other hand, the Control module performs the supervised execution of these paths in an outdoor scenario using a smartphone that connects to a drone. Therefore, a system based on this architecture was developed and tested through two types of tests. The first one involves real user interaction to evaluate the usability of these computational modules (construction, execution and runtime monitoring of flight paths). The second type consists of precision tests that are carried out to evaluate the accuracy between the path planned in VR and the one executed in the real scenario.

WeA5 Room 466

UAS Applications I (Regular Session)

Chair: O'Brien, Richard	United States Naval Academy
Co-Chair: Dhami, Harnaik	University of Maryland

11:00-11:20 WeA5.1

Dynamic Graph Propagation for Performance-Based Tactical Conflict Resolution in Urban Air Mobility, pp. 152-158

Huang, Cheng	Cranfield University
Petrunin, Ivan	Cranfield University
Tsourdos, Antonios	Cranfield University

Tactical conflict management is a crucial issue for time-sensitive urban air mobility (UAM) operations, considering safety, security, and efficiency factors. To achieve real-time conflict resolution in structural UAM corridors, the operational environment is formulated as the graph structure, in which the edge connection is the available routes, and the node feature is collected from the flight states, e.g., arrival time, speed, arrival probability affected by uncertainties, and priority. To resolve the short-term conflict, the graph propagation solution is proposed to generate multiple augmented subgraph views based on the prescribed graph, where each subgraph represents one candidate action, e.g., speed adjustment, local re-routing. Information in each subgraph is then aggregated and assessed by the global cost metric. As the consequence, the final action is determined by ranking the cost values of all possible subgraph views. The study cases about the higher-priority intruder and non-cooperative intruder demonstrate the effectiveness of the proposed solution for eliminating the conflicts and reducing the additional cost.

11:20-11:40 WeA5.2

Unmanned Aerial Vehicles and Livestock Management: An Application in Western Crete, pp. 159-166

Sarantinoudis, Nikolaos	Technical University of Crete
Arampatzis, George	Technical University of Crete
Valavanis, Kimon P.	University of Denver
Tsourveloudis, Nikos	Technical University of Crete

In livestock industry, Unmanned Aerial Vehicles (UAVs) have the potential to revolutionize the way farmers manage animals, as they can be used for a wide variety of applications/reasons, such as herding, health monitoring and welfare of animals or even to detect nutrition deficiencies. This study focuses on an ongoing application of UAVs for livestock management in the island of Crete, taking into consideration the landscape morphology, the weather conditions and farmers' habits in the region. In addition to opportunities, we identify the advantages and challenges of using UAVs in sensitive ecosystems with several socioeconomic restrictions. Potential future research is also being discussed.

11:40-12:00 WeA5.3

How High Can You Detect? Improved Accuracy and Efficiency at Varying Altitudes for Aerial Vehicle Detection, pp. 167-174

Makrigiorgis, Rafael	University of Cyprus
Kyrkou, Christos	University of Cyprus
Kolios, Panayiotis	University of Cyprus

Object detection in aerial images is a challenging task mainly because of two factors, the objects of interest being really small, e.g., people or vehicles, making them indistinguishable from the background; and the features of objects being quite different at various altitudes. Especially, when utilizing Unmanned Aerial Vehicles UAVs) to capture footage, the need for increased altitude to capture a larger field of view is quite high. In this paper, we investigate how to find the best solution or detecting vehicles in various altitudes, while utilizing a single CNN model. The conditions for choosing the best solution are the following: higher accuracy for most of the altitudes and real-time processing (>20 Frames per second FPS)) on an Nvidia Jetson Xavier NX embedded device. We collected footage of moving vehicles from altitudes of 50-500 meters with a 50-meter interval, including a roundabout and rooftop objects as noise for high altitude challenges. Then, a YoloV7 model was trained on each dataset of each altitude along with a dataset including all the images from all the altitudes. Finally, by conducting several training and evaluation experiments and image resizes we have chosen the best method of training objects on multiple altitudes to be the mix-up dataset with all the altitudes, trained on a higher image size resolution, and then performing the detection using a smaller image resize to reduce the inference performance. The main results of the experiments and analysis are explained in this paper.

12:00-12:20 WeA5.4

Proportional Navigation-Based Guidance for an Autonomous Interdiction Mission against a Stationary Target, pp. 175-182

Choudhary, Aman	Indian Institute of Technology Madras
A, Vivek	Indian Institute of Technology Madras
Ghosh, Satadal	Indian Institute of Technology Madras

Due to the rapid increase of unmanned aerial vehicle (UAV) usage, the demand for efficient autonomous interdiction techniques to safeguard protected areas has become increasingly essential. This paper presents novel guidance strategies based on Proportional Navigation (PN) to interdict a stationary target using single and multiple unmanned aerial vehicles (UAVs). While the previous literature has primarily addressed controlling the terminal angle and achieving a desired final time separately for single-pursuer and multi-pursuer setups, designing guidance strategies to achieve both simultaneously poses a significant challenge. Although few existing literature endeavours to satisfy both constraints, they lack in guaranteeing an all-aspect approach. To this end, this paper's main contribution is enabling pursuers to achieve any terminal configuration starting from any initial orientation while satisfying the final time constraint by employing PN-based multi-phase guidance strategies in single and multiple pursuer setups. While the `Preparation phase' at the beginning and the `Final PPN phase' at the end help ensure the desired terminal orientation, the intermediate Roaming phase helps achieve the desired final time. Also, the guarantee on phase transitions and performance of the overall guidance schemes and conditions on achievable final time for the success of the developed guidance schemes are analyzed. Finally, using numerical simulations, the developed guidance algorithms are validated for single and multiple pursuer(s) environments considering realistic constraints.

12:20-12:40 WeA5.5

State-Aware Path-Following with Humans through Force-Based Communication Via Tethered Physical Aerial Human-Robot Interaction, pp. 183-190

Hallworth, Ben W.	ETH Zürich
Allenspach, Mike	ETH Zürich

Siegwart, Roland Y. ETH Zürich
Tognon, Marco Inria

The area of Aerial Physical Interaction has seen significant advancements, creating the opportunity for aerial robots to physically interact with humans. Our previous works established a framework for safe, human-aware path guidance via a tether, physically connecting a human to an aerial vehicle. However, the previous controller is purely reactive and does not leverage modern path-following methods. Further, its design does not properly account for the non-holonomic nature of the tethered human-robot system. In this paper we improved performance by addressing both problems. First, we incorporate modern path-following methods into our guidance framework to account for path geometry and current system velocity. Second, we propose a polar parametrization of the guidance law to achieve faster convergence of the guidance force to the desired value. Finally, the performance and human comfort of the different extensions is evaluated in simulation. The final method is shown to increase guidance accuracy and comfort, thereby increasing the usefulness of guidance via aerial robot interaction.

WeB1 Room 118

Risk Analysis (Regular Session)

Chair: Bertrand, Sylvain ONERA
Co-Chair: Dasari, Mohan University of Luxembourg

16:00-16:20 WeB1.1

Handling Uncertainties in Ground Risk Buffer Computation for Risk Assessment and Preparation of UAV Operations, pp. 191-198

Bertrand, Sylvain ONERA
Lala, Stephanie ONERA
Raballand, Nicolas ONERA

This paper proposes a method for computation of ground impact distance of Unmanned Aerial Vehicles (UAVs), in presence of uncertainties. Descent to ground is described as a sequence of different phases. For each phase, a model is derived to compute the ground distance travelled by the UAV. Uncertainties on different parameters or conditions can be handled by the proposed approach as well as their propagation through the sequence of computation models. It enables to estimate distribution of ground impact distances and help in designing the width of Ground Risk Buffers for UAV operations. An example of risk assessment involving this process is also proposed in the paper based on indexes derived from the SORA guidelines.

16:20-16:40 WeB1.2

Acquisition and Formalization of Knowledge to Ensure Safe Behaviour of Heterogenous Unmanned Autonomous Systems - an Interdisciplinary Approach, pp. 199-206

Sieber, Christoph Helmut Schmidt University Hamburg
Worpenberg, Christian Helmut Schmidt University Hamburg
Vieira da Silva, Luis Miguel Helmut Schmidt University Hamburg
Schuler-Harms, Margarete Helmut Schmidt University Hamburg
Fay, Alexander Helmut Schmidt University Hamburg

Unmanned Systems (US) increase their potential when combined into teams, so-called Multi-Robot-Systems (MRS). This potential can be maximized through heterogeneity among the different team members and autonomy of each individual US. At the same time, however, autonomy also constitutes a risk, as it means that the human being no longer retains total control. It is therefore important that all autonomous US within a MRS behave safely during operation. There are different verification techniques that are in principle suitable to ensure this safety. Despite their differences, they all have in common that they rely on an exhaustive and adequately formalized knowledge base of safety requirements to carry out a verification process. Safety-relevant knowledge that has not fully been acquired and formalized is thus not available for verification and is very difficult to integrate retrospectively. This paper presents an approach to acquire and formalize this knowledge in a methodical and objective manner. Applicable to different modalities (air, land water), this interdisciplinary approach allows to identify relevant legal regulations as sources of knowledge, to extract knowledge regarding the safe behavior of MRS from these regulations, to formalize this knowledge and to align and link it in a multimodal way. This generates a unified and formalized connecting point for different verification techniques to ensure the safe operation of heterogeneous MRS.

16:40-17:00 WeB1.3

Towards Requirements for Third-Party Assessments in the Specific Operations Risk Assessment Process, pp. 207-212

Heikkilä, Eetu VTT Technical Research Centre of Finland Ltd
Tiusanen, Risto VTT Technical Research Centre of Finland Ltd
Öz, Emrehan VTT Technical Research Centre of Finland Ltd

In the European regulatory regime, civil drone operations are divided into three risk-based categories. A large part of professional drone operations belongs to the specific category, in which authority approval is required to operate. The approval can be applied based on the Specific Operations Risk Assessment, SORA. Based on the risk level determined in SORA, the operation is subject to various safety requirements. Fulfilment of these requirements often calls for the involvement of competent third parties to assess various aspects of the operation. In this paper, we provide a structuring of the needs for third-party involvement in SORA. The study shows that currently there is very limited guidance for performing the third-party assessments or for determining requirements for organizations acting as competent third parties. Such requirements exist in other domains like manned aviation but to enable streamlined regulatory processes for safe drone operations, drone industry specific guidelines are needed. In this paper, we provide examples of standards and regulations that can be used as a basis for further development of the third-party assessment procedures.

17:00-17:20 WeB1.4

On SORA for High-Risk UAV Operations under New EU Regulations: Perspectives for Automated Approach, pp. 213-220

Habibi, Hamed University of Luxembourg
Dasari, Mohan University of Luxembourg

Sanchez-Lopez, Jose-Luis University of Luxembourg
Voos, Holger University of Luxembourg

In this paper, we investigate the requirements to prepare an application for Specific Operations Risk Assessment (SORA), regulated by European Union Aviation Safety Agency (EASA) to obtain flight authorization for Unmanned Aerial Vehicles (UAVs) operations and propose some perspectives to automate the approach based on our successful application. Preparation of SORA requires expert knowledge as it contains technicalities. Also, the whole process is an iterative and time-consuming one. It is even more challenging for higher-risk operations, such as those in urban environments, near airports, and multi- and customized models for research activities. SORA process limits the potential socio-economic impacts of innovative UAV capabilities. Therefore, in this paper, we present a SORA example, review the steps and highlight challenges. Accordingly, we propose an alternative workflow, considering the same steps, while addressing the challenges and pitfalls, to shorten the whole process. Furthermore, we present a comprehensive list of preliminary technical procedures, including the pre/during/post-flight checklists, design and installation appraisal, flight logbook, operational manual, training manual, and General Data Protection Regulation (GDPR), which are not explicitly instructed in SORA manual. Moreover, we propose the initial idea to create an automated SORA workflow to facilitate obtaining authorization, which is significantly helpful for operators, especially the scientific community, to conduct experimental operations.

WeB2 Room 130

Manned/Unmanned Aviation II (Regular Session)

Chair: Inoue, Roberto Santos — Universidade Federal De São Carlos
Co-Chair: Valavanis, Kimon P. — University of Denver

16:00-16:20 WeB2.1

Technological Certainties and Regulatory Doubts: An Overlook at Unmanned Aviation and Urban Air Mobility in Europe, pp. 221-228

Trimarchi, Andrea Università Di Verona

This paper explores the current status of regulation concerning unmanned aviation in Europe. In particular, the paper takes into consideration the technological and regulatory advancement pertaining to Urban Air Mobility (UAM), which is believed to revolutionise traditional air transport, as we currently know it. As the paper discusses, UAM does not only raise issues of a technical nature, but also, and more importantly, from a legal, sociological and economic perspective. In this context, for example, the use of drones in urban environments does lay emphasis on a necessary coordination between air traffic management (ATM) and unmanned traffic management (UTM), as well as on the need to regulate entirely new categories of aerospace infrastructures, such as vertiports or U-space.

16:20-16:40 WeB2.2

Enhanced Nonlinear Adaptive Control of a Novel Over-Actuated Reconfigurable Quadcopter, pp. 229-234

Derrouaoui, Saddam Hocine Ecole Supérieure Ali Chabati
Bouzid, Yasser Ecole Militaire Polytechnique
Belmouhoub, Amina University Mohamed El Bachir El Ibrahimi
Guiatni, Mohamed Ecole Militaire Polytechnique

In this paper, we address the control of a novel over-actuated reconfigurable quadcopter that can change its arms to different orientations, to form various configurations models and navigate in a crowded environment. An enhanced Adaptive Nonsingular Fast Terminal Sliding Mode Control (ANFTSMC) method is suggested to manage the impact of the external disturbances. A comparative study with the conventional Backstepping (BS) and Sliding Mode (SM) controllers is provided to illustrate and asses the efficiency of the designed approach.

16:40-17:00 WeB2.3

Preliminary Design and Prototype Development of an Air-Ground Carrier Platform, pp. 235-240

Chen, Tianlang Huazhong University of Science and Technology
Han, Jiaxue Huazhong University of Science and Technology
Wang, Jinglan Huazhong University of Science and Technology
Yan, Sitan Huazhong University of Science and Technology
Wan, Chieh Huazhong University of Science and Technology
Tian, Fengnian Huazhong University of Science and Technology

In recent years, amphibious or tri-amphibious UAVs have gradually received more attention. They have two or three loading methods, which can overcome the limitations of a single carrier method. Compared to existing amphibious or triphibious drones, this study presents a design for an air-ground carrier platform and has made a physical model. This study innovatively proposes a mechanical structure that uses a single lead screw and connecting rod mechanism to simultaneously drive four arms. Additionally, this study also proposes an integrated solution for the drone landing gear and vehicle chassis. This paper discusses the composition, working principle, sub-system structure, key functional design calculations, and field flight tests of the air-ground carrier platform. The results show that the air-ground carrier platform proposed in this study has a simple and reliable deformation structure. The modular drone and vehicle chassis reduces the later maintenance costs. This paper has important practical significance for the research and development of multi-mode drones.

17:00-17:20 WeB2.4

Incremental Nonlinear Dynamic Inversion Controller for a Variable Skew Quad Plane, pp. 241-248

De Ponti, Tomaso Maria Luigi Delft University of Technology
Smeur, Ewoud Delft University of Technology
Remes, Bart Delft University of Technology

This paper presents the design of an Incremental Nonlinear Dynamic Inversion (INDI) controller for the novel, patent pending (NL 2031701) platform Variable Skew Quad Plane (VSQP). Part of the identified challenges is the development of a model for the actuator effectiveness and lift especially as a function of skew, the newly added degree of freedom. The models and assumptions are verified through static and dynamic wind tunnel tests at the Open Jet Facility (OJF) of TU Delft. Transition tests have been successfully performed

thanks to an automatic skew controller derived from the proposed models and aimed to maximize control authority.

WeB3	Room 464
Path Planning II (Regular Session)	
Chair: Kim, Youngjoo	Nearthlab Inc
Co-Chair: Zhang, Youmin	Concordia University

16:00-16:20	WeB3.1

Wind-Aware Path Optimization for an Aerobot in the Atmosphere of Venus Using Genetic Algorithms, pp. 249-256

Puigvert I Juan, Anna — West Virginia University
Martinez Rocamora Junior, Bernardo — West Virginia University
Pereira, Guilherme — West Virginia University

This paper presents a path optimization solution for an autonomous aerial robot (aerobot) in the windy atmosphere of Venus. The aircraft is required to travel from its current position to a goal position by following minimum energy paths. The approach proposed in this paper uses genetic algorithms, a heuristic search that, based on a population of initially feasible paths and a set of biologically inspired operations, finds a low-cost path. The proposed cost function accounts for energy expenditure, such as thrust or drag, and also energy accumulation, such as charging with solar panels and gains from potential energy (e.g., due to upward directional winds). Path feasibility is assured by computing local reachability regions based on the wind velocity and the maximum speed of the aerobot. The method is illustrated through a series of simulations that show our results as a function of the number of iterations and path population sizes.

16:20-16:40	WeB3.2

A Multi-Objective Approach for Unmanned Aerial Vehicle Mapping, pp. 257-264

Moltajaei Farid, Ali — University of Regina
Mouhoub, Malek — University of Regina

Many commercial applications require aerial mapping with multiple UAVs. Mapping is a mission planning problem which requires meeting a set of constraints while optimizing key factors that may conflict with each other, such as fuel/battery consumption, make-span, and the associated risks. Solving this Multi-Objective Optimization (MOO) will therefore result in a set of trade-offs (Pareto optimal solutions) that will be supplied to a decision-maker. Given that the Pareto set can be of a very large size, we propose a Multi-criteria Decision Making (MCDM) system that relies on user's preferences to bring down this set to a manageable size. More precisely, the proposed system captures user's qualitative preferences and uses them through the Fuzzy Vikor to filter and rank Pareto optimal solutions. The designed system is able to work with both or either fixed-wing and multi-rotor UAVs. To evaluate the performance of our system, we conducted a set of experimental simulations considering several scenarios. The findings show that fixed-wing UAVs have higher energy consumption and mission time than multi-rotors due to Dubin's turns, assuming both types have the same charging/fueling endurance and the same velocity. Lastly, it is found that heterogeneity will not always lead to a better mission duration than homogeneous UAV fleets.

16:40-17:00	WeB3.3

Coordinated Multi-Robot Exploration Using Reinforcement Learning, pp. 265-272

Mete, Atharva — University of Regina
Mouhoub, Malek — University of Regina
Moltajaei Farid, Ali — University of Regina

Exploring an unknown environment by multiple autonomous robots is a long-studied problem in robotics. The agents need to coordinate the exploration to minimize the overlapping region and avoid interference with each other. This is particularly challenging in decentralized execution, where no central system guides the exploration. In such scenarios, agents need to incorporate temporal planning and the intentions of other agents into the decision-making process. In this work, we focus on several challenges involved in multi-robot exploration in unseen, unstructured, and cluttered environments. Consequently, we propose a Multi-Agent Reinforcement Learning (MARL) based framework wherein agents learn the effective strategy to allocate and explore the environment. We evaluate the performance of our proposed framework in terms of average distance traveled, percentage of overlapping region, and the rate of exploration against a classical approach.

17:00-17:20	WeB3.4

Urban Air Mobility Trajectory Planning, pp. 273-280

Exadaktylos, Stylianos — University of Cyprus
Vitale, Christian — University of Cyprus
Kolios, Panayiotis — University of Cyprus
Ellinas, Georgios — University of Cyprus

The world's population in urban areas has been increasing rapidly during the last few decades and is expected to continue to grow over the near future. With this major population increase, traffic congestion is expected to worsen significantly in urban areas, and creative solutions will be required for addressing this problem, which has a considerable environmental, economic, and societal impact on the urban population. Urban air mobility could be such an innovative solution. This work introduces urban air mobility trajectory planning, where classical receding horizon optimizations are extended to satisfy on-demand planning of safe trajectories for the aerial vehicles in large and dense environments. Specifically, for reducing the overall problem complexity, a new parameter, i.e., the safety horizon, is introduced and, to model accurately aerial vehicle location uncertainty, a mixed integer quadratic optimization problem is proposed. Extensive simulations are performed to demonstrate the applicability of the proposed framework for on-demand mobility planning in urban environments.

WeB4	Room 465
Simulation II (Regular Session)	
Chair: Rafee Nekoo, Saeed	Universidad De Sevilla
Co-Chair: Manoharan, Amith	University of Tartu

16:00-16:20	WeB4.1

Constrained Design Optimization of a Long-Reach Dual-Arm Aerial Manipulator for Maintenance Tasks, pp. 281-288

Rafee Nekoo, Saeed — Universidad De Sevilla
Suarez, Alejandro — Universidad De Sevilla
Acosta, Jose Angel — Universidad De Sevilla
Heredia, Guillermo — Universidad De Sevilla
Ollero, Anibal — Universidad De Sevilla

Motivated by the convenience of improving the performance of long-reach aerial manipulators in the realization of maintenance tasks on high-voltage power lines, this paper proposes a constrained design optimization method for dual-arm aerial manipulators intended to reduce the weight while increasing the workspace of the robot. This configuration, in which the arms are separated from the aerial platform through a long reach link similar to a pendulum, improves safety in the interaction with human workers, reduces the electromagnetic interference of high voltage power lines on the electronics, as well as the aerodynamic downwash effect due to the propellers. However, the long-reach link introduces undesired vibrations on the manipulator due to its flexibility, so its length imposes a trade-off between the safety of operation as a positive side-effect and vibration as a negative one. Therefore, the cost function in the optimization problem also accounts for this factor, limiting the vibration to a fixed predefined value. A recent optimization approach is used here to minimize the cost function and solve the problem, verified by particle swarm optimization as a basis to confirm the correctness of the obtained data.

16:20-16:40	WeB4.2

Improved Path Planning Algorithm of an Informed RRT Algorithm in 3D Space, pp. 289-296

Tian, Haowen — National University of Singapore
Huang, Sunan — National Universtiy of Singapore
Wang, Pengfei — National University of Singapore
Xiang, Cheng — National University of Singapore
Cao, Jiawei — National University of Singapore
Teo, Rodney — National University of Singapore

The main purpose of drone flight is to find an optimal path without colliding with obstacles. The key point is to design a search algorithm. Path planning for searching a 2-dimensional (2D) map has been studied extensively and reached a mature stage. For a higher-dimensional configuration space, it is quite challenging. In this paper, the sampling-based path planning method is proposed. It uses rapidly exploring random trees (RRT) concept. An improved guidance is proposed for reducing the search space in the present algorithm in a 3D clutter environment. Simulation is given to show the effectiveness of the proposed method.

16:40-17:00	WeB4.3

Multi-Agent Target Defense Game with Learned Defender to Attacker Assignment, pp. 297-304

Manoharan, Amith — University of Tartu
Thakur, Prajwal — University of Tartu
Singh, Arun — University of Tartu

This paper considers a variant of pursuit-evasion games where multiple attackers unmanned aerial vehicles (UAVs) are trying to converge on a target. The goal is to use a set of defender UAVs to save the target by ensuring they converge on the attackers before the latter converge to the target. The core challenge lies in appropriately assigning a particular defender to an attacker. The simple heuristic assignment based on Euclidean distance between the attacker and defender performs poorly. This paper presents a data-driven solution assuming that the attacker uses a known optimal control policy. We show how massive offline simulations can be leveraged to predict the optimal cost/value function incurred by the defender to converge on an attacker for a given target trajectory. We use this optimal cost/value function as a true measure of separation between an attacker and a defender. We use it as the guiding heuristic in the Hungarian algorithm for computing defender-attacker assignments. We perform extensive simulations to validate our approach wherein we couple the learned assignment with a non-linear model predictive controller to perform realistic simulations. We show that our assignment approach outperforms that based on the Euclidean heuristic in terms of the number of successful attempts by the defenders.

17:00-17:20	WeB4.4

Path Gain and Channel Capacity for HAP-To-HAP Communications, pp. 305-312

Yilmaz, Atakan — Hacettepe University
Yılmaz, Nihan — Hacettepe University
Kalem, Gokhan — Turkcell Technology
Durmaz, Mehmet Akif — Turkcell Technology

High Altitude Platforms (HAPs), which are unmanned aerial vehicles (UAV) to provide communication services at high altitudes, are alternative cutting edge communication technologies which combine the benefits of satellite and terrestrial communication systems. HAP systems have several key benefits including simple deployment, reconfigurability, low operating costs, low propagation delay, high elevation angles, wide coverage, broadcast capability and mobility in several scenarios. In this study, we focused on a channel model analysis between HAPs to calculate the channel capacity for a HAP-to-HAP communication link using a model that takes into account the antenna radiation pattern, the effects of atmospheric gases, rain, and cloud/fog, and also the polarization mismatches of the transmitting and receiving antennas. With the simulation results, we demonstrated the path gain characteristics and the channel capacity of the high-altitude air-to-air channel for various scenarios depending on different antenna types, platform altitudes, carrier frequencies, etc. Lastly, we mentioned a future work representing a real-life use case which is also appropriate to apply this method.

WeB5	Room 466
UAS Applications II (Regular Session)	

Chair: Gonzalez, Luis Felipe — Queensland University of Technology

Co-Chair: Kandath, Harikumar — International Institute of Information Technology Hyderabad

16:00-16:20 — WeB5.1

Efficient UAS Sensor Mounting Using Contact Force Feedback, pp. 313-319

Kalaitzakis, Michail — University of South Carolina
Kosaraju, Bhanuprakash — University of South Carolina
Vitzilaios, Nikolaos — University of South Carolina

Uncrewed Aircraft Systems (UAS) are becoming widely used in the inspection of structures. While in most applications, the UAS are used for remote contactless inspections, there are cases where the UAS need to contact the structure and do a measurement or deliver a sensor package. In this paper, we work on the autonomous deployment and retrieval of sensor packages to the underside of structures. The accurate positioning and reliable mounting of the package below a structure is a challenging problem. Based on our prior work in the field, we develop a new control and mission framework that takes into account the estimated contact force to ensure that the package is firmly attached during deployment and securely retrieved when the mission ends. The new system has been thoroughly tested in numerous lab experiments that mimic the conditions of an outdoor setting, and experimental results show that the new approach greatly increases the reliability of the system.

16:20-16:40 — WeB5.2

Drones Practicing Mechanics, pp. 320-327

Uppaluru, Harshvardhan — University of Arizona
Rastgoftar, Hossein — University of Arizona
El Asslouj, Aymane — University of Arizona
Ghufran, Mohammad — University of Arizona

Mechanics of materials is a traditional engineering course that exposes undergraduate students in a variety of engineering fields to the principles of strain and stress analysis. However, material deformation and strain have been evaluated theoretically, numerically, and empirically tested using expensive machinery and instruments. This article describes a novel method for analyzing strain and deformation using quadrotors. We propose to treat quadrotors as a finite number of particles of a deformable body and apply the principles of continuum mechanics to illustrate the concept of axial and shear deformation in 2-D and 3-D motion spaces. The outcome from this work has the potential to significantly impact undergraduate education by bridging the gap between classroom instruction and hardware implementation and experiments using quadrotors. Therefore, we introduce a new role for quadrotors as "teachers," which provides an excellent opportunity to practice theoretical concepts of mechanics in a productive way.

16:40-17:00 — WeB5.3

A Signal Temporal Logic Planner for Ergonomic Human–Robot Collaboration, pp. 328-335

Silano, Giuseppe — Czech Technical University in Prague
Afifi, Amr — University of Twente
Saska, Martin — Czech Technical University in Prague
Franchi, Antonio — University of Twente

This paper proposes a method for designing human-robot collaboration tasks and generating corresponding trajectories. The method uses high-level specifications, expressed as an Signal Temporal Logic (STL) formula, to automatically synthesize task assignments and trajectories. To illustrate the approach, we focus on a specific task: a multi-rotor aerial vehicle performing object handovers in a power line setting. The motion planner considers limitations, such as payload capacity and recharging constraints, while ensuring that the trajectories are feasible. Additionally, the method enables users to specify robot behaviors that take into account human comfort (e.g., ergonomics, preferences) while using high-level goals and constraints. The approach is validated through numerical analyzes in MATLAB and realistic Gazebo simulations using a mock-up scenario.

17:00-17:20 — WeB5.4

Towards Safe Operations in Urban Environments with UAVs, pp. 336-342

Caballero González, Rafael — Center for Advanced Aerospace Technologies
Jiménez Cámara, Pablo — Center for Advanced Aerospace Technologies
Perez-Grau, Francisco Javier — Center for Advanced Aerospace Technologies
Viguria, Antidio — Center for Advanced Aerospace Technologies
Ollero, Anibal — Universidad De Sevilla

The incorporation of uncrewed aerial vehicles (UAV) in urban environments is expanding with countless applications currently under development or even in prototype phase. The industry is facing many challenges, not only technological but also at the regulatory level, as flying in urban environments poses a significant challenge at the bureaucratic and regulatory levels. In this paper, we contribute to mitigating both challenges, showing, on the one hand, the process of obtaining permits to perform flights in a city and the publication of the data obtained with the sensors onboard the UAV for the benefit of the community. Also, to improve operations' safety in urban environments, we propose an obstacle detection algorithm with the data obtained.

WeC1 — Foyer Area

Poster Paper Session (Poster Session)

Chair: Nascimento, Tiago — Czech Technical University in Prague
Co-Chair: Teixeira Vivaldini, Kelen Cristiane — Czech Technical University in Prague

17:30-19:00 — WeC1.1

Assessing the Impact of Soil Contamination on Maize Plant Development Using UAV-Based Multispectral Indices, pp. 343-348

Gargiulo, Massimiliano — Italian Aerospace Research Centre

Savarese, Claudia — Italian Aerospace Research Centre
Tufano, Francesco — Italian Aerospace Research Centre
Parrilli, Sara — Italian Aerospace Research Center
Verrillo, Mariavittoria — Università Di Napoli Federico II
Cozzolino, Vincenza — Università Di Napoli Federico II
Piccolo, Alessandro — Università Di Napoli Federico II
De Mizio, Marco — Italian Aerospace Research Centre

Contamination of the environment with toxic substances is a critical issue. Remote sensing data acquisition using small UAVs equipped with multispectral sensors, provides high-resolution data without the need for destructive samples and can detect plant distress before visible symptoms appear. This study examines the impact of potentially toxic elements (PTEs) and polycyclic aromatic hydrocarbons (PAH) soil contamination on the development of maize plants using these types of data. The findings of this work highlight the usefulness of UAV-based multispectral analysis in predicting characteristic changes of the plants caused by soil changes, providing valuable information for improving environmental monitoring efficiency.

17:30-19:00 WeC1.2

Autonomous Control of UAV for Proximity Tracking of Ground Vehicles with AprilTag and Feedforward Control, pp. 349-353

Yi, JunHak — Chung-Ang University
Lee, Donghee — Chung-Ang University
Park, Wooryong — Chung-Ang University
Byun, Woohyun — Chung-Ang University
Huh, Soobin — Chung-Ang University
Nam, Woochul — Chung-Ang University

Recently, various tracking flight techniques of unmanned aerial vehicle (UAVs) have been developed and used in various applications. However, a proximity tracking flight is still challenging because accurate estimation of the position and velocity of a target ground vehicle (GV) is difficult. This paper presents an autonomous UAV system that can fly close to GVs. If the relative position between the UAV and GV was used for flight control and velocity was not used, the tracking can be unsuccessful. To address this issue, the speed of the ground vehicle was also estimated, and it was feedforwarded into the control loop. Real flight experiments showed that this approach greatly improved the tracking performance; the UAV tracked the GV driving at approximately 4 m/s with an average displacement error of less than 1 m.

17:30-19:00 WeC1.3

Autonomous Soaring Simulation and Glider System Development, pp. 354-359

Jacobs, Stephen — West Virginia University
Gu, Yu — West Virginia University

One major limitation of small battery-powered aerial vehicles is short endurance due to the limitations of battery technology. In its constant motion, the atmosphere contains the energy needed for soaring birds, paragliders, and sailplane pilots to stay aloft during many weather conditions. Over the last 20 years, several researchers have developed small unmanned autonomous thermal soaring gliders designed to exploit rising air in the atmosphere to improve aircraft endurance. In this paper, a survey of autonomous soaring systems is provided. Additionally, a simulation architecture that allows for safe high-fidelity testing is described, a control scheme is proposed along with results from the simulation, a hardware solution is detailed, and several flight tests of the system are presented. Initial testing in simulation shows successful mission behavior such as autonomous take off, climb-out, loitering, and waypoint flying. Preliminary simulations show successful thermal soaring behavior. Initial flight test results demonstrate basic autonomous capabilities and indicate system readiness for future testing.

17:30-19:00 WeC1.4

Bandwidth-Aware Coverage Path Planning for Swarm of UAVs with Aerial Base Station, pp. 360-365

Choi, Uihwan — Electronics and Telecommunications Research Institute
Lee, Soojeon — Electronics and Telecommunications Research Institute

Coverage path planning (CPP) by multiple UAVs has been widely studied for its advantage in wide-area searches. For time-critical missions, a swarm of UAVs equipped with a high-resolution camera can be used to transmit live video streams to a ground control station (GCS). However, as the number of UAVs increases, communication between GCS and the UAVs becomes a challenge due to limited channel bandwidth. This paper presents a bandwidth-aware coverage path planning algorithm for UAV swarm that utilizes an aerial base station to efficiently handle the bandwidth limitations while ensuring aerial video quality, as measured by ground sample distance (GSD). By the proposed method, bandwidth-aware mission altitude and width for swarm CPP are found. The effectiveness of the proposed approach is demonstrated through simulations under various scenarios.

17:30-19:00 WeC1.5

Communications-Aware Robotics: Challenges and Opportunities, pp. 366-371

Bonilla Licea, Daniel — Czech Technical University in Prague
Silano, Giuseppe — Czech Technical University in Prague
Ghogho, Mounir — Czech Technical University in Prague
Saska, Martin — Czech Technical University in Prague

The use of Unmanned Ground Vehicles (UGVs) and Unmanned Aerial Vehicles (UAVs) has seen significant growth in the research community, industry, and society. Many of these agents are equipped with communication systems that are essential for completing certain tasks successfully. This has led to the emergence of a new interdisciplinary field at the intersection of robotics and communications, which has been further driven by the integration of UAVs into 5G and 6G communication networks. However, one of the main challenges in this research area is how many researchers tend to oversimplify either the robotics or the communications aspects, hindering the full potential of this new interdisciplinary field. In this paper, we present some of the necessary modeling tools for

addressing these problems from both a robotics and communications perspective, using the UAV communications relay as an example.

17:30-19:00 WeC1.6

Comparing DNN Performance to Justify Using Transference of Training for the Autonomous Aerial Refuelling Task, pp. 372-376

Miller, Dillon — United States Naval Academy
Mwaffo, Violet — United States Naval Academy
Costello, Donald — United States Naval Academy

To modernize the fleet, the United States Navy is looking to significantly increase the number of unmanned aircraft deployed within a carrier air wing. Yet, no method to certify the autonomous refuelling of uncrewed aerial platforms has been publicly released. Ongoing research efforts at the United States Naval Academy (USNA) are investigating certification evidence that will allow a deep neural network (DNN) to enable the autonomous aerial refuelling task. This poster paper highlights an investigation into developmental flight test videos of an aircraft refuelling from a KC-130 tanker and from a tanker configured F/A-18 jet. In this paper, we evaluate a KC-130 trained DNN and a F/A-18 trained DNN against a F/A-18 data set that was not used in training either DNN. This procedure was aimed at determining whether the resources required to gather training data on each tanker aircraft taken separately are justified or if the performance of the DNN trained on a similar aircraft dataset is sufficient for the task.

17:30-19:00 WeC1.7

Development of a Control Framework to Autonomously Install Clip Bird Diverters on High-Voltage Lines, pp. 377-382

D'Angelo, Simone — Università Di Napoli Federico II
Pagano, Francesca — Università Di Napoli Federico II
Ruggiero, Fabio — Università Di Napoli Federico II
Lippiello, Vincenzo — Università Di Napoli Federico II

Autonomous inspection and maintenance tasks with unmanned aerial vehicles on high-voltage lines require moving in a structured environment and detecting the object to interact with. A preliminary control framework for the autonomous installation of clip bird diverters on high-voltage lines is presented in this paper. The sketched framework shows initial designs and results and underlines functionalities to be developed in the future. The idea has been validated in simulation (employing the Gazebo software endowed with a physics engine) through a drone equipped with a 6-degree-of-freedom robotic arm and in real experiments through a drone equipped with a sensorized stick to be compliant with the environment. This last successfully inserted the bird diverter device on a mock-up structure with minimal disturbances on the aerial platform.

17:30-19:00 WeC1.8

Ensuring Accuracy in Auto-Bounding Box Generation for the Autonomous Aerial Refuelling Mission, pp. 383-388

Doherty, Charles — United States Naval Academy
Costello, Donald — United States Naval Academy
Kutzer, Michael — United States Naval Academy

The United States Navy has a vested interest in developing methods for the certification of autonomous aerial refuelling by uncrewed aircraft. For leadership to accept the risk of allowing an uncrewed platform to act as the receiver for autonomous aerial refuelling there needs to be standards and methods of compliance for allowing an uncrewed platform to complete the task. The United States Naval Academy, with the support of the Office of Naval Research, has begun a line of research into developing certification evidence that will enable an uncrewed aircraft to complete the autonomous aerial refuelling task. This line of research assumes the use of a deep neural network to properly identify the refuelling drogue and coupler. As with most items revolving around training a neural network, they will only perform as well as the labelled data set that was used to train them. The United States Naval Academy has focused on generating large data sets for this line of research through auto-labelling techniques. This paper highlights the generation of one of those data sets and details a follow-on effort for improving the technique.

17:30-19:00 WeC1.9

Heterogeneous Multi-Robot Systems Approach for Warehouse Inventory Management, pp. 389-394

Sales, Augusto Vinicius — Universidade Federal Da Paraiba
Mira, Pedro — Universidade Federal Da Paraiba
Nascimento, Ana Maria P.S. — Universidade Federal Da Paraiba
Brandao, Alexandre Santos — Universidade Federal De Viçosa
Saska, Martin — Czech Technical University in Prague
Nascimento, Tiago — Czech Technical University in Prague

In conjunction with the growth of automated warehouses, a logistical problem also increases. The automated inventory counting problem emerges from the difficulty of managing the products of these large distribution centers. Usually, these centers have long corridors and high shelves with many different products. To solve this problem, this work proposes an approach of a highly scalable low-cost plug-and-play multi-robot system for inventory management. Our approach is composed of a set that includes a micro-drone, an embedded camera module, and a ground mobile robot. In our tests, two situations are analyzed: first with one heterogeneous multi-robot system set and a second situation with two heterogeneous multi-robot system sets. The results demonstrate the advantage of having the interconnected multi-robot system to reduce the time of the inventory management task.

17:30-19:00 WeC1.10

Mixed Reality Human-Robot Interface to Generate and Visualize 6DoF Trajectories: Application to Omnidirectional Aerial Vehicles, pp. 395-400

Allenspach, Mike — ETH Zürich
Laasch, Severin — ETH Zürich
Lawrance, Nicholas — ETH Zürich
Tognon, Marco — ETH Zürich

Siegwart, Roland Y. ETH Zürich

Omnidirectional aerial vehicles are an attractive tool for automated inspection tasks. Planning suitable trajectories in industrial environments is not trivial though and often requires human input. Existing trajectory planning tools generally rely on prior and accurate models of both the environment and the vehicle. Furthermore, their common 2D visualization for human operators is generally unsuitable for intuitive understanding of motions in SE(3). In this work, we exploit Mixed Reality to improve and simplify mission planning, by allowing the user to generate and perceive a trajectory directly in the real environment. The operator can precisely and intuitively plan a dynamically feasible 6DoF trajectory by adding and modifying waypoints. Each waypoint is visualized as a holographic representation of the physical robot including the camera frustum for visual inspection tasks. Dynamic and static holograms corresponding to spatial and temporal information of the resulting trajectory are also overlaid onto the real world, allowing an operator to quickly assess potential collisions and inspection coverage. We experimentally demonstrate the effectiveness of the developed application and indicate its efficiency based on related work. The encouraging results motivate future quantitative evaluations in the form of user studies.

17:30-19:00 WeC1.11

Multirotor Motion Enhancement Using Propeller Speed Measurements, pp. 401-406

Awad, Heba Abdelnasser — Imperial College London
Heggo, Mohammad — Imperial College London
Pang, Oscar — Imperial College London
Kovac, Mirko — Imperial College London
McCann, Julie — Imperial College London

Multirotor autopilots often depend on open-loop control without the feedback of propeller speeds, although they are a critical factor in determining motion characteristics. This paper proposes a system that leverages actual propeller speeds as direct feedback to the autopilot to improve the state estimation and dynamics of the multirotor. Software-in-the-Loop (SITL) and Hardware-in-the-Loop (HITL) simulations with real data, in different scenarios, are conducted to demonstrate the impact of combining propeller speeds with typical drone sensors. The results show that the drone becomes more stable with lower trajectory errors. Further, a noticeable reduction in the vehicle position median error while following a trajectory is shown, and a considerable increase in the flying duration time before crashing in case of a motor fault. These results highlight the potential of adding propeller speed feedback to increase the autopilot's controllability which enhances drone performance in sensitive applications.

17:30-19:00 WeC1.12

Quadcopter Capable of Autonomously Chasing Micro-Aircraft with Real-Time Visual Tracker, pp. 407-412

Lee, Donghee — Chung-Ang University
Park, Wooryong — Chung-Ang University
Yi, JunHak — Chung-Ang University
Byun, Woohyun — Chung-Ang University
Huh, Soobin — Chung-Ang University
Nam, Woochul — Chung-Ang University

It is difficult for unmanned aerial vehicles to chase another micro-aircraft (MA) due to the small size and its fast manoeuvrability. Thus, this study developed a fast and accurate visual tracker for real-time inference. Then, a quadcopter was controlled to chase a target MA by considering the result of the visual tracker. Specifically, the pitch, throttle, and yaw of the quadcopter were determined by the PD controller based on the position, and the size of the MA in the image. The newly developed visual tracker comprises an adaptive search region (SR) and a fully convolutional neural network. The size and the location of the SR were constantly adjusted over image frames by considering the tracking result of the MA in previous frames. Furthermore, if the size and the location of the SR are not precise enough, the SR was updated to minimize the tracking failure. Performance of the SR was improved by using the Kalman filter. In real flight experiments, the quadcopter equipped with the proposed model successfully chased the MA which randomly moved at approximately 5 m/s.

17:30-19:00 WeC1.13

Spatial Mapping of Light Aircraft with Stereo Vision Camera for Use on Unmanned Aircraft System for Defect Localisation, pp. 413-418

Connolly, Luke — South East Technological University
O'Gorman, Diarmuid — South East Technological University
Garland, James — South East Technological University
Tobin, Edmond — South East Technological University

Spatial mapping creates a 3D reconstruction of a visualised area to reproduce a perception of the environment. This can be applied in robotics for manoeuvring in environments where Global Navigation Satellite Systems (GNSSs) are inaccessible. Such devices capable of spatial mapping are stereo-vision cameras. These cameras possess two or more image sensors, simulating human binocular vision and giving it the ability to perceive depth. Using this hardware on an Unmanned Aircraft System (UAS) introduces new capabilities for autonomous navigation and unmanned control. This, in turn, introduces new possibilities for application. Such a use case would be for a General Visual Inspection (GVI) of aircraft in a hangar environment where access to GNSS is limited. Providing a flight plan to a UAS with a stereo-vision camera to assist with collision avoidance and to keep a consistent distance from the aircraft would provide a robust system for defect detection and localisation during a GVI.

17:30-19:00 WeC1.14

The Gannet Solar-VTOL: An Amphibious Migratory UAV for Long-Term Autonomous Missions, pp. 419-424

Carlson, Stephen — University of Nevada - Reno
Moore, Brandon — University of Nevada - Reno
Karakurt, Tolga — University of Nevada - Reno
Arora, Prateek — University of Nevada - Reno
Cooper, Tyler — University of Nevada - Reno

Papachristos, Christos University of Nevada - Reno

Vertical Take-Off and Landing (VTOL) Unmanned Aerial Vehicles (UAVs) provide a versatile platform well-suited to applications requiring the efficiency of fixed-wing flight with the manoeuvrability of a multicopter. Prior work has introduced the concept of using solar energy harvesting using photovoltaic cells embedded in the wings of the vehicle to perform self-recharge in the field when landed and at rest. This work demonstrates a further extension of this concept by optimizing the VTOL aircraft for maximum input-to-output power ratio, such that continuous flight is possible for the majority of a typical day with good sunlight. By also adding amphibious design elements, a transoceanic flight cycle is proposed. The candidate aircraft design is shown with estimated and actual behavioural and performance data for hovering and forward flight. Artwork for design elements such as the tiltrotor nacelle design and interchangeable avionics pod are shown.

ThA1 Room 118

Sensor Fusion (Regular Session)

Chair: Inoue, Roberto Santos — Universidade Federal De São Carlos

Co-Chair: Hamanaka, Masatoshi — RIKEN Center for Advanced Intelligence Project

09:00-09:20 ThA1.1

Systolic Array for Parallel Solution of the Robust Kalman Filter Used for Attitude and Position Estimations in UAVs, pp. 425-432

Campos, Leandro José Evilásio — Universidade Federal De São Carlos
Terra, Marco Henrique — Universidade Federal De São Carlos
Menotti, Ricardo — Universidade Federal De São Carlos
Inoue, Roberto Santos — Universidade Federal De São Carlos

The efficient Kalman filter has been widely used in recent decades to obtain air navigation information in UAVs. However, for a good performance of the Kalman filter, the model that describes the system dynamics must not contain uncertainties. This paper presents the implementation of a robust Kalman filter to estimate the attitude, velocity, and position of UAVs. The robust filter considers uncertainties in the sensor models. A mathematical structure based on the solution of linear systems synthesizes the predictor-corrector robust estimation algorithm. The main contribution of this study is the proposed QR decomposition based on Givens rotation to solve the linear system. The simulated experiments used sensory data collected in Zurich-Switzerland and ground truth referencing attitude, velocity, and position. The offline simulation results express the effectiveness of the robust Kalman filter for this application, with a reduction of up to 18.9% in the estimation error, in relation to the standard Kalman filter. The proposal to use systolic arrays for numerical solutions has shown promise for implementation in parallel processing platforms, such as FPGAs.

09:20-09:40 ThA1.2

Improving Resolution in Deep Learning-Based Estimation of Drone Position and Direction Using 3D Maps, pp. 433-440

Hamanaka, Masatoshi — RIKEN Center for Advanced Intelligence Project

We propose a method to improve the resolution of drone position and direction estimation on the basis of deep learning using three-dimensional (3D) topographic maps in non-global positioning system (GPS) environments. GPS is typically used to estimate the position of drones flying outdoors. However, it becomes difficult to estimate the position if the signal from GPS satellites is blocked by tall mountains or buildings, or if there are interference signals. To avoid this loss of GPS, we previously developed a learning-based flight area estimation method using 3D topographic maps. With this method, the flight area could be estimated with an accuracy of 98.4% in experiments conducted in 25 areas, each 40 meters square. However, a resolution of 40 meters square is difficult to use for drone control. Therefore, in this study, we will verify whether it is possible to improve the resolution by multiplexing the area division and the data acquisition direction. We also investigated whether the flight direction of the drone can be detected using a 3D map. Experimental results show that the position estimation was 96.8% accurate at a resolution of 25 meters square, and the direction estimation was 92.6% accurate for 12-direction estimation.

09:40-10:00 ThA1.3

A Robust and Adaptive Sensor Fusion Approach for Indoor UAV Localization, pp. 441-447

Sajjadi, Sina — Toronto Metropolitan University
Bittick, Jeremy — Toronto Metropolitan University
Janabi Sharifi, Farrokh — Toronto Metropolitan University
Mantegh, Iraj — National Research Council Canada

Localization of unmanned systems in indoor environments is challenging. The fundamental challenge with indoor localization and navigation is that the Global Navigation Satellite Systems (GNSS) signal is either unavailable or not sufficiently accurate for state estimation. Unmanned agents also commonly must navigate through unstructured environments, which can be challenging given the absence of recognizable landmarks or patterns. Furthermore, in dynamic environments where the layout or obstacles may change frequently, the drone may need to continuously update its state estimations. In the absence of GNSS measurements, unmanned systems rely on other onboard sensors for localization. However, each set of sensors contains its own associated uncertainty and/or the possibility of occlusion or malfunction. Hence, the design and development of reliable multi-sensor fusion algorithms for localization are deemed necessary. This paper presents the implementation and performance evaluation of an adaptive and robust Moving Horizon Estimator (MHE) for improving the state estimation of a previously developed indoor localization framework using ArUco markers. The effectiveness of the proposed sensor fusion algorithm is evaluated using an experimental setup in comparison to the high-accuracy Vicon ® motion tracking camera system.

10:00-10:20 ThA1.4

Time-Varying Formation Tracking with Distributed Multi-Sensor Multi-Target Filtering, pp. 448-454

Qi, Jialin — Beihang University
Zhang, Zheng — Beihang University
Dong, Xiwang — Beihang University
Yu, Jianglong — Beihang University

Li, Qingdong	Beihang University
Jiang, Hong	Beihang University
Ren, Zhang	Beihang University

Formation tracking is used widely in targets enclosing, monitoring, and striking, however, in practical scenes, the targets are always uncooperative. The problem of time-varying formation tracking for multiagent with multi-target which states are unknown is studied in this paper. To obtain the accurate state estimations of targets, a distributed multi-sensor multi-target filtering algorithm based on the cubature Kalman filter scheme and multiple heterogeneous sensors is proposed. Then, the state estimations obtained by the filtering algorithm are used to design a time-varying formation tracking protocol for multiagent, enabling multiagent to form a time-varying formation to track the convex combination of targets. Finally, the effectiveness of this proposed algorithm is illustrated by simulation experiments.

10:20-10:40 ThA1.5

Experimental Analysis of Radar/Optical Track-To-Track Fusion for Non-Cooperative Sense and Avoid, pp. 455-462

Vitiello, Federica	Università Di Napoli Federico II
Causa, Flavia	Università Di Napoli Federico II
Opromolla, Roberto	Università Di Napoli Federico II
Fasano, Giancarmine	Università Di Napoli Federico II

In the framework of non-cooperative Sense and Avoid solutions, major attention is reserved to the design of sensing strategies which can enable fast and reliable identification of possible near collision threats, by exploiting passive or active exteroceptive sensors. To overcome the limits of standalone technological architectures and provide more accurate tracking solutions, which can be used to improve conflict detection and thus better support avoidance strategies, data fusion approaches can be considered. Hence, this work proposes a radar/visual fusion method based on the track-to-track fusion approach. The strategy is tested on data gathered during ground-to-air experimental flight tests involving a small UAV commanded to fly near collision approach geometries with respect to a multi-sensor setup placed on the ground. Results collected analyzing three different encounters show that the fusion solution allows retrieving meter and sub-degree level accuracies in the intruder range and bearing estimation, respectively, while ensuring declaration ranges of about 500 meters.

ThA2 Room 130

UAS Testbeds (Regular Session)

Chair: Valavanis, Kimon P.	University of Denver
Co-Chair: Koschlik, Ann-Kathrin	German Aerospace Center

09:00-09:20 ThA2.1

Towards an Integrated Vehicle Health Management for Maintenance of Unmanned Air Systems, pp. 463-470

Koschlik, Ann-Kathrin	German Aerospace Center
Meyer, Hendrik	German Aerospace Center
Arts, Emy	German Aerospace Center
Conen, Philipp	German Aerospace Center
Jacob, Geo	German Aerospace Center
Soria Gomez, Maria	German Aerospace Center
Kamtsiuris, Alexander Athanasios	German Aerospace Center
Jilke, Lukas	German Aerospace Center
Aigner, Johanna	German Aerospace Center
Raddatz, Florian	German Aerospace Center
Wende, Gerko	German Aerospace Center

With rising numbers of Unmanned Aerial System (UAS) national and international authorities are currently negotiating the regulations for the operation of UAS. Even though UASs are smaller and less complex than manned aircraft, Maintenance, Repair and Overhaul (MRO) aspects are not yet sufficiently considered. In a step towards safer and more autonomous operations of UASs, we intend to develop an Integrated Vehicle Health Management (IVHM) for Condition-Based Maintenance. This highly integrated system aims at constantly monitoring the health status of the UAS and at supporting all involved stakeholders. A necessity to IVHM is a vast data gathering process at different points in times as well as at different locations. Multi-stakeholder Digital Twins can achieve this by collecting the necessary data and allowing all stakeholders to base their decisions on the most up-to-date status of their system. We conclude this paper by demonstrating a first prototype operation under realistic conditions.

09:20-09:40 ThA2.2

A Benchmark Framework for Testing, Evaluation, and Comparison of Quadrotor Linear and Nonlinear Controllers, pp. 471-478

Martini, Simone	University of Denver
Stefanovic, Margareta	University of Denver
Rizzo, Alessandro	Politecnico Di Torino
Rutherford, Matthew	University of Denver
Livreri, Patrizia	Università Di Palermo
Valavanis, Kimon P.	University of Denver

A benchmark framework to test, evaluate, and compare different quadrotor controllers is presented. A detailed nonlinear quadrotor model and a set of six mission scenarios are used to evaluate seven state-of-the-art linear and nonlinear controllers. The quadrotor model is based on the Lagrange formulation and includes aerodynamic and gyroscopic effects, allows for sensor feedback noise to be introduced, and account for first order motor dynamics with input saturation. Simulated mission scenarios include realistic disturbances such as abrupt change of mass, wind gust, and aggressive flight maneuvers. The benchmark framework is the primary contribution of this research; the framework allows for performance comparison of multiple control architectures and implementations, and the resulting open access testbed is made available to other researchers. Moreover, the same framework may be used to conduct simulated experiments (using ROS/Gazebo, X-Plane, or other software tools), and, with minor modifications, to compare controller performance based on real flights.

09:40-10:00 ThA2.3

UAV-Based Networked Airborne Computing Simulator and Testbed Design and Implementation, pp. 479-486

Wang, Baoqian — San Diego State University
Xie, Junfei — San Diego State University
Ma, Ke — San Diego State University
Wan, Yan — University of Texas at Arlington

The integration of onboard computing capabilities with unmanned aerial vehicles (UAV) has gained significant attention in recent years as part of mobile computing paradigms such as mobile edge computing (MEC), fog computing, and mobile cloud computing. To enhance the performance of airborne computing, networked airborne computing (NAC) aims to interconnect UAVs through direct flight-to-flight links, with UAVs sharing resources with each other. However, despite the growing interest in NAC and UAV-based computing, existing studies rely heavily on numerical simulations for performance evaluation and lack realistic simulators and hardware testbeds. To fill this gap, this paper presents the development of two NAC platforms: a realistic simulator based on ROS and Gazebo, and a hardware testbed with multiple UAVs communicating and sharing computing resources. Through simulation and real flight tests with two computation applications, we evaluate the platforms and examine the impact of mobility on NAC performance. Our findings offer valuable insights into NAC and provide guidance for future advancements.

10:00-10:20 ThA2.4

Lowering the Entry Barrier to Aerial Robotics Competitions, pp. 487-492

Perez-Grau, Francisco Javier — Center for Advanced Aerospace Technologies
Leon Barriga, Pablo — Center for Advanced Aerospace Technologies
Viguria, Antidio — Center for Advanced Aerospace Technologies

The introduction of autonomous aerial robots in everyday applications has motivated the emergence of multiple competitions, which propose unique challenges to the research community. At the same time, robotic competitions are excellent opportunities to engage engineering students and improve their skills, and also end users to adopt the newest technologies. However, the high effort that teams must devote prevents the broad participation of the research community. Thus, this has motivated the arrival of dataset-based competitions in which teams do not need to integrate and operate an actual aerial robotic system. Nevertheless, succeeding in these offline challenges does not ensure that real robots will work as expected, hence limiting the impact of the developments. We propose a comprehensive strategy to maximize team participation by recording and providing real datasets in the same environment where the competitions take place. The publicly available datasets can be accessed at https://github.com/fada-catec/rami_dataset.

10:20-10:40 ThA2.5

Software Architecture for Controlling in Real Time Aerial Prototypes, pp. 493-498

Offermann, Alexis — Université Grenoble Alpes
De Miras, Jérôme — Université De Technologie De Compiègne
Castillo, Pedro — Université De Technologie De Compiègne

Nowadays, there exists several platforms or experimental prototypes of aerial vehicles to control algorithm validation, most of them being specific for certain applications. The implementation of the control laws in commercial platforms is often restricted to certain criteria and pre-established conditions defined by the commercial system (or the builder). In this paper, a new generic software architecture operating under Linux, MATLAB®, ROS and ArduPilot is introduced for analyzing, evaluating and improving control algorithms for aerial robotics. The tedious programming code is not necessary because the code is generated by MATLAB Simulink®. The proposed architecture is composed of a ground station (GS) and a robot with an embedded system. This platform is validated with a new aerial prototype with tilting four rotors. Experimental results illustrate the good performance of the software architecture even when different maneuvers are demanded to the aerial prototype.

ThA3 — Room 464

Path Planning III (Regular Session)

Chair: Chen, YangQuan — University of California - Merced
Co-Chair: Zhang, Youmin — Concordia University

09:00-09:20 ThA3.1

A Modified Artificial Potential Field for UAV Collision Avoidance, pp. 499-506

Srivastava, Astik — Delhi Technological University
Vasudevan, V.R. — Delhi Technological University
Dalal, Harikesh — Delhi Technological University
Nallanthiga, Raghava — Delhi Technological University
Baliyarasimhuni, Sujit, P. — IISER Bhopal

As UAV applications in civilian airspace in- creases, securely operating them in congested environments becomes more challenging. A Cauchy Artificial Potential Field (CAPF) method is presented in this research to make UAV navigation practical and secure in a cluttered dynamic environment. The CAPF approach enables the UAVs to avoid collision with obstacles that could either be static or dynamic (Another UAV) commanding mostly non-aggressive maneuvers. The approach presented in the research has been verified through simulations and testing. We compare the results of CAPF with MAPF and the proposed approach has shown improvement in terms of total acceleration and in distance traveled by vehicles while providing safer margins at higher speeds.

09:20-09:40	ThA3.2

UAV Path Planning Employing MPC-Reinforcement Learning Method Considering Collision Avoidance, pp. 507-514

Ramezani, Mahya	University of Luxembourg
Habibi, Hamed	University of Luxembourg
Sanchez-Lopez, Jose-Luis	University of Luxembourg
Voos, Holger	University of Luxembourg

In this paper, we tackle the problem of Unmanned Aerial (UAV) path planning in complex and uncertain environments by designing a Model Predictive Control (MPC), based on a Long-Short-Term Memory (LSTM) network integrated into the Deep Deterministic Policy Gradient algorithm. In the proposed solution, LSTM-MPC operates as a deterministic policy within the DDPG network, and it leverages a predicting pool to store predicted future states and actions for improved robustness and efficiency. The use of the predicting pool also enables the initialization of the critic network, leading to improved convergence speed and reduced failure rate compared to traditional reinforcement learning and deep reinforcement learning methods. The effectiveness of the proposed solution is evaluated by numerical simulations.

09:40-10:00	ThA3.3

Nonlinear Model Predictive Control for Repetitive Area Reconnaissance with a Multirotor Drone, pp. 515-522

Marcellini, Salvatore	Università Di Napoli Federico II
Ruggiero, Fabio	Università Di Napoli Federico II
Lippiello, Vincenzo	Università Di Napoli Federico II

This paper considers the problem of a reconnaissance mission in which a single multirotor drone must survey a given map by repetitively visiting different checkpoints. Several points of interest (POIs) are used to discretise the map, and each of them is associated with a time-varying heat value according to the specific application. In that way, each POI has a different visiting priority each time. The proposed solution considers a nonlinear model predictive control (NMPC) approach that minimises the map's overall heat and considers several constraints related to the system dynamics and the environment (e.g., the presence of unknown obstacles). Possible applications are related to the research of gas leaks, area surveillance, patrolling, etc. The methodology is tested in a realistic simulation environment and through experiments.

10:00-10:20	ThA3.4

Battery-Health-Aware UAV Mission Planning Using a Cognitive Battery Management System, pp. 523-528

An, Di	University of California - Merced
Krzysiak, Rafal	University of California - Merced
Hollenbeck, Derek	University of California - Merced
Chen, YangQuan	University of California - Merced

Lithium-ion and Lithium Polymer batteries have been widely used in electric and unmanned aircraft vehicles, enabling many applications and developing a highly commercialized and demanding market. Precisely estimating the battery capacity (State of the charge (SOC)) is still a challenging problem due to many limitations. Prior work assessing battery capacity relies more on the battery's internal physical model and less considers surrounding factors, which makes the accuracy of estimation capacity fluctuation under different scenarios. Therefore, we presented a cognitive battery management system to empower intelligence to the battery so that battery can justify the current capacity and whether it would be enough for the mission and safe landing. Our system leverages the battery temperature as the essential factor for estimating the capacity during flight. We evaluated our capacity estimation function parameters using the least squares. Results show that our approach shows the battery temperature significantly affects assessing capacity, which perfectly accomplishes the first step towards a cognitive battery management system.

10:20-10:40	ThA3.5

Spatiotemporal VRP for Collision-Free Multi-UAV Inspection Planning, pp. 529-536

Im, Jaehan	Nearthlab Inc
Kim, Youngjoo	Nearthlab Inc

The study proposes a method for planning optimal, collision-free routes for multiple UAVs for infrastructure inspections. The conventional approach of using the Vehicle Routing Problem (VRP) has proven to be inadequate due to the complexity of the routing problem and the difficulty in considering inter-vehicle conflict situations. To address these challenges, the Spatiotemporal VRP algorithm is introduced, which considers temporal occupation information over sparse inspection graphs. The proposed algorithm is capable of handling large-sized graphs with several hundreds of nodes and has been shown to be effective in finding feasible solutions without any failure through a series of Monte-Carlo experiments and a case study. The results of the case study demonstrate the potential of the proposed algorithm to be adapted to real-world scenarios and provide a promising solution for optimizing UAV inspection routes.

ThA4	Room 465
Swarms (Regular Session)	
Chair: Zhang, Youmin	Concordia University
Co-Chair: Duan, Haibin	Beihang University

09:00-09:20	ThA4.1

Unmanned Aerial Vehicle Cargo Delivery Assignment Via Time-Varying Constriction Pigeon-Inspired Optimization with Memory Retrospection, pp. 537-542

Liu, Xinghan	Beihang University
Zhang, Yan	Beihang University
Duan, Haibin	Beihang University

Unmanned aerial vehicles (UAVs) collaboration is a key technology to UAV cargo delivery in the near future. In this paper, distribution requirement parameters are identified to establish a multi-objective cargo delivery assignment model where a large number of tasks are

allocated. To optimize high-dimensional multi-UAV task assignment problem, a time-varying constriction pigeon-inspired optimization with memory retrospection (TCMR-PIO) is proposed. A memory retrospection mechanism is developed to increase the multiplicity of pigeon flock and avoid premature convergence. Meanwhile, a time-varying constraint factor is utilized to provide the improved algorithm with higher accuracy and stability. While maintaining the advantage of high convergence speed, an optimized task assignment scheme can be obtained. Comparative simulation experiments with particle swarm optimization (PSO), pigeon-inspired optimization (PIO), quantum pigeon-inspired optimization (QPIO), adaptive weighted pigeon-inspired optimization (AWPIO) and nonlinear dynamic adaptive inertial weight particle swarm optimization (PSO-DAIW) are conducted, and the performance of the TCMR-PIO algorithm validates its effectiveness and superiority on cargo delivery assignment.

09:20-09:40 ThA4.2

Multi-UAV Cooperative Search Planning Algorithm Based on Dynamic Target Probability Model, pp. 543-548

Ao, Zihang — China Satellite Maritime Measurement and Control Department
Zhang, Yulong — Xi'an University of Technology
Huang, Jing — Xi'an University of Technology
Lin, YiCheng — China Satellite Maritime Measurement and Control Department
Zhou, Xiaodeng — China Satellite Maritime Measurement and Control Department
Zhang, Youmin — Concordia University

This paper presents an online planning algorithm for multiple Unmanned Aerial Vehicles (UAVs) cooperative search tracks based on Distributed Model Predictive Control (DMPC) for dynamic targets. To address the centralized multi-UAV collaboration problem, the proposed approach transforms it into a distributed subsystem MPC problem under the framework of DMPC. Firstly, a dynamic target Statistical Probability Map (SPM) update model is established. Next, the system optimal solution is obtained by combining Nash optimization and rolling optimization A-star algorithm through iterating the MPC problem of each subsystem. The simulation results demonstrate the efficacy of the proposed dynamic target SPM model in improving search efficiency. Furthermore, the scrolling-optimized A-star algorithm improves the accuracy and speed of subsystem single-step search. In conclusion, the DMPC method significantly reduces the solving scale of cooperative search problems while ensuring high solving accuracy.

09:40-10:00 ThA4.3

A General Framework for Multi-UAV Communication Connectivity Maintenance through Scalable Task Allocation, pp. 549-556

Cao, Jiawei — National University of Singapore
Leong, Wai Lun — National University of Singapore
Teo, Rodney — National University of Singapore
Huang, Sunan — National Universtiy of Singapore

Despite of great potentials of decentralized multi-UAV systems in many practical applications, limited onboard communication capabilities can significantly impact team performance. Therefore, maintaining good communication connectivity between UAVs and base stations is essential for resilience and robustness of the system. This requirement is challenging due to various factors such as group size, task locations, and communication range. In this paper, we propose a general framework for maintaining connectivity in various situations through seamless degradation from continuous connectivity to periodic/intermittent connectivity. The framework relies on emergent behavior and is built upon our previous work on scalable task allocation to provide flexibility. Extensive simulation tests are conducted to verify its effectiveness.

10:00-10:20 ThA4.4

SwarmGear: Heterogeneous Swarm of Drones with Morphogenetic Leader Drone and Virtual Impedance Links for Multi-Agent Inspection, pp. 557-563

Darush, Zhanibek — Skolkovo Institute of Science and Technology
Martynov, Mikhail — Skolkovo Institute of Science and Technology
Fedoseev, Aleksey — Skolkovo Institute of Science and Technology
Shcherbak, Aleksei — Skolkovo Institute of Science and Technology
Tsetserukou, Dzmitry — Skolkovo Institute of Science and Technology

The continuous monitoring by drone swarms remains a challenging problem due to the lack of power supply and the inability of drones to land on uneven surfaces. Heterogeneous swarms can support longer inspections; however, their capabilities are limited by the mobility of wheeled and legged robots in a cluttered environment. In this paper, we propose a novel concept SwarmGear for autonomous inspection. It leverages a heterogeneous swarm of drones that investigates the environment in a leader-follower formation. The leader drone is able to land on rough terrain and traverse it by four compliant robotic pedipulators, possessing both the functionalities of an aerial and mobile robot. To preserve the formation of the swarm during its motion, virtual impedance links were developed between the leader and the follower drones. The experiments revealed low cross track error (mean value is of 2.2 cm and max one is of 5.3 cm with the Type 2 gait) and the ability of the leader drone to move with a 190 mm step length. Four types of drone formation were considered. The best formation was applied for experiments and showed low overall cross track error for the swarm (mean 3.9 cm for the Type 1 gait and 3.3 cm for the Type 2 gait).

ThA5 Room 466

UAS Applications III (Regular Session)

Chair: Salinas, Lucio Rafael — University of Bristol
Co-Chair: da Silva, Leandro Marcos — University of São Paulo

09:00-09:20 ThA5.1

3D Maps of Vegetation Indices Generated Onboard a Precision Agriculture UAV, pp. 564-571

Ramírez, Germán — Centro De Investigaciones En Óptica
Montes de Oca Rebolledo, Andres — Centro De Investigaciones En Óptica

Flores, Gerardo Centro De Investigaciones En Óptica

Vegetation indices are qualitative indicators that permit the identification of damaged or healthy zones within a vegetation region. Traditionally, the vegetation indices are represented as 2-dimensional maps since they are computed from aerial imagery. However, 3D mapping is more convenient when a detailed study of a plant is required. This work proposes an Unmanned Aerial System that can provide indices for low-height vegetation. Such an output is presented in a dense point cloud format. The proposed system features an NVIDIA Jetson AGX Xavier as the onboard computer and a ZED Mini stereo as the imaging sensor. Since the ZED Mini captures RGB imagery in the visible spectrum, we focus on computing two visible-based vegetation indices: the Green Normalized Difference Vegetation Index and the Visible-band Difference Vegetation Index. We present the results of two experimental flights to prove the system's functionality. In such flights, we perform an online reconstruction using the RTABMap algorithm. After obtaining the dense point cloud of the vegetation regions, our system processes the data to output 3D maps of the vegetation indices above. Additionally, it is presented as a simple quantitative analysis that can be used for vegetation segmentation applications.

09:20-09:40 ThA5.2

Unmanned Aircraft Systems and Urban Air Mobility at the Service of Public Administration for an Acceleration of Essential Services in the Smart Cities of the Future, pp. 572-579

Di Guardo, Giuseppina Agata Italian Ministry of Labour and Social Policy

Gaspari, Francesco Università Guglielmo Marconi

This paper aims to provide a glimpse into the dimension of Unmanned Aircraft Systems (UAS) use and the emerging Urban Air Mobility (UAM) ecosystem as regards territorial control for different purposes and the medical sector. Public authorities are increasingly employing UAS for activities in the public interest, by means of private individuals acting on their behalf. Hence, the aim is to demonstrate, with examples taken mainly from the Italian experience, how their smart, environmental, privacy-compatible use can represent a new frontier for the tools that public administrations are already experimenting with and can in the future implement through the potential offered by UAM. Such deployment will require them to undertake appropriate strategic planning of urban mobility with the support of European and national regulators, through the deployment of multi-level policies and governance in order to enhance the services offered and the quality of life of citizens.

09:40-10:00 ThA5.3

UAV Embedded Real-Time Object Detection by a DCNN Model Trained on Synthetic Dataset, pp. 580-585

Maroquio Bernardo, Ricardo Instituto Federal De Educação, Ciên Cia E Tecnologia Do Espírit

Silva, Luis Centro Federal De Educação Tecnológica Celso Suckow Da Fonseca

Ferreira Rosa, Paulo Fernando Ferreira Rosa Instituto Militar De Engenharia

The utilization of unmanned aerial vehicles (UAVs) in civilian and military applications has significantly increased in recent years. A common task associated with these applications is detecting objects of interest in images captured by onboard UAV cameras. The ongoing development of advanced deep convolutional neural network (DCNN) algorithms has substantially improved the accuracy of general image segmentation and classification. However, applying these techniques to images obtained from UAVs requires a representative dataset for enhanced performance. This paper presents a method for DCNN-based object detection, utilizing resources embedded in a 1.5kg quadrotor-type UAV. To address the lack of representative datasets for our target scope, we employed a DCNN model trained on a self-generated synthetic dataset. The proposed method has been validated through real experiments, and the results demonstrate this approach's feasibility for real-time surveillance with fully onboard processing. Furthermore, this offers a stand-alone, portable, and cost-effective solution for surveillance tasks using a small UAV.

10:00-10:20 ThA5.4

Digital Twin Technology for Wildfire Monitoring Using UAV Swarms, pp. 586-593

Salinas, Lucio Rafael University of Bristol

Tzoumas, Georgios University of Bristol

Pitonakova, Lenka Qubiq Interactive

Hauert, Sabine University of Bristol

Deploying aerial swarm robotic systems in real-life scenarios can be challenging. Using them to monitor wildfires requires the system to be easily used by a swarm operator. To achieve this with the minimum associated costs, advanced frameworks must be developed to optimise, monitor, and control the swarm in real time. One approach to achieve this is the creation of a digital twin where physical counterparts can be mirrored in a virtual world. Our aim was to create a digital twin to support and accelerate the design, testing and deployment of aerial swarms. Our framework is composed of the following main parts: a digital twin system for development and optimisation of swarm algorithms as well as real-time monitoring and control of swarm deployments; a cloud infrastructure to allow data passing between our system components; and a swarm of uncrewed aerial vehicles (UAVs). We developed a user interface that allows a swarm operator to define missions for a swarm to monitor areas in search for a digital wildfire. We tested our system in field trials using a mix of three physical and three digital aircraft. During the trials, an operator was able to task the UAVs to perform autonomous search amongst three different search strategies, to stack at specific locations, and finally to land.

10:20-10:40 ThA5.5

A LiDAR-Based Method to Identify Vegetation Encroachment in Power Networks with UAVs, pp. 594-601

Savva, Antonis University of Cyprus

Papageorgiou, Manos University of Cyprus

Kyrkou, Christos University of Cyprus

Kolios, Panayiotis University of Cyprus

Theocharides, Theocharis University of Cyprus

Panayiotou, Christos University of Cyprus

Vegetation encroachment in power transmission and distribution networks constitutes a major hazard for the environment and the networks' integrity, but also for the society at large, with multifaceted consequences. On many occasions the vegetation near the power lines, in conjunction with the aged infrastructure, caused and spread fires leading to large-scale disasters. To this end, 3D representations

are proactively created using LiDAR sensors to identify locations of vegetation encroachment. Of particular interest is the use of UAVs, which propose a cost-effective alternative to employing airplanes. In this study, UAVs were employed to acquire LiDAR data from the power distribution network and a subtractive data-driven methodology is proposed, whereby irrelevant points are discarded, aiming to identify power lines without employing 3D modelling methods. In this context, geometric features are calculated, and a rigorous analysis is conducted over the feature set, different classifiers and parameters to investigate the robustness of the proposed approach. Extensive evaluation suggests that the Random Forest classifier is able to identify power lines with high performance (F1-Score=97.74% and Accuracy=99.09%), using both geometric and colour-based features, being also robust to the presence of moderate noise and down-sampling levels.

ThB1	Room 118
Current Advances in UAS – Best Paper Finalists (Regular Session)	
Chair: Valavanis, Kimon P.	University of Denver
Co-Chair: Monteriù, Andrea	Università Politecnica Delle Marche

11:00-11:20 ThB1.1

Model-Free Control for Quadrotor Attitude Via Tent Map-Based Pigeon-Inspired Optimization, pp. 602-607

Yuan, Yang — Beihang University
Duan, Haibin — Beihang University
Wei, Chen — Beihang University

The attitude control problem of the quadrotor in the presence of disturbance and model uncertainty is studied in this paper. Firstly, a first-order filter is applied to generate the desired derivate of the reference signal. Then, a model-free adaptive attitude controller is designed for the condition that model parameters are not available. The discrete equation of the angular velocity is obtained by using the compact form dynamic linearization method, and the cascade controller is established based on the continuous kinematics and discrete dynamics. In addition, tent map-based pigeon-inspired optimization is designed to optimize the parameters of the filter and controller. Compared with original pigeon-inspired optimization, the premature problem can be effectively contained. Finally, the simulation results demonstrate the feasibility of the model-free attitude controller and the advantages of the Tent map-based pigeon-inspired optimization.

11:20-11:40 ThB1.2

Design of Prisma: An Omnidirectional Aerial Manipulator Based on a 3-PUU Parallel Mechanism, pp. 608-615

Rubio, Matthias — ETH Zürich
Naef, Joshua — ETH Zürich
Buehlmann, Franz — ETH Zürich
Brigger, Philippe — ETH Zürich
Huesser, Moritz — ETH Zürich
Inauen, Martin — ETH Zürich
Ospelt, Nicole — ETH Zürich
Gisler, Daniel — ETH Zürich
Tognon, Marco — Inria
Siegwart, Roland Y. — ETH Zürich

The study of aerial robots capable to interact with their environment, also known as aerial manipulation, is a particularly new field in robotics research. Most existing solutions of aerial manipulators utilize commercially available multirotors as base flying platforms which are often extended by a suitable robotic arm. Although this design approach allows for fast prototyping, it impedes the development of a well-composed system where the base and the manipulator are designed conjointly. In contrast, this work presents a novel aerial manipulator featuring a 3-PUU (prismatic universal universal) parallel mechanism making up the structure of the flying platform. The key idea of using a parallel mechanism comes from its ability to quickly compensate positional errors of the platform while keeping the inertia of the moving parts low. To enable manipulation from any pose, PrisMAV is further designed to be omnidirectional by utilizing four tiltable rotor groups. The concept was successfully verified in a pick and place mission by grasping and releasing an object from above and from the side. The end-effector position tracking of PrisMAV is proven to be more accurate compared to a hypothetical fixed end-effector. The final result is a full proof of concept of an omnidirectional aerial manipulator.

11:40-12:00 ThB1.3

Investigating the Applicability of LTE-M for Network Identification of Unmanned Aerial Systems in U-Space, pp. 616-625

Jepsen, Jes Hundevadt — University of Southern Denmark
Mader, August Ravn — University of Southern Denmark
Andreasen, Troels Dupont — University of Southern Denmark
Singh, Radheshyam — Technical University of Denmark
Jensen, Kjeld — University of Southern Denmark

Unmanned Aerial System (UAS) Traffic Management (UTM) is a key enabler for unleashing the full potential of the UAS technology. Europe is currently in the progress of implementing the initial services of the U-Space framework, the European Union (EU) version of UTM. With the Commission Implementing Regulation (EU) 2021/664 now in force, defining the regulatory framework for U-Space, the establishment of U-spaces in EU will soon be a reality in some countries.
In this paper, a stand-alone component, named DroneID5G, is designed to comply with the Network Identification (ID) service specified in 2021/664. The Drone5GID is capable of providing the Remote ID of a UAS to the national Common Information Service Provider using LTE for Machine Type Communication (LTE-M) technology. A custom protocol, based on the ASTM F311-19 standard, has been implemented between the DroneID5G and a USSP prototype for reducing the message size being transmitted. Additionally, Detect And Avoid (DAA) capabilities have been implemented by relaying air traffic data, obtained from the Traffic Information service specified in 2021/664, into a UAS's flight controller via the DroneID5G.
We present the initial experimental results, consisting of both ground and flight measurements, for investigating the performance and

reliability of LTE-M network. The RSSI, RSRP, and RSRQ values have been collected at different geographical positions and altitudes from 20 to 100 meters above the ground. The ground measurements demonstrate the handover capabilities and reliability. From the flight measurements, it can be seen that the RSRP and RSRQ values decreases in relation to the altitude. Finally, the DAA capabilities are demonstrated, enabling the UAS to automatically detect an incoming aircraft and activate it.

12:00-12:20 ThB1.4

Deep Learning-Based Reassembling of an Aerial & Legged Marsupial Robotic System-Of-Systems, pp. 626-633

Arora, Prateek — University of Nevada - Reno
Karakurt, Tolga — University of Nevada - Reno
Avloniti, Eleni Spyridoula — University of Thessaly
Carlson, Stephen — University of Nevada - Reno
Moore, Brandon — University of Nevada - Reno
Feil-Seifer, David — University of Nevada - Reno
Papachristos, Christos — University of Nevada - Reno

In this work we address the System-of-Systems reassembling operation of a marsupial team comprising a hybrid Unmanned Aerial Vehicle and a Legged Locomotion robot, relying solely on vision-based systems and assisted by Deep Learning. The target application domain is that of large-scale field surveying operations under the presence of wireless communication disruptions. While most real-world field deployments of multi-robot systems assume some degree of wireless communication to coordinate key tasks such as multi-agent rendezvous, a desirable feature against unrecoverable communication failures or radio degradation due to jamming cyber-attacks is the ability for autonomous systems to robustly execute their mission with onboard perception. This is especially true for marsupial air / ground teams, wherein landing onboard the ground robot is required. We propose a pipeline that relies on Deep Neural Network-based Vehicle-to-Vehicle detection based on aerial views acquired by flying at typical altitudes for Micro Aerial Vehicle-based real-world surveying operations, such as near the border of the 400ft Above Ground Level window. We present the minimal computing and sensing suite that supports its execution onboard a fully autonomous micro-Tiltrotor aircraft which detects, approaches, and lands onboard a Boston Dynamics Spot legged robot. We present extensive experimental studies that validate this marsupial aerial / ground robot's capacity to safely reassemble while in the airborne scouting phase without the need for wireless communication.

12:20-12:40 ThB1.5

Real-Time Applicable Cooperative Aerial Manipulation: A Survey, pp. 634-643

Barakou, Stamatina — National Technical University of Athens
Tzafestas, Costas — National Technical University of Athens
Valavanis, Kimon P. — University of Denver

The objective of this survey paper is to review the state-of-the-art related to quadrotor- and multirotor- based cooperative aerial manipulation, with a focus on comparing and evaluating prototype systems that have been implemented and tested in real-time in diverse applications. The survey aims at providing a useful guide for the design and development of the next generation of prototypes based on preferred characteristics, functionality, operability, and application domain.

ThB2 Room 130

Energy Efficient UAS (Regular Session)

Chair: Theilliol, Didier — Université De Lorraine
Co-Chair: Salinas, Lucio Rafael — University of Bristol

11:00-11:20 ThB2.1

Design and Management of a Hydrogen Fuel Cell Powered Quadrotor, pp. 644-651

Zeng, Dan — Beihang University
Guo, Xiaoyu — The University of Manchester
Guo, Kexin — Beihang University
Dong, Zhen — University of Warwick
Yu, Xiang — Beihang University

This paper presents the design, development and flight testing of a hydrogen fuel cell (FC) powered quadrotor, where a novel online identification and energy management scheme is implemented and studied. Using a hybrid energy source consisting of a 3 kW proton exchange membrane fuel cell and an auxiliary lithium-ion battery, the unmanned aerial vehicle (UAV) could serve as an aerial operating platform with 3 kg load-carrying capability and achieve an endurance of over 50 minutes. The aircraft design and subsystem structure are summarized, with particular focus on safety. In addition, a novel energy management framework based on online identification is proposed to optimize the FC performance in terms of output power. Employing a particle filter, the nonlinear semi-empirical fuel cell model is updated online according to the dynamic flight condition. Then, key fuel cell characteristics including maximum power point (MPP) and maximum efficiency point (MEP) are extracted from the identified model, and the energy source is regulated by a dynamic energy management strategy to track the optimal operating point of the fuel cell. Outdoor flights were conducted to validate the aircraft design, and superior performance of the proposed energy management strategy against conventional strategies is demonstrated using real flight data.

11:20-11:40 ThB2.2

Design and Validation of a Wireless Drone Docking Station, pp. 652-657

Stuhne, Dario — University of Zagreb
Vasiljevic, Goran — University of Zagreb
Bogdan, Stjepan — University of Zagreb
Kovacic, Zdenko — University of Zagreb

Drones are increasingly operating autonomously, and the need for extending drone power autonomy is rapidly increasing. One of the

most promising solutions to extend drone power autonomy is the use of docking stations to support both landing and recharging of the drone. To this end, we introduce a novel wireless drone docking station with three commercial wireless charging modules. We have developed two independent units, both in mechanical and electrical aspects: the energy transmitting unit and the energy receiving unit. We have also studied the efficiency of wireless power transfer and demonstrated the advantages of connecting three receiver modules connected in series and parallel. We have achieved maximum output power of 96.5 W with a power transfer efficiency of 56.6% for the series connection of coils. Finally, we implemented the system in practice on a drone and evaluated both energy transfer and landing.

11:40-12:00	ThB2.3

Unmanned Aerial Vehicles Experimental Characterization in Controlled Extreme Environmental Conditions, pp. 658-662

Parin, Riccardo	Eurac Research
Bojeri, Alex	MAVTech Srl
Benedetto, Fabio	MAVTech Srl
Ristorto, Gianluca	MAVTech Srl
Guglieri, Giorgio	Politecnico Di Torino

The employment of drones in extremely harsh environmental conditions is the main challenge of flight operations in the Alpine scenario. Characterizing the Unmanned Aerial Vehicle (UAV) performance in a controlled simulated environment is crucial to defining the atmospheric condition limits for safe operations. Following the experiments performed previously in the same project, we performed a series of tests at different simulated altitudes (from ground level up to 9000 m) and with different payloads (from 0 kg up to 4 kg) assessing the efficiency of the drones. The test campaign performed in a simulated standard Alpine mountain context led to define the boundaries for planning a safe flight in a such harsh and challenging environment.

12:00-12:20	ThB2.4

Battery Health Based Remaining Mission Time Prediction of UAV in Closed Loop, pp. 663-670

Kanso, Soha	Université De Lorraine
Jha, Mayank Shekhar	Université De Lorraine
Valavanis, Kimon P.	University of Denver
Ponsart, Jean-Christophe	Université De Lorraine
Theilliol, Didier	Université De Lorraine

Unmanned Aerial Vehicles (UAVs) powered by Lithium Polymer (Li-Po) batteries are widely used for a wide spectrum of applications. Usage based discharge of their batteries can greatly impact the success of the UAV mission, hence the necessity to accurately estimate their State of Charge (SoC). The SoC estimate can, then, be used to predict the Remaining Mission Time (RMT), in order to improve the overall performance and reliability of UAVs. This paper presents a model-based prognosis algorithm to first estimate the SoC of Li-Po batteries and then to predict the RMT for a class of multirotor UAVs. Under closed loop tracking, the Linear Quadratic Tracker (LQT) with an integral action is implemented to control the UAV. The effectiveness of the developed control and the proposed algorithm is tested via simulations; obtained results demonstrate the efficacy of the method to accurately predict the RMT during closed loop performance.

12:20-12:40	ThB2.5

Quadrotors with Slung Payloads: Energy Analysis and Experimental Validation, pp. 671-678

Alkomy, Hassan	York University
Shan, Jinjun	York University

This paper analyzes the energy consumption of quadrotors with slung payloads. First, it develops novel expressions for the power and energy consumption for a quadrotor with a slung payload flying in 3D. These expressions are called the power and energy quotients, which are directly proportional to the actual power and energy consumption. However, they do not require any prior knowledge of the motor and propeller parameters. Second, a comprehensive energy investigation is conducted to find the effect of polynomial trajectories, cable length, arbitrary kinematic boundary conditions, and number of waypoints on the energy consumption. This analysis has been conducted via two different Monte Carlo simulations. The results showed that increasing the degree of the polynomial trajectory increases the energy consumption and there is an optimal cable length, at which, the energy consumption is minimal. These results are valid regardless of the kinematic boundary conditions, which implies that these results are valid regardless of the number of waypoints. All results have been validated experimentally.

ThB3	Room 464
Path Planning IV (Regular Session)	

Chair: Givigi, Sidney	Queen's University
Co-Chair: Koschlik, Ann-Kathrin	German Aerospace Center

11:00-11:20	ThB3.1

Spiral Coverage Path Planning for Multi-UAV Photovoltaic Panel Inspection Applications, pp. 679-686

Luna, Marco Andrés	Universidad Politécnica De Madrid
Ale Isaac, Mohammad Sadeq	Universidad Politécnica De Madrid
Fernandez-Cortizas, Miguel	Universidad Politécnica De Madrid
Carlos, Santos	Universidad De Alcalá
Ragab, Ahmed	October 6 University
Molina, Martin	Universidad Politécnica De Madrid
Campoy, Pascual	Universidad Politécnica De Madrid

This paper deals with the problem of coverage path planning for multiple UAVs in disjoint regions. For this purpose, a spiral-coverage path planning algorithm is proposed. Additionally, task assignment methods for multi-region inspection with a swarm of UAVs are applied. The centralized system architecture is described, and an adaptive sliding mode controller is designed. Furthermore, we evaluate the performance of the proposed techniques by obtaining numerical results and simulations with the controller. The results show that the

spiral pattern optimizes the cost of the mission and improves the task distribution of the mission planning system. Additionally, the performance of the proposed controller is robust to simulated disturbances.

11:20-11:40 ThB3.2

UAV Path Planning for the Delivery of Emergency Medical Supplies, pp. 687-694

Aldao Pensado, Enrique — University of Vigo
Fontenla Carrera, Gabriel — University of Vigo
Gonzalez de Santos, Luis Miguel — University of Vigo
Gonzalez Jorge, Higinio — University of Vigo

The use of UAVs for the delivery of emergency medical equipment, such as Automated External Defibrillators (AEDs), has the potential to significantly improve response times in life-threatening situations. This time saving can be crucial for the patient's life. However, the flight in urban areas presents a great challenge due to its complexity and regulatory limitations on the flight over densely populated areas. Therefore, in this work, a UAV route calculation algorithm that minimizes flight time taking into account these restrictions is proposed. Firstly, the horizontal flight profile is computed, generating trajectories avoiding densely populated areas. Then, considering the elevation of the terrain, the vertical profile as well as the aircraft performances are optimized using an Optimal Control algorithm. A practical study case was developed to demonstrate the capabilities of the developed implementation.

11:40-12:00 ThB3.3

Hierarchical Cooperative Assignment Algorithm (CAA) for Mission and Path Planning of Multiple Fixed-Wing UAVs Based on Maximum Independent Sets, pp. 695-702

Cabral, Kleber — Queen's University
Silveira, Jefferson — Queen's University
Rabbath, Camille Alain — Defence Research and Development Canada
Givigi, Sidney — Queen's University

Mission planning can be solved as a combinatorial optimization problem which involves computing the path and selecting the agents that will be assigned to a given task. In scenarios with multiple UAVs, the proper control of the vehicle to achieve the proposed path is also a relevant task. This paper proposes a solution to the mission planning problem that involves probabilistic search and optimization of path planning and a graph-based combinatorial solution of task assignment. In addition, we propose an invariant model predictive controller based on the SO(2) manifold to deal with the execution of UAV missions. Our results demonstrate that the algorithm is capable of assigning all agents to tasks and computing a viable and smooth trajectory for the UAVs to follow. Also, the control strategy is capable of guiding the vehicle through the trajectories generated from a start position to the task location.

12:00-12:20 ThB3.4

Unscented Optimal Control for 3D Coverage Planning with an Autonomous UAV Agent, pp. 703-712

Papaioannou, Savvas — University of Cyprus
Kolios, Panayiotis — University of Cyprus
Theocharides, Theocharis — University of Cyprus
Panayiotou, Christos — University of Cyprus
Polycarpou, Marios M. — University of Cyprus

We propose a novel probabilistically robust controller for the guidance of an unmanned aerial vehicle (UAV) in coverage planning missions, which can simultaneously optimize both the UAV's motion, and camera control inputs for the 3D coverage of a given object of interest. Specifically, the coverage planning problem is formulated in this work as an optimal control problem with logical constraints to enable the UAV agent to jointly: a) select a series of discrete camera field-of-view states which satisfy a set of coverage constraints, and b) optimize its motion control inputs according to a specified mission objective. We show how this hybrid optimal control problem can be solved with standard optimization tools by converting the logical expressions in the constraints into equality/inequality constraints involving only continuous variables. Finally, probabilistic robustness is achieved by integrating the unscented transformation to the proposed controller, thus enabling the design of robust open-loop coverage plans which take into account the future posterior distribution of the UAV's state inside the planning horizon.

12:20-12:40 ThB3.5

Intelligent Method for UAV Navigation and De-Confliction --Powered by Multi-Agent Reinforcement Learning, pp. 713-722

Xia, Bingze — Concordia University
Mantegh, Iraj — National Research Council Canada
Xie, Wenfang — Concordia University

As Uncrewed Aircraft Systems (UAS) become more ubiquitous in urban airspace around the world, the need for reliable navigation and de-confliction technologies becomes paramount. In this paper, the authors improve the popular Deep Reinforcement Learning (RL) methods of Twin Delayed DDPG (TD3) and Proximal Policy Optimization (PPO) and propose two new integrated algorithms for de-confliction with single and multiple intruder UASs in different cases of fixed and variable altitudes. Based on the Actor-Critic method, new RL systems and reward functions are designed that enhance the training efficiency of the navigating UAS agent for the considered environment models. The simulation results show the capability of the trained agent to successfully navigate in a complex environment amid fixed and velocity obstacles. This research contributes to the development of autonomous navigation for UAS in urban airspace.

ThB4 Room 465

Networked Swarms (Regular Session)

Chair: Rastgoftar, Hossein — University of Arizona
Co-Chair: Javidi da Costa, João Paulo — Hamm-Lippstadt University of Applied Sciences

11:00-11:20 ThB4.1

H∞ Optimal Distributed Tracking Control Algorithm for Network Distributed Systems with an Application to UAV, pp. 723-730

Kucuksayacigil, Gulnihal — Uskudar University

In this work, a recursive algorithm has been developed for heterogeneous network distributed systems (NDS) communicating over an undirected network to solve H∞ optimal distributed tracking control problem of continuous-time systems as a convex problem. Recent studies on NDS have studied the tracking control problem with decentralized performance functions defined for each subsystem in the network, on the contrary, a global performance function has been defined in this work for the whole NDS. An optimal distributed control problem has been defined as a sequential convex optimization problem benefiting off-policy reinforcement learning with sparsity constraints introduced on the symmetric positive definite matrix. Finally, the efficacy of the proposed algorithm is shown on a group of heterogeneous unmanned aerial vehicles (UAV) communicating over an undirected network.

11:20-11:40 — ThB4.2

Resilient Leader-Following Formation Control for a Fleet of Unmanned Aerial Vehicles under Cyber-Attacks, pp. 731-737

Vazquez Trejo, Juan Antonio — Université De Lorraine
Guenard, Adrien — Université De Lorraine
Adam-Medina, Manuel — Tecnológico Nacional De México
Ciarletta, Laurent — Université De Lorraine
Ponsart, Jean-Christophe — Université De Lorraine
Theilliol, Didier — Université De Lorraine

Cooperative systems as fleets of unmanned aerial vehicles often use the exchange of information through communication networks to reach an agreement or complete desired tasks. These networks are mainly vulnerable to cyber-attacks which use them to spread malfunctions to all systems in the network. The main contribution of this paper is the design of a resilient strategy such that the UAVs can follow the trajectories of a UAV leader in a consensus despite a type of cyber-attacks. Linear matrix inequalities (LMIs)-based conditions are obtained to guarantee the stability of the consensus against cyber-attacks. The proposed strategy is evaluated through simulations of a fleet of UAV under false-injection data in the inputs as cyber-attacks. A comparison between the proposed resilient strategy and the classical formation control is provided.

11:40-12:00 — ThB4.3

Cloud-Based Control of Drone Swarm with Localization Via Ultra-Wideband, pp. 738-744

Sharma, Deeshant — Indian Institute of Technology Hyderabad
Sahu, Annu — Indian Institute of Technology Hyderabad
Babu Mannam, Naga Praveen — Indian Institute of Technology Hyderabad
P, Rajalakshmi — Indian Institute of Technology Hyderabad

Nowadays, aerial and ground robots can be made cheaper and lighter which makes it possible to deploy them in large numbers and drone swarms have the potential to increase efficiency and safety in certain applications, as well as provide new capabilities that would not be possible with a single drone. Successful implementation of swarm cooperative applications requires low-latency communications and real-time localization. In this paper, we proposed a cloud-based control system architecture to dynamically control the drone swarm or UAV formation in the 3D space using the mobile application. A group of UAVs determine their location using an integrated ultra-wideband module. The base station is connected to the cloud platform (google firebase in our case) which is again connected to a mobile app to get the position and formation commands directly from the user using an interactive interface. The base station will get these commands and position control information from the cloud. The base station then sends the next setpoint to each UAV, enabling UAVs to form a real-time user-controlled formation and fly autonomously until the next command. Our experiment results show that the latency in this architecture is in a range of 0.8 to 1.41 sec. with fixed anchors, the localization error is less than 5 cm.

12:00-12:20 — ThB4.4

Can a Laplace PDE Define Air Corridors through Low-Altitude Airspace?, pp. 745-752

El Asslouj, Aymane — University of Arizona
Atkins, Ella — University of Michigan
Rastgoftar, Hossein — University of Arizona

Urban Uncrewed Aircraft System (UAS) flight will require new regulations that assure safety and accommodate unprecedented traffic density levels. Multi-UAS coordination is essential to both objectives. This paper models UAS coordination as an ideal fluid flow with a stream field governed by the Laplace partial differential equation. Streamlines spatially define closely spaced deconflicted routes through the airspace and define air corridors that safely wrap buildings and other structures so UAS can avoid collision even when flying among low-altitude vertical obstacles and near mountainous terrain. We divide a city into zones, with each zone having its own sub-network, to allow for modularity and assure computation time for route generation is linear as a function of total area. We demonstrate the strength of our proposed approach by computing air corridors through low altitude airspace of select cities with tall buildings. For US cities, we use open LiDAR elevation data to determine surface elevation maps. We select non-US cities with existing high-fidelity three-dimensional landscape models.

12:20-12:40 — ThB4.5

Design and Deployment of an Efficient Communication Service for Multi-UAV Systems, pp. 753-760

Morgan Pereira, Pedro Henrique — Federal University of Rio Grande Do Sul
Pasandideh, Faezeh — Federal University of Rio Grande Do Sul
Basso, Maik — Federal University of Rio Grande Do Sul
Javidi da Costa, João Paulo — Hamm-Lippstadt University of Applied Sciences
Pignaton de Freitas, Edison — Federal University of Rio Grande Do Sul

Recent advances in the areas of microelectronics, information technology, and communication protocols have made possible the development of smaller devices, with increasing processing capacity and low energy consumption. This context contributed to the growth of applications based on the use of one or multiple Unmanned Aerial Vehicles (UAVs). Networks composed of multiple UAVs are being

used as a matter of improving the effectiveness, accuracy, and minoring the time of missions. However, these applications demand a high rate of data exchange, such as the localization information of each UAV, which can be a challenge, due to the limited transmission power of certain drone platforms. This article proposes a communication service for multi-UAV systems based on dividing the UAV-fleet into groups using the communication protocol IEEE 802.11 ac. Each group has its local network, whose participants can be chosen based on the UAV's localization or task assignment. UAVs/Drones within the same group constantly communicate, exchanging pose information and specific mission-related data. On the other hand, communication between different groups is only established by messenger drones in pre-set times. The communication service from its detailed implementation to its simulated and field validation experiments is presented in this paper. The results of three different network topologies provide evidence that the proposed communication service for multi-UAV is efficient and can be used for drone cooperative missions.

ThB5	Room 466
UAS Applications IV (Regular Session)	
Chair: Sarcinelli-Filho, Mário	Federal University of Espirito Santo
Co-Chair: Kandath, Harikumar	International Institute of Information Technology Hyderabad

11:00-11:20	ThB5.1

EAMOS: Execution of Aerial Multidrone Mission Operations and Specifications Framework, pp. 761-768

Gutmann, Markus	Alpen-Adria Universität Klagenfurt
Rinner, Bernhard	Alpen-Adria Universität Klagenfurt

Tools for specifying and executing multi drone missions that go beyond pure orchestration of waypoints are rare. We present the EAMOS framework, which introduces a simple and intuitive text-based mission specification process to execute a multi drone mission onboard different heterogeneous drone. Key benefits of EAMOS are the easy handling of sequential and parallel drone actions and their automatic synchronization. A uniform drone-interface abstracts the handling of different drone types, and specialized mission control structures enable specifying high-level missions. Our EAMOS prototype has been completely implemented in Go and successfully demonstrated in combination with the Airsim multi drone simulation environment and the PX4 flight controller as a software-in-the-loop component. Synchronization among multiple drones w.r.t. their sequentially and concurrently performed actions as well as the correct application of mission control structures behave as expected.

11:20-11:40	ThB5.2

Sliding Mode Control of Tethered Drone: Take-Off and Landing under Turbulent Wind Conditions, pp. 769-774

Azaki, Zakeye	GIPSA-Lab
Dumon, Jonathan	GIPSA-Lab
Meslem, Nacim	GIPSA-Lab
Hably, Ahmad	GIPSA-Lab

Tethered flight is a highly nonlinear and uncertain process that requires robust control approaches to master its operation. However, there have been only a few research on the control of the take-off and landing phases of these systems. This paper proposes a sliding mode controller, for tethered drones, to track a desired flight trajectory. Additionally, a three-dimensional Extended Kalman filter is integrated into the control strategy to estimate and compensate for aerodynamic disturbances. Controller performance is evaluated against wind turbulence conditions and modeling uncertainties. The results are compared with those of a non-linear feedback linearization controller.

11:40-12:00	ThB5.3

Package Delivery Based on the Leader-Follower Control Paradigm for Multirobot Systems, pp. 775-781

Santos Cardoso, Emanuele	Universidade Federal Do Espírito Santo
Bacheti, Vinícius Pacheco	Universidade Federal Do Espírito Santo
Sarcinelli-Filho, Mário	Universidade Federal Do Espírito Santo

This paper proposes the adoption of the leader-follower control paradigm as the support to control an unmanned aerial vehicle (UAV), in this case a quadrotor, in the accomplishment of a package-delivery task. The UAV takes-off from a ground vehicle, here an unmanned ground vehicle (UGV) represented by a unicycle robot, goes to the delivery point, over which it stays hovering for a while, and then goes back to the current position of the ground vehicle and lands on it, thus completing the delivery task. In the first step of the delivery task, to go to the delivery point, the delivery drone considers the delivery point as the formation leader, and composes a leader-follower formation with it, suitable to the delivery procedure. After, the delivery drone establishes a leader-follower formation with the ground vehicle, suitable to allow it to land on the ground vehicle. The main difference between these two leader-follower formations is that in the first case the leader is a static one, whereas in the second case the leader is a moving platform. Results of a real experiment, in lab scale, are also shown, which validate the adopted strategy.

12:00-12:20	ThB5.4

Vision-Based Cooperative Moving Path Following for Fixed-Wing UAVs, pp. 782-789

Félix, Miguel	Academia Da Força Aérea Portuguesa
Oliveira, Tiago	Academia Da Força Aérea Portuguesa
Cruz, Gonçalo	Academia Da Força Aérea Portuguesa
Silva, Diogo	Academia Da Força Aérea Portuguesa
Alves, João Filipe Gomes Moreira	Academia Da Força Aérea Portuguesa
Santos, Luis	Academia Da Força Aérea Portuguesa

This paper addresses the problem of collaborative ground target tracking by a group of fixed-wing Unmanned Aerial Vehicles (UAVs) using vision in the loop. The UAVs adopt a circular path formation centered at the target's coordinates and move together with it, using the Moving Path Following (MPF) method. A distributed control architecture is implemented, where each vehicle obtains the telemetry data from the preceding vehicle, through a chained communication network. A computer vision system based on machine learning techniques is proposed to close the distributed MPF control loop. The obtained results show the efficiency of the proposed control system

in realistic software-in-the-loop simulations.

12:20-12:40 ThB5.5

Multi-Auctioneer Market-Based Task Scheduling for Persistent Drone Delivery, pp. 790-797

Rinaldi, Marco — Politecnico Di Torino
Primatesta, Stefano — Politecnico Di Torino
Guglieri, Giorgio — Politecnico Di Torino
Rizzo, Alessandro — Politecnico Di Torino

Market-based task allocation methods represent an effective strategy for scheduling heterogeneous tasks to a heterogeneous multi-agent system, e.g., a fleet of different Unmanned Aerial Vehicles (UAVs). This is mainly due to their computational efficiency, ease of hybridization with optimization techniques and adaptability to different communication architectures. In this paper, a novel hybrid auction-based task allocation architecture with multi-auctioneer agents' behavior is proposed for an Urban Air Mobility application. The proposed method aims to solve the combined problem of: (i) scheduling parcel pick-up and delivery tasks with time deadlines while minimizing the drones' energy consumption; (ii) scheduling battery re-charge tasks to ensure the service's persistency; and (iii) evaluating safe aerial routes since the UAVs fly overpopulated areas. The validity of the approach is demonstrated through Monte Carlo simulations. Moreover, being the proposed architecture distributed among the UAVs, the impact of communication failures on well-defined solution quality parameters is also investigated.

ThC1 Room 118

Security (Regular Session)

Chair: Branco, Kalinka Regina Lucas Jaquie Castelo — University of São Paulo

Co-Chair: Monteriù, Andrea — Università Politecnica Delle Marche

14:00-14:20 ThC1.1

Human Factors in the Age of Autonomous UAVs: Impact of Artificial Intelligence on Operator Performance and Safety, pp. 798-805

Alharasees, Omar — Budapest University of Technology and Economics
Adali, Osama H. — Technical University of Košice
Kale, Utku — Budapest University of Technology and Economics

This research reviews the current literature on the impact of Artificial Intelligence (AI) in the operation of autonomous Unmanned Aerial Vehicles (UAVs) and examines three key aspects in developing the future of Unmanned Aircraft Systems (UAS) and UAV operations: (i) design, (ii) human factors, and (iii) operation process. The use of widely accepted frameworks such as the "Human Factors Analysis and Classification System (HFACS)" and "Observe–Orient–Decide–Act (OODA)" loops are discussed. The comprehensive review of this research found that as autonomy increases, operator cognitive workload decreases and situation awareness improves, but also found a corresponding decline in operator vigilance and an increase in trust in the AI system. These results provide valuable insights and opportunities for improving the safety and efficiency of autonomous UAVs in the future and suggest the need to include human factors in the development process.

14:20-14:40 ThC1.2

Design of Stealthy Sparse Attacks for Uncertain Cyber Physical Systems, pp. 806-811

Du, Xinyang — Beihang University
Xi, Zhiyu — Beihang University

Due to the wide application of cyber-physical systems (CPSs) into society, sophisticated cyber-attacks on the physical plants have recently become a topic of scientific research. In this article, the issue of designing stealthy sparse attacks is considered for CPSs which aim to realize simultaneous actuator and sensor attacks. First, sensor and actuator attacks that satisfy sparse and stealthy conditions using input-output information are designed with the aid of subspace identification techniques. Then, an attack impact index is proposed to assess the degradation caused to the system performance, which provide reference for the design of the most destructive sparse attack mode. Finally, two numerical examples are provided to verify the effectiveness of proposed methods.

14:40-15:00 ThC1.3

Anomaly-Based Intrusion Detection System for In-Flight and Network Security in UAV Swarm, pp. 812-819

da Silva, Leandro Marcos — University of São Paulo
Ferrão, Isadora — University of São Paulo
Dezan, Catherine — Université De Bretagne Occidentale
Espes, David — Université De Bretagne Occidentale
Branco, Kalinka Regina Lucas Jaquie Castelo — University of São Paulo

Cyberattacks on Unmanned Aerial Vehicles (UAVs) have grown over the years due to the increased popularity of these vehicles. These attacks may involve interrupting control, manipulating information, or hijacking the vehicle. One solution to the problem is using Intrusion Detection System (IDS) to detect attacks and report them to the base station. However, existing IDS focus on specific attack niches and do not mention the application for UAV swarm. The approach proposed in this work is an IDS to detect flight anomalies and network attacks in UAV swarm, applying unsupervised and supervised machine learning approaches, respectively. In the unsupervised approach, a stacked autoencoder and federated learning detect in-flight anomalies. Supervised algorithms such as LightGBM identify Denial of Service (DoS) attacks on the UAV network, and data balancing with Generative Adversarial Networks (GANs). The results obtained in the IDS are promising, indicating the effectiveness of the chosen techniques, especially federated learning, which takes advantage of the distributed characteristic of the UAV swarm and guarantees data privacy.

15:00-15:20 ThC1.4

Onboard Passive Radar System Implementation for Detection and Tracking of Rogue UAVs, pp. 820-826

Souli, Nicolas — University of Cyprus

Kardaras, Panayiotis	University of Cyprus
Kolios, Panayiotis	University of Cyprus
Ellinas, Georgios	University of Cyprus

As the number of unauthorized operations of unmanned aerial vehicles increases, the protection of public spaces, as well as critical infrastructures against malicious actions has become a major concern. In this work, a prototype onboard passive radar system is presented, based on signals of opportunity and software-defined radio, which is able to detect and track illegal/unauthorized drone operations over a specified region of interest. Specifically, the proposed system, mounted on an unmanned aerial vehicle, aims to detect and track rogue drone operations by incorporating the signals of opportunity that are already available in the environment, such as digital video broadcasting - terrestrial signals, in conjunction with the visual measurements of the unmanned aerial agent. The development of the proposed small, low-cost, and versatile onboard passive radar solution is enabled by technological advancements in software-defined radio, embedded processing units, and signal processing. The design and development of the prototype are presented, and its applicability is demonstrated through extensive outdoor experiments.

ThC2 — Room 130

Micro and Mini UAS (Regular Session)

Chair: Hamanaka, Masatoshi	RIKEN Center for Advanced Intelligence Project
Co-Chair: Ma, Ziqing	Delft University of Technology

14:00-14:20 — ThC2.1

Deep Learning Approach to Drogue Detection for Fixed-Wing UAV Autonomous Aerial Refuelling with Visual Camera, pp. 827-834

Liu, Yunxiao	Fudan University
Li, Han	Fudan University
Wang, Liangxiu	Fudan University
Ai, Jianliang	Fudan University

In the unmanned aerial vehicle (UAV) autonomous aerial refuelling process, detection and position feedback of the refuelling drogue by the refuelling UAV are essential. Given the short docking distance and the characteristic of being easily affected by light, weather, and complex environments during the UAV refuelling process, realizing real-time and robust drogue detection is a critical problem. In this study, we designed and implemented a set of tanker UAV-refuelling drogue detection and recognition models based on the YOLOv5s model for real flight scenarios of fixed-wing UAVs. During the research process, the fixed-wing UAV test platform was built. Then, based on an actual flight test, 1900 flight images of the refuelling drogue in various environments were collected, and a tanker UAV-refuelling drogue dataset was produced. Subsequently, based on the YOLOv5s detection model, two detection models, YOLOv5s-D and YOLOv5s-DP, were designed and optimized for detecting tanker UAV and the refuelling drogue. The performance of the fixed-wing UAV test platform was assessed using the detection model to complete the test flight verification in an actual scene. The experimental results showed that the mean average precision (map) of the drogue detection model carried by the refuelling UAV was 97.2%, and the real-time detection frame rate of the tanker UAV and drogue was 33.5 fps, which validated the real-time performance of the detection model. Compared with previous research results, these findings provide advancements in image data acquisition of small fixed-wing UAV refuelling drogues, the design of the target detection algorithm, and the flight test of drogue detection in air.

14:20-14:40 — ThC2.2

Development and Calibration of Autopilot Hardware for Small Fixed-Wing Air Vehicles with Flight Test Validation of Linear Output Feedback Controller, pp. 835-841

Kandath, Harikumar	International Institute of Information Technology Hyderabad
Pushpangathan, Jinraj	International Institute of Information Technology Hyderabad
Bera, Titas	Indian Institute of Science
Dhall, Sidhant	Indian Institute of Science
Bhat, M. Seetharama	Indian Institute of Science

This paper discusses the development of autopilot hardware for small fixed-wing air vehicles. Weight constraint is the critical factor in developing such hardware. The sensors and communication devices are selected based on the requirements and constraints of these air vehicles. The sensors used in the hardware are calibrated using a three-axis rotating platform. The software written in the autopilot hardware is flexible enough to incorporate complex estimation and control algorithms along with the hardware-in-loop simulations. Linear output feedback controllers are designed for fixed wing micro and nano air vehicles. Successful flight trials are conducted to demonstrate the utility of the autopilot hardware for small fixed-wing air vehicles.

14:40-15:00 — ThC2.3

Attitude Control of a Tiltrotor Tailsitter Micro Air Vehicle Using Incremental Control, pp. 842-849

Lovell-Prescod, Gervase Hugo Ludovic Henry	Delft University of Technology
Ma, Ziqing	Delft University of Technology
Smeur, Ewoud	Delft University of Technology

Tailsitter Micro Air Vehicles with two rotors are promising due to their simplicity and efficient forward flight, but actuator saturation due to ineffective pitch control at a high angle of attack flight is a challenge limiting the flight envelope. This paper proposes a novel tiltrotor tailsitter design which features two tilting rotors as the only means for control moment generation. Incremental Nonlinear Dynamic Inversion (INDI) is applied to the attitude control problem of the tiltrotor tailsitter, whose attitude angle tracking performance is validated by indoor and outdoor flight tests. It is found that actuator saturation is largely avoided by using thrust vectoring which provides sufficient capability of pitch moment generation. However, it is also found that the proposed design with only leading-edge tilting motors excluding any aerodynamic control surfaces has limited roll control effectiveness in forward flight.

15:00-15:20 — ThC2.4

Implementation of Partial Observable Markov Decision Process (POMDP) Algorithm Using Bitcraze Crazyflie Drones, pp. 850-857

Graham, Conor John — Queensland University of Technology
Gonzalez, Luis Felipe — Queensland University of Technology
Sanoe, Abdullay — Queensland University of Technology

This paper develops a complex navigation solution for sequential drone swarm configuration using Partially Observable Markov Decision Process (POMDP) with the Bitcraze Crazyflie platform with a single localization anchor. The objective is to generate a stable control system for a swarm of drones to navigate a controlled environment toward a waypoint. The POMDP solver takes observations of the drones' real-world positions and determines specific actions based on a network of functions designed to optimize a path toward the waypoint. Once the solver defines the next action the swarm navigates toward the selected direction sequentially. Through extensive developmental and formal testing, the developed system performs the objective with an average trajectory deviation of fewer than 0.1 meters with a duration of approximately 18 seconds. Deficiencies have been identified in the software control structure. This research highlights the importance of drone control and localization redundancies for complex navigation solutions for micro-UAV swarm configurations.

ThC3 — Room 464

Air Vehicle Operations (Regular Session)

Chair: Sarcinelli-Filho, Mário — Federal University of Espirito Santo
Co-Chair: Ferrão, Isadora — University of São Paulo

14:00-14:20 — ThC3.1

Exploiting the Line Virtual Structure Formation for Cooperation of Two Mobile Robots, pp. 858-862

Villa, Daniel Khede Dourado — Federal University of Espírito Santo
Sarcinelli-Filho, Mário — Federal University of Espirito Santo

This work explores further the problem of controlling a formation composed by two unmanned aerial vehicles (UAVs), or by a UAV and an unmanned ground vehicle (UGV), using the virtual structure paradigm, having the line connecting the two robots as the virtual structure. An alternative version for characterizing the virtual structure is proposed, and the advantages and drawbacks of this novel framework are discussed. The proposed formation controller generates references for the time variation of the formation variables in the formation space, which are transformed to velocities in the robots' space, dynamically compensated using the feedback linearization technique. To validate our proposal experiments are run, considering one quadrotor and one differential drive wheeled mobile robot. The obtained results are presented through illustrations and videos, providing examples of the advantages of the proposed formation characterization.

14:20-14:40 — ThC3.2

RHFSafeUAV: Real-Time Heuristic Framework for Safe Landing of UAVs in Dynamic Scenarios, pp. 863-870

Singh, Jaskirat — University of Petroelum and Energy Studies
Adwani, Neel — University of Petroleum and Energy Studies
Kandath, Harikumar — International Institute of Information Technology Hyderabad
Krishna, Madhava — International Institute of Information Technology Hyderabad

This study presents a technique for multi-rotor unmanned aerial vehicles (UAVs) to efficiently and safely land in dynamic environments. The aim of this method is to locate a secure potential landing zone (PLZ) and choose the best one for landing. The PLZ is initially determined with an area estimation algorithm, which returns the empty region in the image where the UAV can possibly land. The obstacle-free regions that have a higher area than the vehicle's dimensions with tolerance are labelled as safe PLZs. In the second phase of this approach, the velocities of dynamic obstacles moving towards the PLZs are calculated, and their time to reach the zones is taken into consideration. The estimated time of arrival (ETA) of the UAV is calculated, and during the descent of the UAV, dynamic obstacle avoidance is executed. A ToF (Time of Flight) sensor is used for detecting altitude, while a depth camera is used for performing triangulation, area estimation, and computing distance to the target site. The approach, tested in real- world environments, has shown better results compared to existing work as the computation time is significantly lower, while the accuracy is competitive with deep learning counterparts.

14:40-15:00 — ThC3.3

Intelligent Diagnosis of Engine Failure in Air Vehicles Using the Alpha Dataset, pp. 871-878

Ferrão, Isadora — University of São Paulo
da Silva, Leandro Marcos — University of São Paulo
Almeida da Silva, Sherlon — University of São Paulo
Dezan, Catherine — Université De Bretagne Occidentale
Espes, David — Université De Bretagne Occidentale
Branco, Kalinka Regina Lucas Jaquie Castelo — University of São Paulo

Smart cities enable economic and social development through intelligent solutions to various problems, such as access to essential services, mobility, unnecessary energy consumption, security flaws, etc. urban air transport in smart cities. Regarding urban mobility problems, smart cities propose the development of Urban Air Mobility through a safe, sustainable, and affordable air transport system for passenger mobility, cargo delivery, and emergency services within or between metropolitan areas. However, these vehicles are still incipient and their implementation in cities presents challenges such as failures, security, and safety issues. In this sense and also considering a study using the database of the Center for Research and Prevention of Aeronautical Accidents (CENIPA), where engine failures are the main causes of problems in air vehicles, this study was structured using machine learning for the detection of engine failures, intelligently into eVTOLs. The results demonstrate the effectiveness of our technique. Our strategy presents a superior detection, being 21% more effective concerning other recent studies, using the same base of this study, and the same engine failure in aerial vehicles.

ThC4	Room 465
Regulations (Regular Session)	
Chair: Konert, Anna	Łazarski University
Co-Chair: Barbano, Mario	Università Di Genova

14:00-14:20	ThC4.1

Concept for an Automated Detection of Conflicts in UAS Traffic Management, pp. 879-886

von Roenn, Luca — Helmut-Schmidt-Universität
Grebner, Tobias Georg Gerhard — Helmut-Schmidt-Universität
Fay, Alexander — Helmut-Schmidt-Universität

Since January 26, 2023, the Commission Implementing Regulation (EU) 2021/664 applies in the European Union, with the help of which a legal basis has been created for the first time for the integration of the steadily increasing UAS traffic into the existing airspace via a so-called U-space. As the success of this approach stands and falls with acceptance by the public, it is essential that safe solutions are created. Therefore, UAS operators are now legally required to submit a UAS flight authorization request with the intended 4D trajectory prior to their flight and only if no spatial and temporal overlaps are detected, for example with other flight plans or no-fly zones, UAS operations may take place in U-space airspace. To this end, this paper develops a concept for legally compliant conflict detection that addresses both newly submitted UAS flight authorization requests and previously authorized requests. Finally, this concept is validated by means of a simulation. The results show that it is possible to detect all conflicts before the planned departure of an UAS in accordance with the legal basis. The modular design also makes it possible to make simple adjustments to the developed concept with regard to possible legal adjustments in this young research field.

14:20-14:40	ThC4.2

The Practical and Legal Aspects of Geographical Zones for Unmanned Aircraft Systems in Poland - Facilitation or Complication?, pp. 887-894

Fortońska, Agnieszka — University of Silesia
Berus, Matylda — Łazarski University
Fabisiak, Sylwia — Łazarski University
Ostrihansky, Magdalena — Polish Air Navigation Services Agency

Geographical zones for unmanned aircraft systems (UAS) in Poland are still in the deployment phase, though they have already found their vast practical application. Today, not all of the UAS restrictions are yet published as geographical zones for UAS, therefore there is always more than one source of restrictions for UAS pilots and operators that they need to be aware of for UAS operations. For that reason, there is a need to adopt hard law at the national level, as the current regulations in the form of guidelines are often not enough to prevent criminal offenses often deriving from the lack of knowledge or awareness of UAS pilots. The article explains the current legal basis of geozones and explores their possibilities.

14:40-15:00	ThC4.3

Implementing Urban Air Mobility in a Multi-Level Regulatory Framework: Perspectives from the EU, pp. 895-902

Barbano, Mario — Università Di Genova
Costa, Valentina — Università Di Genova

This paper discusses the challenges arising from the extended use of Unmanned Aircraft Systems (UAS) within urban contexts targeting people and freight mobility purposes. First of all, drivers and barriers are examined from the operational and planner's perspective, considering Urban Air Mobility (UAM) as part of the future transportation ecosystem. After a brief overview of the relevant European Union (EU) regulatory framework, issues concerning access to ground infrastructure and U-space governance will be examined, with a focus on Article 18(f) Regulation (EU) 2021/664 and recent European Union Aviation Safety Agency (EASA) guidance on this provision (AMC-GM). A uniform EU regime on UAM, as part of a strategy encompassing Innovative Air Mobility (IAM) as a whole, should be implemented with a certain degree of flexibility in order to adapt it to the peculiarities of each area, especially as far as access to airspace and ground infrastructure (vertiports, etc.) is concerned. For this reason, the role of local authorities remains crucial.

15:00-15:20	ThC4.4

Criminal Liability for Unlawful Usage of Unmanned Aircraft Vehicles in Selected Countries of the World, pp. 903-910

Osiecki, Mateusz — Łazarski University
Fortońska, Agnieszka — University of Silesia
Książek-Janik, Ewelina — Łazarski University

Growing popularity of unmanned aircraft vehicles (UAVs), commonly known as “drones” brings many challenges for lawmakers. If a drone is used irresponsibly or simply falls into “wrong hands” it can pose significant danger to persons and objects. Therefore, state authorities should implement relevant criminal provisions to protect potential victims from harm from the side of rouge drone operator. Hereby article is a brief, but detailed study of criminal legal provisions pertaining to drones’ operations present in international law and adopted by three particular countries representing different geographical zones: Italy, the United States and Australia. Its main role is to discuss the accuracy of those legal provisions and verify whether they reflect reality of drones' sector.

ThC5	Room 466
UAS Applications V (Regular Session)	
Chair: Givigi, Sidney	Queen's University
Co-Chair: Giernacki, Wojciech	Poznan University of Technology

14:00-14:20	ThC5.1

Deep Reinforcement Learning Solution of Reach-Avoid Games with Superior Evader in the Context of Unmanned Aerial Systems, pp. 911-918

Silveira, Jefferson — Queen's University

Cabral, Kleber	Queen's University
Rabbath, Camille Alain	Defence Research and Development Canada
Givigi, Sidney	Queen's University

This paper presents a deep reinforcement learning (DRL) approach to solve a reach-avoid problem that commonly arises in air defence systems. The focus of this paper is to improve the defender's ability to pursue a more capable (faster) attacker that is trying to evade the defender while aiming for a target. We propose and analyze the resulting DRL strategy for scenarios with one and two pursuers against one evader and for two different types of aircraft, multirotor and fixed-wing, on the two-dimensional plane. During training, the pursuers face a faster evader that executes a saddle-point optimal strategy obtained by analytically solving the problem as a differential game (DG). We compare the win rate of the DRL policy with the win rate when pursuers use the DG strategy against the faster evader. Even though the DG strategy is optimal for aircraft with the same speed, it quickly deteriorates from the pursuer's perspective when the evader is faster. In contrast, the results of the learned strategy show that the learned policy deteriorates slowly, which results in higher win rates in many situations with faster evaders when compared to the DG strategy.

14:20-14:40 ThC5.2

Toward Improving Tracking Precision in Motion Capture Systems, pp. 919-925

Retinger, Marek	Poznan University of Technology
Michalski, Jacek	Poznan University of Technology
Kozierski, Piotr	Poznan University of Technology
Giernacki, Wojciech	Poznan University of Technology

Motion capture systems are a must-have part of a modern research laboratory. The system has a wide area of applications such as movie, sport, medicine or experiments validations. The system provides accurate pose (both position and orientation) data and allows tracking several objects at the same time. The calibration process is a crucial part of using the system, which determines the further accuracy of tracking. This paper presents research struggling with this problem and describes a new approach to the camera placement process for the OptiTrack system, using the dedicated application programming interface and its features. The document discusses the general concept, shows the benefits of using it and confirms its usefulness. It helps to improve camera placement to ensure detection and reduction or elimination of "low tracking zones". The working tool is also presented.

14:40-15:00 ThC5.3

Design and Realization of a Cable-Drogue Aerial Recharging Device for Small Electric Fixed-Wing UAVs, pp. 926-932

Wang, Liangxiu	Fudan University
Li, Han	Fudan University
Liu, Yunxiao	Fudan University
Ai, Jianliang	Fudan University

As the application scope of small electric fixed-wing unmanned aerial vehicles (UAVs) becomes increasingly broad, the limitation of endurance caused by the battery technology is also becoming more evident. This paper proposes a cable-drogue aerial recharging method to solve this problem based on the aerial refuelling technology of fuel-powered aircraft. We designed and built a cable-drogue aerial recharging device for small electric fixed-wing UAVs. Using computational fluid dynamics (CFD) numerical simulations and drogue-towing flight experiments, the drag and motion characteristics of a cable-drogue model were obtained, verifying the effectiveness of the drogue-design modeling method. Finally, simulated charging tests of the aerial recharging device was completed, and the feasibility of the cable-drogue aerial recharging method were conducted.

FrA1 Room 118

Aerial Robotic Manipulation (Regular Session)

Chair: Gabellieri, Chiara	University of Twente
Co-Chair: Rafee Nekoo, Saeed	Universidad De Sevilla

10:30-10:50 FrA1.1

Online Trajectory Generation for Aerial Manipulator Subject to Multi-Tasks and Inequality Constraints, pp. 933-939

Chen, Rui	Beihang University
Liu, Qianyuan	Beihang University
Chen, Zeshuai	Beihang University
Guo, Kexin	Beihang University
Yu, Xiang	Beihang University
Guo, Lei	Beihang University

This article tackles the problem of generating coordinated trajectory for unmanned aerial manipulator (UAM) system. The kinematic redundancy nature of this class of system makes it challenging to design constraints-satisfied trajectories of both the aerial vehicle and the robotic arm simultaneously that can accomplish a series of tasks with varying levels of priority. This paper presents a redundancy utilized trajectory generation method based on hierarchical quadratic programming (HQP). The method is computationally inexpensive to execute online, allowing the UAM to dynamically adjust its configuration within inequality constraints (e.g. velocity bounds) to execute multi-tasks such as end-effector tracking, joint limits avoidance, and center of gravity (CoG) alignment. An experiment case study, where UAM is assigned to track and grasp a moving target, has been reported to illustrate the effectiveness of our approach.

10:50-11:10 FrA1.2

CLF-Based Control for Aerial Manipulation Using Multirotor UAVs, pp. 940-947

Namigtle Jimenez, Alfredo	Instituto Nacional De Astrofísica, Óptica Y Electrónica
Alvarez Muñoz, Jonatan Uziel	Institut Polytechnique De Sciences Avancées
Diaz-Tellez, Juan	Instituto Tecnólogico De Puebla
Enriquez Caldera, Rogerio Adrian	Instituto Nacional De Astrofísica, Óptica Y Electrónica

Escareno Castro, Juan Antonio — University of Limoges
Durand, Sylvain — Strasbourg Univeristy
Marchand, Nicolas — GIPSA-Lab
Guerrero-Castellanos, J. Fermi — Benemérita Universidad Autónoma De Puebla

This paper presents the trajectory-tracking control of a Vertical Take-off and Landing (VTOL) rotorcraft endowing a two Degrees of Freedom (DoFs) manipulator arm. The research considers endogenous (parametric) and exogenous (external disturbances) uncertainties as lumped disturbance, which is estimated via an Extended-State Observer (ESO). A feedback controller is synthesized through the Control Lyapunov Function (CLF) aided by feedforward terms composed of the ESO estimates. The compound system, the rotorcraft, and the manipulator dynamics are mathematically modelled based on the energy-based Euler-Lagrange (EL) formalism. The system's stability is analyzed within the Input-State Stability (ISS) framework, guaranteeing closed-loop stability for the overall design (controller-ESO-UAV+arm). Results from an extensive simulation stage prove the effectiveness of the proposed control strategy.

11:10-11:30 — FrA1.3

Theoretical and Experimental Investigation on Body Control after Perching for Flapping-Wing Robots: Extending the Workspace for Manipulation, pp. 948-955

Serrano Luque, Pablo — Universidad De Sevilla
Satué Crespo, Álvaro César — Universidad De Sevilla
Rafee Nekoo, Saeed — Universidad De Sevilla
Acosta, Jose Angel — Universidad De Sevilla
Ollero, Anibal — Universidad De Sevilla

This work investigates a post-perching control for flapping-wing flying robots (FWFRs) to control and move the system on a branch. The flapping-wing aerial systems are lightweight platforms that mimic the birds' flight, and they could serve for monitoring and inspection. The interaction of the FWFRs with the environment needs to fulfil perching on a branch, as a preliminary step, then moving the body to gain access to the desired pose and workspace. The leg of the robot moves the bird to the proper position. This work studies the mathematical modeling, simulation, and experimental implementation of this topic. A three-degree-of-freedom system is presented to model the robot's body, tail, and leg. A nonlinear controller, so-called feedback linearization (FL) is used for the control of the robot. A linear quadratic regulator (LQR), plus an integrator, are embedded in the FL controller to deliver optimal control for the linearized system. The simulation results show that the actuated leg extends the workspace of the robot significantly and confirms the effectiveness of the proposed strategy for body control. Experimental results present similar behavior of the system using the proposed controller for different desired setpoints.

11:30-11:50 — FrA1.4

Physical Human-Aerial Robot Interaction and Collaboration: Exploratory Results and Lessons Learned, pp. 956-962

Afifi, Amr — University of Twente
Corsini, Gianluca — Université De Toulouse
Sable, Quentin — University of Twente
Aboudorra, Youssef — University of Twente
Sidobre, Daniel — Université De Toulouse
Franchi, Antonio — University of Twente

In this work, we present, a first of its kind, physical human-aerial robot interaction (pHARI) experiment, with an articulated aerial manipulator (AM). The robotic platform is a fully actuated multi-rotor aerial vehicle (MRAV) with fixedly- tilted propellers endowed with a 3degree of freedom (DoF) robotic arm. We implemented a state-of-the-art control architecture composed of a feedback linearization motion controller, an admittance filter and a hybrid wrench observer. The experiments prove the viability of a new use case in aerial robotics, namely pHARI. The experimental results also shed light on the limitations of the current state-of-the-art and provide insights into possible research directions. The video of the experiments, which is available at https://youtu.be/LrQxXbQ5IHc, shows an experiment simulating work at height, where a human manually guides an AM and then attaches a tool to its end effector (EE).

11:50-12:10 — FrA1.5

Differential Flatness and Manipulation of Elasto-Flexible Cables Carried by Aerial Robots in a Possibly Viscous Environment, pp. 963-968

Gabellieri, Chiara — University of Twente
Franchi, Antonio — University of Twente

This work considers a system composed of two quadrotors manipulating a deformable and extensible cable. The dynamic model is presented, and it is based on a discrete representation of the cable, which is decomposed into lumped masses interconnected by linear springs through passive spherical joints. A set of flat outputs is found for the system. The flatness is exploited to design a method to manipulate the cable, which is then tested through numerical simulations.

12:10-12:30 — FrA1.6

Nonlinear MPC for Full-Pose Manipulation of a Cable-Suspended Load Using Multiple UAVs, pp. 969-975

Sun, Sihao — University of Twente
Franchi, Antonio — University of Twente

In this work, we propose a centralized control method based on nonlinear model predictive control to let multiple UAVs manipulate the full pose of an object via cables. At the best of the authors knowledge this is the first method that considers the full nonlinear model of the load-UAV system and ensures all the feasibility constraints concerning the UAV maximum and minimum thrusts, the collision avoidance between the UAVs, cables and load, and the tautness and maximum tension of the cables. By considering the above factors, the proposed control algorithm can fully exploit the performance of UAVs and facilitate the speed of operation. Simulations are conducted to validate the algorithm to achieve fast and safe manipulation of the pose of a rigid-body payload using multiple UAVs. We demonstrate that the computational time of the proposed method is sufficiently small (<100 ms) for UAV teams composed by up to 10 units, which makes it suitable for a vast variety of future industrial applications, such as autonomous building construction and heavy-load transportation.

FrA2	Room 130
Reliability of UAS (Regular Session)	
Chair: Giernacki, Wojciech	Poznan University of Technology
Co-Chair: Monteriù, Andrea	Università Politecnica Delle Marche

10:30-10:50	FrA2.1

Actuator Fault Detection in Centrally Powered Variable-Pitch Propeller Quadrotor Vehicles, pp. 976-981

Chaturvedi, Sanjay	Indian Institute of Technology Kanpur
Sahoo, Soumya Ranjan	Indian Institute of Technology Kanpur

Centrally powered variable-pitch propeller (VPP) quadrotors have a single motor that transfers power to all four rotors through a transmission mechanism. All four rotors have their respective blade pitch servo motors controlling the pitch of rotor blades. Unlike conventional quadrotors, these quadrotors are controlled only by varying the pitch angle of each propeller blades. In this work, we have focused on two types of actuator faults common in these types of quadrotors: a Lock-in-Place (LIP) type of failure in rotor blades and Loss of Effectiveness (LoE) of rotor blades. In a LIP failure, the servo motor controlling the blade pitch angle freezes at a position. It does not respond to commands from the flight controller, making the thrust from that rotor constant. In Loss of Effectiveness failure, the actuator responds less or more to the commanded signal. To detect such faults under hover and normal flight conditions, we propose a non-linear observer-based fault detection method. In this method, we design a Thau observer-based residual generator where the generated residuals are used to detect the actuator fault in the quadrotor. The proposed method is simulated under different levels of fault conditions, and the presented results show the designed method's efficacy.

10:50-11:10	FrA2.2

PADRE – Propeller Anomaly Data REpository for UAVs Various Rotor Fault Configurations, pp. 982-989

Puchalski, Radosław	Poznan University of Technology
Kołodziejczak, Marek	Poznan University of Technology
Bondyra, Adam	Poznan University of Technology
Rao, Jinjun	Shanghai University
Giernacki, Wojciech	Poznan University of Technology

The article presents a drone sensory database collected during flights with different types of propeller failures. Measurements from four accelerometers and four gyroscopes were collected during 20 flights with two types of faults occurring in different configurations in one, two, three or four rotors. The paper shows the architecture of the system and the procedure for acquiring and processing the data. Raw sensor outputs, pre-treated data, and digitally processed signals were provided in a publicly available repository, the structure and purpose of which are discussed in the paper. The applicability and potential use of the shared data for other research is indicated. The provided repository should be helpful in developing methods for detecting and classifying faults in actuators of unmanned aerial vehicles (UAVs). It will be particularly useful for researchers working on data-driven methods. The default purpose of the dataset is to train artificial intelligence models that require substantial amounts of data.

11:10-11:30	FrA2.3

Toward Lightweight Acoustic Fault Detection and Identification of UAV Rotors, pp. 990-997

Kołodziejczak, Marek	Poznan University of Technology
Puchalski, Radosław	Poznan University of Technology
Bondyra, Adam	Poznan University of Technology
Sladic, Sasa	University of Rijeka
Giernacki, Wojciech	Poznan University of Technology

Data-driven Fault Detection and Isolation (FDI) systems receive a lot of attention from researchers. Several recent applications utilize acoustic signals recorded on-board of the Unmanned Aerial Vehicle (UAV) to assess the condition of propulsion system and diagnose rotor blade impairments. In this work, we propose two major improvements to the previously developed FDI scheme. They are aimed at reducing the computational load of the deep LSTM-based (Long Short-Term Memory) fault classifier. First, the PCA-based (Principal Component Analysis) feature space reduction allows reducing the size of neural networks and thus decreasing the number of mathematical operations. Secondly, a modified algorithm introduces an ensemble of multiple weak classifiers with a decision-fusion strategy that provides the final status of the system. The developed schemes were evaluated in comparison to the original algorithm, using an extensive dataset of real-flight acoustic data. The results show that the proposed improvements significantly reduce the computation time within the assumed performance constraints.

11:30-11:50	FrA2.4

UAV-FD: A Dataset for Actuator Fault Detection in Multirotor Drones, pp. 998-1004

Baldini, Alessandro	Università Politecnica Delle Marche
D'Alleva, Lorenzo	Università Politecnica Delle Marche
Felicetti, Riccardo	Università Politecnica Delle Marche
Ferracuti, Francesco	Università Politecnica Delle Marche
Freddi, Alessandro	Università Politecnica Delle Marche
Monteriù, Andrea	Università Politecnica Delle Marche

Multirotor drones are equipped with propellers that may get damaged in flight in case of a collision with an obstacle or a rough landing. In view of safety-critical applications, such as flying overcrowded areas or future passenger drones, being aware of a damaged actuator becomes essential to enhance system integrity. Therefore, in this paper we present a public dataset, namely UAV-FD, where real flight data from a multirotor under the effects of a chipped blade are collected. A conventional ArduPilot-based controller is employed, where the ArduPilot firmware is customized to increase the signal logging rate of selected variables, thus capturing information at higher

frequencies. Moreover, the actual speed of each motor is measured and made available. Finally, we provide an illustrative fault detection strategy, based on MATLAB Diagnostic Feature Designer toolbox, to show how the dataset can be used and the blade chipping can be detected.

11:50-12:10	FrA2.5

Quantifying Weather Tolerance Criteria for Delivery Drones – a UK Case Study, pp. 1005-1012

Oakey, Andy	University of Southampton
Cherrett, Tom	University of Southampton

As demand for final mile delivery has increased, the use of delivery drones is being explored in many countries, including the UK. Despite offering perceived benefits over existing methods in terms of delivery speed and reliability, there is little understanding of the design criteria needed for drones to actually realise them. This paper investigates how reliability and resilience of deliveries vary by transport mode, relating to the delivery success (i.e., can a delivery be made in a given time-window), and the flexibility of this success (i.e., how many different time windows are possible). Comparing the performance of current UK ground transport modes and drones using historic weather and reliability data, a review of the factors that contribute to what makes a reliable and weather resistant drone service is presented. Results suggested that a significant wind tolerance would be required to achieve a level of service equal to ground transportation, with VTOL platforms requiring tolerances ranging from 14 m/s (Solent region) to more than 23 m/s (Scottish Hebrides). Fixed-wing platform tolerances were not as high, with a tolerance of 10 m/s achieving flights on almost all days in all case study areas. It is likely that some locations cannot reliably be served by drone and must depend on contingency options when flights are not possible. With significant variations in tolerance requirements, and notable seasonal variances, applications of delivery drones should be considered on a case-by-case basis, comparing to existing modes, to ensure reliable supply chains are realised.

12:10-12:30	FrA2.6

A Reliability Framework for Safe Octorotor UAV Flight Operations, pp. 1013-1020

T., Thanaraj	Nanyang Technological University
Govind, Siddesh	Air Traffic Management Research Institute
Roy, Anurag	Nanyang Technological University
Ng, Bing Feng	Nanyang Technological University
Low, Kin Huat	Nanyang Technological University

Airworthiness of multirotor unmanned aerial vehicles is of utmost importance for ensuring safe flight operations, especially in high-risk airspace. The propulsion system plays a critical role in determining the UAVs' stability and control, and their failures can render UAVs into significant hazards. Assessing the reliability of the propulsion system provides valuable insight into the overall airworthiness of the UAVs, benefitting both regulators and operators. Hence, this paper proposes a framework that integrates controllability analysis with Markov chain modeling to evaluate UAV reliability. The controllability analysis determines combinations of propulsion unit failures in which the UAV remains controllable, which are then modelled as Markov states. This framework is applied to a class of octorotor UAVs, comparing their reliability with other multi-rotor UAVs and examining the influence of different payloads. The results demonstrate the superior reliability of octorotor UAVs, emphasizing their increased suitability for high-risk airspace flight operations compared to other multirotor UAVs.

FrA3	Room 464
Autonomy (Regular Session)	
Chair: Branco, Kalinka Regina Lucas Jaquie Castelo	University of São Paulo
Co-Chair: Causa, Flavia	Università Di Napoli Federico II

10:30-10:50	FrA3.1

BDP-UaiFly System: A Platform for the RoboCup Brazil Open Flying Robot Trial League, pp. 1021-1028

Alves Fagundes Junior, Leonardo	Universidade Federal De Viçosa
Oliveira Barcelos, Celso	Universidade Federal De Viçosa
Gandolfo, Daniel Ceferino	National University of San Juan
Brandao, Alexandre Santos	Universidade Federal De Viçosa

The Flying Robot Trial League (FRTL), from RoboCup Brazil, is a competition that stimulates the development of autonomous and intelligent flying robots for inspection and operation in pipeline lanes and oil installations. In this context, this work presents the system developed by the BDP-UaiFly Team for the 2022 competition, using the off-the-shelf Parrot Bebop 2 to execute the Equipment Transport phase. This paper presents in detail the system platform and the navigation and sensing strategies implemented for autonomous navigation and image processing. In particular, the strategy adopted for cargo transportation based on servo-visual control is presented. Practical experiments validate the proposed solutions for the phases of the challenge.

10:50-11:10	FrA3.2

Creating Trustworthy AI for UAS Using Labeled Backchained Behavior Trees, pp. 1029-1036

Ögren, Petter	KTH Royal Institute of Technology
Alfredson, Jens	Saab Aeronautics

Unmanned Aerial Systems (UAS) have the potential to provide cost effective solutions to many problems, but their control systems need to be safe and trustworthy in order to realize this potential. In this paper we show how behavior trees (BTs), created using backward chaining and using a particular way of labelling subtrees, can be used to meet the requirements of trustworthy autonomy described in a US air force (USAF) report. Behavior Trees represent a modular, reactive, and transparent way of structuring a control system that is receiving increasing interest in the UAS community. While their safety and efficiency have been investigated in prior research, their connection to trustworthy autonomy has not been explored. A set of guidelines for trustworthy autonomy, taken from a USAF report, include items such as: being similar to how humans parse problems, being able to explain its reasoning in a concise way, and being able to be visualized at different levels of resolution. We propose a new way of deriving explanations that conform to these guidelines, using a particular labelling of subtrees in the BT combined with a structured design methodology called backward chaining. The proposed approach is illustrated in a detailed example.

11:10-11:30	FrA3.3

Multi-Agent Reinforcement Learning for Multiple Rogue Drone Interception, pp. 1037-1044

Valianti, Panayiota — University of Cyprus
Malialis, Kleanthis — University of Cyprus
Kolios, Panayiotis — University of Cyprus
Ellinas, Georgios — University of Cyprus

Unmanned aerial vehicles (UAVs) are increasingly being utilized for a wide variety of applications. However, malicious or illegal UAV (drone) activity poses great challenges for public safety. To address such challenges, this work proposes a framework based on reinforcement learning (RL) in which multiple UAVs cooperatively jam multiple rogue drones in flight to safely disable their operation. The main objective is to select mobility and power level control actions for each UAV to best jam the rogue drones, while also accounting for the interference power received by surrounding communication systems. Simulation experiments are conducted to evaluate the performance of the proposed approach, demonstrating its effectiveness and advantages as compared to a centralized solution.

11:30-11:50	FrA3.4

Autonomous Navigation and Control of a Quadrotor Using Deep Reinforcement Learning, pp. 1045-1052

Mansour, Mohamed — German University in Cairo
El-Badawy, Ayman — German University in Cairo

A deep reinforcement learning-based control framework has been proposed in this paper to achieve autonomous navigation and control of a quadrotor. Cascaded reinforcement learning agents form the control framework. First, a path following (PF) agent controls the quadrotor's tracking behavior by directly mapping environment states into motor commands. The second agent modifies the desired path to avoid any detected obstacles along the path. The obstacle avoidance (OA) agent achieves this task by adding an offset distance deflection to the tracking error before sending it to the path-following agent. Generalization of the obstacle avoidance behavior in three-dimensional space was achieved by the usage of frame transformation. The two agents were trained using the "Twin Delayed Deep Deterministic Policy Gradient" (TD3) algorithm, and the developed framework succeeded in avoiding multiple obstacles of different sizes and configurations in simulation.

11:50-12:10	FrA3.5

Multicopters Obstacle Avoidance by Learning Optical Flow with a Balance Strategy, pp. 1053-1058

Gao, Wenhan — Beihang University
Jiang, Shuo — Beihang University
Quan, Quan — Beihang University

Obstacle avoidance using onboard sensors is an important part of the safe and reliable navigation of autonomous aerial vehicles. For Micro aerial vehicles (MAVs), due to the extremely limited payload, it is a better choice to equip only one monocular camera. Although much attention had been paid to using optical flow to avoid obstacles mimicking the behavior of flying insects, these methods have met only limited success. Here, we propose a recognize-and-avoid method drawing lessons from the reactive obstacle avoidance methods. To let MAVs recognize the environmental conditions, we build an optical flow dataset for obstacle avoidance in the simulation environment and use a deep neural network to classify optical flow images into 5 labels. Then an avoidance policy is designed to mimic the ``optical flow balance'' strategy of flying insects. We analyze the proposed method in different simulation scenes and demonstrate the generalization of our method.

12:10-12:30	FrA3.6

Online Reward Adaptation for MDP-Based Distributed Missions, pp. 1059-1066

Hamadouche, Mohand — Université De Bretagne Occidentale
Dezan, Catherine — Université De Bretagne Occidentale
Espes, David — Université De Bretagne Occidentale
Branco, Kalinka Regina Lucas Jaquie Castelo — University of São Paulo

Unmanned aerial vehicles are increasingly used in environments where human intervention is difficult, repetitive, and dangerous. They greatly improve mission quality, productivity, and safety. Mission management of these increasingly complex autonomous vehicles requires independent and online decisions. Markov decision processes (MDPs) are the most widely used probabilistic decision models for describing, modeling, and solving decision-making problems under uncertainty. In order to take into account the physical constraints and safety requirements of the mission, parallel decision models are required with an increase in mission complexity. However, the parallel execution of several MDPs can lead to conflicts. This paper describes a self-adaptation method for resolving conflicts that arise during the mission of a UAV swarm modelled with Markov decision processes (MDPs). The decisions must be taken in priority by the UAV itself but in some cases, it does not have the global view to choose the most adapted to the mission. The proposed method is able to detect and resolve conflicts based on two main phases. The first is the detection of conflicting UAV members by the embedded edge devices. Second, each UAV adjusts its mission plan to avoid conflicts in the swarm. To illustrate the methodology, experimental results obtained with a UAV swarm system performing a target search and tracking mission are presented. Our solution has low overhead and significantly improves the swarm's lifetime, safety, and mission efficiency.

FrA4	Room 465
Control Architectures I (Regular Session)	

Chair: Bertolani, Giulia — Università Di Bologna
Co-Chair: Chen, YangQuan — University of California - Merced

10:30-10:50	FrA4.1

State Dependent Regional Pole Assignment Controller Design for a 3-DOF Helicopter Model, pp. 1067-1072

Arican, Ahmet Cagri — Gazi University
Copur, Engin Hasan — Necmettin Erbakan University

Inalhan, Gokhan — Cranfield University
Salamci, Metin U. — Gazi University

For linear systems, a state feedback control law can be easily designed to keep all closed-loop poles inside a specified disk since the locations of the poles are unique. However, its application to nonlinear systems is not so simple. Therefore, this paper introduces a new pole placement method, named as State Dependent Regional Pole Assignment, for nonlinear systems. This proposed method produces a state dependent feedback control law, enabling the eigenvalues of the closed-loop matrix to be placed in a specified disk to achieve the desired control performance characteristics. The effectiveness of the method is tested on the 3 DOF Helicopter experimental setup. To verify its effectiveness, the experimental results of the nonlinear method are compared with those of the linear method.

10:50-11:10 FrA4.2

Dynamic Modelling and Robust Backstepping Control of Hybrid Unmanned Amphibious Multirotor Robot for Smooth Media Transition in the Presence of Uncertainty, pp. 1073-1080

Khatri, Jay — Indian Institute of Technology Jodhpur
Gupta, Sandeep — Indian Institute of Technology Kanpur
Mohanta, Jayant Kumar — Indian Institute of Technology Jodhpur

This paper proposes a robust backstepping control scheme for the autonomous operation of a hybrid unmanned underwater-aerial vehicle while considering uncertainty in the system model. The simplified mathematical model is presented to show the complete control design process. The simulation is performed to show the effectiveness of the proposed control scheme and with comparative analysis with existing PID and conventional backstepping control. The transient behaviour of drone and aerial and underwater maneuvering is simulated using the PID and proposed Robust backstepping algorithm. The transient behaviour of the vehicle is addressed with six possible maneuvers between air and water media. The simulation results are presented and compared to show the superiority of the proposed backstepping control algorithm over the conventional PID control algorithm with gravity compensation. The Performance parameters are also evaluated and presented to show the superiority of the proposed algorithm in aerial as well as underwater maneuvers.

11:10-11:30 FrA4.3

L1 Adaptive Attitude Augmentation of a Small-Scale Unmanned Helicopter, pp. 1081-1088

Ryals, Andrea Dan — Università Di Pisa
Bertolani, Giulia — Università Di Bologna
Pollini, Lorenzo — Università Di Pisa
Giulietti, Fabrizio — Università Di Bologna

In this paper, the L1 attitude control augmentation of an aerobatic helicopter is described. The baseline controller is divided into two loops, an attitude loop, and an angular speed loop. The attitude loop generates an angular reference speed for the angular speed loop, which finally provides the collective commands to the helicopter. Both loops are augmented through an L1 adaptive controller whose low-pass filter bandwidth is tuned considering a simplified helicopter actuation and flapping dynamics model. Simulation results are shown, and the baseline and the augmented controllers are compared.

11:30-11:50 FrA4.4

A PX4 Integrated Framework for Modeling and Controlling Multicopters with Tiltable Rotors, pp. 1089-1096

Marcellini, Salvatore — Università Di Napoli Federico II
Cacace, Jonathan — Università Di Napoli Federico II
Lippiello, Vincenzo — Università Di Napoli Federico II

This paper presents a general control framework for multicopters equipped with tiltable rotors (tilting multicopters). Differently from classical flat multicopters, tilting multicopters can be fully actuated systems able to decouple position and attitude control. The proposed framework has been transparently integrated into the widely used PX4 control stack, an open-source controller for ground and aerial systems, to fully exploit its high-level interfaces and functionalities and, at the same time, simplify the creation of new devices with tilting propellers. Simulation tools have been also added to the PX4 simulation framework, based on its Software-In-The-Loop (SITL) system and a set of simulated experiments in a dynamic robotic simulator have been conducted to demonstrate the effectiveness of this system. Moreover, to demonstrate the usability of the proposed framework, initial experiments with a real platform have been carried out. The proposed control framework is accessible at the following link: https://github.com/prisma-lab/PX4_tilting_multicopters

11:50-12:10 FrA4.5

Novel Cascaded Incremental Nonlinear Dynamic Inversion Controller Approach for a Tiltrotor VTOL, pp. 1097-1105

Henkenjohann, Mark — Fraunhofer Institute for Mechatronic Systems Design IEM
Nolte, Udo — Fraunhofer Institute for Mechatronic Systems Design IEM
Henke, Christian — Fraunhofer Institute for Mechatronic Systems Design IEM
Traechtler, Ansgar — University of Paderborn

This paper presents a novel cascaded incremental nonlinear dynamic inversion (INDI) flight controller approach for a tiltrotor VTOL. The main focus is the adaption of INDI to a specific tiltrotor VTOL configuration aiming for optimal exploitation of the actuator capabilities combined with the advantages of a cascaded INDI. For this purpose the tilt angle of the overall thrust vector with respect to the aircraft is introduced as important connection between two cascaded INDIs: For the outer INDI linearizing translational dynamics this serves as virtual control variable. For the inner INDI linearizing rotational dynamics this variable is a pseudo control input. Thus, the tilt mechanisms of the aircraft can be utilized creating rotational and translational dynamics in a cascaded INDI approach linearizing translational and rotational dynamics separately. The approach is evaluated in simulation studies focusing on functionality, linearization and decoupling.

12:10-12:30 FrA4.6

Position Control of Crazyflie 2.1 Quadrotor UAV Based on Active Disturbance Rejection Control, pp. 1106-1113

Michalski, Jacek — Poznan University of Technology
Retinger, Marek — Poznan University of Technology

Kozierski, Piotr | Poznan University of Technology
Giernacki, Wojciech | Poznan University of Technology

This paper presents the active disturbance rejection control (ADRC) algorithm applied to control the position of the small flying robot Crazyflie 2.1 in two degrees of freedom (movement in x and y axis). The platform and its functionalities, such as physical attributes and a communication system, were presented. Discrete proportional-integral-derivative (PID) and ADRC controllers were implemented and tuned. Furthermore, comparative tests were performed. Sensory data from the OptiTrack motion capture system was used in real flight experiments, ensuring high precision of measurements and high sampling frequency. Selected time plots and numerical quality indices were compared, especially for different ADRC controller gains. Based on the obtained results, one can conclude about some advantages of the ADRC method for nonlinear system, such as a drone. The presented approach additionally, once tuned, theoretically works fine for any object model.

FrA5 | Room 466

Multirotor Design and Control I (Regular Session)

Chair: Pierri, Francesco | Università Della Basilicata
Co-Chair: Arogeti, Shai | Ben-Gurion University of the Negev

10:30-10:50 | FrA5.1

A Fully Actuated Drone with Rotating Seesaws, pp. 1114-1121

Yecheskel, Dolev | Ben-Gurion University of the Negev
Arogeti, Shai | Ben-Gurion University of the Negev

Standard drones are generally underactuated systems, an attribute that limits their maneuvering ability. This limitation is because of the inherent coupling between the total thrust direction and the angular state of the drone body. To decouple these quantities, we suggest using seesaws, which allow controlling the thrust direction independently. Unlike other structures based on additional actuators to tilt the thrust, our solution is not based on any extra actuator that does not contribute to the lifting force. The presented configuration is an octocopter with eight propellers and four seesaws. These results extend a former suggested structure based on a single seesaw.

10:50-11:10 | FrA5.2

The ODQuad: Design and Experimental Validation of a Novel Fully Actuated Quadrotor, pp. 1122-1127

Nigro, MIchelangelo | Università Della Basilicata
Pierri, Francesco | Università Della Basilicata
Caccavale, Fabrizio | Università Della Basilicata
Ryll, Markus | Technical University Munich

This work experimentally validates a novel fully actuated quadrotor-based unmanned aerial vehicle named ODQuad (OmniDirectional Quadrotor). The ODQuad is composed of three main parts arranged in a gimbal configuration. The internal mechanism is composed by two rotational joints with orthogonal and incident axes which allow to decouple the horizontal motions from the vehicle body rolling and pitching. Firstly, the physical prototype is presented and the motion controller, inherited by [1], has been tailored in such a way to integrate the servo actuators of the internal gimbal mechanism. Three trajectories have been commanded to prove the decoupling between the position and attitude motion. The results confirm the effectiveness of the proposed multirotor design.

11:10-11:30 | FrA5.3

Transition Control Planning and Optimization for a Boxed-Wing eVTOL Tiltrotor Vehicle Using Trim Analysis, pp. 1128-1135

Hyun, Jeongseok | Konkuk University
Jang, Minseok | Konkuk University
Nguyen, Tuan Anh | Konkuk University
Lee, Jae-Woo | Konkuk University

Electric vertical take off and landing aircraft (eVTOL) is a rapidly growing research field with immense potential for its applications in urban air mobility (UAM). One particular type of eVTOL, the Tiltrotor, stands out for its ability to switch between helicopter and fixed-wing modes during the transition flight period. During this phase, the direction of the propulsion system thrust is adjusted, causing a change in the aircraft's shape. Proper tilt angle control is crucial for ensuring stable transition flight, as it is influenced by both the propulsion system and aerodynamics. In this study, we employ trim analysis to identify the tilt corridor and formulate a tilt angle control strategy. The flight performance of the Tiltrotor is then evaluated through simulations that utilize optimization algorithms such as Stochastic Gradient Descent (SGD) and Genetic Algorithm (GA) to find the optimal values of parameters related to the transition flight. Our approach provides valuable insights into the impact of tilt angle control on the stability and efficiency of Tiltrotor eVTOLs during transition flight.

11:30-11:50 | FrA5.4

Finite Integral Terminal Synergetic Control of a Disturbed Quadcopter with Variable Geometry, pp. 1136-1141

Belmouhoub, Amina | University Mohamed El Bachir El Ibrahimi of Bordj Bou Arreridj
Bouzid, Yasser | Ecole Militaire Polytechnique
Derrouaoui, Saddam Hocine | Ecole Supérieure Ali Chabati
Medjmadj, Slimane | University of Bordj Bou Arreridj
Guiatni, Mohamed | Ecole Militaire Polytechnique

This paper puts forward the control of a quadcopter with variable geometry exposed to external disturbances. Using a finite Integral Terminal Synergetic Control (ITSC) scheme, which was designed to solve the trajectory tracking problem. This controller has the advantages of use a continuous control law that eliminates the chattering phenomenon, convergence of states in finite time, good tracking performance and simple structure. Moreover, it is well suited in practice to digital implementation. The dynamics of the proposed system are derived on the basis of Newton-Euler formalism, followed by a robust control method. Lyapunov framework is exploited to ensure the stability of the controlled system. Simulation results of the designed ITSC, are exhibiting the ability of the proposed control technique for rapidly achieving the desired trajectories in a robust manner. A comparative study in both quantitative and qualitative case is carried out between ITSC and Sliding Mode Controller (SMC). Overall, the findings show that the proposed control technique outperforms in terms of accuracy and robustness.

11:50-12:10	FrA5.5

Wall Effect Evaluation of Small Quadcopters in Pressure-Controlled Environments, pp. 1142-1147

David Du Mutel de Pierrepont Franzetti, Iris	Politecnico Di Torino
Parin, Riccardo	Eurac Research
Capello, Elisa	Politecnico Di Torino

Multicopters are used for a wide range of applications that often involve approaching buildings or navigating enclosed spaces. Opposed to the freedom found in outdoor flights, indoor UAVs navigating close to surfaces must take into account the airflow variations caused by its rebound and identify them as disturbances to be compensated. A custom-made quadcopter has been built for the evaluation of wall effect in climate-controlled environments. Two different propeller sizes have been considered for testing. Climate variations consisting in changes of pressure, from 1000 mbar up to the equivalent pressure attained at 5000 m. A fixed 6DOF load cell has been used for the experiments, being able to log forces and moments in three orthogonal axes. The tests simulate a hovering UAV at different wall distances. The influence of the propeller size and air density on the wall effect has been also measured. Experimental data will be used for the definition of a mathematical model, in which the wall effect is considered.

12:10-12:30	FrA5.6

Adaptive Single-Gain Non-Singular Fast Terminal Sliding Mode Control for a Quad-Rotor UAV against Wind Perturbations, pp. 1148-1154

Olivas, Gustavo	Tecnológico De Monterrey
Castaneda, Herman	Tecnologico De Monterrey

This paper introduces a class of adaptive sliding mode controller for a quad-rotor unmanned aircraft vehicle. The control is based on a non-singular fast terminal surface, and an adaptive law involving only two parameters to be tuned, which produces a smoother gain dynamics. In return, a significantly reduction of undesired behavior such as chattering is achieved, while preserving the properties of robustness against perturbations and finite time convergence. Furthermore, in order to evaluate robustness, the proposed control technique along with a Von Kármán model-based wind turbulence generator, are applied in a close-to-real-life scenario. This consists of a 310-meter trajectory inside a city block powered by Unreal Engine. Obtained results support the claim that this control scheme allows the quadrotor to follow desired trajectories even in presence of wind perturbations. This displays the feasibility and robustness needed for such systems to enable more complex tasks while flying in urban environments.

FrB1	Room 118
Aerial Manipulation: Design, Control and Applications (Invited Session)	

Chair: Fumagalli, Matteo	Danish Technical University
Co-Chair: Im, Jaehan	Nearthlab Inc
Organizer: Fumagalli, Matteo	Danish Technical University
Organizer: Nikolakopoulos, George	Luleå University of Technology
Organizer: Tognon, Marco	Inria

14:00-14:20	FrB1.1

PACED-5G: Predictive Autonomous Control Using Edge for Drones Over 5G (I), pp. 1155-1161

Sankaranarayanan, Viswa Narayanan	Luleå University of Technology
Damigos, Gerasimos	Luleå University of Technology
Seisa, Achilleas Santi	Luleå University of Technology
Satpute, Sumeet	Luleå University of Technology
Lindgren, Tore	Ericsson Research
Nikolakopoulos, George	Luleå University of Technology

With the advent of technologies such as Edge computing, the horizons of remote computational applications have broadened multi-dimensionally. Autonomous Unmanned Aerial Vehicle (UAV) mission is a vital application to utilize remote computation to catalyze its performance. However, offloading computational complexity to a remote system increases the latency in the system. Though technologies such as 5G networking minimize communication latency, the effects of latency on the control of UAVs are inevitable and may destabilize the system. Hence, it is essential to consider the delays in the system and compensate for them in the control design. Therefore, we propose a novel Edge-based predictive control architecture enabled by 5G networking, PACED-5G (Predictive Autonomous Control using Edge for Drones over 5G). In the proposed control architecture, we have designed a state estimator for estimating the current states based on the available knowledge of the time-varying delays, devised a Model Predictive controller (MPC) for the UAV to track the reference trajectory while avoiding obstacles, and provided an interface to offload the high-level tasks over Edge systems. The proposed architecture is validated in two experimental test cases using a quadrotor UAV.

14:20-14:40	FrB1.2

Enhancing Human-Drone Interaction with Human-Meaningful Visual Feedback and Shared-Control Strategies (I), pp. 1162-1167

Franceschini, Riccardo	Eurecat
Fumagalli, Matteo	Danish Technical University
Cayero, Julian Cayero	Eurecat

Recent developments in the capabilities of unmanned aerial vehicles (UAVs) have made them suitable for use in various industrial settings. Their ability to access difficult and remote locations, as well as providing remote manipulation and visual inspection capabilities, make them valuable for various industrial applications. However, operating UAVs can be challenging, particularly in cluttered environments. This research aims to enhance the teleoperation experience by providing human-meaningful information on the remote

user interface, thereby improving the operator's situational awareness. Shared autonomy routines utilizing the previously collected information are also developed to further assist the operator with challenging control tasks. The proposed system has been tested in simulated environments and on actual hardware.

14:40-15:00 FrB1.3

Design and Evaluation of a Mixed Reality-Based Human-Robot Interface for Teleoperation of Omnidirectional Aerial Vehicles (I), pp. 1168-1174

Allenspach, Mike — ETH Zürich
Kötter, Till — ETH Zürich
Bähnemann, Rik — ETH Zürich
Tognon, Marco — Inria
Siegwart, Roland Y. — ETH Zürich

Omnidirectional aerial vehicles are an attractive solution for visual inspection tasks that require observations from different views. However, the decisional autonomy of modern robots is limited. Therefore, human input is often necessary to safely explore complex industrial environments. Existing teleoperation tools rely on on-board camera views or 3D renderings of the environment to improve situational awareness. Mixed-Reality (MR) offers an exciting alternative, allowing the user to perceive and control the robot's motion in the physical world. Furthermore, since MR technology is not limited by the hardware constraints of standard teleoperation interfaces, like haptic devices or joysticks, it allows us to explore new reference generation and user feedback methodologies. In this work, we investigate the potential of MR in teleoperating 6DoF aerial robots by designing a holographic user interface to control their translational velocity and orientation. A user study with 13 participants is performed to assess the proposed approach. The evaluation confirms the effectiveness and intuitiveness of our methodology, independent of prior user experience with aerial vehicles or MR. However, prior familiarity with MR improves task completion time. The results also highlight limitation to line-of-sight operation at distances where relevant details in the physical environment can still be visually distinguished.

15:00-15:20 FrB1.4

AIRFRAME - Fast Prototyping Framework for UAVs Definition (I), pp. 1175-1182

Berra, Andrea — Center for Advanced Aerospace Technologies
Sanchez-Cuevas, P. J. — Center for Advanced Aerospace Technologies
Trujillo, Miguel Ángel — Center for Advanced Aerospace Technologies
Heredia, Guillermo — Universidad De Sevilla
Viguria, Antidio — Center for Advanced Aerospace Technologies

Developing a new UAV platform is a long and iterative process that requires a lot of time and effort to be successful. The difficulty of performing a realistic evaluation of system performance during the development process represents a major drawback. As a matter of fact, in most contexts, the first proof of UAVs' capabilities arrives only during the first flights of the real platform. This may lead, in case of possible issues detected in the platform, to a revaluation of the design, which is not optimal at the very last stage of platform development. To overcome this issue, we propose AIRFRAME, a framework for fast-developing UAV prototypes in simulation to allow for systematic evaluation and analysis of UAV performance during the development pro- cess. The developed prototype integrates software and hardware for a better evaluation of the system's capability and performance at an early stage. The implementation of the framework has succeeded with Gazebo-ROS-Matlab in Docker Environment. It allows high integrability and fast evaluation of multiple UAV designs.

15:20-15:40 FrB1.5

A Vision-Based Approach for Unmanned Aerial Vehicles to Track Industrial Pipes for Inspection Tasks (I), pp. 1183-1190

Roos-Hoefgeest Toribio, Sara — Univesity of Oviedo
Cacace, Jonathan — Università Di Napoli Federico II
Scognamiglio, Vincenzo — Università Di Napoli Federico II
Alvarez, Ignacio — Universidad De Oviedo
González de los Reyes, Rafael Corsino — University of Oviedo
Ruggiero, Fabio — Università Di Napoli Federico II
Lippiello, Vincenzo — Università Di Napoli Federico II

Inspecting and maintaining industrial plants is an important and emerging field in robotics. A particular case is represented by the inspection of oil and gas refinery facilities consisting of different long pipe racks to be inspected repeatedly. This task is costly in terms of human safety and operation costs due to the high-altitude location in which the pipes are placed. In this domain, we propose a visual inspection system for unmanned aerial vehicles (UAVs), allowing the autonomous tracking and navigation of the center line of the industrial pipe. The proposed approach exploits a depth sensor to generate the control data for the aerial platform and, at the same time, highlight possible pipe defects. A set of simulated and real experiments in a GPS-denied environment have been carried out to validate the visual inspection system.

15:40-16:00 FrB1.6

Fully-Actuated, Corner Contact Aerial Robot for Inspection of Hard-To-Reach Bridge Areas (I), pp. 1191-1198

Gonzalez-Morgado, Antonio — Universidad De Sevilla
Alvarez-Cia, Carlos — Universidad De Sevilla
Heredia, Guillermo — Universidad De Sevilla
Ollero, Anibal — Universidad De Sevilla

This paper presents the design and development of a fully actuated platform for the visual inspection of difficult-to-reach areas of bridges, such as bridge beams and bearings. The aerial platform incorporates a carbon fiber structure with spherical wheels that facilitates safe contact with the bridge, while the fully actuated configuration allows the movement of the platform while keeping the contact with the surface. In addition, the system mounts a camera that allows an operator to supervise the inspection from the ground. Compared to other solutions developed for bridge inspection, our solution is able to maintain contact while moving across the inspection surface and

is even capable of maintaining contact with two surfaces in corners, allowing the inspection of difficult-to-reach zones like bridge bearings. We describe the design and build process, the dynamic model and the control of the system proposed. We show the capabilities of the fully actuated platform by indoor flights, while the proposed aerial platform is tested in a real scenario, for bridge beams and bearings inspection. The results of field tests demonstrate the feasibility and effectiveness of the proposed platform for bridge inspections.

FrB2	Room 130
Perception and Cognition (Regular Session)	
Chair: Ferrão, Isadora	University of São Paulo
Co-Chair: Bertolani, Giulia	Università Di Bologna

14:00-14:20	FrB2.1

GATSBI: An Online GTSP-Based Algorithm for Targeted Surface Bridge Inspection, pp. 1199-1206

Dhami, Harnaik	University of Maryland
Yu, Kevin	Virginia Tech
Williams, Troi	University of Maryland
Vajipey, Vineeth	University of Maryland
Tokekar, Pratap	University of Minnesota

We study the problem of visual surface inspection of a bridge for defects using an Unmanned Aerial Vehicle (UAV). The geometric model of the bridge is unknown beforehand. We equipped the UAV with a 3D LiDAR and RGB camera to build a semantic map of the environment. Our planner, termed GATSBI, plans a path in a receding horizon fashion to inspect all points on the surface of the bridge. The input to GATSBI consists of a 3D occupancy map created online with LiDAR scans. Occupied voxels corresponding to the bridge in this map are semantically segmented and used to create a bridge-only occupancy map. Inspecting a bridge voxel requires the UAV to take images from a desired viewing angle and distance. We then create a Generalized Traveling Salesperson Problem (GTSP) instance to cluster candidate viewpoints for inspecting the bridge voxels and use an off-the-shelf GTSP solver to find the optimal path for the given instance. As the algorithm sees more parts of the environment over time, it replans the path to inspect novel parts of the bridge while avoiding obstacles. We evaluate the performance of our algorithm through high-fidelity simulations conducted in AirSim and real-world experiments. We compare the performance of GATSBI with a frontier exploration algorithm. Our evaluation reveals that targeting the inspection to only the segmented bridge voxels and planning carefully using a GTSP solver leads to a more efficient and thorough inspection than the baseline algorithm.

14:20-14:40	FrB2.2

Semi-Autonomous Search and Rescue System, pp. 1207-1212

Walz, Eli	United States Naval Academy
Hammonds, Katie	United States Naval Academy
Rumbaugh, Megan	United States Naval Academy
O'Brien, Richard	United States Naval Academy

A proposed semi-autonomous search and rescue system identifies and tracks a person using a piloted unmanned aerial vehicle with a downward-facing vision system. This vehicle communicates the person's location to an autonomous unmanned ground vehicle to recover the target. An object detection neural network and image processing system can detect humans from an aerial perspective using RGB and thermal images. A Python simulation of the ground vehicle demonstrates that the heading and velocity controllers are robust to noise and disturbances.

14:40-15:00	FrB2.3

Assessment of LiDAR Detection Capabilities for Urban Air Mobility Applications, pp. 1213-1220

Aldao Pensado, Enrique	University of Vigo
Fontenla Carrera, Gabriel	University of Vigo
Gonzalez de Santos, Luis Miguel	University of Vigo
Gonzalez Jorge, Higinio	University of Vigo

This paper presents a quantitative analysis of the detection capabilities for U-Space applications using a solid-state LiDAR, specifically the Livox Avia. The focus of this study is the use of this technology as a ground surveillance system, with a particular emphasis on its potential installation in ground infrastructures such as a vertiports. A point cloud simulator was used to replicate the behavior of this device and the acquisition of moving obstacle point clouds was simulated. This information was processed to estimate the position, speed and size of different intruders. Multiple study cases were generated to evaluate the sensor performance under different operating conditions. Finally, a statistical analysis of the results was carried out to evaluate the influence of the distance, speed and size of the intruders on the results.

15:00-15:20	FrB2.4

A System for Real-Time Display and Interactive Training of Predictive Structural Defect Models Deployed on UAV, pp. 1221-1225

Heichel, Jack	University of North Dakota
Mitra, Rajrup	University of North Dakota
Jafari, Faezeh	University of North Dakota
Das, Amrita	University of North Dakota
Dorafshan, Sattar	University of North Dakota
Kaabouch, Naima	University of North Dakota

Periodic inspection of ancillary structures is an important practice for the infrastructure of a public highway system. Using Unmanned Aerial Vehicles (UAVs) can reduce the cost and time of these inspections due to their speed, convenience, and operational flexibility. However, commercially available UAV solutions often do not include all the following key features: real-time data collection, multispectral

sensors, and defect detection model integration. In this paper, a novel system is proposed that accomplishes all these functions. This system includes visual and thermal sensors and a microcomputer capable of running multiple Convolutional Neural Network (CNN) models to detect structural defects. One such CNN was tested with two datasets of different defect types, resulting in accuracy rates over 90% for each dataset. The results indicated a high performance to aid operators in identifying structural defects. A Graphical User Interface (GUI) is designed to interact with the CNN models, allowing an operator to re-classify and re-train the models for continuous improvement. A live stream of the visual and thermal sensors allows the operator to quickly assess the structure and determine which regions need further evaluation. The payload was optimized for weight and power, allowing for long flight times and a variety of UAV platforms.

15:20-15:40	FrB2.5

H2AMI: Intuitive Human to Aerial Manipulator Interface, pp. 1226-1232

Zoric, Filip	University of Zagreb
Orsag, Matko	University of Zagreb

Aerial manipulators are unmanned aerial vehicles (UAVs) coupled with robotic manipulators (RMs). Their ability to interact with the environment and perform service and maintenance tasks in hard-to-reach places makes them interesting for a wide range of applications and industries. Human pose estimation relates to the problem of estimating human body pose. In this paper, we present an intuitive aerial manipulator human interface which enables the control of the aerial manipulator based on the operator's movements. The operator's motions are captured with an affordable depth camera and pose estimation is performed with a neural network. We have developed a system that enables intuitive decoupled control of the unmanned aerial vehicle and robotic manipulator. We compared two neural network architectures for the human pose estimation as a part of the H2AMI. System performance was verified in the simulation environment.

FrB3	Room 464
Navigation (Regular Session)	
Chair: Nascimento, Tiago	Czech Technical University in Prague
Co-Chair: Shan, Jinjun	York University

14:00-14:20	FrB3.1

Open-Source Hardware/Software Architecture for Autonomous Powerline-Aware Drone Navigation and Recharging, pp. 1233-1240

Nyboe, Frederik F	University of Southern Denmark
Malle, Nicolaj Haarhøj	University of Southern Denmark
Duong Hoang, Viet	University of Southern Denmark
Ebeid, Emad Samuel Malki	University of Southern Denmark

Recent research has pushed the applications of UAVs into domains such as infrastructure inspection and interaction. For UAVs to be able to safely and efficiently perform autonomous operations near the target infrastructure, they need to be aware of their surroundings while exposing navigation API to the application software. For powerline inspection UAVs, this yields a requirement for knowledge of the powerline cable positions and a set of actions facilitating specific flight operations in this environment. This work presents a hardware/software system solving these requirements. A framework is shown which allows application software to autonomously fly the UAV to any of the perceived cables, to fly the UAV along a cable, and to land on and take off from a cable. The system relies on an abstract representation of the identified and tracked cables, while solving the flight maneuvers using an MPC based trajectory planning routine. The system is tested in a real powerline environment featuring four cables stretched between two pylons. A GUI application is developed for triggering the actions remotely from a ground control station while providing a visual representation of the perceived cables and planned trajectories.

14:20-14:40	FrB3.2

Cooperative UAS Forest Navigation with Feature Based SLAM, pp. 1241-1248

Martens, Mats	Technische Universität Berlin
Uijt de Haag, Maarten	Technische Universität Berlin

Within forest applications, Unmanned Aircraft Systems (UAS) are highly demanded. However, in forest environments conventional navigation systems that rely on a Global Navigation Satellite System (GNSS) are exposed to navigation performance degradation due to the forest canopy. Within this work, 2D Light Detection and Ranging (LiDAR) scanner equipped UAS swarms explore an unknown forest environment. Each UAS generates its own map estimate based on tree features, which are detected within the LiDAR point cloud. Using an Inertial Navigation System (INS) mechanization, an attitude estimate is calculated that is then used to project the features into the horizontal plane. While one UAS has the reference role and shares its map information, all other UAS are, initially, in the discovery role. These UAS make use of a bootstrap particle filter to localize themselves within the reference map. Once converged, they switch to an exploration role and can add or update features of the reference map. Thereby, the uncertainty of map feature positions is characterized and updated. Simulation and experimental test scenarios are presented, where the performance of the proposed method is demonstrated for different speed scenarios up to 16m/s. It is shown that the cooperative exploration of the forest environment yields a faster and more confident map of the forest. Additionally, the navigation accuracy is found to be 40cm at a maximum over a 225m long track while the noise is smaller than 3cm. Even though drift is present, relative navigation and separation can be ensured if UAS operate close to each other enabling a collision avoidance functionality.

14:40-15:00	FrB3.3

UAV Navigation in 3D Urban Environments with Curriculum-Based Deep Reinforcement Learning, pp. 1249-1255

de Oliveira, Iure Rosa Lima	Universidade Federal De Viçosa
de Carvalho, Kevin Braathen	Universidade Federal De Viçosa
Brandao, Alexandre Santos	Universidade Federal De Viçosa

Unmanned Aerial Vehicles (UAVs) are widely used in various applications, from inspection and surveillance to transportation and delivery. Navigating UAVs in complex 3D environments is a challenging task that requires robust and efficient decision-making

algorithms. This paper presents a novel approach to UAV navigation in 3D environments using a Curriculum-based Deep Reinforcement Learning (DRL) approach. The proposed method utilizes a deep neural network to model the UAV's decision-making process and to learn a mapping from the state space to the action space. The learning process is guided by a reinforcement signal that reflects the performance of the UAV in terms of reaching its target while avoiding obstacles and with energy efficiency. Simulation results show that the proposed method has a positive trade off when compared to the baseline algorithm. The proposed method was able to perform well in environments with a state space size of 220 million, allowing the usage in big environments or in maps with high resolution. The results demonstrate the potential of DRL for enabling UAVs to operate effectively in complex environments.

15:00-15:20 FrB3.4

PredictiveSLAM - Robust Visual SLAM through Trajectory-Aware Object Masking, pp. 1256-1261

Heiß, Micha — Aarhus University
Hansen, Jakob Grimm — Aarhus University
Li, Dengyun — Aarhus University
Kozlowski, Michal — Aarhus University
Kayacan, Erdal — Aarhus University

This paper proposes PredictiveSLAM, a novel extension to ORB-SLAM2, which extracts features from specific regions of interest (ROI). The proposed method was designed with the risk posed both to humans and robotic systems in large-scale industrial sites in mind. The ROI are determined through an object detection network trained to detect moving human beings. The method detects and removes humans from feature extraction, predicting their potential future trajectory. This is done by omitting a specific ROI from extraction, deemed to be occluded in consecutive time steps. Two masking methods -static object and moving object trajectories - are proposed. This approach improves tracking accuracy and the performance of SLAM by removing the dynamic features from the reference for tracking and loop closures. The method is tested on data collected in a laboratory environment and compared against a state-of-the-art ground truth system. The validation data was collected from real-time experiments which aimed at simulating the typical human worker behaviours in industrial environments using an unmanned aerial vehicle (UAV). This study illustrates the advantages of the proposed method over earlier approaches, even with a highly dynamic camera setup on a UAV working in challenging environments.

15:20-15:40 FrB3.5

Visual Navigation Based on Deep Semantic Cues for Real-Time Autonomous Power Line Inspection, pp. 1262-1269

Alexiou, Dimitrios — Centre for Research and Technology Hellas
Zampokas, Georgios — Centre for Research and Technology Hellas
Skartados, Evangelos — Centre for Research and Technology Hellas
Tsiakas, Kosmas — Centre for Research and Technology Hellas
Kostavelis, Ioannis — Centre for Research and Technology Hellas
Giakoumis, Dimitrios — Centre for Research and Technology Hellas
Gasteratos, Antonios — Democritus University of Thrace
Tzovaras, Dimitrios — Centre for Research and Technology Hellas

In this paper, a visual guided navigation method for Unmanned Aerial Vehicles (UAVs) during power line inspections is proposed. Our method utilizes a deep learning-based image segmentation algorithm to extract semantic masks of the power lines from onboard camera images. These masks are then processed and visual characteristics along with geometrical calculations generate velocity commands for the 3D position and yaw control that feed the UAV's navigation system. The accuracy, robustness, and computational efficiency of the power line segmentation module are evaluated on real benchmark datasets. Extensive simulation experiments have been conducted to assess the proposed method's performance in terms of inspection coverage, considering various textured environments and extreme initial states. The proposed method for navigating a UAV towards target PTLs is shown to be effective in terms of robustness and stability. This is achieved through accurate segmentation of the PTLs and the generation of compact velocity directives based on visual information in various environmental conditions. The results indicate a significant improvement in the precision of autonomous UAV-based inspections of power infrastructure due to continuous scoping of the transmission lines and safe yet stable navigation

15:40-16:00 FrB3.6

Vision-Aided Approach and Landing through AI-Based Vertiport Recognition, pp. 1270-1277

Veneruso, Paolo — Università Di Napoli Federico II
Miccio, Enrico — Università Di Napoli Federico II
Opromolla, Roberto — Università Di Napoli Federico II
Fasano, Giancarmine — Università Di Napoli Federico II
Gentile, Giacomo — Collins Aerospace
Tiana, Carlo — Collins Aerospace

This paper presents a vision-aided navigation pipeline to support the approach and landing phase of autonomous Vertical Take-Off and Landing aircraft in Urban Air Mobility scenarios. The proposed filtering scheme is fed by measurements provided by an Inertial Measurement Unit and a GNSS receiver, as well as by pose estimates computed from images collected by onboard cameras. Specifically, the camera frames are processed by a Convolutional Neural Network (CNN) trained to detect the vertiport landing marking in urban scenarios. Subsequently, the relevant 2D features of the pattern inside the resulting bounding box are extracted, recognized and used to solve the Perspective-n-Point problem. The performance of the implemented navigation filter is first analyzed using synthetic data collected simulating realistic landing trajectories. Then, two different training strategies are compared to verify the contribution of real data to the detection performance and to check the capability of the CNN to correctly identify the pattern in the tested scenarios. In addition, the entire pipeline for landing pad detection and pose estimation is tested on real images under various pose, illumination and background conditions.

FrB4 Room 465

Control Architectures II (Regular Session)

Chair: Theilliol, Didier | Université De Lorraine
Co-Chair: Valavanis, Kimon P. | University of Denver

14:00-14:20 FrB4.1

Obstacle Avoidance Based on the Null Space Control Approach for a Formation of an Aerial and a Ground Robot, pp. 1278-1285

Mafra Moreira, Mauro Sergio — Federal University of Espírito Santo
Sarcinelli-Filho, Mário — Federal University of Espirito Santo

This paper complements a previous study on obstacle avoidance using the null space-based behavioral approach to autonomously guide a formation composed of a differential-drive wheeled platform and an unmanned aerial vehicle, to overtake obstacles modelled as potential fields. The highest priority, regarding the null space behavioural control, is assigned to the task of overcoming an obstacle, with the lowest priority assigned to moving the formation to a destination point. The controller is designed considering the paradigm of virtual structure, which is the three-dimensional straight line linking the robots. This approach allows controlling the robots to move in a coordinate way, leading the formation to reach the desired point while keeping the proposed rigid structure. The obstacle avoidance proposal is adopted for the ground and the aerial robots. When the ground robot manoeuvre to avoid an obstacle in the ground the position of the point of interest for control also varies, since it is in the ground vehicle, so that the aerial vehicle does not need to break the formation, continuing "attached" to the ground vehicle during the manoeuvre. However, when the aerial robot faces an obstacle, the formation behaves differently. The formation shape is not guaranteed to be preserved during the manoeuvre of the aerial robot to avoid the obstacle. This is the behavior this paper proposes to discuss: the effect of the null space-based behavioural control over the navigation of the formation. The scenario for this case study is an automated warehouse, inside which several ground platforms and aerial vehicles are moving to suitably store goods, possibly with boxes in the ground, also obstacles for the ground vehicle.

14:20-14:40 FrB4.2

System Identification-Based Fault Detection and Dynamic Inversion Control of an Uncrewed Aerial Vehicle, pp. 1286-1293

Bowes, Robert — University of Kansas
Benyamen, Hady — University of Kansas
Keshmiri, Shawn — University of Kansas

As the wide-scale use of uncrewed aerial systems proceeds towards civilian airspace, guarantees of operational safety over the entire flight envelope become more critical. In this paper, a method of dynamic inversion-based fault tolerant control is proposed, which uses changes in discrete time system identification to estimate onboard actuation faults. A reduced order model is estimated from measurements based on relevant dynamic modes for a defined window of flight data. This system identification algorithm allows faults to be estimated via tracking of calculated model parameters. These failures will be parameterized and fed into the control loop to update the dynamic model and prevent inversion error. The mathematical basis of the fault detection and diagnosis module is discussed and the initial results of the system identification algorithm as well as performance of the base dynamic inversion controller is shown.

14:40-15:00 FrB4.3

A Proportional Closed-Loop Control for Equivalent Vertical Dynamics of Flapping-Wing Flying Robot, pp. 1294-1300

Rafee Nekoo, Saeed — Universidad De Sevilla
Ollero, Anibal — Universidad De Sevilla

The closed-loop position control of a flapping-wing flying robot (FWFR) is a challenging task. A complete six-degree-of-freedom (DoF) modeling and control design is preferable though that imposes complexity on the procedure and analysis of the oscillations in the trajectory. Another approach could be studying independent state variables of the system and designing a controller for them. This will provide the possibility of a better understanding of the dynamic, comparing to experimental data, then use this information for moving forward to complete 6-DoF modeling. In this work, a simple linear proportional closed-loop controller is proposed and analyzed for an equivalent dynamic model of the flapping-wing flying robot. The equivalent dynamic modeling considers the flapping motion as a base excitation that disturbs the system in oscillatory behavior. The frequency of the oscillation and data of the motion was obtained from previous experimental results and used in the modeling. The designed controller performed the regulation task easily and regulated the system to a series of set-point control successfully. The motivation for the selection of a proportional control is to keep the design as simple as possible to analyze the excitation and behavior of the flapping more precisely. A discussion on the transient and steady-state flight and the role of control design on them have been presented in this work.

15:00-15:20 FrB4.4

Equivalent Vertical Dynamics of Flapping-Wing Flying Robot in Regulation Control: Displacement Transmissibility Ratio, pp. 1301-1307

Rafee Nekoo, Saeed — Universidad De Sevilla
Ollero, Anibal — Universidad De Sevilla

This paper presents an equivalent dynamic model for vertical regulation control of a flapping-wing flying robot. The model is presented based on the data of a series of flight experiments for an available platform. The system shows oscillations in motion in all experiments with an approximate frequency between [3.5,4.5] (Hz), changing within a limited range. The behavior of the equivalent model represents a system with base excitation. The displacement transmissibility ratio (TR) is found for the model to investigate the oscillatory behavior in the system during the flight. Reduction of the oscillations through the transmissibility ratio will decrease the uncertainty in flight and consequently, that could increase the success rate of perching on a branch (now it has a 10-15(cm) uncertain periodic motion); perching needs precision on the last meter approaching phase. An analytical expression for TR is presented which is used for parameter selection, tuning, and selection of the flapping frequency, as the base excitation source. The study shows that the robot works in a proper zone of the frequency ratio, and also, the sensitivity of the TR is high concerning the changes in the stiffness constant.

15:20-15:40 FrB4.5

Anafi_ros: From Off-The-Shelf Drones to Research Platforms, pp. 1308-1315

Sarabakha, Andriy — Nanyang Technological University
Suganthan, Ponnuthurai — Nanyang Technological University

The off-the-shelf drones are simple to operate and easy to maintain aerial systems. However, due to proprietary flight software, these drones usually do not provide an open-source interface which can enable them for autonomous flight in research or teaching. This work introduces a package for ROS1 and ROS2 for straightforward interfacing with off-the-shelf drones from the Parrot ANAFI family. The developed ROS package is hardware agnostic, allowing connecting seamlessly to all four supported drone models. This framework can connect with the same ease to a single drone or a team of drones from the same ground station. The developed package was intensively tested at the limits of the drones' capabilities and thoughtfully documented to facilitate its use by other research groups.

15:40-16:00 FrB4.6

Distributed Observer-Based Leader-Following Consensus Control for LPV Multi-Agent Systems: Application to Multiple VTOL-UAVs Formation Control, pp. 1316-1323

Vazquez Trejo, Jesus Avelino — Centro Nacional De Investigación Y Desarrollo Tecnológico
Ponsart, Jean-Christophe — Université De Lorraine
Adam-Medina, Manuel — Centro Nacional De Investigación Y Desarrollo Tecnológico
Valencia-Palomo, Guillermo — Tecnológico Nacional De México
Theilliol, Didier — Université De Lorraine

This paper presents a distributed observer-based leader-following consensus control for linear parameter-varying multi-agent systems. The stability of the observer and the controller is proved by the Lyapunov theory. It is shown that the design conditions of the estimated states and consensus control are expressed in a set of linear matrix inequalities considering Polya's theorem for less conservatism. To show the effectiveness of the proposed strategy, the formation control problem on a team of vertical take-off and landing unmanned aerial vehicles are considered in the simulation results.

FrB5 Room 466

Multirotor Design and Control II (Regular Session)

Chair: Tzes, Anthony — New York University Abu Dhabi
Co-Chair: Zhang, Youmin — Concordia University

14:00-14:20 FrB5.1

Development, Model, Simulation, and Real Test of a New Fully Actuated Quadrotor, pp. 1324-1330

Flores, Alejandro — Centro De Investigaciones En Óptica
Verdìn, Rodolfo Isaac — Centro De Investigaciones En Óptica
Moreno Jimenez, Hugo Alberto — Centro De Investigaciones En Óptica
Flores, Gerardo — Centro De Investigaciones En Óptica

This study presents the design, construction, and testing of a fully actuated quadrotor UAV prototype named FlapPyr that utilizes the "+" arrangement to produce horizontal forces. Four flaps are installed beneath each main motor to capture the airflow from propellers and generate aerodynamic forces perpendicular to them. A control allocation matrix is determined by modeling the complete structure and forces. This UAV suits applications requiring position control while maintaining zero tilting angles. Both software in the loop simulations and real-world tests are conducted to evaluate the system's performance. The real-world tests highlighted the system's sensitivity to external air disturbances, which can be addressed through robust control laws. The developed code for this work is publicly available on GitHub, and a video showcasing the experiments is also provided.

14:20-14:40 FrB5.2

Design and Prototyping of a Ground-Aerial Robotic System, pp. 1331-1336

Kotarski, Denis — Karlovac University of Applied Sciences
Šćuric, Alen — University of Zagreb
Piljek, Petar — University of Zagreb
Petrovic, Tamara — University of Zagreb

This paper presents an investigation into the feasibility of using a ground-aerial robotic system for data collection missions. It outlines the design of a system consisting of a tracked unmanned ground vehicle (UGV) and a multirotor unmanned aerial vehicle (UAV). The UGV is designed to enable the possibility of changing and charging batteries for the UAV, which is equipped with sensors for precise landing on the UGV platform. Rapid prototyping technologies were used to create a small experimental aircraft with a simple battery change airframe that can be tested indoors or outdoors. Parts of the chassis and drive elements were designed and manufactured for the UGV platform, and then the drive assembly and testing were carried out. The control systems of the UAV and UGV robots were evaluated through preliminary experiments. In future work, the integration of the control system and prototyping of the mechanism and electronics of the module for charging and changing batteries are planned in order to facilitate further advancements in the field of data collection missions.

14:40-15:00 FrB5.3

Mechatronic Design and Control of a Hybrid Ground-Air-Water Autonomous Vehicle, pp. 1337-1342

Chaikalis, Dimitris — New York University
Evangeliou, Nikolaos — New York University Abu Dhabi
Nabeel, Muhammed — New York University Abu Dhabi
Giakoumidis, Nikolaos — New York University Abu Dhabi
Tzes, Anthony — New York University Abu Dhabi

This article describes the development of a hybrid autonomous vehicle capable of flying and navigating on ground terrain and water surface. This is achieved by combination of a typical coaxial tricopter with a flotation device, coupled with omniwheels and water propellers. The mechatronic design is presented, starting with the hardware component description, the supervisory control architecture and the redesign based on the hardware-in-the-loop simulation. The water-resistant autonomous vehicle uses one autopilot copter-component and another one for the vehicle/vessel. The supervising computer switches between these autopilots depending on the

needed mode of operation using alterations in the firmware in designing the control effort. Simulation and experimental studies are offered to highlight the efficiency of the developed system.

15:00-15:20 FrB5.4

A Load Compensation Controller for Off-The-Shelf Unmanned Aerial Vehicles, pp. 1343-1348

Bacheti, Vinícius Pacheco — Federal University of Espirito Santo
Villa, Daniel Khede Dourado — Federal University of Espírito Santo
Brandao, Alexandre Santos — Universidade Federal De Viçosa
Sarcinelli-Filho, Mário — Federal University of Espirito Santo

This paper addresses the problem of controlling a system composed of a unmanned aerial vehicle and a payload attached to it via a cable, while compensating for the payload effects on the drone. This work considers that many off-the-shelf UAVs have their own low-level controller which the user cannot access and attempts to merge the classical approach of modeling a drone-mass system with controllers previously developed for use with drones equipped with low-level controllers. In order to test such an approach the robot Anafi, from Parrot Drones SAS, was used with a mass attached to it. The experiments show a consistent reduction on navigation errors, which validate the proposed method.

15:20-15:40 FrB5.5

Adaptive Fault-Tolerant Trajectory Tracking and Attitude Control of a Quadrotor UAV Subject to Actuator Faults, pp. 1349-1355

Hu, Xinyue — Northwestern Polytechnical University
Fu, Yifang — Northwestern Polytechnical University
Huang, Yulu — Northwestern Polytechnical University
Wang, Ban — Northwestern Polytechnical University
Li, Ni — Northwestern Polytechnical University
Zhang, Youmin — Concordia University

In this paper, an adaptive sliding mode control strategy is proposed to achieve desired trajectory tracking and attitude control for a quadrotor unmanned aerial vehicle in the presence of actuator faults. Firstly, the nominal controller is constructed by using an integral sliding mode control method with a cascaded control structure. Then, to compensate for the adverse effect of actuator faults, an adaptive sliding mode control strategy is presented to maintain desired trajectory and attitude tracking performance. Finally, a series of simulation tests are conducted to verify the capabilities and effectiveness of the adaptive fault-tolerant control method. The comparative simulation results validate the benefits and effectiveness of the proposed adaptive fault-tolerant control strategy.

15:40-16:00 FrB5.6

Experimental Quadrotor Physical Parameters Estimation, pp. 1356-1362

Rodríguez-Cortés, Hugo — Centro De Investigación Y De Estudios Avanzados Del IPN
Romero, Jose-Guadalupe — Instituto Tecnológico Autónomo De México
Tlatelpa-Osorio, Y. E. — Centro De Investigación Y De Estudios Avanzados Del IPN
Martinez-Ramirez, Marco A. — Centro De Investigación Y De Estudios Avanzados Del IPN
Corte´s-Benito, I. — Centro De Investigación Y De Estudios Avanzados Del IPN

This paper addresses the experimental quadrotor physical parameter identification using two versions of the recently proposed technique known as dynamic regressor extension and mixing (DREM). This technique preprocesses, algebraically and dynamically, the regressor to alleviate the persistency of excitation constraints. From the recorded data in experimental flights, the quadrotor physical parameters: inertia, mass, and aerodynamic drag, are identified using a power balance-based regressor.

ICUAS ’23 Key Word Index

ICUAS '23 Author Index

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