2020 INTERNATIONAL CONFERENCE ON UNMANNED AIRCRAFT SYSTEMS

ICUAS'20

June 9-12, 2020
(Moved to September 1-4, 2020)

DIVANI CARAVEL HOTEL
ATHENS, GREECE, GR-16121

FINAL PROGRAM

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Due to the COVID-19 pandemic the ICUAS' 20 actual dates have moved to September 1 – 4, 2020

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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 *2020 International Conference on Unmanned Aircraft Systems* (ICUAS'20).

I write this welcome message while the COVID-19 pandemic is still spreading all over the world, although it appears that we have passed the peak and have contained the virus – for the time being. It is everybody's hope and wish to get through this 'unknown challenge' as soon as possible and with the least possible number of deaths. Everything else, except human loss, is rectifiable in due time. Once this is finally over, society and our communities will be stronger and, hopefully, much wiser!

This year, 2020, marks the first time the annual conference leaves the United States and goes international, to Athens, Greece. Our conference is "truly international" as evidenced by the submitted papers and registered participants. Therefore, it is natural and logical to start 'touring the world' and organize our conference in other countries. As such, and if the after the COVID-19 'new normal' will allow, from 2021 onwards, the plan is to organize the conference in Europe, again, Canada, South America, South East Asia, and in the United States. We will keep you informed, and we will update the Association's web, www.icuas.com, with the latest information.

I also take this opportunity to update you about the ICUAS Association, Inc., which, as you know, is a non-profit organization that was launched in 2012, registered in the State of Colorado. The Association's web has been modernized and updated and now includes important links with information items. Moreover, a quarterly Newsletter has been launched, the first three issues of which were published in the Winter, Spring, and Summer of 2020. The Fall 2020 issue will be published after the September conference takes place. Issues will be sent to you electronically.

We are looking forward to your active involvement in the Association and the conference, and to your contributions and feedback. We do welcome your participation and we are open to your ideas and suggestions to register the Association and the annual technical conference as primary contributors that: benefit students, researchers, scientists, engineers, practitioners and end-users; advance the state-of-the-art in unmanned aviation; promote higher education.

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

Kimon P. Valavanis

Welcome Message from the Honorary Chairs

Dear participants and attendees:

On behalf of the 2020 ICUAS Organizing Committee and in our capacity as Honorary Chairs, it is a privilege and a great pleasure to welcome you to this year's conference. This is the first time we have the honor to host ICUAS in Europe. The conference is organized in Athens, Greece. Athens is a magnificent location for such an international event like the 2020 ICUAS.

As Europeans, we are very proud to greet and host this important scientific event that spans a three-day technical conference, preceded by a one-day Workshop/Tutorials program. We are convinced that you will appreciate and enjoy the conference. We are certain that all of us will take pleasure in visiting Athens and in travelling through the city's incredible history.

We look forward to seeing all of you in Athens. We wish you have a satisfying and pleasant attendance, coupling business and pleasure.

With our warmest regards,

Fulvia Quagliotti, Didier Theilliol

Welcome Message from the General Chairs

Dear participants and attendees:

On behalf of the 2020 ICUAS Organizing Committee, it is a privilege and a great pleasure to welcome you to this year's conference. ICUAS '20 is organized in Athens, Greece. The venue is the Divani Caravel Hotel. The three-day conference is preceded by a one-day Workshops/Tutorials program, which is composed of four (4) Tutorials. We are certain you will be very pleased with the conference venue, and you will enjoy all the attractions that Athens offers.

As in previous years, 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 unmanned aircraft systems. In response to the Call for Papers, we received 327 contributed and invited session papers. This is the highest ever compared to all previous years. Following a very thorough and in-depth peer review process in which each paper had at least three reviews (plus an additional review from a member of the organizing committee), roughly 75% of contributed, invited session and poster papers were accepted. All papers were also checked following the *iThenticate Document Viewer Guide* receiving a 'similarity score' and a 'm percentage match' before the final decision was made. We have assembled a full three-day top-quality Technical Program. We also have four plenary Lectures in which the keynote speakers address pressing, and important issues related to autonomy, and several aspects of unmanned aviation.

The Organizing Committee members have devoted an enormous amount of time and effort to make sure that the conference is exciting, informative and educational. We are privileged to know all the members. We are honored to have worked with them and we are truly indebted to everyone for their dedication and professionalism. We also extend a wholehearted "thank you" to all reviewers, Associate Editors and members of the Technical Program Committees; their help is integral to assembling a top-quality Technical Program.

The peer review process is coordinated by the Program Chairs, who assign groups of papers to the Associate Editors. We thank all of them for their extremely valuable contributions and dedication. Dr. Pradeep Misra is the "glue" that keeps everything together, as papers are submitted through the PaperCept Conference Management System (https://controls.papercept.net), managed by Pradeep. Pradeep is indispensable throughout, and we wouldn't have been able to complete the paper review process without his help.

We thank you for your participation and contributions. We hope you enjoy the conference, as well as Athens, the other surrounding areas and the Greek Islands.

With our warmest regards,

Youmin Zhang, Antonios Tzes

Welcome Message from the Program Chairs

Dear participants and attendees:

Welcome to ICUAS'20. This year we received a record number of 327 contributed and invited session full-length papers, and poster papers. Submitted papers come from the following countries:

Algeria	3	Argentina	1
Australia	8	Austria	1
Brazil	16	Canada	14
China	65	Colombia	1
Croatia	4	Cyprus	4
Czech Rep.	2	Denmark	3
Egypt	1	France	13
Germany	10	Greece	22
Hungary	2	India	13
Indonesia	1	Iran	4
Israel	1	Italy	10
Japan	2	Korea, South	6
Latvia	1	Luxembourg	1
Malaysia	2	Mexico	13
Netherlands	3	Nigeria	1
Norway	3	Paraguay	1
Poland	8	Portugal	1
Romania	1	Russia	2
Saudi Arabia	1	Singapore	8
South Africa	1	Spain	11
Sweden	1	Switzerland	1
Taiwan	4	Thailand	1
Turkey	3	UAE	1
UK	6	USA	45

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 reviews. We met and exceeded this goal as each of the submitted papers, in addition to the reviews, was also checked/reviewed by one of the Program Chairs or members of the Organizing Committee.

Authors of submitted papers used among the following key words to classify their paper: Airspace Control, Airspace Management, Airworthiness, Air Vehicle Operations, Autonomy, Biologically Inspired UAS, Certification, Control Architectures, Energy Efficient UAS, Environmental Issues, Fail-Safe Systems, Frequency Management, Integration, Interoperability, Levels of Safety, Manned/Unmanned Aviation, Micro- and Mini- UAS, Navigation, Networked Swarms, Payloads, Path Planning, Regulations, Reliability of UAS, Risk Analysis, See-and-avoid Systems, Security, Sensor Fusion, Simulation, Smart Sensors, Standardization, Swarms, Technology Challenges, Training, UAS Applications, UAS Communications, UAS Testbeds.

The review process resulted in the technical program composed of 238 contributed, invited and poster session peer reviewed papers. The technical program spans three days, during which all accepted papers are presented. Accepted papers are from the following countries (based on the corresponding author's affiliation) Czech Republic, Denmark, Egypt, France, Germany, Greece, India, Israel, Italy, Japan, South Korea, Latvia, Luxembourg, Mexico, Netherlands, Norway, Paraguay, Poland, Portugal, Russia, Singapore, Spain, Sweden, Switzerland, Taiwan, Turkey, United Arab Emirates, United Kingdom, and USA.

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 in unmanned aircraft systems. We thank all reviewers for their professional service.

Dr. Pradeep Misra helped us in working and using effectively the on-line paper submission and review system. He has been very responsive and helpful in technical issues related to the on-line system. In most cases, our questions were due to our novice and inexperience with the on-line system. We acknowledge that 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!

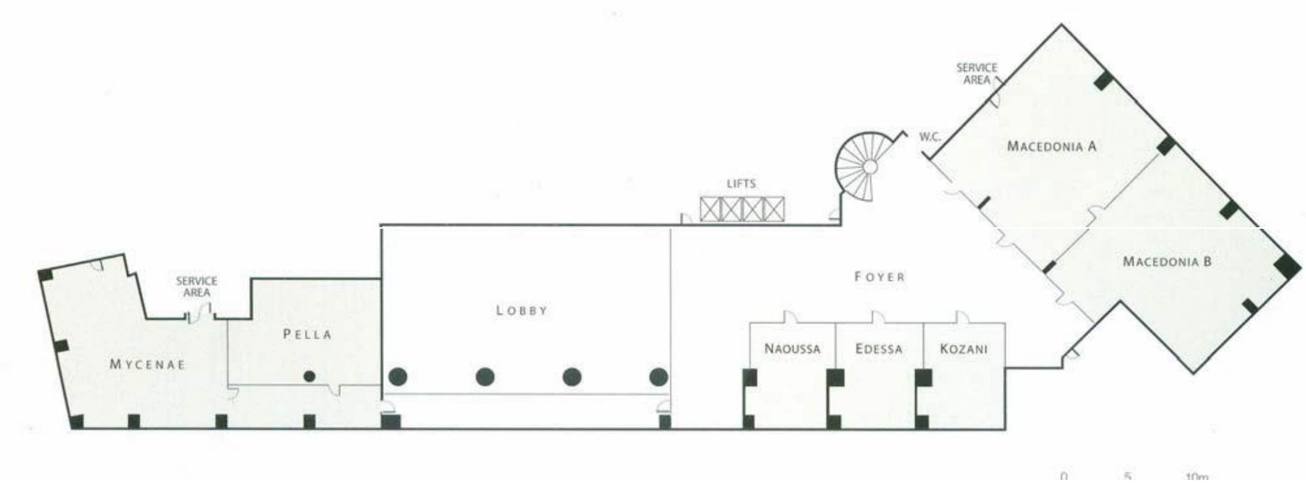
We hope you enjoy not only the technical aspects of the conference but also beautiful Athens. Fly high and safe, to the next ICUAS!

Antonio Franchi, Kostas Alexis

General Information

The Venue
The Conference will take place in Athens, Greece. The venue is the luxurious Divani Caravel Hotel (https://divanicaravelhotel.com), which is located close to the city's most exclusive neighborhood (Kolonaki), and to the old city (Plaka). The street address of the Divani Caravel hotel is Vassileos Alexandrou 2, 16121 Athens, Greece.

General Information
ICUAS '20 is a four-day event. The conference area is situated in the Mezzanine Level of the Hotel, above the main Lobby, as shown in the figure below. All Workshops, Tutorials, and Technical Sessions will be in the rooms, *Macedonia Hall* (A and B), *Kozani*, *Edessa*, *Naousa*, *Mycenae*, and *Pella*. Tutorials and Workshops will take place on Tuesday, followed by the three-day conference on Wednesday to Friday. All keynote/plenary talks will take place in the *Macedonia Hall*. The *Foyer* area will be used for Poster Papers, exhibits, research demo booths, etc.



Conference Technical Sessions - Wednesday, September 2 – Friday, September 4
In addition to the Plenary/Keynote lectures, there are four parallel technical sessions each day. All conference sessions, including Workshops and Tutorials, will be in the Mezzanine Level. Technical Sessions and Workshops/Tutorials will be in *Macedonia Hall, Kozani, Edessa,* and *Naousa.*

Exhibits
Exhibits will be in the Mezzanine Level, in the *Foyer* area, to maximize traffic and exposure.

Poster Papers
Poster papers will be on display for presentation on Wednesday, September 2. All poster papers will be in the main *Foyer* area.

Conference Registration
All Conference attendees must register by using the on-line registration when they upload the final version of their papers. This is the preferred option. Late and on-site 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 wear their badges at all times when attending any ICUAS '20 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 2020 - Choose ICUAS 2020 (from the list of conferences)
- ✓ Click on Register for ICUAS'20
- ✓ 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.

The registration area is the *Foyer* area outside the *Macedonia Hall* (A and B). The registration desk will be open during the following hours:

TUESDAY, SEPTEMBER 1:	*Workshop/Tutorial Registration* (**Only**)	8:00 AM – 10:00 AM
	Conference Registration	3:00 PM – 5:00 PM
WEDNESDAY, SEPTEMBER 2:		8:00 AM – 5:00 PM
THURSDAY, SEPTEMBER 3:		8:00 AM – 4:00 PM
FRIDAY, SEPTEMBER 4:		8:00 AM – 12:00 PM

On-site conference registration policy & fees

Attendees will be able to register for the Conference under the following registration categories/rates, which, due to COVID-19 are the same with Advanced- or Pre- Registration fees:

ATTENDEE STATUS	ON-SITE REGISTRATION FEE
Academic, Industry, Government, Others	$500
Student	$300
Tutorial - T1	$120
Tutorial - T2	$120
Tutorial - T3	$150
Tutorial - T4	$150
Extra Banquet Ticket	$100
Extra Proceedings	$40

Internet Access

All registered attendees will have complementary internet access.

Full Buffet Breakfast for participants with accommodations in the Divani Caravel Hotel

We encourage you to take advantage of the package the conference venue and ICUAS offers.

For participants who have made accommodations in the conference venue, the Divani Caravel Hotel, full buffet Breakfast is included in their hotel room rate. Please make sure you have completed breakfast by 8.30 AM – this is the time the conference will start.

Exclusive for participants with accommodations in the Divani Caravel Hotel – Box Lunches
Box lunches will be served to conference participants who have made accommodations in the conference venue, the Divani Caravel Hotel. Lunch tickets will be provided.

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. Coffee breaks will be served in the *Foyer* area.

Events and Receptions
The ICUAS'20 social agenda includes: *Welcome Reception* on Tuesday, September 1; *Banquet*, on Thursday, September 3. The Welcome Reception will be in the *Roof Garden Pool area*.

Travel to Athens
Athens is easily accessible by air, sea, and road. Once there, the public transportation system provides a safe, dependable and efficient way to move around the city. The public transportation network consists of underground (metro), train, suburban railways, buses, trolley buses, and trams. Athens is also connected with other parts of the mainland through a network of roads and railways.

Visitors arriving by air will land in the *Athens International Airport "Eleftherios Venizelos"* (IATA code: ATH). This award-winning airport is one of the world's leading airports in overall passenger satisfaction and has been named the Airport of the Year (2014) in the 10-30 million-passenger category by internationally acclaimed web portal Air Transport News. During World Routes 2019, the biggest global networking route development annual forum, the Athens International Airport received one more significant distinction, voted by airlines as "Highly Commended" in the competitive 20-50 million passenger category. In Routes Europe 2019 in Hannover, the Athens Airport received the Marketing Award - the Greek gateway took the winning title in the over 20 million annual passenger category.

The Athens International Airport is serviced by all major airlines, offering direct non-stop flights from/to most of the major European cities, New York, Philadelphia, Montreal/Toronto, North Africa, Gulf States, South Africa, and easy connections to the rest of the world. ATH is also serviced by low-cost and/or charter airlines that offer attractive packages.

Transportation from/to Airport to/from Divani Caravel Hotel
Upon arrival to the airport, one may reach the Divani Caravel Hotel by taxi, subway ("metro"), bus or private car.

Taxi: Taxis are available at the designated taxi waiting area located by Exit 3 at the Arrivals level. Ask the driver to get you to the Divani Caravel Hotel. The average cost on normal traffic is 40 EUR and it takes about 30 minutes to arrive at the hotel. In general, the drive from the airport to locations in the city center takes about 35-40 minutes and costs 38 EUR (flat rate – regular fare, from 5 a.m. until midnight) and 54 EUR (flat rate – night fare, from midnight to 5 a.m.).

Metro: The airport is connected to the city center via Metro Line 3 (Blue line) *Aghia Marina – Douk. Plakentias – Aghia Marina*. The Athens metro is convenient, clean and safe. The trip to the city center takes about 40 minutes and costs 10 EUR (one way). Walk to the metro station, adjacent to the Airport. Take the Blue line. Get off the metro at the Evangelismos Station. While exiting from the station, take the left exit towards Vas. Sofia's avenue. Walk pass the Hilton hotel (on your left-hand side), cross Michalakopoulou Street, continue straight on Vas. Alexandrou Street. You will see the Divani Caravel Hotel on your right. If you do not want to walk (approximately 5-7-minute walk), you may take the 224 bus (the stop is across the metro station exit), and get off at "Caravel Bus Stop", right in front of the hotel.

Bus: Bus X95 to Syntagma Square takes about 40 minutes and costs 6 EUR one way.

Car: Exit from the Airport, take the Attiki Odos highway following the signs for the Imittos ring. Exit right at the Katechaki / Mesogion avenue signs. Where Katechaki meets Mesogion avenue, turn left and follow directions to Michalakopoulou avenue. Driving down on Michalakopoulou avenue you will see the Hilton hotel on your right-hand side. At this point, make a left turn into Vas. Alexandrou avenue and you will see the Divani Caravel Hotel, 2 Vas. Alexandrou avenue.

ICUAS Tutorials and Workshops

ICUAS'20 offers four 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 the Conference web site, www.uasconferences.com, and they may use the on-line system for registration. Tutorials/Workshops will take place on Tuesday, September 1, 2020. Duration is either *Full-Day* (09:00 - 17:00) or *Half-Day* (09:00 - 13:00, or 14:00 – 18:00).

TUTORIALS / WORKSHOPS - Tuesday, September 1, 2020		
Location	**Time**	**Title**
Kozani-T1	Half-Day 14:00 – 18:00	*Integrated Prognostics and Health Management Technologies for UAS Resilience and Safety*
Kozani-T2	Half-Day 9:00 - 13:00	*Networked Airborne Computing: State-of-the-Art in Challenges, Applications and Enabling Technologies*
Naousa-T3	Full-Day 9:00 – 17:00	*State-of-the-Art in Fault-Tolerant Control (FTC), Fault-Tolerant Cooperative Control (FTCC) and Sense-and-Avoid in Unmanned Aircraft Systems*
Edessa-T4	Full-Day 9:00 - 17:00	*Drones as Edge Devices: Challenges, Technologies and Applications*

ICUAS Plenary Lectures

ICUAS'20 includes four Keynote and Plenary Lectures given by leading authorities in their respective fields. We are proud to include them in the technical program. All Plenary/Keynote lectures will be in the General Session Room, *Macedonia Hall*.

The schedule for the lectures is shown next.

WEDNESDAY – September 2, MACEDONIA HALL	
8:45 – 9:45 AM	***New Aerial Robotic Manipulators for Efficient and Safe Operation****, Dr. Anibal Ollero, University of Seville, Head of the Robotics, Vision and Control Group, and Scientific Advisor of the Center for Advanced Aerospace Technologies*
13:45 – 14:45 PM	***Control Systems and AI in the Quest for Autonomy****, Dr. Panos J. Antsaklis H. C. & E. A. Brosey Professor, University of Notre Dame*

THURSDAY – September 3, MACEDONIA HALL	
8:45 – 9:45 AM	***Unmanned Aerial Systems, Societal Challenges and Systems Efficiency*** *Grégoire Guerout, Lead Project Manager, Alerion, France, Member, French Bureau de Normalisation de l'Aéronautique et de l'Espace (BNAE).*
13:45 – 14:45 PM	***Integrated Coastal Zone Aerial Perception with UAVs****, Dr. Hai-Long Pei, Key Lab of Autonomous Systems and Networked Control, Ministry of Education, Unmanned System Engineering Center of Guangdong Province, South China University of Technology, Guangzhou.*

ICUAS' 20 TECHNICAL PROGRAM AT A GLANCE

Wednesday, Sept. 2

Macedonia Hall	Kozani	Edessa	Naousa
10:00-12:00 WeA1 Autonomy I	10:00-12:00 WeA2 Path Planning I	10:00-12:00 WeA3 Swarms	10:00-12:00 WeA4 Control Architectures I
15:00-17:00 WeB1 Autonomy II	15:00-17:00 WeB2 Path Planning II	15:00-17:00 WeB3 Networked Swarms I	15:00-17:00 WeB4 Control Architectures II
17:00-19:00 WeC1 AI and its Applications to Unmanned Flight Systems	17:00-19:00 WeC2 Path Planning III	17:00-19:00 WeC3 Networked Swarms II	17:00-19:00 WeC4 Control Architectures III
13:00 – 18:00 Foyer, Mezzanine Level, WeP5 Poster Papers			

Thursday, Sept. 3

10:00-12:00 ThA1 See and Avoid Systems I	10:00-12:00 ThA2 Path Planning IV	10:00-12:00 ThA3 UAS Applications I	10:00-12:00 ThA4 Control Architectures IV
15:00-17:00 ThB1 See and Avoid Systems II	15:00-17:00 ThB2 Safety, Security & Reliability	15:00-17:00 ThB3 UAS Applications II	15:00-17:00 ThB4 Micro and Mini UAS I
17:00-19:00 ThC1 Sensor Fusion	17:00-19:00 ThC2 Fail-Safe Systems	17:00-19:00 ThC3 UAS Applications III	17:00-19:00 ThC4 Micro and Mini UAS II

Friday, Sept. 4

09:00-11:00 FrA1 Navigation	09:00-10:40 FrA2 Levels of Safety	09:00-11:00 FrA3 UAS Applications IV	09:00-11:00 FrA4 Airspace Control
11:30-13:30 FrB1 Energy Efficient UAS	11:30-13:30 FrB2 Risk Analysis	11:30-13:30 FrB3 UAS Applications V	11:30-13:30 FrB4 Airspace Management
14:30-16:30 FrC1 Technology Challenges	14:30-16:30 FrC2 Biologically Inspired and Energy Efficient UAS	14:30-16:30 FrC3 Manned / Unmanned Aviation	14:30-16:30 FrC4 Air Vehicle Operations
16:30-18:10 FrD1 UAS Testbeds	16:30-18:10 FrD2 Simulation	16:30-18:10 FrD3 Manned / Unmanned Aviation and Testbeds	

ICUAS ’20 Technical Sessions and Content List

Technical Program for Wednesday September 2, 2020

WeA2	Kozani
Path Planning I (Regular Session)	

10:00-10:20	WeA2.1
A Path Planning Method for a Low Observable UAV in Radar Field, pp. 41-47.	
Orhan, Ethem Hakan	Turkish Aerospace Industries, Inc.

10:20-10:40	WeA2.2
Collision Avoidance of Fixed-Wing UAVs in Dynamic Environments Based on Spline-RRT and Velocity Obstacle, pp. 48-58.	
Zhang, Shuiqing	Sun Yat-Sen University
Xu, Tianye	Sun Yat-Sen University
Cheng, Hui	Sun Yat-Sen University
Liang, Fan	Sun Yat-Sen University

10:40-11:00	WeA2.3
Generation of Window-Traversing Flyable Trajectories Using Logistic Curve, pp. 59-65.	
Upadhyay, Saurabh	University of Bristol
Richards, Arthur	University of Bristol
Richardson, Thomas	University of Bristol

11:00-11:20	WeA2.4
UAV-Deployment for City-Wide Area Coverage and Computation of Optimal Response Trajectories, pp. 66-71.	
Tsoukalas, Athanasios	New York University Abu Dhabi
Tzes, Anthony	New York University Abu Dhabi
Papatheodorou, Sotiris	Imperial College London
Khorrami, Farshad	New York University

11:20-11:40	WeA2.5
2D and 3D A Algorithm Comparison for UAS Traffic Management Systems*, pp. 72-76.	
Pötter Neto, Carlos Augusto	Instituto Tecnológico De Aeronáutica
de Carvalho Bertoli, Gustavo	Instituto Tecnologico De Aeronáutica
Saotome, Osamu	Instituto Tecnológico De Aeronáutica

11:40-12:00	WeA2.6
UAV 3D Path and Motion Planning in Unknown Dynamic Environments, pp. 77-84.	
Margraff, Julien	University of Limoges
Stephant, Joanny	University of Limoges
Labbani-Igbida, Ouiddad	University of Limoges

WeA3	Edessa
Swarms (Regular Session)	

10:00-10:20	WeA3.1
Formation Control and Target Interception for Multiple Multi-Rotor Aerial Vehicles, pp. 85-92.	
Karras, George	University of Thessaly
Bechlioulis, Charalampos	National Technical University of Athens
Fourlas, George K.	University of Thessaly
Kyriakopoulos, Kostas J.	National Technical University of Athens

10:20-10:40	WeA3.2

Cooperative Game Theory Based Multi-UAV Consensus-Based Formation Control, pp. 93-99.

Jiang, Liwei	University of Stuttgart
Gonzalez, Luis Felipe	Queensland University of Technology
Mcfadyen, Aaron	Queensland University of Technology

10:40-11:00	WeA3.3

Distributed Algorithm for the Navigation of a Swarm of Nano-Quadrotors in Cluttered Environments, pp. 100-109.

Karydes, Florian	Ecole Polytechnique De Montréal
Saussie, David	Ecole Polytechnique De Montréal

11:20-11:40	WeA3.5

Wilderness Search and Rescue with Heterogeneous Multi-Robot Systems, pp. 110-116.

Rodríguez, Marcos	Universidad Carlos III De Madrid
Al-Kaff, Abdulla	Universidad Carlos III De Madrid
Madridano, Angel	Universidad Carlos III De Madrid
Martín Gómez, David	Universidad Carlos III De Madrid
de La Escalera, Arturo	Universidad Carlos III De Madrid

11:40-12:00	WeA3.6

Disturbance Perception Based Quadrotor UAV Maneuvering Formation against Unknown External Disturbance, pp. 117-122.

Guo, Kexin	Beihang University
Liu, Cai	Beihang University
Zhang, Xiao	Beihang University
Yu, Xiang	Beihang University
Guo, Lei	Beihang University
Zhang, Youmin	Concordia University

WeA4 — Naousa

Control Architectures I (Regular Session)

10:00-10:20	WeA4.1

Distributed Multiple Model MPC for Target Tracking UAVs, pp. 123-130.

Wolfe, Sean	Royal Military College of Canada
Givigi, Sidney	Royal Military College of Canada
Rabbath, Camille Alain	DRDC

10:20-10:40	WeA4.2

Constrained Control Allocation Approaches in Trajectory Control of a Quadrotor under Actuator Saturation, pp. 131-139.

Tariq, Talha	McGill University
Nahon, Meyer	McGill University

10:40-11:00	WeA4.3

Aerial Combat Tactics in Overwhelming Numbers, pp. 140-148.

Day, Michael	Georgia Tech Research Institute
Magree, Daniel	Georgia Tech Research Institute
DeMarco, Kevin	Georgia Tech Research Institute

Squires, Eric	Georgia Tech Research Institute
Strickland, Laura	Georgia Tech Research Institute
Vlahov, Bogdan	Georgia Tech Research Institute
Pippin, Charles	Georgia Tech Research Institute

11:00-11:20 WeA4.4

Longitudinal Dynamics Analysis and Autopilot Design for a Fixed-Wing, Tactical Blended-Wing-Body UAV, pp. 149-157.

Kitsios, Ioannis	Hellenic Air Force Electronics & Telecoms Depot
Dimopoulos, Thomas	Aristotle University of Thessaloniki
Panagiotou, Pericles	Aristotle University of Thessaloniki
Yakinthos, Kyriakos	Aristotle University of Thessaloniki

11:20-11:40 WeA4.5

Inertial Estimation and Energy-Efficient Control of a Cable-Suspended Load with a Team of UAVs, pp. 158-165.

Petitti, Antonio	National Research Council of Italy
Sanalitro, Dario	LAAS-CNRS
Tognon, Marco	ETH Zurich
Milella, Annalisa	Institute of Intelligent Industrial Technologies and Systems For
Cortés, Juan	LAAS-CNRS
Franchi, Antonio	University of Twente

11:40-12:00 WeA4.6

Differential Sweep Attitude Control for Swept Wing UAVs, pp. 166-175.

Harms, Marvin Chayton	ETH Zürich
Kaufmann, Noah	ETH Zürich
Rockenbauer, Friedrich Martin	ETH Zurich
Lawrence, Nicholas	The University of Sydney
Stastny, Thomas	ETH Zurich
Siegwart, Roland Y.	ETH Zürich

WeB1 Macedonia Hall

Autonomy II (Regular Session)

15:00-15:20 WeB1.1

Backstepping-Based Adaptive Fault-Tolerant Control Design for Satellite Attitude System, pp. 337-342.

Yan, Kun	Nanjing University of Aeronautics and Astronautics
Wu, Qingxian	Nanjing University of Aeronautics and Astronautics
Yang, Chenguang	University of the West of England
Chen, Mou	Nanjing University of Aeronautics and Astronautics

15:20-15:40 WeB1.2

Disturbance Observer-Based Control of Quadrotors with Motor Response Delay and Throttle Nonlinearity, pp. 343-348.

Song, Yansui	Northwestern Polytechnical University
Liu, Xi	Unit 36485 of the Chinese People's Liberation Army
Xu, Bin	Northwestern Polytechnical University
Zhang, Yu	Zhejiang University

Yang, Chenguang	University of the West of England

16:00-16:20	WeB1.4

Fuzzy Kinodynamic RRT: A Dynamic Path Planning and Obstacle Avoidance Method, pp. 349-356.

Chen, Long	Concordia University
Mantegh, Iraj	National Research Council Canada
He, Tong	Concordia University
Xie, Wenfang	Concordia University

16:20-16:40	WeB1.5

Required Navigation Performance Specifications for Unmanned Aircraft Based on UTM Flight Trials, pp. 357-364.

Kallinen, Valtteri	Queensland University of Technology
Martin, Terrence	NOVA
Mcfadyen, Aaron	Queensland University of Technology

16:40-17:00	WeB1.6

A Decentralized Framework to Support UAS Merging and Spacing Operations in Urban Canyons, pp. 365-371.

Balachandran, Sweewarman	National Institute of Aerospace
Manderino, Christopher	NSF Center for Space, High-Performance, and Resilient Computing
Munoz, Cesar	NASA Langley Research Center
Consiglio, Maria	NASA Langley Research Center

WeB2	Kozani
Path Planning II (Regular Session)	

15:00-15:20	WeB2.1

UAS Flight Path Planning for Dynamic, Multi-Vehicle Environment, pp. 209-217.

He, Tong	Concordia University
Mantegh, Iraj	National Research Council Canada
Chen, Long	Concordia University
Vidal, Charles	National Research Council Canada
Xie, Wenfang	Concordia University

15:20-15:40	WeB2.2

A Chaotic Path Planning Method for 3D Area Coverage Using Modified Logistic Map and a Modulo Tactic, pp. 218-225.

Moysis, Lazaros	Aristotle University of Thessaloniki
Petavratzis, Eleftherios	Aristotle University of Thessaloniki
Volos, Christos	Aristotle University of Thessaloniki
Nistazakis, Hector	Aristotle University of Thessaloniki
Stouboulos, Ioannis	Aristotle University of Thessaloniki
Valavanis, Kimon P.	University of Denver

15:40-16:00	WeB2.3

Optimal Multi-Agent Coverage and Flight Time with Genetic Path Planning, pp. 226-235.

Olson, Jacob	Brigham Young University
Bidstrup, Craig	Uber ATG
Anderson, Brady	Brigham Young University

Parkinson, Alan	Brigham Young University
McLain, Tim	Brigham Young University

16:00-16:20 WeB2.4

Fast Trajectory Optimization for Quadrotor Landing on a Moving Platform, pp. 236-243.

Zhang, Guoxu	Beijing Institute of Technology
Kuang, Hailiang	Beijing Institute of Technology
Liu, Xinfu	Beijing Institute of Technology

16:20-16:40 WeB2.5

Unmanned Aerial Vehicle Trajectory Planning Via Staged Reinforcement Learning, pp. 244-253.

Xi, Chenyang	Beijing Institute of Technology
Liu, Xinfu	Beijing Institute of Technology

16:40-17:00 WeB2.6

Optimization in Multiphase Homing Trajectory of Unpowered Parafoil with High-Altitude, pp. 254-260.

Guo, Yiming	Northwestern Polytechnical University
Jianguo, Yan	Northwestern Polytechnical University
Luo Yu, Yu	Shaanxi Polytechnic Institute
Wu, Cihang	Northwestern Polytechnical University
Li, Fenghao	Northwestern Polytechnical University
Xing, Xiaojun	Northwestern Polytechnical University

WeB3 Edessa

Networked Swarms I (Regular Session)

15:20-15:40 WeB3.2

A Geometrical Approach Based on 4D Grids for Conflict Management of Multiple UAVs Operating in U-Space, pp. 261-268.

Acevedo, José Joaquín	University of Seville
Capitán, Carlos	University of Seville
Capitan, Jesus	University of Seville
Castaño, Ángel Rodríguez	University of Seville
Ollero, Anibal	University of Seville

15:40-16:00 WeB3.3

Decentralized Task Allocation for Multiple UAVs with Task Execution Uncertainties, pp. 269-276.

Liu Ruifan	Northwestern Polytechnical University
Seo, Min-Guk	Cranfield University
Yan, Binbin	Northwestern Polytechnical University
Tsourdos, Antonios	Cranfield University

16:00-16:20 WeB3.4

Communication-Based and Communication-Less Approaches for Robust Cooperative Planning in Construction with a Team of UAVs, pp. 277-286.

Umili, Elena	Sapienza Università di Roma
Tognon, Marco	ETH Zurich
Sanalitro, Dario	LAAS-CNRS
Oriolo, Giuseppe	Sapienza Università di Roma
Franchi, Antonio	University of Twente

16:20-16:40	WeB3.5

Evaluation of Cooperative Guidance for Formation Flight of Fixed-Wing UAVs Using Mesh Network, pp. 287-292.

Kim, SuHyeon	Korea Aerospace University
Cho, Hyeong Jun	Korea Aerospace University
Jung, Dongwon	Korea Aerospace University

16:40-17:00	WeB3.6

Design, Implementation and Validation of a Multipurpose Localization Service for Cooperative Multi-UAV Systems, pp. 293-300.

Pignaton de Freitas, Edison	Federal University of Rio Grande Do Sul
Leite Francisco da Costa, Luis Antonio	Federal University of Rio Grande Do Sul
Emygdio de Melo, Carlos Felipe	Federal University of Rio Grande Do Sul
Basso, Maik	Federal University of Rio Grande Do Sul
Rodrigues Vizzotto, Marcos	Federal University of Rio Grande Do Sul
Schein Cavalheiro Corrêa, Mateus	Federal University of Rio Grande Do Sul
Dapper e Silva, Túlio	Federal University of Rio Grande Do Sul

WeB4	Naousa
Control Architectures II (Regular Session)	

15:00-15:20	WeB4.1

Transition Control of a Tail-Sitter UAV Using Recurrent Neural Networks, pp. 301-307.

Flores, Alejandro	Center for Research in Optics
Flores, Gerardo	Center for Research in Optics

15:20-15:40	WeB4.2

Modeling and Control of Mid-Flight Coupling of Quadrotors: A New Concept for Quadrotor Cooperation, pp. 308-313.

Larsson, Daniel	Georgia Institute of Technology
Nguyen, Chuong	Arizona State University
Artemiadis, Panagiotis	University of Delaware

15:40-16:00	WeB4.3

Multibody Dynamic Modeling and Control of an Unmanned Aerial Vehicle under Non-Holonomic Constraints, pp. 314-319.

Lanteigne, Eric	University of Ottawa
O'Reilly, Joshua	University of Ottawa

16:00-16:20	WeB4.4

Trajectory Tracking Control for a Quadrotor with a Slung Load, pp. 320-326.

Rodriguez Cortes, Hugo	CINVESTAV-IPN
Mosco Luciano, Alan Paz	CINVESTAV-IPN
Castro-Linares, Rafael	CINVESTAV-IPN

16:20-16:40	WeB4.5

Modeling and Control of a Novel Over-Actuated Tri-Rotor UAV, pp. 327-336.

Wang, Yunhe	Zhejiang University
Zhu, Zhangzhen	Zhejiang University
Zhang, Yu	Zhejiang University

WeC1 Macedonia Hall

Artificial Intelligence and Its Applications to Unmanned Flight Systems (Invited Session)

Organizer: Liu, Hao	Beihang University
Organizer: Wang, Qingling	Southeast University
Organizer: Liang, Yang	Beihang University

17:00-17:20 WeC1.1

Discrete Sliding Mode Tracking Control of Hypersonic Vehicle under Incomplete Data Transmission (I), pp. 176-184.

Song, Jia	Beihang University
Zhang, Yanxue	Beihang University
Weng, Huiyan	Beihang University
Zhu, Hao	Beihang University
Yu, Nanjia	Beihang University
Cai, Guobiao	Beihang University

17:20-17:40 WeC1.2

Robust Optimal Control Law Learning for Heterogeneous Rotorcraft Formation Involving Unknown Parameters (I), pp. 185-190.

Liu, Hao	Beihang University
Meng, Qingyao	Beihang University
Liang, Yang	Beihang University
Tian, Hui	Beihang University
Junya, Yuan	Beihang University

17:40-18:00 WeC1.3

Image-Based Visual Servo Control for Ground Target Tracking Using a Fixed-Wing UAV with Pan-Tilt Camera (I), pp. 191-198.

Yang, Lingjie	National University of Defense Technology
Zhihong, Liu	National University of Defense Technology
Wang, Guanzheng	National University of Defense Technology
Wang, Xiangke	National University of Defense Technology

18:00-18:20 WeC1.4

Implementation on Benchmark of SC2LE Environment with Advantage Actor - Critic Method (I), pp. 199-203.

Hu, Huan	Southeast University
Wang, Qingling	Southeast University

18:20-18:40 WeC1.5

Precipitation Forecast Based on Multi-Channel ConvLSTM and 3D-CNN (I), pp. 204-208.

Dan, Niu	Southeast University
Diao, Li	Shanghai Jiao Tong University
Xu, Liujia	Southeast University
Zang, Zengliang	Institute of Meteorology and Oceanography, National University
Xisong, Chen	Southeast University

Liang, Shasha	Southeast University

WeC2 Kozani

Path Planning III (Regular Session)

17:00-17:20 WeC2.1

Evaluation of a Commercially Available Autonomous Visual Inertial Odometry Solution for Indoor Navigation, pp. 372-381.

Agarwal, Ankit	Pennsylvania State University
Crouse, Jacob	Pennsylvania State University
Johnson, Eric	Pennsylvania State University

17:20-17:40 WeC2.2

Disturbance Observer-Based Integral Backstepping Control for UAVs, pp. 382-388.

Moeini, Amir	U of Alberta
Rafique, Muhammad Awais	U of Alberta
Xue, Zhijun	Huazhong University of Science & Technology
Lynch, Alan	U of Alberta
Zhao, Qing	U of Alberta

17:40-18:00 WeC2.3

Spare Drone Optimization for Persistent Task Performance with Multiple Homes, pp. 389-397.

Hartuv, Erez	Bar-Ilan University
Agmon, Noa	Bar-Ilan University
Kraus, Sarit	Bar-Ilan University

18:00-18:20 WeC2.4

HorizonBlock: Implementation of an Autonomous Counter-Drone System, pp. 398-404.

Souli, N.	University of Cyprus
Makrigiorgis, R.	University of Cyprus
Anastasiou, Andreas	University of Cyprus
Petrides, Petros	University of Cyprus
Zacharia, A.	University of Cyprus
Lazanas, A.	University of Cyprus
Valianti, Panayiota	University of Cyprus
Kolios, Panayiotis	University of Cyprus
Ellinas, G.	University of Cyprus

18:20-18:40 WeC2.5

A Task-Oriented Assignment Algorithm for Collaborative Unmanned Aerial Systems, pp. 405-411.

Lindsay, Nathan	New Mexico State University
Sun, Liang	New Mexico State University

18:40-19:00 WeC2.6

Wildfire Remote Sensing with UAVs: A Review from the Autonomy Point of View, pp. 412-420.

Bailon-Ruiz, Rafael	LAAS-CNRS
Lacroix, Simon	LAAS-CNRS

WeC3	Edessa
Networked Swarms II (Regular Session)	

17:00-17:20	WeC3.1

Observer-Based Event-Triggered Model Reference Control for Multi-Agent Systems, pp. 421-428.

Vazquez Trejo, Juan Antonio	University of Lorraine
Rotondo, Damiano	University of Stavanger
Adam-Medina, Manuel	National Center for Research and Technological Development
Theilliol, Didier	University of Lorraine

17:20-17:40	WeC3.2

Integrated Perception and Tactical Behaviours in an Auto-Organizing Aerial Sensor Network, pp. 429-438.

Leong, Wai Lun	National University of Singapore
Martinel, Niki	University of Udine
Huang, Sunan	National University of Singapore
Micheloni, Christian	University of Udine
Foresti, Gianluca	University of Udine
Teo, Rodney	Temasek Laboratories, National University of Singapore

17:40-18:00	WeC3.3

Distributed UAV Formation Control with Prescribed Performance, pp. 439-445.

Gkesoulis, Athanasios	National Technical University of Athens
Psillakis, Haris	National Technical University of Athens

18:00-18:20	WeC3.4

Swarm Control for Autonomous Navigation Support, pp. 446-455.

Gipson, Jonathon	Air Force Institute of Technology
Leishman, Robert	Air Force Institute of Technology
Schubert Kabban	Air Force Institute of Technology

18:20-18:40	WeC3.5

Swarm Path Planning for the Deployment of Drones in Emergency Response Missions, pp. 456-465.

Anastasiou, Andreas	University of Cyprus
Kolios, Panayiotis	University of Cyprus
Panayiotou, Christos	University of Cyprus
Papadaki, Katerina	London School of Economics and Political Sciences

18:40-19:00	WeC3.6

Designing and Flight-Testing a Swarm of Small UAS to Assist Post-Nuclear Blast Forensics, pp. 466-472.

Kopeikin, Andrew	US Military Academy
Russell, Conner	Army
Trainor, Hayden	United States Military Academy
Rivera, Ashley	United States Military Academy
Jones, Tyrus	United States Military Academy
Baumgartner, Benjamin	United States Military Academy
Manjunath, Pratheek	United States Military Academy
Heider, Samuel	DTRA
Surdu, Thomas	United States Military Academy
Galea, Matthew	United States Military Academy

WeC4	Naousa
Control Architectures III (Regular Session)	

17:00-17:20	WeC4.1

Unified Controller for Take-Off and Landing for a Fixed-Wing Aircraft, pp. 473-479.

Montes de Oca Rebolledo, Andres	Center for Research in Optics
Flores, Gerardo	Center for Research in Optics

17:20-17:40	WeC4.2

Target Tracking with Multi-Rotor Aerial Vehicles Based on a Robust Visual Servo Controller with Prescribed Performance, pp. 480-487.

Karras, George	University of Thessaly
Bechlioulis, Charalampos	National Technical University of Athens
Fourlas, George K.	University of Thessaly
Kyriakopoulos, Kostas J.	National Technical University of Athens

17:40-18:00	WeC4.3

Path-Following with a UGV-UAV Formation Considering That the UAV Lands on the UGV, pp. 488-497.

Bacheti, Vinicius	Federal University of Espirito Santo
Brandao, Alexandre Santos	Federal University of Vicosa
Sarcinelli-Filho, Mário	Federal University of Espirito Santo

18:00-18:20	WeC4.4

Adaptive Control Approaches for an Unmanned Aerial Manipulation System, pp. 498-503.

Chaikalis, Dimitris	New York University Abu Dhabi
Khorrami, Farshad	New York University
Tzes, Anthony	New York University Abu Dhabi

18:20-18:40	WeC4.5

A Decentralized Approach for the Aerial Manipulator Trajectory Tracking, pp. 504-511.

Tlatelpa-Osorio, Y. Elizabeth	CINVESTAV-IPN
Rodriguez Cortes, Hugo	CINVESTAV-IPN
Acosta, Jose Angel	University of Seville

WeP5	Foyer Mezzanine Level
Poster Papers Session (Poster Session)	

13:00-18:00	WeP5.1

Adaptive Fast Terminal Sliding Mode (FTSM) Control Design for Quadrotor UAV under External Windy Disturbances, pp. 512-516.

Shi, Xiaoyu	University of Electronic Science and Technology of China
Cheng, Yuhua	University of Electronic Science and Technology of China

13:00-18:00	WeP5.2

Towards Long-Term Autonomy for UAS, pp. 517-522.

Mersha, Abeje Yenehun	Saxion University of Applied Sciences
Reiling, Mark	Saxion University of Applied Sciences
Meijering, Rene	Saxion University of Applied Sciences

13:00-18:00	WeP5.3

Fast Nonlinear Model Predictive Control for Very-Small Aerial Vehicles, pp. 523-528.

Nascimento, Tiago	Universidade Federal da Paraiba
Saska, Martin	Czech Technical University in Prague

13:00-18:00 WeP5.4

Controller Design for Highly Maneuverable Aircraft Technology Using Structured Singular Value and Direct Search Method, pp. 529-533.

Dlapa, Marek	Tomas Bata University in Zlin

13:00-18:00 WeP5.5

LAIDR: A Robotics Research Platform for Entertainment Applications, pp. 534-539.

Elsharkawy, Ahmed	Gwangju Institute of Science and Technology
Naheem, Khawar	Gwangju Institute of Science and Technology
Lee, Yundong	Gwangju Institute of Science and Technology
Koo, Dongwoo	Gwangju Institute of Science and Technology
Kim, Mun Sang	Gwangju Institute of Science and Technology

13:00-18:00 WeP5.6

Research on Meteorological Technology Development Using Rotary Multicopter Unmanned Aerial Vehicles and Its Application, pp. 540-544.

Chong, Jihyo	National Institute of Meteorological Sciences
Lee, Seungho	International Climate & Environment Center
Shin, Seungsook	National Institute of Meteorological Sciences
Hwang, SungEun	National Institute of Meteorological Sciences
Lee, Young Tae	National Institute of Meteorological Sciences
Kim, Seungbum	National Institute of Meteorological Sciences

13:00-18:00 WeP5.7

Image-Based Sense and Avoid of Small Scale UAV Using Deep Learning Approach, pp. 545-550.

Huang, Zong-Ying	National Cheng Kung University
Lai, Ying-Chih	National Cheng Kung University

13:00-18:00 WeP5.8

Collision Avoidance of SDRE Controller Using Artificial Potential Field Method: Application to Aerial Robotics, pp. 551-556.

Nekoo, Saeed Rafee	Universidad De Sevilla
Acosta, Jose Angel	Universidad De Sevilla
Ollero, Anibal	Universidad De Sevilla

13:00-18:00 WeP5.9

Deep Learning Based Anomaly Detection for a Vehicle in Swarm Drone System, pp. 557-561.

Ahn, Hyojung	Korea Aerospace Research Institute

13:00-18:00 WeP5.10

Good Choices: Technological and Ethical Considerations to Increase Public Trust in Unmanned Aerial Systems, pp. 562-567.

Coulter, Corina	University of Denver
Haring, Kerstin Sophie	University of Denver

13:00-18:00 WeP5.11

C4ISR Systems Applied to Amazonian Constraints, pp. 568-572.

Machado Figueira, Nina	Brazilian Army

Niedermeier Belmonte, Giancarlo	Brazilian Army
Pignaton de Freitas, Edison	Federal University of Rio Grande Do Sul

13:00-18:00	WeP5.13

Towards a Social-Media Driven Multi-Drone Tasking Platform, pp. 573-581.

Terzi, Maria	University of Cyprus
Kolios, Panayiotis	University of Cyprus
Panayiotou, Christos	University of Cyprus
Theocharides, Theocharis	University of Cyprus

13:00-18:00	WeP5.14

Control System Design for Hybrid Power Supply of an Unmanned Aerial Vehicle Based on Linearized Averaged Process Models, pp. 582-587.

Krznar, Matija	University of Zagreb
Pavkovic, Danijel	University of Zagreb
Kozhushko, Yuliia	Igor Sikorsky Kyiv Polytechnic Institute
Cipek, Mihael	University of Zagreb
Zorc, Davor	University of Zagreb
Crneković, Mladen	University of Zagreb

13:00-18:00	WeP5.15

Flight Controller Optimization of Unmanned Aerial Vehicles Using a Particle Swarm Algorithm, pp. 588-593.

Gomez Redondo, Nicolas Alberto	Universidad Nacional De Asunción
Gomez Valenzuela, Victor Sebastián	Universidad Nacional De Asunción
Paiva, Enrique	Universidad Nacional De Asunción
Rodas, Jorge	Universidad Nacional De Asunción
Gregor Recalde, Raul Igmar	Universidad Nacional De Asunción

13:00-18:00	WeP5.16

A Probabilistic Based UAV Mission Planning and Navigation for Planetary Exploration, pp. 594-599.

Galvez, Julian	Queensland University of Technology
Gonzalez, Luis Felipe	Queensland University of Technology
Vanegas Alvarez, Fernando	Queensland University of Technology
Flannery, David Timothy	Queensland University of Technology

Technical Program for Thursday September 3, 2020

ThA1	Macedonia Hall
See-And-Avoid Systems I (Regular Session)	

10:00-10:20	ThA1.1

A Novel Technique for Rejecting Non-Aircraft Artefacts in above Horizon Vision-Based Aircraft Detection, pp. 600-606.

James, Jasmin	Queensland University of Technology
Ford, Jason	Queensland University of Technology

Molloy, Timothy L.	University of Melbourne

10:20-10:40	ThA1.2

Collision Detection and Avoidance System for Multicopter UAVs Using Optical Flow, pp. 607-614.

Urieva, Natallia	California State Polytechnic University, Pomona
McDonald, Jeffrey	California State Polytechnic University, Pomona
Ramos, April Sandy Rose	California State Polytechnic University, Pomona
Uryeva, Tatsiana	Mt. San Antonio Community College
Bhandari, Subodh	California State Polytechnic University, Pomona

10:40-11:00	ThA1.3

Hybrid Motion-Based Object Detection for Detecting and Tracking of Small and Fast-Moving Drones, pp. 615-621.

Srigrarom, Sutthiphong	National University of Singapore
Chew, Kim Hoe	Technical University of Munich

11:00-11:20	ThA1.4

LiDAR Imaging-Based Attentive Perception, pp. 622-626.

Tsiourva, Maria	University of Nevada, Reno
Papachristos, Christos	University of Nevada, Reno

11:20-11:40	ThA1.5

Monocular Vision-Based Obstacle Avoidance Trajectory Planning for Unmanned Aerial Vehicles, pp. 627-632.

Zhang, Zhouyu	Nanjing University of Aeronautics and Astronautics
Zhang, Youmin	Concordia University
Cao, Yunfeng	Nanjing University of Aeronautics and Astronautics

11:40-12:00	ThA1.6

Obstacle Detection and Avoidance System for Small UAVs Using a LiDAR, pp. 633-640.

Moffatt, Andrew	California State Polytechnic University, Pomona
Platt, Eric	California State Polytechnic University, Pomona
Mondragon, Brandon	California State Polytechnic University, Pomona
Kwok, Aaron	California State Polytechnic University, Pomona
Uryeu, Dzianis	Walnut High School
Bhandari, Subodh	California State Polytechnic University, Pomona

ThA2	Kozani
Path Planning IV (Regular Session)	

10:00-10:20	ThA2.1

A Risk-Based Path Planning Strategy to Compute Optimum Risk Path for Unmanned Aircraft Systems Over Populated Areas, pp. 641-650.

Primatesta, Stefano	Politecnico Di Torino
Scanavino, Matteo	Politecnico Di Torino
Guglieri, Giorgio	Politecnico Di Torino
Rizzo, Alessandro	Politecnico Di Torino

10:20-10:40	ThA2.2

Optimal Mission Planning for Fixed-Wing UAVs with Electro-Thermal Icing Protection and Hybrid-Electric Power Systems, pp. 651-660.

Narum, Edvard Frimann	Norwegian University of Science and Technology

Løes
Hann, Richard — Norwegian University of Science and Technology
Johansen, Tor Arne — Norwegian University of Science and Technology

10:40-11:00 ThA2.3

Cooperative Path Planning for Multiple MAVs Operating in Unknown Environments, pp. 661-667.
Ahmad, Afzal — Czech Technical University in Prague
Vonasek, Vojtech — Czech Technical University in Prague
Saska, Martin — Czech Technical University in Prague

11:00-11:20 ThA2.4

Exploring the Use of Reverse Thrust in a Dynamic UAS Landing Maneuver Using Kinodynamic RRT, pp. 668-675.
Givens, Matthew — University of Colorado Boulder
Coopmans, Calvin — Utah State University

11:20-11:40 ThA2.5

A Recurrent Planning Strategy for UAV Optimum Path Identification in a Dynamic Environment Based on Bit-Coded Flight Maneuvers, pp. 676-685.
Bassolillo, Salvatore — University of Campania
Blasi, Luciano — Università Degli Studi Della Campania "L.Vanvitelli"
D'Amato, Egidio — University of Naples "Parthenope"
Mattei, Massimiliano — Seconda Università di Napoli
Notaro, Immacolata — University of Campania "Luigi Vanvitelli"

11:40-12:00 ThA2.6

Exploiting Null Space in Aerial Manipulation through Model-In-The-Loop Motion Planning, pp. 686-693.
Ivanovic, Antun — University of Zagreb
Car, Marko — University of Zagreb
Orsag, Matko — University of Zagreb
Bogdan, Stjepan — University of Zagreb

ThA3 Edessa
UAS Applications I (Regular Session)

10:00-10:20 ThA3.1

UAV Target Tracking in Urban Environments Using Deep Reinforcement Learning, pp. 694-701.
Bhagat, Sarthak — IIIT Delhi
P B, Sujit — IISER Bhopal

10:20-10:40 ThA3.2

Autonomous Airborne Multi-Rotor UAS Delivery System, pp. 702-708.
Jackson, Seth — US Army
Riccoboni, Nena — United States Military Academy
Abdul Rahim, Abdul Halim — United States Military Academy
Tobin, Ronald — United States Military Academy
Bluman, James — United States Military Academy
Kopeikin, Andrew — United States Military Academy
Manjunath, Pratheek — United States Military Academy
Prosser, Ekaterina — US Army

10:40-11:00	ThA3.3

Autonomous Wind Turbine Inspection Using a Quadrotor, pp. 709-715.

Gu, Weibin	University of Denver
Hu, Dewen	Shanghai FOIA Co
Cheng, Liang	Shanghai FOIA Co
Cao, Yabing	Shanghai FOIA Co
Rizzo, Alessandro	Politecnico di Torino
Valavanis, Kimon P.	University of Denver

11:00-11:20	ThA3.4

Outdoor Navigation Using Two Quadrotors and Adaptive Sliding Mode Control, pp. 716-721.

Villa, Daniel Khede Dourado	Federal University of Espírito Santo
Brandao, Alexandre Santos	Federal University of Vicosa
Sarcinelli-Filho, Mário	Federal University of Espirito Santo

11:20-11:40	ThA3.5

Barrier Lyapunov Function Based Trajectory Tracking Controller for Autonomous Vehicles with Guaranteed Safety Bounds, pp. 722-728.

Kumar, Yogesh	IIIT Delhi
Roy, Sayan Basu	IIIT Delhi
P B, Sujit	IISER Bhopal

11:40-12:00	ThA3.6

POSITRON: Lightweight Active Positioning Compliant Joints Robotic Arm in Power Lines Inspection, pp. 729-736.

Perez Jimenez, Manuel	University of Seville
Montes Grova, Marco Antonio	University of Seville
Ramon Soria, Pablo	University of Seville
Arrue, B.C.	University of Seville
Ollero, Anibal	University of Seville

ThA4	Naousa
Control Architectures IV (Regular Session)	

10:00-10:20	ThA4.1

Robust Geometric Control of a Helicopter Using Sliding Mode Control, pp. 737-743.

B Krishna, Akhil	IIT Kanpur
Sen, Arijit	IIT Kanpur
Kothari, Mangal	IIT Kanpur

10:20-10:40	ThA4.2

Load Manipulation by a Triangular Formation of Quadrotors, pp. 744-753.

Ernandes-Neto, Valentim	Federal University of Espírito Santo
Brandao, Alexandre Santos	Federal University of Vicosa
Sarcinelli-Filho, Mário	Federal University of Espirito Santo

10:40-11:00	ThA4.3

Omni-Plus-Seven (O+7): An Omnidirectional Aerial Prototype with a Minimal Number of Uni-Directional

Thrusters, pp. 754-761.

Hamandi, Mahmoud	LAAS-CNRS
Sawant, Kapil	IIT
Tognon, Marco	ETH Zurich
Franchi, Antonio	University of Twente

11:00-11:20 ThA4.4

Scaling Effects on Controllers for Multirotors, pp. 762-770.

Thai, Lam Ngoc	McGill University
Nahon, Meyer	McGill University
Charland-Arcand, Guillaume	ARA Robotics

11:20-11:40 ThA4.5

Vision-Based Autonomous Landing Using an MPC-Controlled Micro UAV on a Moving Platform, pp. 771-780.

Mohammadi, Alireza	University of Michigan-Dearborn
Feng, Yi	University of Michigan-Dearborn
Zhang, Cong	University of Michigan-Dearborn
Rawashdeh, Samir	University of Michigan-Dearborn
Baek, Stan	United States Air Force Academy

ThB1 Macedonia Hall

See-And-Avoid Systems II (Regular Session)

15:00-15:20 ThB1.1

Experimental Comparison of Fiducial Markers for Pose Estimation, pp. 781-789.

Kalaitzakis, Michail	University of South Carolina
Carroll, Sabrina	University of South Carolina
Ambrosi, Anand	University of South Carolina
Whitehead, Camden	University of South Carolina
Nikolaos, Vitzilaios	University of South Carolina

15:20-15:40 ThB1.2

Point Cloud-Based Target-Oriented 3D Path Planning for UAVs, pp. 790-798.

Zheng, Zhaoliang	University of California Los Angeles
Bewley, Thomas R.	University of California San Diego
Kuester, Falko	University of California San Diego

15:40-16:00 ThB1.3

Intercepting a Target Moving on a Racetrack Path, pp. 799-806.

Manyam, Satyanarayana Gupta	Infoscitex Corporation
Casbeer, David	Air Force Research Laboratory

16:00-16:20 ThB1.4

Mono-LSDE: Lightweight Semantic-CNN for Depth Estimation from Monocular Aerial Images, pp. 807-814.

Astudillo Olalla, Armando	Universidad Carlos III De Madrid
Al-Kaff, Abdulla	Universidad Carlos III De Madrid
Madridano, Angel	Universidad Carlos III De Madrid
García Fernández,	Universidad Carlos III De Madrid

Fernando

Martín Gómez, David	Universidad Carlos III De Madrid
de La Escalera, Arturo	Universidad Carlos III De Madrid

16:20-16:40 ThB1.5

Obstacle Avoidance Manager for UAVs Swarm, pp. 815-821.

Madridano, Angel	Universidad Carlos III De Madrid
Al-Kaff, Abdulla	Universidad Carlos III De Madrid
Flores Peña, Pablo	Drone Hopper S.L
Martín Gómez, David	Universidad Carlos III De Madrid
de La Escalera, Arturo	Universidad Carlos III De Madrid

16:40-17:00 ThB1.6

From Simulation to Reality: A Implementable Self-Organized Collision Avoidance Algorithm for Autonomous UAVs, pp. 822-831.

Casas Melo, Victor Fernando	Technische Universität Ilmenau
Mitschele-Thiel, Andreas	Technische Universität Ilmenau

ThB2 Kozani

Safety, Security, and Reliability (Regular Session)

15:00-15:20 ThB2.1

Adaptive Fault-Tolerant Control of a Quadrotor Helicopter Based on Sliding Mode Control and Radial Basis Function Neural Network, pp. 832-838.

Wang, Ban	Northwestern Polytechnical University
Zhang, Wei	Northwestern Polytechnical University
Zhang, Lidong	China Aeronautical Radio Electronics Research Institute
Zhang, Youmin	Concordia University

15:20-15:40 ThB2.2

H2 Optimized PID Control of Quad-Copter Platform with Wind Disturbance, pp. 839-844.

Kim, Sunsoo	Texas A&M University
Deshpande, Vedang Mohanrao	Texas A&M University
Bhattacharya, Raktim	Texas A&M University

15:40-16:00 ThB2.3

Controller Design and Flight Experiments for the Dual Tilt Rotor Unmanned Aerial Vehicle in Helicopter Mode, pp. 845-853.

Zheng, Ruijian	Northeastern University
Gu, FENG	Shenyang Institute of Automation, Chinese Academy of Sciences
Liu, Zhong	Shenyang Institute of Automation Chinese Academy of Sciences
Zhou, Hao	Shenyang Institute of Automation, Chinese Academy of Sciences
He, Yuqing	Shenyang Institute of Automation, Chinese Academy of Sciences

16:00-16:20 ThB2.4

Real-Time Motion Planning of Curvature Continuous Trajectories for Urban UAV Operations in Wind, pp. 854-861.

Patrikar, Jay	Carnegie Mellon University
Dugar, Vishal	Carnegie Mellon University

Arcot, Vaibhav — University of Pennsylvania
Scherer, Sebastian — Carnegie Mellon University

16:20-16:40 ThB2.5

Transition Flight Dynamics of a Dual Tilt-Wing UAV, pp. 862-866.

Sanchez-Rivera, Luz — CINVESTAV
Lozano, Rogelio — University of Technology of Compiègne
AriasMontano, Alfredo — IPN ESIME Ticoman

16:40-17:00 ThB2.6

A Data-Driven FCE Method for UAV Condition Risk Assessment Based on Feature Engineering and Variable Weight Coefficients, pp. 867-874.

Su, Xuanyuan — Beihang University
Tao, Laifa — Beihang University
Zhang, Tong — Beihang University
Cheng, Yujie — Beihang University
Ma, Jian — Beihang University
wang, chao — Beihang University

ThB3 Edessa
UAS Applications II (Regular Session)

15:00-15:20 ThB3.1

Design of a Quad-Jet VTOL UAS for Heavy-Lift Applications, pp. 875-882.

Türkmen, Abdullah — Istanbul Technical University
Altug, Erdinc — Istanbul Technical University

15:20-15:40 ThB3.2

Unmanned Aerial Vehicle and Artificial Intelligence for Thermal Target Detection in Search and Rescue Applications, pp. 883-891.

McGee, Joseph John — Queensland University of Technology
Joseph Mathew, Sajith — Queensland University of Technology
Gonzalez, Luis Felipe — Queensland University of Technology

15:40-16:00 ThB3.3

Design and Testing of Recycled 3D Printed Foldable Unmanned Aerial Vehicle for Remote Sensing, pp. 892-901.

Nieamnd, Jason — Queensland University of Technology
Joseph Mathew, Sajith — Queensland University of Technology
Gonzalez, Luis Felipe — Queensland University of Technology

16:00-16:20 ThB3.4

OpenREALM: Real-Time Mapping for Unmanned Aerial Vehicles, pp. 902-911.

Kern, Alexander — Technical University Braunschweig
Bobbe, Markus — Technical University Braunschweig
Khedar, Yogesh — Technical University Braunschweig
Bestmann, Ulf — Technical University Braunschweig

16:20-16:40 ThB3.5

An Integrated Tool to Compute the Dynamic Model and Assess the Lateral Controller Parameters of a UAV Equipped with a Piccolo Autopilot, pp. 912-921.

Dias Ferreira, Fernando — Portuguese Air Force Academy

Roque	
Oliveira, Tiago	Portuguese Air Force
Chá, Silvia	Portuguese Air Force Academy

16:40-17:00 ThB3.6

Radar Based Autonomous Precision Takeoff and Landing System for VTOLs in GNSS Denied Environments, pp. 922-931.

Doer, Christopher	Karlsruhe Institute of Technology
Koenig, Ronja	RWTH Aachen University
Trommer, Gert F.	Karlsruhe Institute of Technology
Stumpf, Eike	RWTH Aachen University

ThB4 Naousa

Micro and Mini UAS I (Regular Session)

15:00-15:20 ThB4.1

Control Allocation of Bidirectional Thrust Quadrotor Subject to Actuator Constraints, pp. 932-938.

Jothiraj, Walter	McGill University
Sharf, Inna	McGill University
Nahon, Meyer	McGill University

15:20-15:40 ThB4.2

High-Level Modeling and Control of the Bebop 2 Micro Aerial Vehicle, pp. 939-947.

Pinto, Anthony	Federal University of Espirito Santo
Marciano, Harrison	Federal University of Espirito Santo
Bacheti, Vinicius	Federal University of Espirito Santo
Mafra Moreira, Mauro Sergio	Federal University of Espírito Santo
Brandao, Alexandre Santos	Federal University of Vicosa
Sarcinelli-Filho, Mário	Federal University of Espirito Santo

15:40-16:00 ThB4.3

Collision-Free Path Planning Based on a Genetic Algorithm for Quadrotor UAVs, pp. 948-957.

Gutierrez Martinez, Manuel Alejandro	CIIIA-FIME-UANL
Rojo Rodriguez, Erik Gilberto	Universidad Autonoma De Nuevo Leon
Cabriales Ramirez, Luis Enrique	CIIIA-FIME-UANL
Reyes Osorio, Luis Arturo	CIIIA-FIME-UANL
Castillo, Pedro	Université De Technologie De Compiègne
Garcia Salazar, Octavio	CIIIA-FIME-UANL

16:00-16:20 ThB4.4

State and Parameter Estimation of Suspended Load Using Quadrotor Onboard Sensors, pp. 958-967.

Prkacin, Vicko	University of Dubrovnik
Palunko, Ivana	University of Dubrovnik
Petrović, Ivan	University of Zagreb

16:20-16:40 ThB4.5

UAV Flight Risk Identification and Evaluation Scheme, pp. 968-974.

Zhang, Zhaoyue	Civil Aviation University of China
Chaohui, Feng	Civil Aviation University of China
Wang, Zhisen	Civil Aviation University of China
Li, Shanmei	Civil Aviation University of China
Qingjun, Xia	Civil Aviation University of China

16:40-17:00 ThB4.6

The Solution Development for Performance Analysis and Optimal Design of Multicopter-Type Small Drones, pp. 975-982.

Oh, Soohun	Korea Aerospace Research Institute
Kim, Minwoo	Korea Aerospace Research Institute
Kim, Hyeongseok	Seoul National University
Lim, Daejin	Seoul National University
Yee, Kwanjung	Seoul National University
Kim, Dongmin	Korea Aerospace Research Institute

ThC1 Macedonia Hall

Sensor Fusion (Regular Session)

17:00-17:20 ThC1.1

GPS Denied Localization and Magnetometer-Free Yaw Estimation for Multi-Rotor UAVs, pp. 983-990.

Balaji, Naveen	Indian Institute of Technology Kanpur
Kothari, Mangal	Indian Institute of Technology Kanpur
Abhishek, Abhishek	Indian Institute of Technology Kanpur

17:20-17:40 ThC1.2

Joint Probabilistic Data Association Filter Using Adaptive Gibbs Sampling, pp. 991-997.

He, Shaoming	Cranfield University
Shin, Hyo-Sang	Cranfield University
Tsourdos, Antonios	Cranfield University

17:40-18:00 ThC1.3

Real-Time Moving Horizon Estimation of Air Data Parameters and Wind Velocities for Fixed-Wing UAVs, pp. 998-1006.

Wenz, Andreas Wolfgang	Norwegian University of Science and Technology
Johansen, Tor Arne	Norwegian University of Science and Technology

18:00-18:20 ThC1.4

Improved State Estimation in Distorted Magnetic Fields, pp. 1007-1013.

Brommer, Christian	University of Klagenfurt
Boehm, Christoph	University of Klagenfurt
Steinbrener, Jan	University of Klagenfurt
Brockers, Roland	JPL, California Institute of Technology
Weiss, Stephan	University of Klagenfurt

18:20-18:40 ThC1.5

Semantic Situation Awareness of Ellipse Shapes Via Deep Learning for Multirotor Aerial Robots with a 2D LIDAR, pp. 1014-1023.

Sanchez-Lopez, Jose-Luis	University of Luxembourg
Castillo-Lopez, Manuel	University of Luxembourg

Voos, Holger	University of Luxembourg

18:40-19:00	ThC1.6

Complementary Multi-Modal Sensor Fusion for Resilient Robot Pose Estimation in Subterranean Environments, pp. 1024-1029.

Khattak, Shehryar	University of Nevada, Reno
Nguyen, Dinh	University of Nevada, Reno
Mascarich, Frank	University of Nevada, Reno
Dang, Tung	University of Nevada, Reno
Alexis, Kostas	University of Nevada, Reno

ThC2	Kozani
Fail-Safe Systems (Regular Session)	

17:00-17:20	ThC2.1

A Fault-Tolerant Control Scheme for Fixed-Wing UAVs with Flight Envelope Integration, pp. 1030-1039.

Zogopoulos Papaliakos, Georgios	National Technical University of Athens
Karras, George	University of Thessaly
Kyriakopoulos, Kostas J.	National Technical University of Athens

17:20-17:40	ThC2.2

Agent Fault-Tolerant Strategy in a Heterogeneous Triangular Formation, pp. 1040-1047.

Vasconcelos, João Vítor	University Federal of Viçosa
Villa, Daniel Khede Dourado	Federal University of Espírito Santo
Gomes Caldeira, Alexandre	Federal University of Vicosa
Sarcinelli-Filho, Mário	Federal University of Espirito Santo
Brandao, Alexandre Santos	Federal University of Vicosa

17:40-18:00	ThC2.3

UAV Mission Monitoring and Sequencing, pp. 1048-1055.

Goudarzi, Hirad	University of Bristol
Richards, Arthur	University of Bristol

18:00-18:20	ThC2.4

Automated Emergency Landing System for Drones: SafeEYE Project, pp. 1056-1064.

Bektash, O.	Aalborg University
Ramirez Gomez, Aitor	Aalborg University
Naundrup Pedersen, Jacob	Aalborg University
la Cour-Harbo, Anders	Aalborg University

18:20-18:40	ThC2.5

Fault-Tolerant Final Approach Navigation for a Fixed-Wing UAV by Using Long-Range Stereo Camera System, pp. 1065-1074.

Watanabe, Yoko	ONERA
Manecy, Augustin	ONERA
Amiez, Alexandre	ONERA
Aoki, Shin	RICOH Co. Ltd
Nagai, Sho	RICOH Co. Ltd

18:40-19:00	ThC2.6
Distributed Fault Detection for UAV Formation Missions, pp. 1075-1084.	
Kladis, Georgios P.	Hellenic Army Academy
Tsourveloudis, Nikos	Technical University of Crete

ThC3 Edessa

UAS Applications III (Regular Session)

17:00-17:20	ThC3.1
RCPNet: Deep-Learning Based Relative Camera Pose Estimation for UAVs, pp. 1085-1092.	
Yang, Chenhao	University of Tübingen
Liu, Yuyi	Kyoto University
Zell, Andreas	University of Tübingen

17:20-17:40	ThC3.2
Aerial Following of a Non-Holonomic Mobile Robot Subject to Velocity Fields: A Case Study for Autonomous Vehicles Surveillance, pp. 1093-1102.	
Sanchez, Anand	CINVESTAV
Castillo, Pedro	Université De Technologie De Compiègne
Oliva-Palomo, Fatima	CINVESTAV
Betancourt Vera, Guillermo Julio Cesar	Université De Technologie De Compiègne
Parra-Vega, Vicente	CINVESTAV
Gallegos Bermúdez, Luis Eduardo	Centro De Investigación Y De Estudios Avanzados Instituto Polité
Ruiz Sanchez, Francisco Jose	CINVESTAV

17:40-18:00	ThC3.3
Improved Multi-Camera Coverage Control of Unmanned Multirotors, pp. 1103-1112.	
Huang, Sunan	National University of Singapore
Yang, Hong	National University of Singapore
Leong, Wai Lun	National University of Singapore
Teo, Rodney	National University of Singapore

18:00-18:20	ThC3.4
An Approach for Multi-UAV System Navigation and Target Finding in Cluttered Environments, pp. 1113-1120.	
Zhu, Xiaolong	Queensland University of Technology
Vanegas Alvarez, Fernando	Queensland University of Technology
Gonzalez, Luis Felipe	Queensland University of Technology

18:20-18:40	ThC3.5
An Adaptive Informative Path Planning Algorithm for Real-Time Air Quality Monitoring Using UAVs, pp. 1121-1130.	
Velasco, Omar	Wageningen University and Research
Valente, João	Wageningen University and Research
Mersha, Abeje Yenehun	Saxion University of Applied Sciences

18:40-19:00	ThC3.6
Towards an Integrated Low-Cost Agricultural Monitoring System with Unmanned Aircraft System, pp. 1131-1138.	

Karatzinis, Georgios	Democritus University of Thrace
Apostolidis, Savvas	Democritus University of Thrace
Kapoutsis, Athanasios	Democritus University of Thrace
Panagiotopoulou, Liza	GEOTOPOS S.A
Boutalis, Yiannis	Democritus University of Thrace
Kosmatopoulos, Elias	Democritus University of Thrace and CERTH

ThC4 Naousa

Micro and Mini UAS II (Regular Session)

17:00-17:20 ThC4.1

Implementation of a Natural User Interface to Command a Drone, pp. 1139-1144.

Yam-Viramontes, Brandon Alberto	Instituto Tecnológico Superior De Jerez
Mercado Ravell, Diego Alberto	Center for Research in Mathematics CIMAT

17:20-17:40 ThC4.2

Aerial Interaction Control in Outdoor Environments for a Micro Aerial Vehicle Equipped with a Robotic Arm, pp. 1145-1153.

Lopez Luna, Aaron	INAOE
Cruz, Israel	INAOE
Martinez-Carranza, Jose	Instituto Nacional De Astrofisica Optica Y Electronica

17:40-18:00 ThC4.3

A Lightweight Waterproof Casing for an Aquatic UAV Using Rapid Prototyping, pp. 1154-1161.

Tan, Yu Herng	National University of Singapore
Chen, Ben M.	Chinese University of Hong Kong

18:00-18:20 ThC4.4

Characterization of Ground-To-Air Emissions with sUAS Using a Digital Twin Framework, pp. 1162-1166.

Hollenbeck, Derek	MESA Lab at UC Merced
Chen, YangQuan	University of California, Merced

18:20-18:40 ThC4.5

A Generalized Framework Designing Monopulse Tracking of OFDM-Aided Aircraft Communication, pp. 1167-1174.

Yan, Chaoxing	Beijing Research Institute of Telemetry
Fu, Lingang	Beijing Research Institute of Telemetry
Liu, Tongling	Beijing Research Institute of Telemetry
Chen, Ming	Beijing Research Institute of Telemetry

18:40-19:00 ThC4.6

Situation Awareness and Routing Challenges in Unmanned HAPS/UAV Based Communications Networks, pp. 1175-1182.

Anicho, Ogbonnaya	Liverpool Hope University
Charlesworth, Philip	Liverpool Hope University
Baicher, Gurvinder	Liverpool Hope University
Nagar, Atulya	Liverpool Hope University

Technical Program for Friday September 4, 2020

FrA1	Macedonia Hall
Navigation (Regular Session)	

09:00-09:20	FrA1.1
Finite-Time Convergent Sliding-Mode Guidance Law for High-Speed Flight Vehicle with Bearings-Only Measurement, pp. 1183-1188.	
Qu, Yaohong	Northwestern Polytechnical University
Wang, Kai	Northwestern Polytechnical University
Yu, Ziquan	Nanjing University of Aeronautics and Astronautics

09:20-09:40	FrA1.2
Leader-Follower Formation Feedback Control Composed of Turning Rate and Velocity Controllers, pp. 1189-1198.	
Milutinovic, Dejan	University of California at Santa Cruz
Casbeer, David	Air Force Research Laboratory

09:40-10:00	FrA1.3
3D Map Exploration Via Learning Submodular Functions in the Fourier Domain, pp. 1199-1205.	
Lu, Bing-Xian	National Central University
Tseng, Kuo-Shih	National Central University

10:00-10:20	FrA1.4
Multi-Layer Map: Augmenting Semantic Visual Memory, pp. 1206-1212.	
Papapetros, Ioannis Tsampikos	Democritus University of Thrace
Balaska, Vasiliki	Democritus University of Thrace
Gasteratos, Antonios	Democritus University of Thrace

10:20-10:40	FrA1.5
Regions of Interest Segmentation from LiDAR Point Cloud for Multirotor Aerial Vehicles, pp. 1213-1220.	
Kulathunga, Geesara	Innopolis University
Fedorenko, Roman	Innopolis University
Klimchik, Alexandr	Innopolis University

10:40-11:00	FrA1.6
Multi-Agent Mapping and Navigation of Unknown GPS-Denied Environments Using a Relative Navigation Framework, pp. 1221-1230.	
Olson, Jacob	Brigham Young University
Toombs, Nathan	Brigham Young University
McLain, Tim	Brigham Young University

FrA2	Kozani
Levels of Safety (Regular Session)	

09:00-09:20	FrA2.1
Coordinated Coverage and Fault Tolerance Using Fixed-Wing Unmanned Aerial Vehicles, pp. 1231-1240.	
Shriwastav, Sachin	University of Hawaii at Manoa
Song, Zhuoyuan	University of Hawaii at Manoa

09:20-09:40	FrA2.2

UAVs and Their Role in the Health Supply Chain: A Case Study from Malawi, pp. 1241-1248.

Triche, Ryan	Chemonics in Support of USAID GHSC-PSM
Greve, Ashley	USAID GHSC-PSM
Dubin, Scott	USAID GHSC-PSM

09:40-10:00 FrA2.3

Estimation of Actuator Faults in Quadrotor Vehicles: From Theory to Validation with Experimental Flight Data, pp. 1249-1256.

Baldini, Alessandro	Università Politecnica Delle Marche
Felicetti, Riccardo	Università Politecnica Delle Marche
Freddi, Alessandro	Università Politecnica Delle Marche
Monteriù, Andrea	Università Politecnica Delle Marche
Tempesta, Matteo	Università Politecnica Delle Marche

10:00-10:20 FrA2.4

UAV Collision Avoidance with Varying Trigger Time, pp. 1257-1264.

Lin, Zijie	University of Maryland, College Park
Castano, Lina	University of Maryland, College Park
Xu, Huan	University of Maryland, College Park

10:20-10:40 FrA2.5

Cybersecurity of the Unmanned Aircraft System (UAS), pp. 1265-1269.

Pyzynski, Mariusz	Lazarski University

FrA3 Edessa

UAS Applications IV (Regular Session)

09:00-09:20 FrA3.1

Automatic Condition Monitoring of Railway Overhead Lines from Close-Range Aerial Images and Video Data, pp. 1270-1277.

Andert, Franz	German Aerospace Center
Kornfeld, Nils	German Aerospace Center
Nikodem, Florian	Deutsches Zentrum Für Luft Und Raumfahrt
Li, Haiyan	Siemens Mobility GmbH
Kluckner, Stefan	Siemens Mobility GmbH
Gruber, Laura	Siemens Mobility GmbH
Kaiser, Christian	Copting GmbH

09:20-09:40 FrA3.2

FDI Attack Detection for Formation Control of Quantized UAV Systems by Coding Sensor Outputs, pp. 1278-1285.

Liu, Lin	Beihang University
Wu, Hanyuan	Beihang University
Xi, Zhiyu	Beihang University
Cui, Yucheng	Beihang University

09:40-10:00 FrA3.3

Reactive Mission Planning for UAV Based Crane Rail Inspection in an Automated Container Terminal, pp. 1286-1293.

Bobbe, Markus	Technical University of Braunschweig
Khedar, Yogesh	Technical University of Braunschweig

Backhaus, Jan	Technical University of Braunschweig
Gerke, Markus	Technical University of Braunschweig
Ghassoun, Yahya	Technical University of Braunschweig
Plöger, Frank	HHLA

10:00-10:20 FrA3.4

Optimal Sensor Management for Multiple Target Tracking Using Cooperative Unmanned Aerial Vehicles, pp. 1294-1300.

Baek, Stan	United States Air Force Academy
York, George	Academy Center for Unmanned Aircraft Systems Research

10:20-10:40 FrA3.5

UAV Vision-Based Nonlinear Formation Control Applied to Inspection of Electrical Power Lines, pp. 1301-1308.

Uzakov, Timur	Czech Technical University in Prague
Saska, Martin	Czech Technical University in Prague
Nascimento, Tiago	Universidade Federal da Paraiba

10:40-11:00 FrA3.6

Range Estimation and Visual Servoing of a Dynamic Target Using a Monocular Camera, pp. 1309-1316.

Srivastava, Raunak	Indian Institute of Technology Bombay
Maity, Arnab	Indian Institute of Technology Bombay
Lima, Rolif	TCS Innovation Labs
Das, Kaushik	TATA Consultancy Service

FrA4 Naousa

Airspace Control (Regular Session)

09:00-09:20 FrA4.1

The Wild West of Drones: A Review on Autonomous-UAV Traffic-Management, pp. 1317-1322.

Rumba, Rudolfs	Riga Technical University
Nikitenko, Agris	Riga Technical University

09:20-09:40 FrA4.2

Aircraft Stall Recovery Using Sliding-Mode Based Pitch-Attitude and Altitude Control, pp. 1323-1328.

Gazi, salahudden	IIT Kanpur
Giri, Dipak Kumar	IIT Kanpur
Ghosh, A.K. Ghosh	IIT Kanpur

09:40-10:00 FrA4.3

Hover-To-Cruise Transition Control for High-Speed Level Flight of Ducted Fan UAV, pp. 1329-1337.

Cheng, Zihuan	South China University of Technology
Pei, Hai-Long	South China University of Technology

10:00-10:20 FrA4.4

Observer Based Appointed-Finite-Time Nonsingular Sliding Mode Based Disturbance Attenuation Control for Quadrotor UAV, pp. 1338-1343.

Gong, Wenquan	Shanghai Maritime University
Li, Bo	Shanghai Maritime University
Xiong, Hang	Shanghai Maritime University
Yang, Yongsheng	Shanghai Maritime University
Bing, Xiao	Northwestern Polytechnical University

10:20-10:40	FrA4.5

Adaptive Finite-Time Tracking Control for Spacecraft Proximity Operations under Actuator Saturation, pp. 1344-1349.

Liu, Kang	University of Science and Technology of China
Wang, Yu	University of Science and Technology of China
Ji, Haibo	University of Science and Technology of China

10:40-11:00	FrA4.6

Wireless Longitudinal Motion Controller Design for Quadrotors, pp. 1350-1358.

Kouvakas, Nikolaos	National and Kapodistrian University of Athens
Koumboulis, Fotios	National and Kapodistrian University of Athens
Giannaris, Georgios	Sterea Ellada Institute of Technology
Vouyioukas, Demosthenes	University of the Aegean

FrB1 Macedonia Hall

Energy Efficient UAS (Regular Session)

11:30-11:50	FrB1.1

State-Of-Technology and Barriers for Adoption of Fuel Cell Powered Multirotor Drones, pp. 1359-1367.

Apeland, Jørgen	University of Stavanger
Pavlou, Dimitrios	University of Stavanger
Hemmingsen, Tor	University of Stavanger

11:50-12:10	FrB1.2

Turn Decision-Making for Improved Autonomous Thermalling of Unmanned Aerial Gliders, pp. 1368-1375.

El Tin, Fares	McGill University
Borowczyk, Alexandre	Notos Technologies
Sharf, Inna	McGill University
Nahon, Meyer	McGill University

12:10-12:30	FrB1.3

Online ADP Based Oxygen Excess Ratio Control of the PEM Fuel Cell System Applying to UAVs, pp. 1376-1383.

Zhu, Jing	Nanjing University of Aeronautics and Astronautics
Zhang, Peng	Nanjing University of Aeronautics and Astronautics
Jiang, Bin	Nanjing University of Aeronautics and Astronautics

12:50-13:10	FrB1.5

Energy Efficiency Improvement Potential of a Tactical BWB UAV Using Renewable Energy Sources, pp. 1384-1391.

Dimitriou Stylianos	Aristotle University of Thessaloniki
Kapsalis, Stavros	Aristotle University of Thessaloniki
Panagiotou, Pericles	Aristotle University of Thessaloniki
Yakinthos, Kyriakos	Aristotle University of Thessaloniki

13:10-13:30	FrB1.6

Aerial Worker for Skyscraper Fire Fighting Using a Water-Jetpack Inspired Approach, pp. 1392-1397.

Chaikalis, Dimitris	New York University Abu Dhabi
Tzes, Anthony	New York University Abu Dhabi
Khorrami, Farshad	New York University

FrB2	Kozani
Risk Analysis (Regular Session)	

11:30-11:50	FrB2.1

Efficient Generation of Ground Impact Probability Maps by Neural Networks for Risk Analysis of UAV Missions, pp. 1398-1406.

Levasseur, Baptiste	ONERA
Bertrand, Sylvain	ONERA
Raballand, Nicolas	ONERA

11:50-12:10	FrB2.2

Situational Risk Assessment within Safety-Driven Behavior Management in the Context of UAS, pp. 1407-1415.

Hägele, Georg	Semcon Sweden AB
Sarkheyli-Hägele, Arezoo	Malmö University

12:10-12:30	FrB2.3

A Sociotechnical Approach to UAV Safety for Search and Rescue Missions, pp. 1416-1424.

Charalampidou, Stavroula	Democritus University of Thrace
Lygouras, Eleftherios	Democritus University of Thrace
Dokas, Ioannis	Democritus University of Thrace
Gasteratos, Antonios	Democritus University of Thrace
Zacharopoulou, Aikaterini	Democritus University of Thrace

12:30-12:50	FrB2.4

Preliminary Evaluation of Thrust Loss in Commercial Aircraft Engine Due to Airborne Collision with Unmanned Aerial Vehicles (UAVs), pp. 1425-1432.

Che Man, Mohd Hasrizam	Nanyang Technological University
Liu, Hu	Nanyang Technological University
Ng, Bing Feng	Nanyang Technological University
Low, Kin Huat	Nanyang Technological University

12:50-13:10	FrB2.5

Toward Cybersecurity of Unmanned Aircraft System Operations under "Specific" Category, pp. 1433-1441.

Tran, Trung Duc	SOGILIS Company and Univ. Grenoble Alpes, CNRS
Thiriet, Jean-Marc	GIPSA-Lab, CNRS
Marchand, Nicolas	GIPSA-Lab CNRS
El Mrabti, Amin	SOGILIS Company

13:10-13:30	FrB2.6

Ground Impact Probability Distribution for Small Unmanned Aircraft in Ballistic Descent, pp. 1442-1451.

la Cour-Harbo, Anders	Aalborg University

FrB3	Edessa
UAS Applications V (Regular Session)	

11:30-11:50	FrB3.1

Surface-Condition Detection System of Drone-Landing Space Using Ultrasonic Waves and Deep Learning, pp. 1452-1459.

Hamanaka, Masatoshi	RIKEN
Nakano, Fujio	Kyoto University

11:50-12:10	FrB3.2

Dense Crowds Detection and Surveillance with Drones Using Density Maps, pp. 1460-1467.

Gonzalez-Trejo, Javier	CIMAT Zacatecas
Mercado Ravell, Diego Alberto	Center for Research in Mathematics CIMAT

12:10-12:30 FrB3.3

UAS Based Methodology for Measuring Glide Slope Angles of Airport Precision Approach Path Indicators (PAPI), pp. 1468-1474.

Lin, Yi-Chun	Purdue University
Hasheminasab, Seyyed Meghdad	Purdue University
Bullock, John	Purdue University
Horton, Deborah	Purdue University
Baxmeyer, Adam	Purdue University
Habib, Ayman	Purdue University
Bullock, Darcy	Purdue University

12:30-12:50 FrB3.4

Coordinated CRLB-Based Control for Tracking Multiple First Responders in 3D Environments, pp. 1475-1484.

Papaioannou, Savvas	University of Cyprus
Kim, Sungjin	Hanyang University
Laoudias, Christos	University of Cyprus
Kolios, Panayiotis	University of Cyprus
Kim, Sunwoo	Hanyang University
Theocharides, Theocharis	University of Cyprus
Panayiotou, Christos	University of Cyprus
Polycarpou, Marios M.	University of Cyprus

12:50-13:10 FrB3.5

Estimating Crop Coefficients Using Linear and Deep Stochastic Configuration Networks Models and UAV-Based Normalized Difference Vegetation Index (NDVI), pp. 1485-1490.

Niu, Haoyu	UC, Merced
Wang, Dong	USDA ARS Parlier
Chen, YangQuan	University of California, Merced

13:10-13:30 FrB3.6

UAV-Assisted Aerial Survey of Railways Using Deep Learning, pp. 1491-1500.

Kafetzis, Dimitrios	Athens University of Economics and Business
Fourfouris, Ioannis	Athens University of Economics and Business
Argyropoulos, Savvas	StreamOwl
Koutsopoulos, Iordanis	Athens University of Economics and Business

FrB4 Naousa

Airspace Management (Regular Session)

11:30-11:50 FrB4.1

Cooperative Robust Line-Of-Sight Guidance Law for Aerial Target Defense, pp. 1501-1507.

Luo, Hongbing	University of Science and Technology of China
Ji, Haibo	University of Science and Technology of China
Wang, Xinghu	University of Science and Technology of China

Qu, Xinyu — University of Science and Technology of China

11:50-12:10 — FrB4.2

Imitation Learning for Neural Network Autopilot in Fixed-Wing Unmanned Aerial Systems, pp. 1508-1517.

Shukla, Daksh — The University of Kansas
Keshmiri, Shawn — University of Kansas
Beckage, Nicole — Intel Labs

12:10-12:30 — FrB4.3

Variable L1 Guidance Strategy for Path Following of UAVs, pp. 1518-1524.

R, Saurav — Indian Institute of Technology Madras
Laad, Dhruv — Indian Institute of Technology Madras
Ghosh, Satadal — Indian Institute of Technology Madras

12:30-12:50 — FrB4.4

Gradient-Based Augmentation to Maxima Turn Switching Strategy for Source-Seeking Using Sensor-Equipped UAVs, pp. 1525-1532.

Kamthe, Aniket — Indian Institute of Technology Madras
Ghosh, Satadal — Indian Institute of Technology Madras

12:50-13:10 — FrB4.5

Online Hybrid Motion Planning for Unmanned Aerial Vehicles in Planar Environments, pp. 1533-1540.

Lapasi, Manikandan — Indian Institute of Technology Madras
Ghosh, Satadal — Indian Institute of Technology Madras

13:10-13:30 — FrB4.6

Lateral Fractional Order Controller Design and Tuning for a Flying-Wing UAS, pp. 1541-1545.

Flanagan, Harold — University of Kansas
Chao, Haiyang — University of Kansas
Chen, YangQuan — University of California, Merced

FrC1 — Macedonia Hall
Technology Challenges (Regular Session)

14:30-14:50 — FrC1.1

Wind Field Estimation by Small UAVs for Rapid Response to Contaminant Leaks, pp. 1546-1552.

Ayala-Alfaro, Victor — University of Guanajuato
Torres del Carmen, Felipe de Jesus — University of Guanajuato
Ramirez Paredes, Juan Pablo — University of Guanajuato

14:50-15:10 — FrC1.2

Development of an Automated Monitoring Platform for Invasive Plants in a Rare Great Lakes Ecosystem Using Uncrewed Aerial Systems and Convolutional Neural Networks, pp. 1553-1564.

Cohen, Joshua — Michigan Natural Features Inventory, Michigan State University E
Lewis, Matthew — Michigan Aerospace Corporation

15:10-15:30 — FrC1.3

Modeling and Multimode Analysis of Electrically Driven Flying Car, pp. 1565-1571.

Ai, Tianfu — Beijing Institute of Technology
Xu, Bin — Beijing Institute of Technology

Xiang, Changle	Beijing Institute of Technology
Fan, Wei	Beijing Institute of Technology
Zhang, Yibo	Beijing Institute of Technology

15:30-15:50 FrC1.4

Capability Caution in UAV Design, pp. 1572-1581.

Cawthorne, Dylan	University of Southern Denmark
Devos, Arne	Southern University of Denmark

15:50-16:10 FrC1.5

A Genetic Algorithm Based Method for the Airfoil Optimization of a Tactical Blended-Wing-Body UAV, pp. 1582-1589.

Mathioudakis, Nikolaos	Aristotle University of Thessaloniki
Panagiotou, Pericles	Aristotle University of Thessaloniki
Kaparos, Pavlos	Aristotle University of Thessaloniki
Yakinthos, Kyriakos	Aristotle University of Thessaloniki

16:10-16:30 FrC1.6

LS-SVM for LPV-ARX Identification: Efficient Online Update by Low-Rank Matrix Approximation, pp. 1590-1595.

Cavanini, Luca	Università Politecnica Delle Marche
Ferracuti, Francesco	Università Politecnica Delle Marche
Longhi, Sauro	Università Politecnica Delle Marche
Monteriù, Andrea	Università Politecnica Delle Marche

FrC2 Kozani

Biologically Inspired and Energy Efficient UAS (Regular Session)

14:30-14:50 FrC2.1

Effects of Unsteady Aerodynamics on Gliding Stability of a Bio-Inspired UAV, pp. 1596-1604.

Sanchez-Laulhe, Ernesto	University of Seville
Fernandez-Feria, Ramón	University of Málaga
Acosta, Jose Angel	University of Seville
Ollero, Anibal	University of Seville

14:50-15:10 FrC2.2

Fault Recognition of Electric Servo Steering Gear Based on Long and Short-Term Memory Neural Network, pp. 1605-1613.

Xu, Yixiang	Zhejiang University
Yang, Chunning	Zhejiang University

15:10-15:30 FrC2.3

Internal Combustion Engine Control System Design Suitable for Hybrid Propulsion Applications, pp. 1614-1619.

Pavkovic, Danijel	University of Zagreb
Krznar, Matija	University of Zagreb
Cipek, Mihael	University of Zagreb
Zorc, Davor	University of Zagreb
Trstenjak, Maja	University of Zagreb

15:30-15:50 FrC2.4

Control of a Passively Coupled Hybrid Aircraft, pp. 1620-1627.

Patience, Christian	McGill University

Nahon, Meyer	McGill University

15:50-16:10	FrC2.5

Design and Fabrication of a Nomadic Solar-Powered Quadrotor, pp. 1628-1635.

Henderson, Travis	University of Minnesota
Jenson, Devon	University of Minnesota
D'Sa, Ruben	University of Minnesota
Kilian, Jack	University of Minnesota
Papanikolopoulos, Nikos	University of Minnesota

16:10-16:30	FrC2.6

A Methodology for Preliminary Performance Estimation of a Hybrid-Electric Tilt-Wing Aircraft for Emergency Medical Services, pp. 1636-1643.

Barra, Federico	Politecnico Di Torino
Capone, Pierluigi	Zurich University of Applied Sciences
Guglieri, Giorgio	Politecnico Di Torino

FrC3 Edessa

Manned/Unmanned Aviation (Regular Session)

14:30-14:50	FrC3.1

Rotor Performance Analysis and Modeling of Multirotor Using Wind-Tunnel Test, pp. 1644-1649.

Ye, Jianchuan	Beijing Institute of Technology
Jiang, Wang	Beijing Institute of Technology
He, Shaoming	Cranfield University
Song, Tao	Beijing Institute of Technology

14:50-15:10	FrC3.2

Flight Dynamics and Control of a New VTOL Aircraft in Fixed-Wing Mode, pp. 1650-1657.

Gao, Honggang	Northwestern Polytechnical University
Liu, Zhenbao	Northwestern Polytechnical University
Wang, Ban	Northwestern Polytechnical University
pang, chao	Northwestern Polytechnical University

15:10-15:30	FrC3.3

Reporting UAS Related Incidents under Aviation Occurrence Reporting Legislation, pp. 1819-1827.

Kasprzyk, Piotr	Lazarski University in Warsaw
Konert, Anna	Lazarski University in Warsaw

15:50-16:10	FrC3.5

Autonomous Teammates for Squad Tactics, pp. 1658-1663.

Tyler, James	Northeastern University
Arnold, Ross	US Department of Defense
Abruzzo, Benjamin	US Department of Defense
Korpela, Christopher	United States Military Academy

16:10-16:30	FrC3.6

Operator Controlled, Reactive UAV Behaviors in Manned-Unmanned Teaming Scenarios with Selective Datalink Availability, pp. 1664-1670.

Meyer, Carsten	University of the Bundeswehr Munich
Schulte, Axel	University of the Bundeswehr Munich

FrC4	Naousa
Air Vehicle Operations (Regular Session)	

14:30-14:50	FrC4.1

UTM System Operational Implementation As a Way for U-Space Deployment on Basis of Polish National Law, pp. 1671-1678.

Kotlinski, Mateusz	Polish Air Navigation Services Agency

14:50-15:10	FrC4.2

A New Method to Combine Detection and Tracking Algorithms for Fast and Accurate Human Localization in UAV-Based SAR Operations, pp. 1679-1687.

Lygouras, Eleftherios	Democritus University of Thrace
Gasteratos, Antonios	Democritus University of Thrace

15:10-15:30	FrC4.3

Perching Upside down with Bi-Directional Thrust Quadrotor, pp. 1688-1694.

Yu, Pengfei	The University of Sydney
Chamitoff, Gregory	The University of Sydney
Wong, KC	The University of Sydney

15:30-15:50	FrC4.4

Fuzzy Model Predictive Control of a Quadrotor Unmanned Aerial Vehicle, pp. 1695-1704.

Hossny, Mohamed	German University in Cairo
El-Badawy, Ayman	German University in Cairo
Hassan, Ragi	German University in Cairo

15:50-16:10	FrC4.5

Dynamic Modeling of a Transformable Quadrotor, pp. 1705-1710.

Derrouaoui, Saddam Hocine	Ecole Militaire Polytechnique
Guiatni, Mohamed	Ecole Militaire Polytechnique
Bouzid, Yasser	Ecole Militaire Polytechnique
Islam, Dib	Ecole Militaire Polytechnique
Nour Eddine, Moudjari	, Ecole Militaire Polytechnique

16:10-16:30	FrC4.6

Robust Immersion and Invariance Adaptive Control with Disturbance Observer for a Quadrotor UAV, pp. 1711-1716.

Han, Qi	Beijing Jiao Tong University
Liu, Xiangbin	Beijing Jiao Tong University
Zou, Lang	Beijing Jiao Tong University

FrD1	Macedonia Hall
UAS Testbeds (Regular Session)	

16:30-16:50	FrD1.1

Joint Virtual and Physical Prototype Design and Testing of a Sensor Fusion Workbench for Fixed-Wing UAVs, pp. 1717-1723.

Huang, Peng	Technische Universität Dresden
Meyr, Heinrich	Barkhausen Institut
Fettweis, Gerhard	Technische Universität Dresden

16:50-17:10	FrD1.2
Bebop 2 Quadrotor As a Platform for Research and Education in Robotics and Control Engineering, pp. 1724-1732.	
Giernacki, Wojciech	Poznan University of Technology
Kozierski, Piotr	Poznan University of Technology
Michalski, Jacek	Poznan University of Technology
Retinger, Marek	Poznan University of Poznan
Madonski, Rafal	Jinan University
Campoy, Pascual	Universidad Politecnica Madrid

17:10-17:30	FrD1.3
Omnibot: A Small Versatile Robotic Platform Capable of Air, Ground, and Underwater Operation, pp. 1733-1738.	
Canelon-Suarez, Dario	University of Minnesota
Wang, Youbing	University of Minnesota
Papanikolopoulos, Nikos	University of Minnesota

17:30-17:50	FrD1.4
Modeling and Control of an Overactuated Aerial Vehicle with Four Tiltable Quadrotors Attached by Means of Passive Universal Joints, pp. 1739-1747.	
Iriarte, Imanol	Tecnalia
Otaola, Erlantz	Tecnalia
Culla, David	Tecnalia
Iglesias, Iñaki	Tecnalia
Lasa, Joseba	Tecnalia
Sierra, Basi	University of Basque Country

17:50-18:10	FrD1.5
UAS Testing in Low Pressure and Temperature Conditions, pp. 1748-1756.	
Scanavino, Matteo	Politecnico di Torino
Avi, Arrigo	Eurac Research
Vilardi, Andrea	Eurac Research
Guglieri, Giorgio	Politecnico di Torino

17:50-18:10	FrD1.6
EuroDRONE, a European UTM Testbed for U-Space, pp. 1757-1765.	
Lappas, Vaios	University of Patras
Shin, Hyo-Sang	Cranfield University
Tsourdos, Antonios	Cranfield University

FrD2	Kozani
Simulation (Regular Session)	

16:30-16:50	FrD2.1
The Simulator-In-Hardware: A Low Cost and Hard Real-Time Hardware-In-The-Loop Simulator for Flying Vehicles, pp. 1766-1772.	
Chiappinelli, Romain	McGill University
Nahon, Meyer	McGill University
Apkarian, Jacob	Coriolis G, Toronto, Canada

16:50-17:10	FrD2.2

Flight Control Simulation and Battery Performance Analysis of a Quadrotor under Wind Gust, pp. 1773-1782.

Kim, Hyeongseok	Seoul National University
Lim, Daejin	Seoul National University
Yee, Kwanjung	Seoul National University

17:10-17:30 FrD2.3

Simulating GPS-Denied Autonomous UAV Navigation for Detection of Surface Water Bodies, pp. 1783-1791.

Singh, Arnav Deo	Queensland University of Technology
Vanegas Alvarez, Fernando	Queensland University of Technology

17:30-17:50 FrD2.4

Modelling and Simulation of a Tethered UAS, pp. 1792-1799.

Dicembrini, Emilio	Politecnico di Torino
Scanavino, Matteo	Politecnico di Torino
Dabbene, Fabrizio	Politecnico di Torino
Guglieri, Giorgio	Politecnico di Torino

17:50-18:10 FrD2.5

Model-In-The-Loop Testing of Control Systems and Path Planner Algorithms for QuadRotor UAVs, pp. 1800-1809.

David Du Mutel de Pierrepont Franzetti, Iris	Universidad Politécnica de Cataluña
Carminati, Davide	Politecnico di Torino
Scanavino, Matteo	Politecnico di Torino
Capello, Elisa	Politecnico di Torino

17:50-18:10 FrD2.6

A Gazebo/ROS-Based Communication-Realistic Simulator for Networked SUAS, pp. 1810-1818.

Moon, Sangwoo	University of Colorado Boulder
Bird, John	University of Colorado Boulder
Borenstein, Steve	University of Colorado
Frew, Eric W.	University of Colorado, Boulder

FrD3 Edessa

Manned/Unmanned Aviation and Testbeds (Regular Session)

16:50-17:10 FrD3.1

A Prescribed Performance Adaptive Optimal Control Scheme for Flying-Wing Aircraft, pp. 1828-1833.

Huang, Chenyu	Nanjing University of Aeronautics and Astronautics
Zhang, Shaojie	Nanjing University of Aeronautics and Astronautics

17:10-17:30 FrD3.2

A Systematic Modelling Framework for Commercial Unmanned Hexacopter Considering Fractional Order System Theory, pp. 1834-1843.

Sridhar, Nithya	TCS Research and Innovation
N S, Abhinay	Tata Consultancy Services
Bodduluri, Chaithanya Krishna	Tata Consultancy Services
Das, Kaushik	TATA Consultancy Service
Maity, Arnab	Indian Institute of Technology Bombay

17:30-17:50	FrD3.3
UAS, Data and Privacy Protection within the European Union: The Case of Greece, pp. 1844-1851.	
Sansaridis, Serafeim	Attorney at Law, DUTH and University of Macedonia

17:50-18:10	FrD3.4
Wake Interactions of a Tetrahedron Quadcopter, pp. 1852-1859.	
Epps, Jeremy	Georgia Institute of Technology
Garanger, Kevin	Georgia Institute of Technology
Feron, Eric	King Abdullah University of Science and Technology

17:50-18:10	FrD3.5
A 4D Trajectory Follower Based on the 'Carrot Chasing' Algorithm for UAS within the U-Space Context, pp. 1860-1867.	
Perez-Leon, Hector	University of Seville
Acevedo, José Joaquín	AICIA
Maza, Ivan	University of Seville
Ollero, Anibal	University of Seville

18:10-18:30	FrD3.6
Safe Flyable and Energy Efficient UAV Missions Via Biologically Inspired Methods, pp. 1868-1877	
Platanitis, Konstantinos	Technical University of Crete
Kladis, Georgios P.	Hellenic Army Academy
Tsourveloudis, Nikos	Technical University of Crete

ICUAS '20 Paper Abstracts

Wednesday September 2, 2020

WeA1	Macedonia Hall
Autonomy I (Regular Session)	

10:00-10:20 WeA1.1

Deep Reinforcement Learning Automatic Landing Control of Fixed-Wing Aircraft Using Deep Deterministic Policy Gradient, pp. 1-9

Tang, Chi — National Cheng Kung University
Lai, Ying-Chih — National Cheng Kung University

Landing phase remains to be one of the most crucial and difficult tasks to achieve among the flight envelope of an aircraft. The proof-of-concept controller in this research implemented the use of DDPG (Deep Deterministic Policy Gradient), a DRL (Deep Reinforcement Learning) approach in attempt to find policies of aircraft landings given designed requirements, or rewards. This research provided new methods in reward shaping, or reward engineering used during training and the investigation of the effects of hyperparameters and different network topologies of Neural Networks in training of aircraft landing control. The results of outer loop control and direct control in this research using DDPG on aircraft landing, with comparisons of numerous baseline and Neural Network approaches, proves the ability and potential of such DRL method, and is validated in numerous wind disturbance conditions, which demonstrated the robustness of DDPG agent. It is also found that besides the ability of DDPG agents to develop control policies for aircraft landings, such method provides insights of the controls and states of aircraft during landing, enabling guidelines of the flight characteristics of the aircraft in landing for pilots or design of controllers.

10:20-10:40 WeA1.2

Extensions of the Open-Source Framework Aerostack 3.0 for the Development of More Interactive Flights between UAVs, pp. 10-16

Giernacki, Wojciech — Poznan University of Technology
Cieślak, Jacek — Poznan University of Technology
Molina, Martin — Universidad Politecnica Madrid
Campoy, Pascual — Universidad Politecnica Madrid

The basis for properly verified R&D works is to provide reliable prototyping tools at three most important stages: computer simulation, laboratory tests and real-world experiments. In the laboratory-limited conditions, particular importance is attributed to the first two stages, especially in the context of the safety development of autonomous flights of unmanned aerial vehicle (UAV) groups in various missions. The open-source framework Aerostack support those needs, and its effectiveness has been proven in the International Micro Air Vehicle Indoor Competitions (IMAV 2013, 2016, 2017) and Mohammed Bin Zayed International Robotics Challenge (MBZIRC 2020). In the paper, the exemplary functionalities for the new version of Aerostack Version 3.0 Distribution Sirocco (Aerial robotics framework for the industry), extended additionally with a library of new behaviors, are presented. The mission of UAVs can be developed fast and effectively in order to conduct test flights with real drones in lab, before one will decide to fly autonomously outdoor. The representative results obtained for low-cost AR.Drone 2.0 UAV models in two missions, are presented. The first mission is autonomous patrolling the area by a pair of UAVs, the second – intercepting the intruder in guarded area by the guard UAV.

11:00-11:20 WeA1.4

An UAV Autonomous Maneuver Decision-Making Algorithm for Route Guidance, pp. 17-25

Zhang, Kun — Northwestern Polytechnical University
Li, Ke — Northwestern Polytechnical University
He, Jianliang — Science and Technology on Electro-Optic Control Laboratory
SHI, Haotian — Northwestern Polytechnical University
Wang, Yongting — Science and Technology on Electro-Optic Control Laboratory
Niu, Chen — Xi'an Jiao Tong University

In order to improve the autonomy of UAV for route guidance, an UAV autonomous maneuver decision- making algorithm is proposed. The optimal UAV maneuver policy is developed in an interactive environment. Firstly, the UAV maneuver decision-making model based on MDPs was established, where the flight state space, the flight action space and the flight assessment function are designed. Then, we proposed the algorithm based on Double Deep Q-Learning with Prioritized Experience Replay. Finally, according to the simulation results, the efficiency and autonomy of algorithm we proposed is proved.

11:20-11:40 WeA1.5

UAV Path-Following Strategy for Crossing Narrow Passages, pp. 26-31

Gomes Caldeira, Alexandre — University Federal of Viçosa
Vasconcelos, João Vítor — University Federal of Viçosa
Sarcinelli-Filho, Mário — Federal University of Espirito Santo

Brandao, Alexandre Santos — University Federal of Viçosa

Integration of unmanned aerial vehicles in different tasks and services rely on their ability to deliberate and plan solutions to navigate an environment, which is often subject to geometric constraints that frequently cannot be tackled with classic obstacle avoidance. Therefore, we propose a smooth, closed path that ensures safe passage through challenging locations while respecting a robot's physical limitations. A novel approach for proposing control points in Bèzier curve path planning is outlined and a multi-layer control scheme is presented and validated in simulation and experiments with a varying number of robots and restrictions in motion.

11:40-12:00 — WeA1.6

Autonomous Drone with Ability to Track and Capture an Aerial Target, pp. 32-40

Garcia Rivero, Manuel — FADA-CATEC
Caballero González, Rafael — FADA-CATEC
González Leiva, Fidel — FADA-CATEC
Viguria, Antidio — FADA-CATEC
Ollero, Anibal — Universidad De Sevilla

This article presents an autonomous aerial system developed for the first challenge of Mohamed Bin Zayed International Robotics Competition (MBZIRC) 2020, consisting of the autonomous interception of an aerial target flying on a variable trajectory and speed, and also bursting several balloons randomly placed over a certain area, also fully autonomous. This work presents a prototype of a capture aerial robot designed specifically for the scenario under consideration, with the aim of integrating the necessary equipment to autonomously detect, track and capture the target drone. Both the hardware architecture and the software that allows to perform this fully autonomous complex mission are described in the paper, as well as the tools used for the integration and execution of the different functional modules. Apart from that, the Guidance, Navigation and Control (GNC) algorithms implemented for the tracking of the target are also explained. Finally the system is tested in a simulation environment and also validated with real experiments, which most interesting results are presented.

WeA2 — Kozani

Path Planning I (Regular Session)

10:00-10:20 — WeA2.1

A Path Planning Method for a Low Observable UAV in Radar Field, pp. 41-47

Orhan, Ethem Hakan — Turkish Aerospace Industries, Inc

In this paper we propose a two-step method for the problem of path planning for a low observable unmanned air vehicle in a radar field. In the first step, we convert the problem into a constrained shortest path problem defined on a directed network graph and then we apply an efficient graph search algorithm for solving it. We implement a probabilistic cost function for the path, assuming an anisotropic vehicle radar cross section. The length of the path is constrained by the maximum range of the vehicle. In the second step, the initial polygonal path is refined using B-Splines. We take the vehicle maneuvering limits into account for the smoothed path.

10:20-10:40 — WeA2.2

Collision Avoidance of Fixed-Wing UAVs in Dynamic Environments Based on Spline-RRT and Velocity Obstacle, pp. 48-58

Zhang, Shuiqing — Sun Yat-Sen University
Xu, Tianye — Sun Yat-Sen University
Cheng, Hui — Sun Yat-Sen University
Liang, Fan — Sun Yat-Sen University

It is crucial to online plan a smooth, continuous and collision-free path to navigate a fixed-wing unmanned aircraft through complex environments. In a static environment, given priori knowledge of the map, the sampling based RRT (rapidly exploring random tree) method and its variants are efficient to provide global path planning to navigate the fixed wing aircraft through static obstacles. However, in complex and dynamic situations, the fixed-wing aircraft may encounter dynamic obstacles when following the planned global path. In the presence of dynamic obstacles within the sensing range of the fixed-wing aircraft, it is challenging to on-line generate a new collision-free and smooth path. In this paper, a real-time collision-free path planning strategy is proposed for fixed-wing aircraft in dynamic environments. Specifically, the proposed collision-free path planner named as Spline-RRT-VO is presented incorporating the spline-RRT algorithm and the velocity obstacle (VO) method to avoid a high-speed dynamic obstacle. In the proposed spline-RRT-VO approach, a random tree grows in the local area, meanwhile, the VO method is used to extend tree edges and reject unavailable nodes. It improves the tree growing in a more efficient and smooth manner. Simulation results verify the effectiveness of the spline-RRT-VO method to navigate the fixed-wing UAVs through dynamic environments.

10:40-11:00 — WeA2.3

Generation of Window-Traversing Flyable Trajectories Using Logistic Curve, pp. 59-65

Upadhyay, Saurabh — University of Bristol
Richards, Arthur — University of Bristol
Richardson, Thomas — University of Bristol

This work considers point-to-point flyable trajectory generation through constrained planar regions referred as windows. A four-parameter logistic curve trajectory planning tool is proposed for generating feasible trajectories that (i) connect the given initial and final positions with (ii) smooth bounded velocity and acceleration variations (flyability), and (iii) pass through the prescribed windows. A two-step approach is proposed, first narrowing down the search space to a restricted set in six dimensions, parameterizing a variety of trajectories that satisfy the derived closed form flyability conditions. The final solutions are found by sampling that set using closed-form window traversal conditions. Numerical examples are presented to analyze the performance of the proposed approach in terms of number of solutions and computation time.

11:00-11:20	WeA2.4

UAV-Deployment for City-Wide Area Coverage and Computation of Optimal Response Trajectories, pp. 66-71

Tsoukalas, Athanasios	New York University Abu Dhabi
Tzes, Anthony	New York University Abu Dhabi
Papatheodorou, Sotiris	Imperial College London
Khorrami, Farshad	New York University

The selection of the UAV-dispatching stations within the city's border is amongst the topics addressed in this article. Under the assumption of a concave planar city area, a constrained minimization problem is formulated, which provides a set of near-optimum UAV-locations. Following this selection, and given the capacity of the on-board energy and the tetrahedralized-based decomposition of the concave hull of the allowable 3D-space that the UAV's can fly, an A*- algorithm optimized by an iterative procedure relying on ray casting is provided to compute the boundary of the UAV's reachable space. At the end, this article provides the necessary on-board energy so that every point within the metropolitan area can be reached by a certain number of UAVs.

11:20-11:40	WeA2.5

2D and 3D A Algorithm Comparison for UAS Traffic Management Systems*, pp. 72-76

Pötter Neto, Carlos Augusto	Instituto Tecnologico De Aeronautica
de Carvalho Bertoli, Gustavo	Instituto Tecnologico De Aeronautica
Saotome, Osamu	Instituto Tecnológico De Aeronáutica

In this work, we propose to implement a path planning algorithm for simulating an UAS Traffic Management system using ROS and Gazebo environment. From the 3D model generated for the simulation, both two-dimensional and three-dimensional node grids were extracted in order to allow the application of the search algorithm in both scenarios. After selecting the A* algorithm for this application, a preliminary efficiency analysis was carried out, considering the distance to be covered by the drone and the execution time of the route planning method, aiming to support the choice of the algorithm based on the environment in which it will be applied. As a result of the tradeoff analysis between distance and execution time for small maps (200m x 200m x 120m), the routes generated by the 2D algorithm are about 6% longer compared to the 3D approach, but with the execution time nine times lower, on average.

11:40-12:00	WeA2.6

UAV 3D Path and Motion Planning in Unknown Dynamic Environments, pp. 77-84

Margraff, Julien	University of Limoges, CNRS
STEPHANT, Joanny	ENSIL - Limoges University
LABBANI-IGBIDA, Ouiddad	ENSIL-ENSCI - University of Limoges

Unmanned aerial vehicles (UAVs) are used in increasingly complex environments. This paper deals with path and motion planning, based on the local perception of the UAV, generating autonomously a safe 3D path in dynamic cluttered environments under different constraints. The latter are formulated in a multi-criteria real-time optimization process that aims to minimize an objective function while satisfying the dynamic constraints of the UAV and the safety requirements. The considered constraints impact the velocity and the acceleration of the UAV, but also its curvature along the trajectory. Safety constraints are ensured by a minimal-security distance and by locally shifting the heading of the UAV to avoid obstacles while maintaining attractiveness to the goal location. Simulation results under ROS/Gazebo show the effectiveness and robustness of the approach even in highly cluttered environments. We study the effect of several parameters on the optimization process and the resulting trajectories.

WeA3	Edessa
Swarms (Regular Session)	

10:00-10:20	WeA3.1

Formation Control and Target Interception for Multiple Multi-Rotor Aerial Vehicles, pp. 85-92

Karras, George	University of Thessaly
Bechlioulis, Charalampos	National Technical University of Athens
Fourlas, George K.	University of Thessaly
Kyriakopoulos, Kostas J.	National Technical University of Athens

In this paper, we present a distance-based formation control strategy for multiple multi-rotor aerial vehicles participating in a target interception mission. The target moves arbitrarily, following a smooth 3D trajectory, while the intercepting vehicles aim at establishing

a predefined enclosing formation around it, by attaining specific distances among them and simultaneously avoiding inter-agent collisions and connectivity breaks. More specifically, we propose a decentralized motion control protocol based on the prescribed performance control notion, which is of low computational complexity and is able to achieve robust and accurate formation establishment. Each agent requires local and relative state feedback, which can be acquired by a common onboard sensor suite without necessitating for explicit network communication. A realistic simulation study with one target and four multi-rotor interceptors was conducted to prove the efficacy of the proposed strategy.

10:20-10:40 WeA3.2

Cooperative Game Theory Based Multi-UAV Consensus-Based Formation Control, pp. 93-99

Jiang, Liwei — University of Stuttgart
Gonzalez, Luis Felipe — Queensland University of Technology
Mcfadyen, Aaron — Queensland University of Technology

This paper presents a cooperative differential game theory approach to designing a consensus-based formation control strategy for multi-UAVs(agents). The consensus-based formation control problem is defined as tracking task where the states of each agent are required to follow a given reference. Position states are given as fixed offsets between each agent to achieve a formation whilst velocity and attitude are should be identical amongst agents to archive consensus. Using a cooperative game theory based approach, each agent acts to reduce the weighted team cost to reach consensus. The control strategy design is based on open-loop design, closed-loop design, and a semi-open-loop design concept to better account for different hardware configurations. The control approach is validated via simulations to show how cooperative game theory based consensus formation control can outperform non-cooperative game theory control and general optimal control with respect to reducing formation deviation. The semi-open loop design is proven to be suitable for practical applications.

10:40-11:00 WeA3.3

Distributed Algorithm for the Navigation of a Swarm of Nano-Quadrotors in Cluttered Environments, pp. 100-109

Karydes, Florian — Polytechnique Montréal
Saussie, David — Ecole Polytechnique De Montreal

In this article, a simple distributed solution is proposed for the leader-follower navigation of a swarm of nano-quadrotors in cluttered environments. Using only one-hop neighbors' information and nearby obstacles detection, control inputs are computed to ensure collision avoidance, obstacle avoidance, and connectivity maintenance. In addition, a ranking system is introduced so that each follower is aware of the leader position. This feature enhances the cohesion of the swarm which becomes critical when operating a large one. Also, simple distributed rules for changing the swarm topology are designed so that the swarm can squeeze when passing through narrow spaces. The effectiveness of the proposed solution is demonstrated in simulations with swarms up to hundred agents.

11:20-11:40 WeA3.5

Wilderness Search and Rescue with Heterogeneous Multi-Robot Systems, pp. 110-116

Rodríguez, Marcos — Universidad Carlos III De Madrid
Al-Kaff, Abdulla — Universidad Carlos III De Madrid
Madridano, Angel — Universidad Carlos III De Madrid
Martín Gómez, David — Universidad Carlos III De Madrid
de La Escalera, Arturo — Universidad Carlos III De Madrid

Recent developments in autonomous and communication technologies led the use of cooperative aerial and ground vehicles in Wilderness Search and Rescue missions (WiSAR). The use of a heterogeneous Multi-Robot System (MRS) improves the robustness and efficiency in achieving these tasks, comparing to the homogeneous systems with vehicles of the same characteristics. From this point, this paper proposed a Multi-Robot Task Allocation (MRTA) algorithm for heterogeneous vehicles (UAVs and UGVs) using the Market-based Approach to optimize the mission resources. The algorithm checks the availability of the vehicles, the characteristics of each task, and the payload required as inputs, then it provides each vehicle with a plan of tasks and charging commands. The proposed algorithm has been validated by performing several missions in simulations of mountains terrain with real dimensions, and the obtained results show the robustness and efficiency of the proposed system.

11:40-12:00 WeA3.6

Disturbance Perception Based Quadrotor UAV Maneuvering Formation against Unknown External Disturbance, pp. 117-122

Guo, Kexin — Beihang University
Liu, Cai — Beihang University
Zhang, Xiao — Beihang University
Yu, Xiang — Beihang University
Guo, Lei — Beihang University
Zhang, Youmin — Concordia University

This paper proposes an anti-disturbance formation control of quadrotor unmanned aerial vehicles (UAVs). A disturbance observer is designed for the quadrotor UAVs to estimate external disturbances which is compensated in attitude control algorithm. Based on

this disturbance estimate, an anti-disturbance formation control law is proposed to maneuver the formation and maintain consensus to ensure that the follower quadrotors suffer the external disturbances slightly and save energy for the formation flights. The simulation results demonstrate the effectiveness of the proposed anti-disturbance formation control scheme.

WeA4	Naousa
Control Architectures I (Regular Session)	

10:00-10:20	WeA4.1

Distributed Multiple Model MPC for Target Tracking UAVs, pp. 123-130

Wolfe, Sean	Royal Military College of Canada
Givigi, Sidney	Royal Military College of Canada
Rabbath, Camille Alain	DRDC

In this paper, the idea of using teams of Unmanned Aerial Vehicles (UAVs) to track a ground vehicle and exploiting the benefits of multiple UAVs is considered. The design and testing of a Distributed Multiple Model MPC (DMMMPC) controller for tracking in formation flight is investigated. Using information from state estimation about which target model is performing best, the DMMMPC changes its target motion model accordingly to match the target. This MPC controller is first implemented for a single UAV, then tested in both a real-time simulation environment and indoor flight. The MPC is then expanded to the multi-UAV scenario, which is tested in the same real-time simulation environment, demonstrating effective target tracking in formation flight for the team of UAVs. Lastly, the strength of the distributed topology is shown by exposing specific agents in the formation to measurement occlusions and observing the degradation of the tracking performance of the occluded UAVs.

10:20-10:40	WeA4.2

Constrained Control Allocation Approaches in Trajectory Control of a Quadrotor under Actuator Saturation, pp. 131-139

Tariq, Talha	McGill University
Nahon, Meyer	McGill University

Quadrotors are highly maneuverable vehicles that can be used to perform extremely aggressive maneuvers. Commanding a quadrotor to perform a maneuver that is beyond the physical capabilities of its actuators leads to actuator saturation. A prolonged state of saturated actuators can cause the vehicle to behave unpredictably. This work investigates the use of constrained control allocation methods in a cascaded control structure to mitigate the adverse effects of actuator saturation. More specifically, a weighted least squares approach is used in the position controller and mixer to prioritize certain control efforts while considering constraints on the actuators and, optionally, vehicle attitude. Additionally, a yaw-decoupled attitude controller is adopted to complement the control allocation method employed in the mixer. The proposed strategy offers a more comprehensive approach to addressing actuator saturation and was found to enhance the stability and tracking performance of the vehicle when compared to conventional approaches in simulation.

10:40-11:00	WeA4.3

Aerial Combat Tactics in Overwhelming Numbers, pp. 140-148

Day, Michael	Georgia Tech Research Institute
Magree, Daniel	Georgia Institute of Technology
DeMarco, Kevin	Georgia Tech Research Institute
Squires, Eric	Georgia Tech Research Institute
Strickland, Laura	Georgia Tech Research Institute
Vlahov, Bogdan	Georgia Tech Research Institute
Pippin, Charles	Georgia Tech Research Institute

This paper describes research performed in pursuit of autonomous swarm tactics for unmanned aerial vehicles (UAVs) as part of an internally funded effort at the Georgia Tech Research Institute (GTRI). Human engineered swarming tactics, reinforcement learned tactics, and aggressive flight maneuvers are explored. Aggressive flight maneuvers included autonomous descents, rolls, and an Immelmann maneuver. These efforts expand on preliminary control capabilities and are intended to enable groups of UAVs to act as a defensive swarm to counter aggressor swarms. All tactics have been validated in simulation using the GTRI-developed SCRIMMAGE [1], [2] simulation engine and were further proven in live-fly experiments throughout the duration of the ACTION effort, which ran from 2017-2019.

11:00-11:20	WeA4.4

Longitudinal Dynamics Analysis and Autopilot Design for a Fixed-Wing, Tactical Blended-Wing-Body UAV, pp. 149-157

Kitsios, Ioannis	Hellenic Air Force Electronics & Telecoms Depot
Dimopoulos, Thomas	Aristotle University of Thessaloniki
Panagiotou, Pericles	Aristotle University of Thessaloniki
Yakinthos, Kyriakos	Aristotle University of Thessaloniki

The article at hand analyzes the longitudinal flight dynamics properties of a Blended Wing Body (BWB) UAV that is based on a medium-fidelity six degree of freedom model and designs the relevant autopilot system using an H∞ output feedback methodology. Current state-of-the-art design guidelines are defined and used in the development process. The multipoint linear model analysis at the extend of the flight envelope verifies the suitability of the design, enlightens the unique flight characteristics of a BWB UAV and identifies the control difficulties encountered on this unconventional aircraft.

11:20-11:40	WeA4.5

Inertial Estimation and Energy-Efficient Control of a Cable-Suspended Load with a Team of UAVs, pp. 158-165

Petitti, Antonio	National Research Council of Italy
Sanalitro, Dario	LAAS-CNRS
Tognon, Marco	ETH Zurich
Milella, Annalisa	Institute of Intelligent Industrial Technologies and Systems For
Cortés, Juan	LAAS-CNRS
Franchi, Antonio	University of Twente

The Fly-Crane is a multi-robot aerial manipulator system composed of three aerial vehicles towed to a platform by means of six cables. This paper presents a method to estimate the mass and the position of the center of mass of a loaded platform (i.e. the Fly-Crane platform including a transported load). The precise knowledge of these parameters allows to sensibly minimize the total effort exerted during a full-pose manipulation task. The estimation is based on the measure of the forces applied by the aerial vehicles to the platform in different static configurations. We demonstrate that only two different configurations are sufficient to estimate the inertial parameters. Far-from-ideal numerical simulations show the effectiveness of the estimation method. Once the parameters are estimated, we show the enhancement of the system performances by minimizing the total exerted effort. The validity of the proposed algorithm in non-ideal conditions is presented through simulations based on the Gazebo simulator.

11:40-12:00	WeA4.6

Differential Sweep Attitude Control for Swept Wing UAVs, pp. 166-175

Harms, Marvin Chayton	ETH Zürich
Kaufmann, Noah	ETH Zürich
Rockenbauer, Friedrich Martin	ETH Zurich
Lawrance, Nicholas	The University of Sydney
Stastny, Thomas	ETH Zurich
Siegwart, Roland Y.	ETH Zürich

A novel approach for attitude control of swept wing unmanned aerial vehicles (UAVs) is presented, involving the use of only differential wing sweep and rudder deflection. An analytic aerodynamic model of the aircraft based on simple sweep theory is derived in a first step. The prediction of a vortex lattice method is then compared to the initial model. Based on the body moment analysis of the two models, design constraints and a control structure are proposed and implemented on a small-scale UAV with variable sweep wings. The control structure involves a cascaded PID controller with a nonlinear mapping from controller output to sweep angles. The obtained simulation results show that simultaneous bank and elevation inputs can be tracked successfully by the attitude controller. Tracking of step inputs and dynamic inputs in the roll direction using only wing sweep is demonstrated in flight tests. The results show that the nonlinear mapping achieves decoupling of the roll and pitch movement, but performance is limited by the inertia of the moving wings.

WeB1	Macedonia Hall
Autonomy II (Regular Session)	

15:00-15:20	WeB1.1

Backstepping-Based Adaptive Fault-Tolerant Control Design for Satellite Attitude System, pp. 337-342

Yan, Kun	Nanjing University of Aeronautics and Astronautics
Wu, Qingxian	Nanjing University of Aeronautics and Astronautics
Yang, Chenguang	University of the West of England
Chen, Mou	Nanjing University of Aeronautics and Astronautics

Combining with the backstepping technique, a robust fault-tolerant control (FTC) scheme is proposed for the satellite attitude system. Because the actuator fault and external disturbance are unknown, an auxiliary system is constructed firstly. Then, by means of the projection function, the adaptive fault observer is presented to tackle the actuator fault. Meanwhile, the negative effect of external disturbance is compensated by the adaptive estimation. In view of Lyapunov analysis, a robust FTC law is developed to guarantee the desired tracking properties. Numerical simulations elucidate the efficiency of the presented controller.

15:20-15:40	WeB1.2

Disturbance Observer-Based Control of Quadrotors with Motor Response Delay and Throttle Nonlinearity, pp. 343-348

Song, Yansui	Northwestern Polytechnical University

Liu, Xi — Unit 36485 of the Chinese People's Liberation Army
Xu, Bin — Northwestern Polytechnical University
Zhang, Yu — Zhejiang University
Yang, Chenguang — University of the West of England

This paper proposes a nonlinear disturbance observer-based controler (NDOBC) for quadrotors considering the motor response delay and the throttle nonlinear. A simplified quadrotor dynamic model which includes the attitude model and propulsion system is used to design the nonlinear disturbance observer. The NDOBC is sensitive to the motor response delay, which is founded by the experiment. Furthermore, if this is not handled appropriately, the system might go unstable. An equivalent motor response delay module is inserted between the observer and the controller output. To eliminate the influence of the throttle nonlinearity, a method is given by solving quadratic functions about the pseudo throttle. The simulation results show that the proposed method can guarantee the system stability and get a well noise suppression capability. In addition, a higher attitude control accuracy is achieved by eliminating the throttle nonlinearity.

16:00-16:20 WeB1.4

Fuzzy Kinodynamic RRT: A Dynamic Path Planning and Obstacle Avoidance Method, pp. 349-356

Chen, Long — Concordia University
Mantegh, Iraj — National Research Council Canada
He, Tong — Concordia University
Xie, Wenfang — Concordia University

Path planning is the essential capability for autonomous navigation of UAV (Unmanned Aerial Vehicle) in unknown environments. In this paper, a Fuzzy logic inferencing system has been designed to achieve obstacle avoidance in a dynamic environment. We introduce Fuzzy-Kinodynamic RRT, method which generates dynamic path based on the traditional rapidly exploring random tree (RRT) algorithm. A set of simple Fuzzy rules are proposed for simple 2D and 3D path planning cases. It is an optimized path planning method which uses Kinodynamic RRT algorithm to do global path planning and utilizes Fuzzy logic to avoid obstacles. A set of heuristics Fuzzy rules are proposed to lead the UAV away from un-modeled ground-based obstacles and to guide the UAV towards the goal. In addition, the designed Fuzzy rules can augment traditional RRT for dealing with new obstacles in the environment. Various simulations are conducted in 2D and 3D environment and the results illustrate the effectiveness of the algorithm in simple dynamic environment.

16:20-16:40 WeB1.5

Required Navigation Performance Specifications for Unmanned Aircraft Based on UTM Flight Trials, pp. 357-364

Kallinen, Valtteri — Queensland University of Technology
Martin, Terrence — NOVA
Mcfadyen, Aaron — Queensland University of Technology

Aircraft separation standards for manned aircraft are influenced by Required Navigation Performance (RNP) specifications under the Performance Based Navigation concept. Unmanned aircraft operating in a Unmanned Traffic Management (UTM) environment will require separation and thus similar standards need to be derived. This work expands on UTM flight trials conducted in Singapore to characterize the navigation performance of common multi-rotor platforms. Real flight test results enable derivation of the navigation error distributions which are subsequently used to suggest suitable RNP values for the platforms. Additionally, it is found that navigation capability of UAS in close proximity to buildings cannot yet be meaningfully evaluated.

16:40-17:00 WeB1.6

A Decentralized Framework to Support UAS Merging and Spacing Operations in Urban Canyons, pp. 365-371

Balachandran, Sweewarman — National Institute of Aerospace
Manderino, Christopher — NSF Center for Space, High-Performance, and Resilient Computing
Munoz, Cesar — NASA Langley Research Center
Consiglio, Maria — NASA Langley Research Center

This paper presents a distributed consensus algorithm for autonomous merging and spacing that enables unmanned aircraft systems (UAS) to coordinate their passage through an aerial intersection (i.e., merging fix) via a distributed control mechanism. The algorithm is incorporated into the Independent Configurable Architecture for Reliable Operations of Unmanned Systems (ICAROUS). In-trail spacing between aircraft is achieved with the integration of sense and avoid functionality (SAA) within the ICAROUS framework. This approach allows vehicles to maintain required spacing while entering or exiting the merging fix. Enabling autonomously coordinating vehicles in merging and spacing operations is a key capability in facilitating vehicle traffic in urban airspace and air-mobility operations involving small UAS and other Electrical-Vertical Takeoff/Landing (E-VTOL) vehicles.

WeB2 Kozani

Path Planning II (Regular Session)

15:00-15:20 WeB2.1

UAS Flight Path Planning for Dynamic, Multi-Vehicle Environment, pp. 209-217

He, Tong — Concordia University

Mantegh, Iraj	National Research Council Canada
Chen, Long	Concordia University
Vidal, Charles	National Research Council Canada
XIE, WENFANG	Concordia University

This paper proposes a new path planning method for Unmanned Aerial Systems (UAS) flying in a dynamic 3D environment shared by multiple aerial vehicles posing potential conflict risks. It primarily targets applications such as Urban Aerial Mobility (UAM). A new multi-staged algorithm is designed that combines Artificial Potential Field (AFP) method and Harmonic functions with Kalman filtering and Markov Decision Process (MDP) for dynamic path planning. It starts with estimating the aircraft traffic density in the area and then generates the UAS flight path in a way to minimize the risk of encounters. Hardware-in-the-loop simulations of the algorithm in various scenarios are presented, with a RGB-D camera (⟦RealSense⟧^TM) and Pixhawk autopilot to track the target. Numerical simulations show satisfactory results for path planning in various scenarios with increasing degree of complexity.

15:20-15:40 WeB2.2

A Chaotic Path Planning Method for 3D Area Coverage Using Modified Logistic Map and a Modulo Tactic, pp. 218-225

Moysis, Lazaros	Aristotle University of Thessaloniki
Petavratzis, Eleftherios	Aristotle University of Thessaloniki
Volos, Christos	Aristotle University of Thessaloniki
Nistazakis, Hector	Aristotle University of Thessaloniki
Stouboulos, Ioannis	Aristotle University of Thessaloniki
Valavanis, Kimon P.	University of Denver

This paper addresses the problem of chaotic path planning for the case of an autonomous mobile robot or an autonomous unmanned aerial vehicle (UAV) moving in a 3D environment. The aim is to derive a method to generate a series of chaotic motion commands for a UAV that is tasked to explore a given 3D grid. The objective is to generate an unpredictable motion, that will also give good coverage results relative to the number of motions generated. This work adapts a combination of a modified logistic map and a modulo operator to generate the motion directions. An inverse pheromone memory approach is also considered to improve performance. Simulations are then performed to evaluate the performance of the method.

15:40-16:00 WeB2.3

Optimal Multi-Agent Coverage and Flight Time with Genetic Path Planning, pp. 226-235

Olson, Jacob	Brigham Young University
Bidstrup, Craig	Uber ATG
Anderson, Brady	Brigham Young University
Parkinson, Alan	Brigham Young University
McLain, Tim	Brigham Young University

When generating 3D maps with unmanned aerial vehicles (UAVs), it is important for the mapping algorithm to have good coverage of the environment. It is also important, especially when planning paths for multiple agents, to have loop closures along each flight path and with other agents. Because multirotor UAVs are limited in flight time, the flight paths must be limited in length. Generating a good flight path to map a new environment can be difficult and tedious because of the free-form nature of a flight path. To solve this problem, we propose using a genetic algorithm designed to maximize total area coverage while minimizing flight time and enforcing sufficient loop closures. The natural ability of genetic algorithms to rapidly explore a design space is advantageous when solving complex free-form problems like path planning.

16:00-16:20 WeB2.4

Fast Trajectory Optimization for Quadrotor Landing on a Moving Platform, pp. 236-243

Zhang, Guoxu	Beijing Institute of Technology
Kuang, Hailiang	Beijing Institute of Technology
Liu, Xinfu	Beijing Institute of Technology

This paper addresses the trajectory optimization problem of quadrotor landing on a moving platform. Various state and control constraints are imposed, and a combined optimization objective of minimum-energy and minimum-time is considered. The contribution of the paper is to convert the original nonconvex optimal control problem into a second-order cone programming (SOCP) mainly utilizing the change of variables, equivalent transformation, and linearization. And the SOCP problem can be solved by the interior point method quickly. Then, a successive solution algorithm is proposed, which is found to be able to converge quickly. Especially, the algorithm is guaranteed to converge when the moving platform has a constant velocity vector. Numerical examples have been provided to show the efficiency and effectiveness of the proposed algorithm for quadrotor landing on moving platforms.

16:20-16:40 WeB2.5

Unmanned Aerial Vehicle Trajectory Planning Via Staged Reinforcement Learning, pp. 244-253

Xi, Chenyang	Beijing Institute of Technology
Liu, Xinfu	Beijing Institute of Technology

Unmanned Aerial Vehicle (UAV) trajectory planning problem has always been a popular but still an open topic, where online planning is desired in unknown environments. This paper investigates how to combine human knowledge with reinforcement learning to train the UAV in a staged manner. With the novel framework we design, the UAV learns well to avoid densely arranged no-fly-zones and reach stationary or moving targets via calling the trained policy online. We demonstrate the advantages of our approach in terms of the flight time and the success rate of reaching target and avoiding no-fly-zones. The experimental results are performed in a set of new designed environments including dynamic no-fly-zones and moving targets.

16:40-17:00	WeB2.6

Optimization in Multiphase Homing Trajectory of Unpowered Parafoil with High-Altitude, pp. 254-260

Guo, Yiming	Northwestern Polytechnical University
Jianguo, Yan	Northwestern Polytechnical University
Luo Yu, Yu	Shaanxi Polytechnic Institute
Wu, Cihang	Northwestern Polytechnical University
Li, Fenghao	Northwestern Polytechnical University
Xing, Xiaojun	Northwestern Polytechnical University

In this paper, an improved multiphase homing algorithm of unpowered parafoil with high-altitude configuration is developed. The algorithm reduces the unnecessary energy consumption caused by multiple circling to consume altitude in the classical algorithm. Firstly, this paper derives the mathematical problems in the multiphase homing algorithm by the analytic method and then optimizes the algorithm by particle swarm optimization to minimize energy expenditure. Afterward, the planned trajectory and the energy changes of the two algorithms are obtained. The comparison shows that the algorithm in this paper, which can significantly save control energy, has some engineering significance and practical value.

WeB3	Edessa
Networked Swarms I (Regular Session)	

15:20-15:40	WeB3.2

A Geometrical Approach Based on 4D Grids for Conflict Management of Multiple UAVs Operating in U-Space, pp. 261-268

Acevedo, José Joaquín	University of Seville
Capitán, Carlos	University of Seville
Capitan, Jesus	University of Seville
Castaño, Ángel Rodríguez	University of Seville
Ollero, Anibal	University of Seville

This paper addresses the problem of conflict management from the tactical point of view for multiple UAVs operating in a common U-space. The proposed solution is based on the representation of the trajectories into a 4D grid to optimize the conflict searching tool and an iterative geometric approach to resolve the conflicts, splitting the multi-conflict problem into several simpler sub-problems, and provide an alternative set of trajectories free of conflicts. The method is assessed through two different metrics: the processing time to find the solution and the deviation from initial trajectories; getting a significantly better performance in comparison with other traditional method.

15:40-16:00	WeB3.3

Decentralized Task Allocation for Multiple UAVs with Task Execution Uncertainties, pp. 269-276

Liu, Ruifan	Northwestern Polytechnical University
Seo, Min-Guk	Cranfield University
Yan, Binbin	Northwestern Polytechnical University
Tsourdos, Antonios	Cranfield University

This work builds on a robust decentralized task allocation algorithm to address the multiple unmanned aerial vehicle (UAV) surveillance problem under task duration uncertainties. Considering the existing robust task allocation algorithm is computationally intensive and also has no optimality guarantees, this paper proposes a new robust task assignment formulation that reduces the calculation of robust scores and provides a certain theoretical guarantee of optimality. In the proposed method, the Markov model is introduced to describe the impact of uncertain parameters on task rewards and the expected score function is reformulated as the utility function of the states in the Markov model. Through providing the high precision expected marginal gain of tasks, the task assignment gains a better accumulative score than the state of art robust algorithms do. Besides, this algorithm is proven to be convergent and could reach a prior optimality guarantee of at least 50%. Numerical Simulations demonstrate the performance improvement of the proposed method compared with basic CBBA, robust extension to CBBA and cost-benefit greedy algorithm.

16:00-16:20	WeB3.4

Communication-Based and Communication-Less Approaches for Robust Cooperative Planning in Construction with a Team of UAVs, pp. 277-286

Umili, Elena	Sapienza Università di Roma

Tognon, Marco ETH Zurich
Sanalitro, Dario LAAS-CNRS
Oriolo, Giuseppe Sapienza Università di Roma
Franchi, Antonio University of Twente

In this paper, we analyze the coordination problem of groups of aerial robots for assembly applications. With the enhancement of aerial physical interaction, construction applications are becoming more and more popular. In this domain, the multi-robot solution is very interesting to reduce the execution time. However, new methods to coordinate teams of aerial robots for the construction of complex structures are required. In this work, we propose an assembly planner that considers both assembly and geometric constraints imposed by the particular desired structure and employed robots, respectively. An efficient graph representation of the task dependencies is employed. Based on this framework, we design two assembly planning algorithms that are robust to robot failures. The first is centralized and communication based. The second is distributed and communication-less. The latter is a solution for scenarios in which the communication network is not reliable. Both methods are validated by numerical simulations based on the assembly scenario of Challenge 2 of the robotic competition MBZIRC2020.

16:20-16:40 WeB3.5

Evaluation of Cooperative Guidance for Formation Flight of Fixed-Wing UAVs Using Mesh Network, pp. 287-292

Kim, SuHyeon Korea Aerospace University
Cho, Hyeong Jun Korea Aerospace University
Jung, Dongwon Korea Aerospace University

This paper presents an algorithm for cooperative guidance control for multi fixed-wing UAVs with the results of hardware-in-the-loop simulation and the actual flight test. The proposed formation guidance law provides the reference target information for the follower UAV to maintain the formation effectively. The target heading angle and the target speed are incorporated as feedforward terms during the formation control to enable the follower UAV to compensate for the turn dynamics of the leader UAV. The formation control law divided into the separate longitudinal and lateral control has been designed via Lyapunov direct method with a brief stability analysis. The results from the hardware-in-the-loop simulation and the flight test confirm that the proposed algorithm can be effectively applied to formation flight of multi fixed-wing UAVs.

16:40-17:00 WeB3.6

Design, Implementation and Validation of a Multipurpose Localization Service for Cooperative Multi-UAV Systems, pp. 293-300

Pignaton de Freitas, Edison Federal University of Rio Grande Do Sul
Leite Francisco da Costa, Luis Antonio Federal University of Rio Grande Do Su
Emygdio de Melo, Carlos Felipe Federal University of Rio Grande Do Sul
Basso, Maik Federal University of Rio Grande Do Sul
Rodrigues Vizzotto, Marcos Federal University of Rio Grande Do Sul
Schein Cavalheiro Corrêa, Mateus Federal University of Rio Grande Do Sul
Dapper e Silva, Túlio Federal University of Rio Grande Do Sul

Systems composed of groups of Unmanned Aerial Vehicles (UAVs) are emerging as an extension of the usage of single UAVs in a number of applications. Besides of very desirable, the possibility of using multi-UAV systems requires that each UAV in the group has information about the locations of the others, so that the system as a whole can work smoothly, i.e. keeping configured flight formation, without collisions, evenly distributing the tasks, and even authenticating one another so that no malicious node access the group. To support such multi-UAV systems setup, this work reports the proposal of a multipurpose localization service to disseminate positioning information of the UAVs to the group as well as to estimate the positions that are not received due to communication errors. The proposal consists in a complete methodology to setup, test and perform multi-UAV missions, which are firstly planned, setup and tested in a simulated environment, and then performed in the real-world. Design and implementation details of the proposed infrastructure service are presented, along with a complete validation of the proposal, from simulation to the field experiments. The acquired results provide evidence that the proposed service and methodology are efficient to support fleet of UAVs performing cooperative missions.

WeB4 Naousa

Control Architectures II (Regular Session)

15:00-15:20 WeB4.1

Transition Control of a Tail-Sitter UAV Using Recurrent Neural Networks, pp. 301-307

Flores, Alejandro Center for Research in Optics
Flores, Gerardo Center for Research in Optics

This paper presents the implementation of a Recurrent Neural Network (RNN) based-controller for the stabilization of the flight transition maneuver (hover-cruise and vice versa) of a tail-sitter UAV. The control strategy is based on attitude and velocity

stabilization. For that aim, the RNN is used for the estimation of high nonlinear aerodynamic terms during the transition stage. Then, this estimate is used together with a feedback linearization technique for stabilizing the entire system. Results show convergence of linear velocities and the pitch angle during the transition maneuver. To analyze the performance of our proposed control strategy, we present simulations for the transition from hover to cruise and vice versa.

15:20-15:40 WeB4.2

Modeling and Control of Mid-Flight Coupling of Quadrotors: A New Concept for Quadrotor Cooperation, pp. 308-313

Larsson, Daniel — Georgia Institute of Technology
Nguyen, Chuong — Arizona State University
Artemiadis, Panagiotis — University of Delaware

Multirotor vehicles, quadrotors specifically, have formed a fast-growing field in robotics, with the range of applications spanning from surveillance and reconnaissance to agriculture and large area mapping. Although in most applications, a single quadrotors is used, there is an increasing interest in architectures controlling multiple quadrotors executing a collaborative task. This paper introduces a new concept of control involving more than one quadrotors, according to which two quadrotors can be physically coupled in mid-flight. This concept equips the quadrotors with new capabilities, e.g. increased payload or pursuit and capturing of other quadrotors. A comprehensive analysis of the approach is presented for the system of two coupled quadrotors. The dynamics and modeling of the coupled system is presented together with a discussion regarding the coupling mechanism and the overall control architecture. Controller gains were found using Linear Quadratic Control (LQR) techniques combined with Proportional Integral Derivative (PID) gain scheduling to account for the change in system dynamics to ensure stability and satisfactory response characteristics in actual experiments. Finally, the proposed methods are evaluated through an experiment that involved physical coupling and coupled flight of a pair of quadrotors.

15:40-16:00 WeB4.3

Multibody Dynamic Modeling and Control of an Unmanned Aerial Vehicle under Non-Holonomic Constraints, pp. 314-319

Lanteigne, Eric — University of Ottawa
O'Reilly, Joshua — University of Ottawa

This paper presents the application of the Boltzmann-Hamel equations to the modeling of a multibody lighter-than-air vehicle. The vehicle is composed of a lifting gas envelope and movable gondola for performing rapid descent maneuvers. The vehicle pitch is primarily controlled by the position of the gondola on the keel of the envelope. The pitch control law was treated as a non-holonomic constraint applied to the system dynamics. The derivation of the equations of motion are presented for a simplified case, and the effectiveness and performance are demonstrated through numerical simulations using theoretical and experimental aerodynamic model parameters

16:00-16:20 WeB4.4

Trajectory Tracking Control for a Quadrotor with a Slung Load, pp. 320-326

Rodriguez Cortes, Hugo — CINVESTAV-IPN
Mosco Luciano, Alan Paz — CINVESTAV-IPN
Castro-Linares, Rafael — CINVESTAV-IPN

This paper presents the synthesis of a nonlinear controller to deal with the trajectory tracking problem for a quadrotor with a slung load constrained to flight on a plane. The control design procedure starts by designing a linearizing saturated controller for the vertical dynamics; then, the backstepping method is employed to synthesize a controller for the resulting closed-loop dynamics. The controller performance is evaluated using numerical simulations, and some experimental results are also reported.

16:20-16:40 WeB4.5

Modeling and Control of a Novel Over-Actuated Tri-Rotor UAV, pp. 327-336

Wang, Yunhe — Zhejiang University
Zhu, Zhangzhen — Zhejiang University
Zhang, Yu — Zhejiang University

This paper presents a novel tilting tri-rotor unmanned aerial vehicle (UAV) based on the conventional trirotor configuration, with each rotor having two tilting degrees of freedom, which is an over-actuated system. Herein, the dynamic model of this novel UAV is developed, which has nine controllable variables. Owing to the nonlinear and coupled nature of the system, many conventional nonlinear control allocation algorithms are too computationally complex to be calculated online. Therefore, a new control allocation method is proposed by using a reversible mapping to transform the nonlinear control allocation problem to the corresponding linear control allocation problem. The feedback linearization method is used to implement the entire control architecture using the new control allocation algorithm. Furthermore, a nonlinear disturbance observer (NDOB) is used to combat the low robustness of the feedback linearization controller. Finally, several simulation experiments are conducted to validate the proposed method. The simulations reveal that the fuselage can successfully track different spatial trajectories with different attitudes, which corroborates the high maneuverability of the fuselage over the conventional quadrotor.

WeC1 Macedonia Hall

Artificial Intelligence and its Applications to Unmanned Flight Systems (Invited Session)

Organizer: Liu, Hao — Beihang University
Organizer: Wang, Qingling — Southeast University
Organizer: Liang, Yang — Beihang University

17:00-17:20 WeC1.1

Discrete Sliding Mode Tracking Control of Hypersonic Vehicle under Incomplete Data Transmission (I), pp. 176-184

Song, Jia — Beihang University
Zhang, Yanxue — Beihang University
Weng, Huiyan — Beihang University
Zhu, Hao — Beihang University
Yu, Nanjia — Beihang University
Cai, Guobiao — Beihang University

In this paper, an improved discrete sliding mode control (SMC) is investigated for hypersonic vehicle (HV) cruise control system with packet dropouts. Packet dropouts are common faults in networked control systems (NCS), which occur in the sensor-controller and controller-actuator channels. A Lyapunov function is derived from the HV asynchronous dynamic model to design the state feedback. Set the HV system with state feedback as an augmentation system. A discrete SMC system is established for the augmentation system to improve the tracking performance and anti-fault robustness. We verify the discrete SMC approach in the cruising flight. A simulation example supports the theory.

17:20-17:40 WeC1.2

Robust Optimal Control Law Learning for Heterogeneous Rotorcraft Formation Involving Unknown Parameters (I), pp. 185-190

Liu, Hao — Beihang University
Meng, Qingyao — Beihang University
Liang, Yang — Beihang University
Tian, Hui — Beihang University
Junya, Yuan — Beihang University

A distributed robust optimal formation control problem is discussed via reinforcement learning for the heterogeneous rotorcrafts with unknown parameters. The formation system involves equivalent disturbance including nonlinearity and external disturbance. The proposed robust optimal controller consists of a nominal controller and a robust compensator. The reinforcement learning algorithm is used to obtain the unknown system parameters. Then, the nominal controller is applied to achieve the desired optimal control input; the robust compensator is constructed to counteract the equivalent disturbance in the overall system. Simulation result verifies the effectiveness of the proposed control approach.

17:40-18:00 WeC1.3

Image-Based Visual Servo Control for Ground Target Tracking Using a Fixed-Wing UAV with Pan-Tilt Camera (I), pp. 191-198

Yang, Lingjie — National University of Defense Technology
Zhihong, Liu — National University of Defense Technology
Wang, Guanzheng — National University of Defense Technology
Wang, Xiangke — National University of Defense Technology

This paper proposes a control framework to achieve the tracking of the moving target by a fixed-wing unmanned aerial vehicle (UAV) with a monocular pan-tilt camera. This control framework is based on the image-based visual servoing (IBVS) method, which takes the target feature point on the captured image as the input and outputs the control signals directly with the aid of image Jacobian matrix. However, the image is affected by the attitude of both the UAV and the pan-tilt, and the attitude of the pan-tilt is coupled with that of the UAV simultaneously. To solve this problem, we present an Ideal State as the reference state, and make sure the coordinates of the feature point in the state are only affected by the change of the yaw angle of the UAV. In this way, we can integrate the attitude control of the UAV and the pan-tilt. By using this control framework, the fixed-wing UAV can track the ground target continuously on the one hand, and the target will tend to locate at image center on the other hand. This prevents the target from moving toward to the edge of the image or even disappearing. Besides, we prove the controller is exponentially convergent by the Lyapunov method. In order to evaluate the performance of our controller, we build a hardware-in-the-loop (HIL) simulation platform and a prototype platform. Based on these platforms, extensive experiments including simulations and real flight tests are conducted. The results show that our controller can achieve continuous and robust tracking of the target with a speed of 20km/h when the speed of the UAV is 16m/s.

18:00-18:20 WeC1.4

Implementation on Benchmark of SC2LE Environment with Advantage Actor - Critic Method (I), pp. 199-203

Hu, Huan — Southeast University
Wang, Qingling — Southeast University

Deep reinforcement learning has already surpassed human performance in many video games, which is mainly achieved with reinforcement learning algorithms based on the actor-critic framework. With the release of PySC2 reinforcement learning environment by Google DeepMind and Blizzard Entertainment, deep reinforcement learning algorithms have attracted the attention of many AI developers on StarCraft II games. In this paper, we used the advantage actor - critic algorithm to achieve the training of agents on seven mini-maps released by DeepMind, we obtain the experimental results and compare them with DeepMind's experimental benchmark. The experimental results show that the agent trained based on the advantage actor-critic algorithm has excellent performance on SC2LE environment.

18:20-18:40 WeC1.5

Precipitation Forecast Based on Multi-Channel ConvLSTM and 3D-CNN (I), pp. 204-208

Dan, Niu — Southeast University
Diao, Li — Shanghai Jiao Tong University
Xu, Liujia — Southeast University
Zang, Zengliang — Institute of Meteorology and Oceanography
Xisong, Chen — Southeast University
Liang, Shasha — Southeast University

The short-term precipitation change has a profound impact on people's daily lives, thus it is vital to predict short-term precipitation accurately. Compared with conventional 2D sequence prediction based on radar echo images, a multi-channel ConvLSTM and 3D-CNN structure for multi-dimensional sequence prediction is proposed. Firstly, data preprocessing is carried out, and radar image dataset are denoised by ground-object elimination and 2D wavelet transform. To solve the problem of unbalanced distribution of original precipitation data, different weights are assigned to different precipitation rates and a new balanced loss function is established. Finally, the data fusion of radar echo images, grid pattern temperature and total precipitation extends 2D data to 3D data, and a short-term precipitation forecast algorithm based on multi-channel ConvLSTM and 3D-CNN structure is proposed. Moreover, a meteorological data mapping method based on the power and logarithmic transformation is put forward, which balances the data distribution. Experimental results show that compared with some machine learning methods, the proposed model can obtain higher precipitation prediction accuracy.

WeC2 Kozani

Path Planning III (Regular Session)

17:00-17:20 WeC2.1

Evaluation of a Commercially Available Autonomous Visual Inertial Odometry Solution for Indoor Navigation, pp. 372-381

Agarwal, Ankit — Pennsylvania State University
Crouse, Jacob — Pennsylvania State University
Johnson, Eric — Pennsylvania State University

In this paper, an Unmanned Aerial System (UAS) navigation solution using the Intel RealSense T265, a commercially available Visual Inertial Odometry device, is developed and presented in conjunction with an Extended Kalman Filter framework. Comparisons of raw and estimated position and yaw angle data from the device are made against ground truth measurements obtained via a motion capture system. Preliminary results from hand-carry tests show promising localization capability as the device continues to gather information about its environment. Further localization improvements may be achievable with varied software configurations. The performance of the Extended Kalman Filter during closed-loop flight is also evaluated and shows smoothing of noisy measurements from the T265 and generally precise trajectory following capabilities. Future work to extend this characterization shall involve testing the performance of the device across varying flight envelopes, and especially for longer durations.

17:20-17:40 WeC2.2

Disturbance Observer-Based Integral Backstepping Control for UAVs, pp. 382-388

Moeini, Amir — U of Alberta
Rafique, Muhammad Awais — U of Alberta
Xue, Zhijun — Huazhong University of Science and Technology
Lynch, Alan — U of Alberta
Zhao, Qing — U of Alberta

In this paper a disturbance observer-based integral backstepping nonlinear motion control for a multirotor unmanned aerial vehicle (UAV) is proposed. The closed loop is proven globally exponentially stable for the complete UAV dynamics and constant disturbances. Software-in-the-loop (SITL) simulation is used to evaluate the performance of the proposed control on the open-source PX4 autopilot. The simulation results demonstrate the proposed method's robustness and steady state error performance.

17:40-18:00 WeC2.3

Spare Drone Optimization for Persistent Task Performance with Multiple Homes, pp. 389-397

Hartuv, Erez — Bar-Ilan University
Agmon, Noa — Bar Ilan University
Kraus, Sarit — Bar-Ilan University

In this paper we examine the problem of persistent task performance by a team of multiple drones, where the drones suffer from energy limitations. The drones are required to occupy a set of m locations in order to perform a task, for example surveillance, indefinitely. Since the drones have a limited battery supply, they must be replaced in order to refuel, recharge or change their battery at a fixed set of refueling stations called homes. Therefore, in order to enable the persistent task performance, it is essential to add spare drones to the system that will replace the drones in their task. We examine two problems in this context: determining the minimal number of spare drones that will guarantee that the task will be carried out persistently and indefinitely and finding a schedule for drone-replacements. The novelty of this work is twofold: (i) Proving that a simple drone replacement scheduling is enough with respect to minimizing the number of spare drones, thus reducing the need to cope with $O(m^2)$ pairwise travel costs of the given m locations to only O(m) travel costs between the m locations and the homes; and (ii) The introduction of an innovative approximation approach for the minimum number of spare drones required, and providing a replacement scheduling strategy by combining a Voronoi tessellation with a Bin-Packing variant (Bin Maximum Item Double Packing-BMIDP) for the Multi-homes problem, which is much harder than the single home problem and is NP-Hard even for a single spare drone.

18:00-18:20	WeC2.4

HorizonBlock: Implementation of an Autonomous Counter-Drone System, pp. 398-404

Souli, N.	University of Cyprus
Makrigiorgis, R.	University of Cyprus
Anastasiou, Andreas	University of Cyprus
Petrides, Petros	University of Cyprus
Zacharia, A.	University of Cyprus
Lazanas, A.	University of Cyprus
Valianti, Panayiota	University of Cyprus
Kolios, Panayiotis	University of Cyprus
Ellinas, G.	University of Cyprus

Unmanned Aircraft Systems (UASs) are technologically advancing at such a rapid pace that domain experts are now highly concerned of the potential misuse of the technology that can be used for unlawful actions with detrimental effects. The most effective measure to counteract the operation of rogue drones are electronic anti-drone systems that in one way or another intercept the normal operation of a rogue agent. In this work we develop an intelligent pursuer drone that implements novel lightweight functions to meet all necessary interception steps (i.e., detection, tracking and interception) in addition to self-localizing using signals of opportunity in order to maintain perception when performing wireless jamming against a rogue drone.

18:20-18:40	WeC2.5

A Task-Oriented Assignment Algorithm for Collaborative Unmanned Aerial Systems, pp. 405-411

Lindsay, Nathan	New Mexico State University
Sun, Liang	New Mexico State University

In this paper, we propose a new distributed algorithm for task assignment problems for unmanned aerial systems (UAS). Inspired by the Hungarian method, the proposed algorithm, namely, the task-oriented distributed assignment algorithm (TODAA), uses a mechanism that updates the label and the slack variables in a heuristic manner throughout the assignment process for each individual UAS. We compare the proposed TODAA with the Consensus-Based Auction Algorithm (CBAA) in terms of computational time and cost optimality errors. The results show that the TODAA outperforms the CBAA in assignment cost whereas is outperformed in computational time.

18:40-19:00	WeC2.6

Wildfire Remote Sensing with UAVs: A Review from the Autonomy Point of View, pp. 412-420

Bailon-Ruiz, Rafael	LAAS-CNRS
Lacroix, Simon	LAAS-CNRS

This article analyses the state of the art on wildfire remote sensing using UAVs, an application context that has now gained significant interest. It reviews a selection of relevant publications and proposes a classification scheme to synthesize them from an autonomy perspective. Three metrics are introduced: situation awareness, decisional ability, and collaboration ability. A discussion about the current state and the outlook of UAV systems for wildfire observation concludes the paper.

WeC3	Edessa
Networked Swarms II (Regular Session)	

17:00-17:20	WeC3.1

Observer-Based Event-Triggered Model Reference Control for Multi-Agent Systems, pp. 421-428

Vazquez Trejo, Juan Antonio	University of Lorraine
Rotondo, Damiano	University of Stavanger
Adam-Medina, Manuel	National Center for Research and Technological Development
Theilliol, Didier	University of Lorraine

The main contribution of this paper is the design of an observer-based model reference control for multi-agent systems with event-triggered mechanism using a dynamic-threshold. Since the full state vector is not always available, an observer is considered for each agent. In order to guarantee convergence of all the agents to the reference trajectory, linear matrix inequality (LMI)-based conditions are obtained for computing the controller and observer gains. Based on the closed-loop multi-agent system, an event-triggered mechanism is designed to reduce the information exchange between agents. The effectiveness of the proposed approach is illustrated through numerical examples.

17:20-17:40	WeC3.2

Integrated Perception and Tactical Behaviours in an Auto-Organizing Aerial Sensor Network, pp. 429-438

Leong, Wai Lun	National University of Singapore
Martinel, Niki	University of Udine
Huang, Sunan	National University of Singapore
Micheloni, Christian	University of Udine
Foresti, Gianluca	University of Udine
Teo, Rodney	National University of Singapore

We investigated the feasibility and conducted a proof-of-concept demonstration of an auto-organizing sensor network composed of UAVs and ground cameras, for urban surveillance. The solution is based on a decentralized paradigm with tightly coupled perception and tactical behavior algorithms. The sensor network can perform self-organization. New cameras that could be added any time would assign themselves to tasks. The network would reconfigure when cameras are removed or lost to ensure that high priority tasks are always served. Tracked targets could also be handed over from one camera to another, to ensure continuous tracking. This was achieved by means of our target re-identification algorithm and handover logic. To realize our network, we selected and improved the state-of-the-art algorithms. We developed the architecture and integrated the algorithms. Extensive simulations and tests were conducted and finally, we successfully ran real world proof-of-concept tests, demonstrating the feasibility of our tightly coupled perception and tactical behavior auto-organizing aerial sensor network.

17:40-18:00	WeC3.3

Distributed UAV Formation Control with Prescribed Performance, pp. 439-445

Gkesoulis, Athanasios	National Technical University of Athens
Psillakis, Haris	National Technical University of Athens

In this paper, a distributed prescribed performance formation control for 3-degree of freedom (3-DOF) unmanned aerial vehicles (UAVs) is presented. The information flow between the UAVs is described by a directed graph having a spanning tree with the leader UAV as a root. Only position measurements need to be transmitted between the UAVs. The UAV dynamics are derived from kinematic equations and the UAV drag coefficients and masses are considered unknown. For the controller design, a distributed low complexity backstepping approach is adopted. A Lyapunov-like stability analysis proves the efficiency of the proposed methodology. Simulation results are provided that validate our theoretical results.

18:00-18:20	WeC3.4

Swarm Control for Autonomous Navigation Support, pp. 446-455

Gipson, Jonathon	Air Force Institute of Technology
Leishman, Robert	Air Force Institute of Technology
Schubert Kabban, Schubert Kabban	Air Force Institute of Technology

In a denied environment, vehicles equipped with all-source navigation capabilities (e.g. magnetic, visual, etc.) can maintain assured PNT solutions and serve as anchors for other vehicles in a surveillance network. Mission vehicles not equipped with these features are subject to integration drift and can benefit from relative navigation updates. In a surveillance network, vehicles can perform relative measurement updates using radio ranging. In a time-synchronized network, localization accuracy for vehicles equipped only with radio ranging is primarily dependent on multilateration geometry. The primary contribution of this paper is a real-time distributed swarm control scheme to autonomously optimize multilateration for offboard mission vehicles in a surveillance network. Swarm guidance is provided by Semi-Cooperative Self-Aligning Swarm (SCSAS), a distributed greedy algorithm which uses surveillance data to control navigation support vehicles to optimize multilateration for selected offboard mission vehicles. Using multiple 10K-trial Monte Carlo simulations, the proposed algorithm demonstrates distributed control which results in consensus-like optimization of 2-D position MSE for selected offboard mission vehicles broadcasting surveillance data.

18:20-18:40	WeC3.5

Swarm Path Planning for the Deployment of Drones in Emergency Response Missions, pp. 456-465

Anastasiou, Andreas	University of Cyprus
Kolios, Panayiotis	University of Cyprus
Panayiotou, Christos	University of Cyprus
Papadaki, Katerina	London School of Economics and Political Sciences

The rapid development of Unmanned Aerial Vehicles (UAV) technologies over the recent years has been decisive for their integration in emergency response missions. While initial use by first responders focused on manual operations, the need to improve utilization

necessitates higher levels of automation. Contributing towards that end-goal, this work derives swarm path planning algorithms that can effectively and efficiently be employed to search and monitor the operating field. A swarm is composed by two or more units, that coordinate to achieve the mission objectives including minimizing search time while ensuring coverage of the field. A graph theoretic approach is followed to model the underlying swarm path planning problem and mathematical programming is employed to describe a number of important variants of the cooperative strategies that arise. Thereafter, 4 algorithms are derived to solve the swarm path planning problem that are computationally efficient to implement and use in practice. A thorough performance evaluation is conducted to understand the advantages and disadvantages of each heuristic using a number of key performance metrics.

18:40-19:00 WeC3.6

Designing and Flight-Testing a Swarm of Small UAS to Assist Post-Nuclear Blast Forensics, pp. 466-472

Kopeikin, Andrew	United States Military Academy
Russell, Conner	United States Army
Trainor, Hayden	United States Military Academy
Rivera, Ashley	United States Military Academy
Jones, Tyrus	United States Military Academy
Baumgartner, Benjamin	United States Military Academy
Manjunath, Pratheek	United States Military Academy
Heider, Samuel	DTRA
Surdu, Thomas	United States Military Academy
Galea, Matthew	United States Military Academy

Nuclear blasts leave plumes of residue and sources of radiation behind that can be used to determine their origin. To assist in locating the best areas to collect ground samples a team from West Point developed an autonomous Unmanned Aircraft System (UAS) swarm system for expedited remote sensing. The system includes several distributed control algorithms to enable a team of quadrotor UAS to rapidly survey regions for radiation. Each vehicle is equipped with a sensor suite to measure radiation and estimate the source strength on the surface. While UAS survey the area, their data is fused into a single heatmap which becomes available in real-time to end-users employing the Android Tactical Assault Kit (ATAK). A rapid deployment system was developed to streamline how UAS are configured in pre-flight and enables them to launch directly from a box used for transport. The system was successfully demonstrated in a live flight test event over an active radiation field at Savannah River Site SC in April 2019.

WeC4 Naousa

Control Architectures III (Regular Session)

17:00-17:20 WeC4.1

Unified Controller for Take-Off and Landing for a Fixed-Wing Aircraft, pp. 473-479

Montes de Oca Rebolledo, Andres	Center for Research in Optics
Flores, Gerardo	Center for Research in Optics

Take-off and landing are the most important maneuvers for an aircraft's flight. Deployment for small fixed-wing aircraft is usually made by hand but when payload increases, take-off, and landing maneuvers are then performed on a runway making the procedures more complex. For that reason, we address the performance of the two maneuvers in order to develop a unique controller using the feedback control technique. We present the longitudinal aircraft dynamics to model the take-off and landing considering the rolling resistance forces during ground roll through a friction model. We also present the controller design for such a model. A stability proof is conducted to validate the stability of the system with the developed control law. Additionally, simulations are carried out to corroborate that the control law is effective applied to the dynamic model presented.

17:20-17:40 WeC4.2

Target Tracking with Multi-Rotor Aerial Vehicles Based on a Robust Visual Servo Controller with Prescribed Performance, pp. 480-487

Karras, George	University of Thessaly
Bechlioulis, Charalampos	National Technical University of Athens
Fourlas, George K.	University of Thessaly
Kyriakopoulos, Kostas J.	National Technical University of Athens

In this paper, we present an image-based visual servo control scheme for tracking a moving target using a multirotor aerial vehicle. The proposed scheme is based on the prescribed performance control notion and it is able to impose appropriately selected performance specifications on the image feature errors to satisfy visibility constraints arising from the camera limited field of view, while exhibiting robustness against calibration and depth estimation errors. The proposed controller is of low complexity and computational cost and thus can be easily implemented on the embedded control unit of an autonomous aerial vehicle. The resulting scheme has analytically guaranteed stability and convergence properties, while its applicability and performance are verified via a realistic simulation scenario, where a quadrotor successfully tracks a visual target located on top of a moving mobile robot.

17:40-18:00 WeC4.3

Path-Following with a UGV-UAV Formation Considering That the UAV Lands on the UGV, pp. 488-497

Bacheti, Vinicius — Federal University of Espirito Santo
Brandao, Alexandre Santos — Federal University of Vicosa
Sarcinelli-Filho, Mário — Federal University of Espirito Santo

This paper addresses the control of a formation composed of an unmanned ground vehicle (UGV) and an unmanned aerial vehicle (UAV). The formation navigates in a coordinated way, with the UAV following the UGV while keeping a relative pose with respect to the UGV as long as the UGV follows a specified path, so that the UAV can land on the UGV at any desired instant. This application is conceived in a context in which the UAV has finished a package delivery task and comes back to land over a platform used as a base for the package delivery operation. Experimental results are presented, which validate the approach adopted to accomplish such a task.

18:00-18:20 WeC4.4

Adaptive Control Approaches for an Unmanned Aerial Manipulation System, pp. 498-503

Chaikalis, Dimitris — New York University Abu Dhabi
Khorrami, Farshad — New York University
Tzes, Anthony — New York University Abu Dhabi

This paper focuses on the modelling and control of Unmanned Aerial Vehicles (UAVs) equipped with robotic arms, known as Unmanned Aerial Manipulators (UAMs). The main objective is to tackle the problem of controlling the UAV independently of the robot manipulator using adaptive backstepping techniques utilizing a lower dimensional simplified model of the overall system. To this end, we derive the full dynamics of the UAM. The proposed adaptive controller results in an aerial robot capable of all motions, while keeping computations to a minimum. The system studied consists of a UAV capable of lifting large payloads, equipped with 3 Degree of Freedom (DoF) revolute robotic manipulator. The efficiency of the proposed methods is verified by simulating the designed aerial worker in various target tracking scenarios, which require simultaneous movement of all its components.

18:20-18:40 WeC4.5

A Decentralized Approach for the Aerial Manipulator Trajectory Tracking, pp. 504-511

Tlatelpa-Osorio, Y. Elizabeth — CINVESTAV-IPN
Rodriguez Cortes, Hugo — CINVESTAV-IPN
Acosta, Jose Angel — University of Seville

This work addresses the problem of controlling an Unmanned Aerial Manipulator, constrained to flight on a Cartesian plane, considering a decentralized approach. In this approach, the quadrotor dynamics is an exogenous disturbance for the manipulator and vice versa. The Unmanned Aerial Manipulator is composed of a quadrotor and a two degrees of freedom planar manipulator. The control design procedure has two steps. In the first step, it is proposed a decoupling controller to guarantee that the disturbances produced by the manipulator to the quadrotor, and vice versa, are indeed exogenous. The second step adapts a previously reported robust controller to command the quadrotor. Computed torque control is proposed to command the manipulator. The proposed solution is validated through numerical simulations and some preliminary experimental results.

WeP5 Foyer Mezzanine level

Poster Papers Session (Poster Session)

13:00-18:00 WeP5.1

Adaptive Fast Terminal Sliding Mode (FTSM) Control Design for Quadrotor UAV under External Windy Disturbances, pp. 512-516

Shi, Xiaoyu — University of Electronic Science and Technology of China
Cheng, Yuhua — University of Electronic Science and Technology of China

In this article, an adaptive fast terminal sliding mode (FTSM) control methodology is constructed for quadrotor UAV with windy disturbances. The proposed control algorithm combines the advantages of adaptive control with fast terminal sliding mode control. The fast terminal sliding mode (FTSM) control algorithm increases the speed of converge to the desired point. In addition, it guarantees the system reaches a steady state at a finite time. The Lyapunov function ensure that the system is asymptotic globally stable. In addition, the adaptive law reduces the chattering about the sliding mode control and increases the robustness of the closed-loop system. Simulation results present that this strategy have better robustness and faster transient response than the traditional sliding mode control method.

13:00-18:00 WeP5.2

Towards Long-Term Autonomy for UAS, pp. 517-522

Mersha, Abeje Yenehun — Saxion University of Applied Sciences
Reiling, Mark — Saxion University of Applied Sciences
Meijering, Rene — Saxion University of Applied Sciences

In this work, we present a generic, modular and scalable ”Replenishing Store” for Unmanned Aerial Systems (UAS). The ”Replenishing Store” is aimed at enabling UAS have Long-term autonomy, such that they can be used flexibly for multiple missions

24/7. The Replenishing Store is essentially a docking station composed of a base station, a charging module, a mission-specific swapping module and modular interfaces with the UAS. The electromechanical and software interfaces between the UAS and the docking station have been developed to be generic, such that they can be used for commercial as well as custom-made UAS. Moreover, both the charging and the swapping modules have been developed to be robust by design against pose errors during landing. The applicability of the developed "Replenishing Store" has been successfully demonstrated in a security-related application scenario.

13:00-18:00 WeP5.3

Fast Nonlinear Model Predictive Control for Very-Small Aerial Vehicles, pp. 523-528

Nascimento, Tiago — Universidade Federal Da Paraiba

Saska, Martin — Czech Technical University in Prague

Highly dynamic systems such as Micro Multirotor Aerial Vehicles (Micro-MAVs) require control approaches that enable safe operation where extreme limitations in embedded systems, such as energy, processing capability and memory, are present. Nonlinear model predictive control (NMPC) approaches can respect operational constraints in a safe manner. However, they are typically challenging to implement using embedded computers on-board of Micro-MAVs. Implementations of classic NMPC approaches rely on high-performance computers. In this work, we propose a fast nonlinear model predictive control approach that ensures the stabilization and control of Micro Multirotor Aerial Vehicles (Micro-MAVs). This aerial robotic system uses a low processing power board that relies solely on on-board sensors to localize itself, which makes it suitable for experiments in GPS-denied environments. The proposed approach has been verified in numerical simulations using processing capabilities that are available on Micro-MAVs.

13:00-18:00 WeP5.4

Controller Design for Highly Maneuverable Aircraft Technology Using Structured Singular Value and Direct Search Method, pp. 529-533

Dlapa, Marek — Tomas Bata University in Zlin

The algebraic approach is applied to the HiMAT (Highly Maneuverable Aircraft Technology) control. The objective is to find a robust controller which guarantees robust stability and decoupled control of longitudinal model of a scaled remotely controlled vehicle version of the advanced fighter HiMAT. Control design is performed by decoupling the nominal multi-input multi-output system into two identical single-input single-output plants which are approximated by a 4th order transfer function. The algebraic approach is then used for pole placement design and the nominal closed-loop poles are tuned so that the peak of the μ-function is minimal. As an optimization tool, evolutionary algorithm Differential Migration is used in order to overcome the multimodality of the cost function yielding simple controller with decoupling for nominal plant which is compared with the D-K iteration through simulations of standard longitudinal maneuvers documenting decoupled control obtained from algebraic approach for nominal plant as well as worst case perturbation.

13:00-18:00 WeP5.5

LAIDR: A Robotics Research Platform for Entertainment Applications, pp. 534-539

Elsharkawy, Ahmed — Gwangju Institute of Science and Technology

Naheem, Khawar — Gwangju Institute of Science and Technology

Lee, Yundong — Gwangju Institute of Science and Technology

Koo, Dongwoo — Gwangju Institute of Science and Technology

Kim, Mun Sang — Gwangju Institute of Science and Technology

In this paper, a Lighter Than Air Indoor Robot (LAIDR) is developed for entertainment applications. An Adaptive Propulsion Mechanism (APM) is proposed to actuate the LAIDR using the minimal number of Propulsion Units (PUs) and facilitate the variable in-mission PU configurations within the same airframe. Usually, the helium-inflated vehicle poses instability due to body inertia and indoor disturbance, i.e., air stream. Therefore, a customized control system is designed using MathWorks PX4 autopilots support from embedded coder. The designed controllers stabilize the motion by controlling PU's in-frame angle and rotational speed. Moreover, the Ultra-wide Band (UWB) sensors are used to localize the LAIDR in the indoor environment. Finally, a real-time implementation is elaborated to justify the LAIDR applicability in the entertainment applications.

13:00-18:00 WeP5.6

Research on Meteorological Technology Development Using Rotary Multicopter Unmanned Aerial Vehicles and Its Application, pp. 540-544

Chong, Jihyo — National Institute of Meteorological Sciences

Lee, Seungho — International Climate and Environment Center

Shin, Seungsook — National Institute of Meteorological Sciences

Hwang, SungEun — National Institute of Meteorological Sciences

Lee, YoungTae — National Institute of Meteorological Sciences

Kim, Seungbum — National Institute of Meteorological Sciences

In the era of the Fourth Industrial Revolution, UAVs (or drones) have become a flexible device that can be integrated with new technologies. The drones were originally developed as military unmanned aircraft and are now being used in various fields. In the weather observation area, the atmospheric boundary layer is near the surface where the atmosphere is the most active in the meteorological phenomenon and has a close influence on human activities. In order to carry out the study of these atmospheric boundary layers, it is necessary to observe precisely the lower atmosphere and secure the observation technology. The drones in the meteorological field can be used for meteorological observations at a relatively low maintenance cost compared to existing equipment. When used in conjunction with various sensors, the drones can be widely used in atmospheric boundary layer and local meteorological studies. In this study, the feasibility of meteorological observations using UAVs was confirmed by conducting vertical meteorological (temperature and relative humidity) observation experiments equipped with a radiosonde on UAVs owned by National Institute of Meteorological Sciences (NIMS).

13:00-18:00 WeP5.7

Image-Based Sense and Avoid of Small Scale UAV Using Deep Learning Approach, pp. 545-550

Huang, Zong-Ying — National Cheng Kung University
Lai, Ying-Chih — National Cheng Kung University

Distance detection of target object is an important information for obstacle avoidance in many fields, such as autonomous car. When the distance of the obstacle is calculated, one can determine the potential risk of collision. In this paper, a single camera was utilized to get the distance from an incoming unmanned aerial vehicle (UAV) using deep learning approach. The distance detection of an UAV using You Only Look Once (YOLO) object detector was proposed in this study. The region which contain the detected UAV was processed into 100 by 100 pixel and was input into the proposed model to estimate the distance of the target object. For the proposed model, a Convolutional Neural Network (CNN) was adopted to solve the regression problem. First, the feature extraction based on VGG network was performed, and then its results was applied to the distance network to estimate distance. Finally, Kalman filter was used to improve the object tracking when YOLO detector is not able to detect UAV and to smooth the estimated distance. The proposed model was trained only by using synthetic images from animation software and was validated by using both synthetic and real flight videos.

13:00-18:00 WeP5.8

Collision Avoidance of SDRE Controller Using Artificial Potential Field Method: Application to Aerial Robotics, pp. 551-556

Nekoo, Saeed Rafee — Universidad De Sevilla
Acosta, Jose Angel — Universidad De Sevilla
Ollero, Anibal — Universidad De Sevilla

This work presents the problem of collision avoidance of the state dependent Riccati equation (SDRE) controller using the artificial potential field (APF) method. Two themes were selected to illustrate the importance of the problem, collision avoidance between the end-effectors of serial links manipulators and unmanned aerial vehicles (UAVs), working in a shared workspace. The structure of the SDRE has a good potential to accommodate APF formulation in the weighting matrix of states. The distance between the end-effectors or the center-of-mass (CoM) of UAVs is penalized to autonomously guide the robots in a collision-free trajectory while they are working in a common environment. If the robots get close to each other, the weighting matrix of states increases, which actuates the systems to escape from a possible collision. Several simulation studies were done to investigate the proposed controller and the effect of collision avoidance function. It was found that the higher power of the collision avoidance function handles the threat of the impact better. The distance between robots was considered as an index to assess the performance of the controller which showed successful results in the simulations.

13:00-18:00 WeP5.9

Deep Learning Based Anomaly Detection for a Vehicle in Swarm Drone System, pp. 557-561

Ahn, Hyojung — Korea Aerospace Research Institute

In this paper, we perform the actual verification of the anomaly detection (AD) model of each drone that indicates the anomaly in swarm drone flight using the actual flight data. For this purpose, we use a model-based AD method that uses data accumulated through actual flight tests. The AD model uses a deep neural network-based generation model to create a training model with normal data and perform tests with abnormal data. As a result, the diagnostic results of mainly three cases are derived and analyzed for validity. The proposed AD method can be integrated with a machine learning based framework that can immediately detect abnormal behavior of swarm drone flights, which can be utilized to improve the reliability of swarm drone flight operations.

13:00-18:00 WeP5.10

Good Choices: Technological and Ethical Considerations to Increase Public Trust in Unmanned Aerial Systems, pp. 562-567

Coulter, Corina — University of Denver
Haring, Kerstin Sophie — University of Denver

This work discusses how public trust in Unmanned Aerial Systems (UAS, or drone) could be increased through the implementation of ethical guidelines in drone behaviors. It elaborates the challenges of transparency, ethical decisions in current drone use and potential ways forward to increase public trust before drones become ubiquitous to people's daily lives.

13:00-18:00 WeP5.11

C4ISR Systems Applied to Amazonian Constraints, pp. 568-572

Machado Figueira, Nina — Brazilian Army

Niedermeier Belmonte, Giancarlo — Brazilian Army
Pignaton de Freitas, Edison — Federal University of Rio Grande Do Sul

The state of the art of military thinking is directed towards combined operations, joint operations and mosaic warfare in a concept of interoperability. In this context, there are technological and operational challenges to deal with the vertiginous advance of data acquisition and processing platforms, sensors, communications systems and their diversity. The Amazon rainforest is one of the critical operational areas for the Brazilian armed forces, being an environment with severe constraints on mobility and communications, which directly impact on the viability of intelligence, surveillance and reconnaissance (ISR) missions. This work aims to present an architecture for Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance - C4ISR System, including the description of 4 important intelligent subsystems embedded in a Unmanned Aerial Vehicle (UAV): (1) An intelligent communication middleware from Brazilian Navy called Command and Control Interoperability (INTERC2) System; (2) the Mission-Oriented Sensors Array (MOSA)System from Brazilian Army, that automates and optimizes the data acquisition, the data fusion and the data sharing; (3) the Inflight Awareness (IFA) System from Brazilian Air Force, that provides security for UAV navigation; and a (4) Software Defined Radio System from Brazilian Ministry of Defense, that promote flexibility and interoperable communications in a Unmanned Aerial System (UAS). A case study will also be presented, describing the survey of requirements for the application of the referred proposal, in the fulfillment of (ISR) missions, in the complex Amazonian region.

13:00-18:00 WeP5.13

Towards a Social-Media Driven Multi-Drone Tasking Platform, pp. 573-581

Terzi, Maria — University of Cyprus
Kolios, Panayiotis — University of Cyprus
Panayiotou, Christos — University of Cyprus
Theocharides, Theocharis — University of Cyprus

We present a framework for utilizing social media for tasking drone swarms in search and rescue missions. As elaborated in this work, social media are a source of timely and valuable information regarding the occurrence, the evolution and the damage produced in disasters. Exploiting this source of knowledge can be very valuable in planning search and rescue missions and identifying tasks to be conducted. In this work a novel multi-drone search and rescue framework is developed that considers social-media signals in the creation of search tasks. The key design challenges of implementing the proposed framework are discussed and a simulated scenario based on a real-life Twitter data set is presented as a means of providing evidence of the effectiveness of the proposed framework.

13:00-18:00 WeP5.14

Control System Design for Hybrid Power Supply of an Unmanned Aerial Vehicle Based on Linearized Averaged Process Models, pp. 582-587

Krznar, Matija — University of Zagreb
Pavkovic, Danijel — University of Zagreb
Kozhushko, Yuliia — Igor Sikorsky Kyiv Polytechnic Institute
Cipek, Mihael — University of Zagreb
Zorc, Davor — University of Zagreb
Crneković, Mladen — University of Zagreb

The paper presents the hybrid propulsion control system design for a multi-rotor unmanned aerial vehicle (UAV) equipped with internal combustion engine (ICE) and generator as a primary energy source and direct-current (DC) power system with DC/DC buck converters controlling the input voltage of propeller electrical drives. Control system design is based on averaged linearized process models of the engine-generator set and buck converter, and utilization of damping optimum criterion, with control systems featuring proportional-integral (PI) feedback controllers augmented with feed-forward load compensators. The overall control system is validated by means of simulations within MATLAB/Simulink environment.

13:00-18:00 WeP5.15

Flight Controller Optimization of Unmanned Aerial Vehicles Using a Particle Swarm Algorithm, pp. 588-593

Gomez Redondo, Nicolas Alberto — Laboratorio De Sistemas De Potencia Y Control
Gomez Valenzuela, Victor Sebastián — Universidad Nacional De Asunción
Paiva, Enrique — Universidad Nacional De Asunción
Rodas, Jorge — Universidad Nacional De Asunción
Gregor Recalde, Raul Igmar — Universidad Nacional De Asunción

In this paper, a simultaneous calibration algorithm of the parameters of the attitude and altitude control for an unmanned aerial vehicle (UAV) is proposed. The algorithm is based on the multi-objective particle swarm optimization (MOPSO) technique. This algorithm is implemented by using the free PX4 software for the Pixhawk2 controller. The behavior of the UAV is simulated given its physical characteristics by means of a non-linear model and a search of the controller parameters. This latter is based on a proportional (P) position controller in cascade with a proportional-integral-derivative (PID) speed controller of its height and each

one of its Euler angles. To perform this search, the PID gains Kp1,Kp2, Ki and Kd of each of the degrees of freedom are used to define vectors considered particle positions by the MOPSO algorithm, which moves them through a search space to find sets of optimum values according to Pareto, or the Pareto Front. The search is carried out based exclusively on Pareto dominance concepts, comparing parameters of step responses (overshoot, rise time, root-mean-square error) of each of the degrees of freedom. In order to show the efficiency of the proposal, simulation results are provided by using the calibration methodology obtaining good results.

13:00-18:00 WeP5.16

A Probabilistic Based UAV Mission Planning and Navigation for Planetary Exploration, pp. 594-599

Galvez, Julian	Queensland University of Technology
Gonzalez, Luis Felipe	Queensland University of Technology
Vanegas Alvarez, Fernando	Queensland University of Technology
Flannery, David Timothy	Queensland University of Technology

The use of Unmanned Aerial Vehicles (UAVs) for Search and Rescue (SAR), powerlines, air quality and other applications is increasing. Their use has also been considered for planetary exploration (e.g. Mars, Titan). One exciting development in UAVs is a test planned by NASA of an unmanned helicopter in the atmosphere of Mars; this aims to establish a new dimension and direction for the planetary exploration field. Future missions will require advanced navigation tools supporting mission planning. The autonomy of UAVs systems will continue to grow for Earth applications supported by mathematical tools, models and formulations that help the UAV to deal with critical aspects of the mission. Planetary exploration is challenging and is influenced by different levels of uncertainty in UAV localization and the environment itself. Probabilistic navigation allows planning with uncertainty. This paper presents a high-level mission planning and navigation architecture for planetary exploration based on Partially Observable Markov Decision Process (POMDP). We focus on planetary exploration missions for biosignature detection. The paper presents a mission planning architecture and describes the results of a POMDP-based navigation and target finding module emulating biosignatures with ArUco markers in a Mars simulated environment.

Thursday September 3, 2020

ThA1 Macedonia Hall

See-And-Avoid Systems I (Regular Session)

10:00-10:20 ThA1.1

A Novel Technique for Rejecting Non-Aircraft Artefacts in above Horizon Vision-Based Aircraft Detection, pp. 600-606

James, Jasmin	Queensland University of Technology
Ford, Jason	Queensland University of Technology
Molloy, Timothy L.	University of Melbourne

Unmanned aerial vehicle (UAV) operations are steadily expanding into many important applications. A key technology for better enabling their commercial use is an onboard sense and avoid (SAA) technology which can detect potential mid-air collision threats in the same manner expected from a human pilot. Ideally, aircraft should be detected as early as possible whilst maintaining a low false alarm rate, however, textured clouds and other unstructured terrain make this trade-off a challenge. In this paper we present a new technique for the modelling and detection of small to medium fixed-wing aircraft above the horizon that is able to penalize non-aircraft artefacts (such as textured clouds and other unstructured terrain). We evaluate the performance of our proposed system on flight data of a Cessna 172 on a near collision course encounter with a ScanEagle UAV data collection aircraft. By penalizing non-aircraft artefacts we are able to demonstrate, for a zero false alarm rate, a mean detection range of 2445m corresponding to an improvement in detection ranges by 9.8% (218m).

10:20-10:40 ThA1.2

Collision Detection and Avoidance System for Multicopter UAVs Using Optical Flow, pp. 607-614

Urieva, Natallia	California State Polytechnic University, Pomona
McDonald, Jeffrey	California State Polytechnic University, Pomona
Ramos, April Sandy Rose	California State Polytechnic University, Pomona
Uryeva, Tatsiana	Mt. San Antonio Community College
Bhandari, Subodh	California State Polytechnic University, Pomona

This paper presents the collision avoidance system for multicopter UAVs for autonomous navigation around obstacles using a simple camera as a main sensor and optical flow as the primary machine vision technique for obstacle detection. This is a very affordable and easily accessible combination to be used on UAVs of any type. Optical flow is a method that is used to detect the motion of pixels between pairs of images. If the clusters of like-colored pixels of an object move in a similar direction, the object is in a relative motion. An S1000 Octocopter was used as a test platform for the project. The vehicle is equipped with a Pixhawk 2 flight controller for autonomous navigation. Intel NUC processor was used as an onboard flight computer to process the video input from the sensor (camera) for collision detection, and to run the collision avoidance algorithms. The developed algorithm was tested in multiple flight tests in a flight test site with both natural and man-made obstacles present. Prior to flight tests, the algorithm was tested in simulation. Simulation and flight test results are shown.

10:40-11:00	ThA1.3

Hybrid Motion-Based Object Detection for Detecting and Tracking of Small and Fast-Moving Drones, pp. 615-621

Srigrarom, Sutthiphong — National University of Singapore
Chew, Kim Hoe — Technical University of Munich

A hybrid detecting and tracking system that is made especially for small and fast-moving drones in which the other existing techniques cannot detect is presented. This new automatic system integrates geometry estimation, 2D object detection, 3D localization, trajectory estimation and tracking for dynamic scene interpretation. This caters to moving cameras, e.g. those mounted on a separate flying platform. The technique is built on the unified two-step real-time algorithm for detection and tracking of moving objects (DATMO) in dynamic outdoor environments. The first step is built on the motion-based detection approach for early detection of an object when the targeted object is still far away and appears very small in the scene. The second step is based on the appearance-based detection approach for continual detection, further identification and verification of the object. The camera's own position is estimated by 3D triangulation of the static landscape in the scene, doubled up as ground truth. This includes both the pan-tilt-zoom motion and the camera's vibration compensation. Therefore, the drone can be tracked, even when the camera is in motion and/or under jittery condition. As a result, the position of the tracked drone in the global inertial coordinate is further improved. Subsequently, the drone motion is tracked using the Extended Kalman Filter scheme. Initial results show that this hybrid system is able to detect a small drone from a distance away in less than a few frames after such a drone appears in the scene. The drone is always tracked as long as it is in the camera's field of view. As this technique is vision-based, this drone detection and tracking system can expand to detect multiple drones.

11:00-11:20	ThA1.4

LiDAR Imaging-Based Attentive Perception, pp. 622-626

Tsiourva, Maria — University of Nevada, Reno
Papachristos, Christos — University of Nevada, Reno

In this paper we present a novel approach on attentive robotic perception by developing a saliency model on LiDAR imaging. Modern LIDAR sensors provide access to a multitude of structured images, namely intensity, reflectivity, ambient, and range. These images can in turn be fused and a saliency model can be developed in a manner analogous to the human attentive system but tailored to the uniqueness of LiDAR perception. The derived LiDAR-based saliency model exploits a bottom-up approach according to which the reflectivity, intensity, range, and ambient images are compared to each other and through a sequence of image processing steps multiple conspicuity maps are acquired which in turn give rise to a unified saliency map that efficiently encodes which objects are most important and worth further analysis. This attentive perception system on LiDAR imaging gives rise to efficient obstacle detection for robotic systems that provides 360deg coverage and allows millisecond-order execution times on embedded processors. The derived model is experimentally evaluated on a set of datasets from ground and flying robots.

11:20-11:40	ThA1.5

Monocular Vision-Based Obstacle Avoidance Trajectory Planning for Unmanned Aerial Vehicles, pp. 627-632

Zhang, Zhouyu — Nanjing University of Aeronautics and Astronautics
Zhang, Youmin — Concordia University
Cao, Yunfeng — Nanjing University of Aeronautics and Astronautics

Monocular vision has become a promising sensing method for Unmanned Aerial Vehicle (UAV) Sense and Avoid (SAA), with the advantages of low cost and small size. However, obstacle perception capability of monocular vision is limited due to the restriction of optical imaging properties, which have significant influence on avoidance trajectory planning. By considering the characteristics of monocular vision-based optical measurement, a receding horizon-based collision avoidance trajectory planning algorithm is proposed for eliminating the hazard of both static and dynamic obstacles in this paper. This paper aims at dealing with two core problems: 1) how to localize obstacle via monocular vision; 2) how to generate a collision free trajectory with partially observed obstacle information obtained by monocular vision. To solve the first problem, monocular vision-based optical measurement for obstacle estimation is firstly analyzed and orthogonal iteration-based localization is further adopted. To solve the second problem, with the constraints containing obstacle avoidance and UAV aerodynamics, a receding horizon-based collision-free trajectory planning method is proposed. Simulation results demonstrate the algorithm proposed in this paper increases the safety level of UAV and is capable of avoiding both static and dynamic obstacles.

11:40-12:00	ThA1.6

Obstacle Detection and Avoidance System for Small UAVs Using a LiDAR, pp. 633-640

Moffatt, Andrew — California State Polytechnic University, Pomona
Platt, Eric — California State Polytechnic University, Pomona
Mondragon, Brandon — California State Polytechnic University, Pomona
Kwok, Aaron — California State Polytechnic University, Pomona
Uryeu, Dzianis — Walnut High School
Bhandari, Subodh — California State Polytechnic University, Pomona

This paper presents the obstacle detection and avoidance system for a multicopter UAV. A Velodyne VLP-16 LiDAR is used for obstacle detection. The LiDAR generates a 360° view of the environment around the multicopter, enabling the multicopter to navigate around any obstacles in any direction. An Intel NUC processor is used as an onboard flight computer, which processes the LiDAR

data and obstacle avoidance algorithm. The flight computer communicates with the flight controller (Pixhawk2 autopilot) using a Python library called DroneKit to send the obstacle avoidance commands. This results in the multicopter safely navigating around obstacles autonomously. Simulation and ground test results are shown.

ThA2	Kozani
Path Planning IV (Regular Session)	

10:00-10:20	ThA2.1

A Risk-Based Path Planning Strategy to Compute Optimum Risk Path for Unmanned Aircraft Systems Over Populated Areas, pp. 641-650

Primatesta, Stefano	Politecnico Di Torino
Scanavino, Matteo	Politecnico Di Torino
Guglieri, Giorgio	Politecnico Di Torino
Rizzo, Alessandro	Politecnico Di Torino

The large diffusion of Unmanned Aircraft Systems (UAS) requires a suitable strategy to design safe flight missions. In this paper, we propose a novel path planning strategy to compute optimum risk path for UAS over populated areas. The proposed strategy is based on a variant of the RRT* (Rapidly exploring Random Tree "Star") algorithm, performing a risk assessment during the path planning phase. Like other RRT-based algorithms, the proposed path planning explores the state space by constructing a graph. Each time a new node is added to the graph, the algorithm estimates the risk level involved by the new node, evaluating the flight direction and velocity of the UAS placed in the analyzed node. The risk level quantifies the risk of flying over a specific location and it is defined using a probabilistic risk assessment approach taking into account the drone parameters and environmental characteristics. Then, the proposed algorithm computes an asymptotically optimal path by minimizing the overall risk and flight time. Simulation results in realistic environments corroborate the proposed approach proving how the proposed risk-based path planning is able to compute an effective and safe path in urban areas.

10:20-10:40	ThA2.2

Optimal Mission Planning for Fixed-Wing UAVs with Electro-Thermal Icing Protection and Hybrid-Electric Power Systems, pp. 651-660

Narum, Edvard Frimann Løes	Norwegian University of Science and Technology
Hann, Richard	Norwegian University of Science and Technology
Johansen, Tor Arne	Norwegian University of Science and Technology

Harsh weather conditions such as wind and icing are severe debilitators to the operations of unmanned aerial vehicles in terms of performance, safety and reliability. Forecasts of atmospheric parameters in the mission area can open many options in terms of how to best traverse said environment. The use of hybrid electric propulsion systems in such vehicles significantly alter operational flexibility and range, and subsequently the versatility of the platform, but they are equally vulnerable to atmospheric conditions. This work will show that taking meteorological forecasts into account when performing path planning optimization on such a platform can lead to improvements in energy efficiency of up to 43% or reduce the flight time between two points by up to 42%, when compared to a standard, straight cruising flight.

10:40-11:00	ThA2.3

Cooperative Path Planning for Multiple MAVs Operating in Unknown Environments, pp. 661-667

Ahmad, Afzal	Czech Technical University in Prague
Vonasek, Vojtech	Czech Technical University in Prague
Saska, Martin	Czech Technical University in Prague

In recent years, Micro Aerial Vehicles (MAVs) have become widely available and are successfully used in many real scenarios. While the early applications like surveillance mostly utilized single MAVs or a group of multiple, yet non-cooperative MAVs, recent research is more focused on a group of cooperating MAVs. A typical example is the payload transport task, where multiple MAVs carry a single object. This problem has been studied mainly from the control theory point of view, providing robust control to cooperating MAVs using the dynamics of the whole system. Real applications, however, require operating in unknown environments with obstacles, which needs motion planning. In this paper, we propose a novel motion planning method for multiple MAVs operating in unknown environments. The proposed work is based on the Sensor-based Random Trees method (SRT), which was originally intended for exploration of unknown environments. We extend the method for online path planning of multi MAVs. In the proposed method, each MAV makes a motion plan and exchanges key waypoints with other MAVs to ensure that their mutual positions satisfy the mission constraints. The performance of the method is demonstrated in various simulation experiments.

11:00-11:20	ThA2.4

Exploring the Use of Reverse Thrust in a Dynamic UAS Landing Maneuver Using Kinodynamic RRT, pp. 668-675

Givens, Matthew	University of Colorado Boulder
Coopmans, Calvin	Utah State University

The concept of reversing the direction of the main propeller (and thereby the thrust) of an electric, fixed wing unmanned aerial system (UAS) during landing maneuvers is examined in this paper. The physical performance of a propeller and motor combination is first

tested using a custom thrust test bench. A two-dimensional simulation of a fixed-wing UAS is then created using a nonlinear dynamics model and the dynamics are used in a Rapidly Exploring Random Tree (RRT) algorithm to search for feasible trajectories and their necessary control inputs. The possible usefulness of the reverse thrust maneuver is then demonstrated and shown in simulation with favorable results.

11:20-11:40 ThA2.5

A Recurrent Planning Strategy for UAV Optimum Path Identification in a Dynamic Environment Based on Bit-Coded Flight Maneuvers, pp. 676-685

Bassolillo, Salvatore — University of Campania
Blasi, Luciano — Università Degli Studi Della Campania "L.Vanvitelli"
D'Amato, Egidio — University of Naples "Parthenope"
Mattei, Massimiliano — Seconda Università Di Napoli
Notaro, Immacolata — University of Campania "Luigi Vanvitelli"

The applicability of a novel algorithm identifying optimal paths for Unmanned Aerial Vehicles in 2-D dynamic environments has been preliminarily assessed in this paper. Optimality is evaluated taking path length or flight time as objective functions. Flight trajectories, compliant with both air vehicle and environmental constraints, are made up of a finite number of circular arcs and straight lines. Such a geometrical sequence is converted into a finite sequence of two bit-coded basic flight maneuvers. Identification of optimum path is obtained coupling such a maneuvering model with a Particle Swarm Optimizer (PSO). To deal with the problem of a dynamic environment a recurrent planning strategy has been developed. Following this approach, final path is obtained by performing both the path planning and the path tracking phase within a series of constant time windows. While the air vehicle is tracking the current sub-optimal trajectory, the algorithm identifies a new sub-optimal trajectory, based on the obstacles estimated position at the end of the current time window, that will be tracked by the air vehicle in the next time window. This way, the computed path turns out to be a piecewise sequence of sub-optimal trajectories reaching the destination point. The identification of obstacles future position is carried out by the algorithm only by monitoring their current position. To test the effectiveness of the proposed flight path planner, we set different 2-D scenarios with obstacles having both constant and variable speed.

11:40-12:00 ThA2.6

Exploiting Null Space in Aerial Manipulation through Model-In-The-Loop Motion Planning, pp. 686-693

Ivanovic, Antun — University of Zagreb
Car, Marko — University of Zagreb
Orsag, Matko — University of Zagreb
Bogdan, Stjepan — University. of Zagreb

This paper presents a method for aerial manipulator end-effector trajectory tracking by encompassing dynamics of the Unmanned Aerial Vehicle (UAV) and null space of the manipulator attached to it in the motion planning procedure. The proposed method runs in phases. Trajectory planning starts by not accounting for roll and pitch angles of the underactuated UAV system. Next, we propose simulating the dynamics on such a trajectory and obtaining UAV attitude through the model. The full aerial manipulator state obtained in such a manner is further utilized to account for discrepancies in planned and simulated end-effector states. Finally, the end-effector pose is corrected through the null space of the manipulator to match the desired end-effector pose obtained in trajectory planning. Furthermore, we have applied the TOPP-RA approach on the UAV by invoking the differential flatness principle. Finally, we conducted experimental tests to verify effectiveness of the planning framework.

ThA3 Edessa

UAS Applications I (Regular Session)

10:00-10:20 ThA3.1

UAV Target Tracking in Urban Environments Using Deep Reinforcement Learning, pp. 694-701

Bhagat, Sarthak — IIIT Delhi
P B, Sujit — IISER Bhopal

Persistent target tracking in urban environments using UAV is a difficult task due to the limited field of view, visibility obstruction from obstacles, and uncertain target motion. The vehicle needs to plan intelligently in 3D such that the target visibility is maximized. In this paper, we introduce Target Following DQN (TF-DQN), a deep reinforcement learning technique based on Deep Q-Networks with a curriculum training framework for the UAV to persistently track the target in the presence of obstacles and target motion uncertainty. The algorithm is evaluated through simulations. The results show that the UAV tracks the target persistently in diverse environments while avoiding obstacles on the trained environments as well as on unseen environments.

10:20-10:40 ThA3.2

Autonomous Airborne Multi-Rotor UAS Delivery System, pp. 702-708

Jackson, Seth — US Army
Riccoboni, Nena — United States Military Academy
Abdul Rahim, Abdul Halim — USMA
Tobin, Ronald — United States Military Academy

Bluman, James — United States Military Academy
Kopeikin, Andrew — US Military Academy
Manjunath, Pratheek — United States Military Academy
Prosser, Ekaterina — US Army

Within current combat environments, there is a demand for rapid and extremely precise re-supply missions. Typical combat airdrops require long periods of planning and can produce a large signature in an operating environment which relies on stealth for various mission sets. Team Hermes, made up of four members from the West Point graduating class of 2019, offers a new re-supply method to answer this demand. The design will allow for the delivery of a quadcopter carrying 1.5 pounds of cargo within a 5-meter radius of an impact point on the ground. Each quadcopter is first transported via a wooden dispenser which is linked to the Air Force's Joint Precision Airdrop System (JPADS). JPADS is executed with a C-130. The dispenser payload is loaded into the back of the aircraft, and upon command, is dropped to route toward the impact point. JPADS descends and the dispenser releases the drones once it reaches a target altitude and proximity. The team worked through an extensive design process and developed a system capable of achieving the mission with autonomy. Through calculated testing procedures, Team Hermes achieved success and proved the capability to autonomously deliver the microlight payload to within 5 meters of a waypoint on the ground.

10:40-11:00 ThA3.3

Autonomous Wind Turbine Inspection Using a Quadrotor, pp. 709-715

Gu, Weibin — University of Denver
Hu, Dewen — Shanghai FOIA Co
Cheng, Liang — Shanghai FOIA Co
Cao, Yabing — Shanghai FOIA Co
Rizzo, Alessandro — Politecnico Di Torino
Valavanis, Kimon P. — University of Denver

There has been explosive growth of wind farm installations in recent years due to the fact that wind energy is gaining worldwide popularity. However, the maintenance of these offshore or onshore wind turbines, especially in remote areas, remains a challenging task. In this work, vision-based autonomous wind turbine inspection using a quadrotor is designed based on realistic assumptions. Both simulation and Hardware-In-the-Loop (HIL) testing results have shown the effectiveness of the proposed approach.

11:00-11:20 ThA3.4

Outdoor Navigation Using Two Quadrotors and Adaptive Sliding Mode Control, pp. 716-721

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

In this work, a solution to outdoor trajectory tracking using quadrotors is presented. The unmanned aerial vehicles (UAVs) navigate under the leader-follower formation, where the pose of the leader is estimated using its onboard sensors, and the pose of the follower by position-based visual servoing. To handle the outdoor environment perturbations, unmodeled vehicle dynamics, and dynamic disturbances caused by wind and varying lightning conditions, a robust sliding mode controller is used. The proposal is experimentally validated using two Parrot Bebop 2 quadrotors in an outdoor scenario. The obtained results allow concluding that the proposed control system is able to accomplish trajectory tracking under parametric uncertainties and real-world disturbances.

11:20-11:40 ThA3.5

Barrier Lyapunov Function Based Trajectory Tracking Controller for Autonomous Vehicles with Guaranteed Safety Bounds, pp. 722-728

Kumar, Yogesh — IIIT Delhi
Roy, Sayan Basu — IIIT Delhi
P B, Sujit — IISER Bhopal

Accurate trajectory tracking is essential in many applications involving autonomous vehicles. However, due to the coupled nonlinear dynamics of the vehicle and external disturbances, this may not be the case. This paper presents a Barrier Lyapunov Function (BLF) based trajectory tracking controller design technique for autonomous vehicles with task-specific constrained state requirements. A BLF candidate is introduced based on the constraints and using the Lyapunov direct method a controller is designed which guarantees that the tracking errors remain within the defined bounds. The proposed technique is demonstrated on two applications. In the first scenario, we consider a trajectory tracking problem with a safety bound (circle) around the desired trajectory and in the second we consider a moving target tracking problem using an unmanned aerial vehicle (UAV) with guaranteed visibility. The simulation results along with the software-in-the-loop (SITL) results show the adaptability of the proposed method to various applications.

11:40-12:00 ThA3.6

POSITRON: Lightweight Active Positioning Compliant Joints Robotic Arm in Power Lines Inspection, pp. 729-736

Perez Jimenez, Manuel — University of Seville
Montes Grova, Marco Antonio — University of Seville

Ramon Soria, Pablo | University of Seville
Arrue, B.C. | University of Seville
Ollero, Anibal | University of Seville

This paper presents the design and implementation of a compliant lightweight manipulator with a special end-effector to attach to powerlines. The manipulator can be mounted in aerial robots allowing to compute its relative position from the contact point. The purpose of this device is to obtain an estimate of the UAV's position to close the control loop. Controlling the position of the UAV close to the powerline enables a new wide range of inspection and maintenance tasks in this infrastructure. The article describes the model of the positioning tool and the sensors it uses to provide the necessary information for the UAV controller. It can be built using additive manufacturing techniques and its components are low-cost and available in common robotic stores so anyone can reproduce and use it. Validation experiments have been carried out in an OptiTrack system as ground-truth.

ThA4 Naousa
Control Architectures IV (Regular Session)

10:00-10:20 ThA4.1

Robust Geometric Control of a Helicopter Using Sliding Mode Control, pp. 737-743

B Krishna, Akhil | IIT Kanpur
Sen, Arijit | IIT Kanpur
Kothari, Mangal | IIT Kanpur

This paper presents a robust attitude controller for a small-scale helicopter based on sliding mode control theory. The attitude dynamics is considered to be evolving on non-Euclidean space to develop a globally defined controller. The attitude of fuselage is represented by the rotation matrix. An interconnected hybrid model of a helicopter is considered to be consisting of fuselage modeled as a single rigid body and rotor modeled as a disc whose flapping motion is represented by first order dynamics. It is assumed that an unknown disturbance is acting on the rotor. Sliding mode theory is employed to develop a robust controller assuming that the bound of external disturbance is known. The convergence of controller is shown by using Lyapunov theory. The performance of proposed approach is demonstrated through numerical simulations.

10:20-10:40 ThA4.2

Load Manipulation by a Triangular Formation of Quadrotors, pp. 744-753

Ernandes-Neto, Valentim | Federal University of Espirito Santo
Brandao, Alexandre Santos | Federal University of Vicosa
Sarcinelli-Filho, Mário | Federal University of Espirito Santo

This work discusses a trajectory tracking task accomplished by a group of three Bebop 2 quadrotors working cooperatively to transport a load. Such unmanned aerial vehicles (UAVs) are considered as a triangular formation, and the load, a triangle-shaped structure, is attached to them through massless flexible cables. The reason to use three quadrotors is the gain in terms of the payload capability and the stability of the load, since it is attached to three vehicles, staying vertically aligned with the center of mass of the triangle correspondent to the formation. A formation controller, actually a kinematic controller applied to a virtual massless robot correspondent to the center of mass of the triangle, is adopted, which generates reference velocities for the three UAVs, whose movement generates the movement and reshaping of the triangular formation. Then, individual dynamic compensators are adopted for each UAV, whose input is the reference velocity delivered by the formation controller. Finally, experimental results are discussed, which validate the proposal.

10:40-11:00 ThA4.3

Omni-Plus-Seven (O+7): An Omnidirectional Aerial Prototype with a Minimal Number of Uni-Directional Thrusters, pp. 754-761

Hamandi, Mahmoud | LAAS-CNRS
Sawant, Kapil | IIT
Tognon, Marco | ETH Zurich
Franchi, Antonio | University of Twente

The aim of this paper is to present the design of a novel omnidirectional Unmanned Aerial Vehicle (UAV) with seven unidirectional thrusters, called O+7. The paper formally defines the O+ design for a generic number of propellers and presents its necessary conditions; then it illustrates a method to optimize the placement and orientation of the platform's propellers to achieve a balanced O+ design. The paper then details the choice of the parameters of the O+7 UAV and highlights the required mechanical and electrical components. The resultant platform is tested in simulation, before being implemented as a prototype. The prototype is firstly static bench tested to match its nominal and physical models, followed by hovering tests in multiple orientations. The presented prototype shows the ability to fly horizontally, upside down and at a tilted angle.

11:00-11:20 ThA4.4

Scaling Effects on Controllers for Multirotors, pp. 762-770

Thai, Lam Ngoc | McGill University
Nahon, Meyer | McGill University

Charland-Arcand, Guillaume — ARA Robotics

Multirotors are complex non-linear systems with controllers containing multiple control loops. The control gains can be difficult to tune, and these gains in turn can be substantially different for multirotors of different sizes. This research develops a method to adapt the control gains tuned for a multirotor of one size to another multirotor of a different size, using the Buckingham Pi Theorem. The theory was first validated by considering a multirotor and its theoretically scaled counterpart such that the two multirotors are precisely similar, i.e., the second quadrotor is an exact scaled version of the first. The results showed that the relationship between a multirotor's physical parameters and its control gains was accurately captured by the Buckingham Pi Theorem. Two more realistic multirotors were then studied to determine an appropriate method to estimate the control gains for these dissimilar systems of different sizes. The results show that the proposed approach provides a simple yet rigorous approach to map the control gains between two multirotors of different sizes.

11:20-11:40 — ThA4.5

Vision-Based Autonomous Landing Using an MPC-Controlled Micro UAV on a Moving Platform, pp. 771-780

Mohammadi, Alireza — University of Michigan-Dearborn
Feng, Yi — University of Michigan-Dearborn
Zhang, Cong — University of Michigan-Dearborn
Rawashdeh, Samir — University of Michigan-Dearborn
Baek, Stan — United States Air Force Academy

Autonomous landing of micro unmanned aerial vehicles (UAVs) on moving targets has the potential to resolve many limitations of small-scale UAVs, such as uninterrupted flight tasks, rapid deployment and recovery of multiple UAVs, and extended operational ranges through mobile recharging stations. In this work, we present and experimentally verify a new vision-based method that enables a micro UAV to land autonomously on a mobile landing platform. Our method, which can be implemented on small-scale UAVs with limited payload capabilities and computational resources, incorporates model predictive control, vision-based localization, and extended Kalman filter for path following, navigation, and guidance. Our method uses a closed loop controlled gimbaled camera for visual navigation and relative localization of the landing platform, a sensor fusion technique based on extended Kalman filters for target localization, and a model predictive control scheme for autonomous landing of the UAV under system uncertainties and wind disturbances. We demonstrate flight experiments of autonomous landing with an average error of 39 cm from the center of a mobile platform.

ThB1 — Macedonia Hall

See-And-Avoid Systems II (Regular Session)

15:00-15:20 — ThB1.1

Experimental Comparison of Fiducial Markers for Pose Estimation, pp. 781-789

Kalaitzakis, Michail — University of South Carolina
Carroll, Sabrina — University of South Carolina
Ambrosi, Anand — University of South Carolina
Whitehead, Camden — University of South Carolina
Nikolaos, Vitzilaios — University of South Carolina

Accurate localization is crucial for the autonomous navigation and control of Unmanned Aircraft Systems (UAS). In most applications, localization is provided from a Global Navigation Satellite System like GPS and Galileo or more recently from Visual Odometry, Visual-Inertial Odometry, and Simultaneous Localization and Mapping methods. In many cases though, especially when precise maneuvers are required, fiducial markers are used. Fiducial markers are able to provide accurate localization data and have been used in many applications where reliable pose measurements are needed for specific objects or locations. This paper presents an experimental comparison of four different open-source fiducial markers that are widely used in UAS applications (ARTag, AprilTag, ArUco, and STag). The fiducial markers are evaluated based on their localization capabilities as well as their computational efficiency. To facilitate the comparison, a ROS package for the STag marker is developed and publicly released.

15:20-15:40 — ThB1.2

Point Cloud-Based Target-Oriented 3D Path Planning for UAVs, pp. 790-798

Zheng, Zhaoliang — University of California Los Angeles
Bewley, Thomas R. — University of California San Diego
Kuester, Falko — University of California San Diego

This paper explores 3D path planning for unmanned aerial vehicles (UAVs) in 3D point cloud environments. Derivative maps such as dense point clouds, mesh maps, octomaps, etc. are frequently used for path planning purposes. A target-oriented 3D path planning algorithm, directly using point clouds to compute optimized trajectories for a UAV, is presented in this article. This approach searches for obstacle-free, low computational cost, smooth, and dynamically feasible paths by analyzing a point cloud of the target environment, using a modified connect RRT-based path planning algorithm, with a k-d tree-based obstacle avoidance strategy and three-step optimization. This presented approach bypasses the common 3D map discretization, directly leveraging point cloud data. Following trajectory generation, the algorithm creates waypoint based, closed-loop quadrotor controls for pitch, roll, and yaw attitude angle as well as dynamics commands for the UAV. Simulations of UAV 3D path planning based on different target points in the point

cloud map are presented, showing the effectiveness and feasibility of this approach.

15:40-16:00 ThB1.3

Intercepting a Target Moving on a Racetrack Path, pp. 799-806

Manyam, Satyanarayana Gupta — Infoscitex Corporation

Casbeer, David — Air Force Research Laboratories

We consider a continuous monitoring application where multiple agents coordinate their positions while traveling along a racetrack. In practice, agents may need to leave the loop for maintenance or recharging, and a new agent has to take its place. The focus of this paper is on the off-the-loop planner that generates a path back to the racetrack, such that the agent arrives to the loop at the appropriate (moving) point with the shortest possible path. Assuming the distance from pursuer's initial position to any location on the racetrack is greater than four times the turn radius of that agent, we develop a planner to find the shortest path that intercepts the moving point on the racetrack and satisfies the agent's kinematic constraints. To develop this planner, Dubins paths are considered, and we present algorithms to find the intercepting path to a point moving on a straight line or a circular arc. These algorithms are integrated together to find the path that intercepts a target moving in the racetrack pattern. We prove that the algorithm finds the optimal solution and demonstrate the results with a few examples.

16:00-16:20 ThB1.4

Mono-LSDE: Lightweight Semantic-CNN for Depth Estimation from Monocular Aerial Images, pp. 807-814

Astudillo Olalla, Armando — Universidad Carlos III De Madrid

Al-Kaff, Abdulla — Universidad Carlos III De Madrid

Madridano, Angel — Universidad Carlos III De Madrid

García Fernández, Fernando — Universidad Carlos III De Madrid

Martín Gómez, David — Universidad Carlos III De Madrid

de La Escalera, Arturo — Universidad Carlos III De Madrid

In the last decade, with the advances in autonomous technologies, Unmanned Aerial Vehicles (UAVs) have been encountered a significant focus on several applications. With the complexity of the tasks performed by the UAVs, this addresses the necessity to obtain information about the surrounding environment. Estimating depth maps from monocular images is considered a key role when working small or micro UAVs, this is due to the Size, Weight, and Power (SWaP) constraints on these vehicles. Therefore, this paper proposed a lightweight Semantic Neural Network based on Encoder-Decoder architecture; to obtain a depth map from a monocular camera. The proposed method has been tested in several scenarios of complex environments, and the obtained results show its robustness and efficiency against different weather and light conditions, illustrating the functionality of the proposed method in real-time applications.

16:20-16:40 ThB1.5

Obstacle Avoidance Manager for UAVs Swarm, pp. 815-821

Madridano, Angel — Universidad Carlos III De Madrid

Al-Kaff, Abdulla — Universidad Carlos III De Madrid

Flores Peña, Pablo — Drone Hopper S.L

Martín Gómez, David — Universidad Carlos III De Madrid

de La Escalera, Arturo — Universidad Carlos III De Madrid

Multi-Robot Systems for a swarm of autonomous UAVs are critical in providing essential solutions to numerous applications. However, working in complex environments requires higher levels of safety in navigation. One of the problems is the detection and avoidance of static and dynamic obstacles that appear in the UAVs paths. In this paper, two complementary methods are presented; to provide safe autonomous navigation of a swarm of UAVs. On the one hand, a method based on the Velocity Obstacle (VO) is responsible for avoiding collisions between the UAVs of the swarm by decreasing the velocity of the UAVs when they approach the same location. This method has the advantage of reducing the use of UAV resources and computational time. On the other hand, a method based on Light Detection and Ranging (LiDAR) information and Probabilistic Roadmaps (PRM) allows detecting dynamic obstacles appear in the path, exploring the environment in search of alternative paths, and finally establishing the one that minimizes the distance, and allows reaching a location avoiding the detected obstacles. The proposed methods have been tested and validated in simulation environments; as a previous step to their implementation in real UAVs. Moreover, the obtained results show the robustness and the efficiency of the system in detecting and avoiding the possible collisions.

16:40-17:00 ThB1.6

From Simulation to Reality: A Implementable Self-Organized Collision Avoidance Algorithm for Autonomous UAVs, pp. 822-831

Casas Melo, Victor Fernando — Technische Universität Ilmenau

Mitschele-Thiel, Andreas — Technische Universität Ilmenau

We present an implementable self-organized collision avoidance algorithm for UAVs (Unmanned Aerial Vehicle). The algorithm generates roundabouts to avoid collisions. It also calculates a safe reaction distance to start the collision avoidance maneuver based on relative velocity, UAV acceleration, communication frequency, and GPS inaccuracy. We also present our experimental testbed for autonomous UAVs, in which we have designed, developed, and validated the collision avoidance algorithm. The developed testbed comprises a modular architecture that includes a simulation environment, a set of real autonomous UAVs, and communication hardware. This architecture allows us to improve realistic models in the simulation and to test the same implementation in simulation as well as in real UAVs. We validate our collision algorithm in simulation and experiment and analyze in which conditions both results are similar and in which ones differ.

ThB2	Kozani
Safety, Security, and Reliability (Regular Session)	

15:00-15:20	ThB2.1

Adaptive Fault-Tolerant Control of a Quadrotor Helicopter Based on Sliding Mode Control and Radial Basis Function Neural Network, pp. 832-838

Wang, Ban	Northwestern Polytechnical University
Zhang, Wei	Northwestern Polytechnical University
Zhang, Lidong	China Aeronautical Radio Electronics Research Institute
Zhang, Youmin	Concordia University

In this paper, an adaptive fault-tolerant control strategy is proposed for a quadrotor helicopter in the presence of actuator faults and model uncertainties by integrating sliding mode control and radial basis function neural network. By assuming knowledge of the bounds on external disturbances, a baseline sliding mode control is first designed to achieve the desired system tracking performance and retain insensitive to disturbances. Then, regarding actuator faults and model uncertainties of the quadrotor helicopter, neural adaptive control schemes are constructed and incorporated into the baseline sliding mode control to deal with them. Finally, a series of simulation tests are conducted to validate the effectiveness of the proposed control strategy where a quadrotor helicopter is subject to inertial moment variations and different level of actuator faults. The capability of the proposed control strategy is confirmed and verified by the demonstrated results.

15:20-15:40	ThB2.2

H2 Optimized PID Control of Quad-Copter Platform with Wind Disturbance, pp. 839-844

Kim, Sunsoo	Texas A&M University
Deshpande, Vedang Mohanrao	Texas A&M University
Bhattacharya, Raktim	Texas A&M University

Proportional-Integral-Derivative (PID) scheme is the most commonly used algorithm for designing the controllers for unmanned aerial vehicles (UAVs). However, tuning PID gains is a nontrivial task. A number of methods have been developed for tuning the PID gains for UAV systems. However, these methods do not handle wind disturbances, which is a major concern for small UAVs. In this paper, we propose a new method for determining optimized PID gains in the H2 optimal control framework, which achieves improved wind disturbance rejection. The proposed method compares the classical PID control law with the H2 optimal controller to determine the H2 optimal PID gains and involves solving a convex optimization problem. The proposed controller is tested in two scenarios, namely, vertical velocity control, and vertical position control. The results are compared with the existing LQR based PID tuning method.

15:40-16:00	ThB2.3

Controller Design and Flight Experiments for the Dual Tilt Rotor Unmanned Aerial Vehicle in Helicopter Mode, pp. 845-853

Zheng, Ruijian	Northeastern University
Gu, FENG	Shenyang Institute of Automation, Chinese Academy of Sciences
Liu, Zhong	Shenyang Institute of Automation Chinese Academy of Sciences
Zhou, Hao	Shenyang Institute of Automation, Chinese Academy of Sciences
He, Yuqing	Shenyang Institute of Automation, Chinese Academy of Sciences

Vertical take-off and landing (VTOL) are the important flying stage of tilt rotor unmanned aerial vehicles (TR-UAV) in helicopter mode. Therefore, the performance of the controller for the helicopter mode will directly impact the safety of DTR-UAV during VTOL stage. To solve this problem, a passivity theory-based controller for helicopter mode of dual tilt rotor UAV (DTR-UAV) is proposed and the stability of the method is proved in this work. In the first, the system model of dual tilt rotor is built and divided into longitudinal and lateral dynamic model. Then based on the passivity theory, the robust controller is designed and proved. Finally and more importantly, a dual tilt rotor experiment platform is designed and implemented to verify the feasibility and validity of the proposed method. The results of simulation and experiment show the good performance of the proposed controller.

16:00-16:20	ThB2.4

Real-Time Motion Planning of Curvature Continuous Trajectories for Urban UAV Operations in Wind, pp. 854-861

Patrikar, Jay	Carnegie Mellon University
Dugar, Vishal	Carnegie Mellon University
Arcot, Vaibhav	University of Pennsylvania

Scherer, Sebastian — Carnegie Mellon University

A key challenge in enabling autonomous Unmanned Aerial Vehicles (UAVs) to operate in cluttered urban environments is to plan collision-free, smooth, dynamically feasible trajectories between two locations with the wind in real-time. This paper presents a novel path planning strategy using sampling-based planning that uses a two-point boundary value problem (BVP) to connect states in the presence of wind. Unlike most approaches that use a curvature discontinuous solution, the proposed BVP is formulated as a nonlinear constrained optimization problem with curvature and curvature-rate continuous profile to generate smoother trajectories. To achieve real-time performance, our method uses surrogate solutions from a pre-calculated library while solving the planning problem and then runs a repair routine to generate the final trajectory. To validate the feasibility of the offline-online strategy, simulation results on a 3D model of an actual city block with a realistic wind-field are presented. Results with a trochoid based BVP solver are also presented for comparison. For the given simulation scenario, we could demonstrate a 93% success rate for the algorithm in finding a valid trajectory.

16:20-16:40 — ThB2.5

Transition Flight Dynamics of a Dual Tilt-Wing UAV, pp. 862-866

Sanchez-Rivera, Luz — CINVESTAV
Lozano, Rogelio — University of Technology of Compiègne
AriasMontano, Alfredo — IPN ESIME Ticoman

A hybrid unmanned autonomous vehicle (UAV) combines the high-speed cruise capability of a fixed-wing airplane, with the hovering flight, vertical take-off and landing capabilities of a helicopter. The change between both flight modes refers to as a transition flight process. This paper presents the flight dynamics during the transition stage of a hybrid UAV of Dual Tilt-Wing type. A non-linear mathematical model is developed that includes the UAV complete dynamics, which presents significant changes in aerodynamic characteristics, especially during the transition flight. These changes are analyzed and characterized by flight tests and CFD simulations. The adaptation to the variation of aerodynamic characteristics caused by tilt angle changes of transition system is verified, so a PD controller for altitude is implemented.

16:40-17:00 — ThB2.6

A Data-Driven FCE Method for UAV Condition Risk Assessment Based on Feature Engineering and Variable Weight Coefficients, pp. 867-874

Su, Xuanyuan — Beihang University
Tao, Laifa — Beihang University
Zhang, Tong — Beihang University
Cheng, Yujie — Beihang University
Ma, Jian — Beihang University
Wang, Chao — Beihang University

Evaluating the risk effectively is critical for the security and reliability of unmanned aerial vehicles (UAVs). With the improvement of related technologies, more and more condition monitoring (CM) parameters are collected from UAVs, which contains considerable information related to the condition risk. For the powerful capability to analyze these massive CM data, a data-driven fuzzy comprehensive evaluation method is proposed in this paper, which employs the feature engineering and the variable weight coefficients to achieve the accurate and timely condition risk assessment for UAVs. Given the CM data, the feature engineering is utilized to adaptively represent its historical normal status and provide the quantitative risk indications accurately reflecting its real-time risk. According to the real-time quantitative risk indications, the variable weight coefficients is utilized to dynamically adjust the initial weights of evaluating indices, which allows us to timely capture the slight condition risk of UAVs under the early abnormal status. At last, the risk membership vector of UAVs is obtained through the comprehensive evaluation to support the related decision-making. A case study using the real CM data of a UAV shows that the evaluation results provided by our proposed method are reasonable, comprehensive and interpretable.

ThB3 — Edessa

UAS Applications II (Regular Session)

15:00-15:20 — ThB3.1

Design of a Quad-Jet VTOL UAS for Heavy-Lift Applications, pp. 875-882

Türkmen, Abdullah — Istanbul Technical University
Altug, Erdinc — Istanbul Technical University

Payload capacity, range and flight duration of a Unmanned Aerial System (UAS) depends mainly on thrust system. Thrust system of a typical electrical multi-rotor UAS consists of electric motors, rotors and electric speed controllers (ESCs). Electric motors are easy to use, and their response time is short, which is highly desired and required for control, but they limit potential payload capacity, range and flight duration. In this paper, we propose a Quad-Jet VTOL (vertical take-off and land) UAS with a thrust system consisting of four mini jet engines. Such a vehicle could be useful heavy-lift applications. The UAS model, controllers, thrust direction system (to overcome the response time disadvantage and to improve motion) are presented, along with a first prototype system.

15:20-15:40 — ThB3.2

Unmanned Aerial Vehicle and Artificial Intelligence for Thermal Target Detection in Search and Rescue

Applications, pp. 883-891

McGee, Joseph John — Queensland University of Technology
Joseph Mathew, Sajith — Queensland University of Technology
Gonzalez, Luis Felipe — Queensland University of Technology

Recent developments in unmanned aerial vehicles (UAV), artificial intelligence and miniaturized thermal imaging systems represent a new opportunity for SAR experts to survey relatively large areas. The system presented in this paper includes thermal image acquisition as well as a video processing pipeline to perform object detection, classification and of people in need for SAR in forest or open areas. The system is tested on thermal video data from ground based and test flight footage and is found to be able to detect all the target people located in the surveyed area. The system is flexible in that the user can readily define the types of objects to classify and the object characteristics that should be considered during classification. The training dataset is a combination of gathered data and internet sourced data. The initial data procurement utilized online academic thermal databases and also the simulation of the UAV mounted camera environment. The simulated data was completed at Kangaroo Point cliffs, Brisbane, Australia giving an approximate elevation of 26 m. Datasets were also collected at South Bribie Island, QLD, Australia at a range of heights and vegetation density. These datasets where collected at different times of the day allowing for a range of contrast level between background and intended target. Once all data was collected, individual frames where extracted from each image and augmentation and annotation was completed. The images were gaussian blurred, lightened and darkened, once all annotation was completed. A total of 2751 original images were annotated, with the augmented dataset comprising of 10380 images. Two main models were trained using different hyperparameters for comparison.

15:40-16:00 ThB3.3

Design and Testing of Recycled 3D Printed Foldable Unmanned Aerial Vehicle for Remote Sensing, pp. 892-901

Nieamnd, Jason — Queensland University of Technology
Joseph Mathew, Sajith — Queensland University of Technology
Gonzalez, Luis Felipe — Queensland University of Technology

Substantial progress in battery and control technology has drastically enabled unmanned aerial vehicles (UAVs) to evolve and develop for utilization across a broader array of applications. Remote sensing imagery in UAVs are evidently exhibiting its remarkable reliability, efficiency and integrability. Furthermore, technological advancements in additive manufacturing enable rapid prototyping of designs in a more cost-effective manner. This paper describes the design, construction and testing of a UAV with a foldable airframe, manufactured from recycled Polyethylene Terephthalate (PET) plastic, through 3D printing filament for the purpose of remote sensing. Previous contributions demonstrated the ability of manufacturing UAVs from recycled plastic and the feasibility of utilizing PET. This paper further develops the design, functionality and application of the UAV through additional material testing, design optimization and added design features. The new UAV design features include; propeller protection to enable remote sensing in isolated and inaccessible areas, integrated printed circuit board (PCB) to power onboard systems and reduce cable clutter, and material testing and analysis for usability of PET in multiple extreme weather environments. Moreover, the optimized UAV design will allow ease of integration with onboard systems, as well as cater for multiple interchangeable rotor arm designs, including protected and unprotected propeller designs. The objective of the research and investigation is focused on the development and implementation of cost-effective and environmentally sustainable UAVs. This paper strives to enable UAV manufacturers to rapidly prototype and optimize UAV designs, while simultaneously deterring PET plastic pollution globally.

16:00-16:20 ThB3.4

OpenREALM: Real-Time Mapping for Unmanned Aerial Vehicles, pp. 902-911

Kern, Alexander — Technical University of Braunschweig
Bobbe, Markus — Technical University of Braunschweig
Khedar, Yogesh — Technical University of Braunschweig
Bestmann, Ulf — Technical University of Braunschweig

This paper presents OpenREALM, a real-time mapping framework for Unmanned Aerial Vehicles (UAVs). A camera attached to the onboard computer of a moving UAV is utilized to acquire high resolution image mosaics of a targeted area of interest. Different modes of operation allow OpenREALM to perform simple stitching assuming an approximate plane ground, or to fully recover complex 3D surface information to extract both elevation maps and geometrically corrected orthophotos. Additionally, the global position of the UAV is used to georeference the data. In all modes incremental progress of the resulting map can be viewed live by an operator on the ground. Obtained, up to date surface information will be a push forward to a variety of UAV applications. For the benefit of the community, source code is public at https://github.com/laxnpander/OpenREALM.

16:20-16:40 ThB3.5

An Integrated Tool to Compute the Dynamic Model and Assess the Lateral Controller Parameters of a UAV Equipped with a Piccolo Autopilot, pp. 912-921

Dias Ferreira, Fernando Roque — Portuguese Air Force Academy
Oliveira, Tiago — Portuguese Air Force
Chá, Silvia — Portuguese Air Force Academy

This paper presents a new computational tool that allows to estimate a mathematical model of a given Unmanned Aerial Vehicle (UAV) equipped with a Piccolo autopilot, and subsequently, assess its lateral controller parameters, in order to tune the desired

response of the closed-loop system. It starts by presenting an estimate of the Piccolo autopilot's lateral control laws (which are not provided by the manufacturer), by updating those proposed in the literature. Then, a mathematical model of the ANTEX-X02 Alfa 07 UAV is derived and validated using flight test results. Finally, our proposed computational tool is outlined, and a new set of controller gains is computed. Real-world flight test results present a 53% reduction on the rise time and a decrease of 65% on the settling time to reach a desired bank command, when compared to the standard autopilot gains. Moreover, for a standard flight plan, the signal tracking delay between the reference command and the UAV's attitude was reduced by 62%. The obtained results demonstrate the effectiveness of the proposed tool.

16:40-17:00 ThB3.6

Radar Based Autonomous Precision Takeoff and Landing System for VTOLs in GNSS Denied Environments, pp. 922-931

Doer, Christopher — Karlsruhe Institute of Technology
Koenig, Ronja — RWTH Aachen University
Trommer, Gert F. — Karlsruhe Institute of Technology
Stumpf, Eike — RWTH Aachen University

Current research on Vertical Takeoff and Landing Vehicles (VTOLs) like urban air mobility, parcel delivery, search and rescue or human aid require precise autonomous takeoff and landing systems. Safe and reliable flight operations have to be ensured even for challenging conditions like fog, night or direct sunlight. In addition, robust, low-cost and low-maintenance infrastructure is required. Since using the Global Navigation Satellite System (GNSS) is not reliable in particular close to landing areas due to multi path errors or jamming, an GNSS denied navigation technique is required. This paper presents a radar based autonomous takeoff and landing system for VTOLs. The localization system requires only passive radar reflectors on the ground. A standard automotive radar, as used for driver assistance systems, is applied for detection. Fusion with an Inertial Measurement Unit (IMU) further improves the localization accuracy. A dedicated landing platform is developed along with a flight guidance such that autonomous precision takeoff and landing can be conducted. Our system has been tested in extensive flight experiments. Indoor flight experiments proved the overall system performance even with bad visual conditions which we simulated with a fog machine. The system achieved a high localization accuracy with a mean absolute error below 0.08m. All test flights resulted in a successful landing in the center of our landing platform.

ThB4 Naousa

Micro and Mini UAS I (Regular Session)

15:00-15:20 ThB4.1

Control Allocation of Bidirectional Thrust Quadrotor Subject to Actuator Constraints, pp. 932-938

Jothiraj, Walter — McGill University
Sharf, Inna — McGill University
Nahon, Meyer — McGill University

In this paper, we work with a quadrotor vehicle capable of producing bidirectional thrust by reversing the rotation of its propellers. These vehicles have a number of unique functions, such as inverted hover, faster than gravity acceleration for descent and, generally, superior agility compared to their unidirectional conventional designs. However, thrust reversal presents a set of unique challenges for controlling these vehicles due to the particular transient dynamics of the propellers as they transition from positive to negative rotation. To deal with the limitations of bidirectional actuators, we propose an optimal control allocation strategy that produces the best match to the desired force and moments prescribed by the controller, while respecting the limits on actuator thrusts and their rate of change. The latter are identified through transient response characterization of the bidirectional propellers. The optimal allocation is evaluated in simulation for a half-flip maneuver between upright and inverted hover. Outdoor flight tests demonstrate the superior performance of the optimal solution as compared to direct allocation commonly used in flight controllers of quadrotors.

15:20-15:40 ThB4.2

High-Level Modeling and Control of the Bebop 2 Micro Aerial Vehicle, pp. 939-947

Pinto, Anthony — Federal University of Espirito Santo
Marciano, Harrison — Federal University of Espirito Santo
Bacheti, Vinicius — Federal University of Espirito Santo
Mafra Moreira, Mauro Sergio — Federal University of Espírito Santo
Brandao, Alexandre Santos — Federal University of Vicosa
Sarcinelli-Filho, Mário — Federal University of Espirito Santo

This paper deals with a simplified dynamic model for the Parrot Bebop 2 micro aerial vehicle, whose parameters are identified through a least-mean square error procedure. Moreover, such a model is used to design high-level controllers to autonomously guide a single vehicle or a formation of two of them, in tasks of positioning and trajectory-tracking. The controllers thus designed are used in experiments of autonomous navigation, whose results validate the proposed model and the designed controllers.

15:40-16:00 ThB4.3

Collision-Free Path Planning Based on a Genetic Algorithm for Quadrotor UAVs, pp. 948-957

Gutierrez Martinez, Manuel Alejandro — CIIIA-FIME-UANL
Rojo Rodriguez, Erik Gilberto — Universidad Autonoma De Nuevo Leon
Cabriales Ramirez, Luis Enrique — CIIIA-FIME-UANL
Reyes Osorio, Luis Arturo — CIIIA-FIME-UANL
Castillo, Pedro — Université De Technologie De Compiègne
Garcia Salazar, Octavio — CIIIA-FIME-UANL

Path planning is one of the most important topics for applications of UAVs. Genetic algorithms are minimization tools that are widely used to process large amounts of data. In this research, a genetic algorithm capable of generating navigation waypoints, achieving short distances and avoiding collision with obstacles, is presented. The genetic algorithm uses a multi-objective function to obtain the waypoints; this functions are the length of the path, the distance from the waypoints to the obstacles, and the probability of the final trajectory to cross an obstacle within a safe zone. Since a path generated by only the waypoints is discontinuous, these are fed to a continuous path generator to find a trajectory based on parametric equations, considering a minimum radius of turn. Real-time experiments are obtained in order to validate the proposed algorithm.

16:00-16:20 — ThB4.4

State and Parameter Estimation of Suspended Load Using Quadrotor Onboard Sensors, pp. 958-967

Prkacin, Vicko — University of Dubrovnik
Palunko, Ivana — University of Dubrovnik
Petrović, Ivan — University of Zagreb

In this paper, we address the problem of state and parameter estimation of a suspended load using quadrotor onboard sensors. Flying with a suspended load alters the quadrotor flight dynamics, sometimes to a large extent, making it a challenging and hazardous task. Monitoring the state of the suspended load is vital for safe flight operations while parameter estimation decouples the control design from specific parameter-dependent solutions. We take advantage of the fact that the forces and torques the suspended load exerts on the quadrotor can be detected in the aircraft IMU measurements as a low frequency harmonic. Thus, by combining the available measurements and system mass we are able to estimate the state of the suspended load. Since our approach stems from understanding the aircraft-load interaction, we start off by delineating the full system model of the quadrotor with a suspended load. To isolate the natural frequency of the suspended load and determine the length of suspension cable, we employ the Fast Fourier Transform (FFT). The proposed estimation algorithms are validated through extensive numerical simulations and experimentally.

16:20-16:40 — ThB4.5

UAV Flight Risk Identification and Evaluation Scheme, pp. 968-974

Zhang, Zhaoyue — Civil Aviation University of China
Chaohui, Feng — Civil Aviation University of China
Wang, Zhisen — Civil Aviation University of China
Li, Shanmei — Civil Aviation University of China
Qingjun, Xia — Civil Aviation University of China

To achieve flight risk identification and assessment in the new field of UAVs, two index systems of risk prediction and safety evaluation are constructed in this work by categorizing the set of UAV flight risks, and the identification subset is set according to the UAV characteristics and use. Risk identification elements are set for the identification subset, and the qualitative attributes of risk identification elements are quantified by set-valued statistics. A general quantitative model for the flight risk identification of UAVs is established. According to the different flight risk factors, UAV flight risks are categorized, the fuzzy comprehensive evaluation method is adopted, and case data are used to quantitatively evaluate different types of risks. Finally, the application of the techno-economic evaluation method to the feasibility evaluation of the UAV flight risk prevention scheme is proposed to provide support for UAV flight risk management.

16:40-17:00 — ThB4.6

The Solution Development for Performance Analysis and Optimal Design of Multicopter-Type Small Drones, pp. 975-982

Oh, Soohun — Korea Aerospace Research Institute
Kim, Minwoo — Korea Aerospace Research Institute
Kim, Hyeongseok — Seoul National University
Lim, Daejin — Seoul National University
Yee, Kwanjung — Seoul National University
Kim, Dongmin — Korea Aerospace Research Institute

We have developed a solution that enables the performance analysis and optimal design of multicopter type small drones that meet various mission profiles named CLOUDS (Conceptual Layout Optimization of Universal Drone Systems) and verified its hovering time prediction capability. Even though similar research has been carried out in the past, as far as the authors know CLOUDS is the

first solution capable of not only performing performance analysis for all flight regimes such as climb, descent, hovering, and forward flight, but also optimal design based on mission profile.

ThC1	Macedonia Hall
Sensor Fusion (Regular Session)	

17:00-17:20 ThC1.1

GPS Denied Localization and Magnetometer-Free Yaw Estimation for Multi-Rotor UAVs, pp. 983-990

Balaji, Naveen — Indian Institute of Technology Kanpur
Kothari, Mangal — Indian Institute of Technology Kanpur
Abhishek, Abhishek — Indian Institute of Technology Kanpur

This paper presents a range-based localization scheme for multi-rotor systems in GPS denied environments and proposes a novel methodology to estimate yaw attitude. The attitude and position are estimated using accelerometer, gyroscope, and range information with Extended Information Filter (EIF). The heading estimation is incorporated without the aid of magnetic sensors. All family of Gaussian filters requires the correct noise parameters for convergence and accurate estimation. We use an optimization technique for tuning the estimator's parameter (covariance matrices). Particle-Swarm Optimization (PSO) method is used for tuning the noise (covariance matrices) in the filter with the aid of ground truth in the initial flight. The effectiveness of tuned EIF is validated on the quadcopter platform with different environments, which shows superior performance compared to the manually tuned noise parameter.

17:20-17:40 ThC1.2

Joint Probabilistic Data Association Filter Using Adaptive Gibbs Sampling, pp. 991-997

He, Shaoming — Cranfield University
Shin, Hyo-Sang — Cranfield University
Tsourdos, Antonios — Cranfield University

This paper proposes a novel adaptive Gibbs sampling algorithm to implement joint probabilistic data association filter for multiple targets tracking. Instead of uniformly visiting and sampling each single element in one joint association hypothesis, the proposed algorithm selects an optimal element visiting sequence that tends to keep the most probable single association hypothesis. Compared to the random Gibbs sampling, it has been demonstrated that the proposed adaptive Gibbs sampling provides faster convergence speed, thus improving the tracking accuracy when the number of samples is limited, and improved robustness against the variation of the number of burn in samples. Extensive empirical simulations are undertaken to validate the performance of the proposed approach.

17:40-18:00 ThC1.3

Real-Time Moving Horizon Estimation of Air Data Parameters and Wind Velocities for Fixed-Wing UAVs, pp. 998-1006

Wenz, Andreas Wolfgang — Norwegian University of Science and Technology
Johansen, Tor Arne — Norwegian University of Science and Technology

We present a real-time implementation of an estimation algorithm for angle of attack, airspeed and wind velocities estimation on a single board computer. The estimator uses only sensor data from a standard fixed-wing UAV autopilot, which consists of a Global Navigation Satellite System receiver, an inertial measurement unit and a pitot-static tube. This sensor data is fused with a combination of kinematic, aerodynamic and stochastic wind models in a nonlinear moving horizon estimator using numerical optimization. An algorithmic differentiation toolbox and automatic code generation is used to create a real- time capable estimator which is able to run within a UAV on an on-board computer. Hardware in the Loop simulation results show that the latency of the estimator is significantly below the expected wind gust period and gives low root-mean-square estimation errors for angle of attack (0.29 degrees) , airspeed (0.21m/s) and wind velocities (0.44 m/s)

18:00-18:20 ThC1.4

Improved State Estimation in Distorted Magnetic Fields, pp. 1007-1013

Brommer, Christian — Universität Klagenfurt
Boehm, Christoph — Universität Klagenfurt
Steinbrener, Jan — Universität Klagenfurt
Brockers, Roland — JPL, California Institute of Technology
Weiss, Stephan — Universität Klagenfurt

The magnetic field of the Earth - besides varying naturally - may be disturbed locally by the (man-made) environment. State estimation and corresponding navigation frameworks that use magnetometers on-board of mobile platforms suffer from severe performance loss or failure upon local magnetic distortions if these are not detected and mitigated adequately. Advanced estimators include the magnetic variation in the state vector. However, Cartesian coordinates, although widely used in the literature, suffer from observability issues when it comes to disturbance detection. This paper shows the importance of representing the magnetic variation in a spherical coordinate system and subsequent improvements with respect to the common representation in Cartesian coordinates. The spherical representation improves estimator consistency and allows for accurate and fast mitigation of magnetic disturbances

through consistent statistical tests which leads to better system state estimates in magnetically distorted areas. The approach is validated by performing tests with simulated and real-world data on embedded hardware.

18:20-18:40 ThC1.5

Semantic Situation Awareness of Ellipse Shapes Via Deep Learning for Multirotor Aerial Robots with a 2D LIDAR, pp. 1014-1023

Sanchez-Lopez, Jose-Luis — University of Luxembourg
Castillo-Lopez, Manuel — University of Luxembourg
Voos, Holger — University of Luxembourg

In this work, we present a semantic situation awareness system for multirotor aerial robots equipped with a 2D LIDAR sensor, focusing on the understanding of the environment, provided to have a drift-free precise localization of the robot (e.g. given by GNSS/INS or motion capture system). Our algorithm generates in real-time a semantic map of the objects of the environment as a list of ellipses represented by their radii, nd their pose and velocity, both in world coordinates. Two different Convolutional Neural Network (CNN) architectures are proposed and trained using an artificially generated dataset and a custom loss function, to detect ellipses in a segmented (i.e. with one single object) LIDAR measurement. In cascade, a specifically designed indirect-EKF estimates the ellipses based semantic map in world coordinates, as well as their velocity. We have quantitative and qualitatively evaluated the performance of our proposed situation awareness system. Two sets of Software-In-The-Loop simulations using CoppeliaSim with one and multiple static and moving cylindrical objects are used to evaluate the accuracy and performance of our algorithm. In addition, we have demonstrated the robustness of our proposed algorithm when handling real environments thanks to real laboratory experiments with non-cylindrical static (i.e. a barrel) objects and moving persons.

18:40-19:00 ThC1.6

Complementary Multi-Modal Sensor Fusion for Resilient Robot Pose Estimation in Subterranean Environments, pp. 1024-1029

Khattak, Shehryar — University of Nevada, Reno
Nguyen, Dinh — University of Nevada, Reno
Mascarich, Frank — University of Nevada, Reno
Dang, Tung — University of Nevada, Reno
Alexis, Kostas — University of Nevada, Reno

Resilient pose estimation for autonomous systems, and especially small unmanned aerial robots, is one of the core capabilities required for these robots to perform their assigned tasks in a reliable and efficient manner. Different sensing modalities have been utilized for the robot pose estimation process, particularly in GPS-denied environments. However, as aerial robots are deployed in more complex environments, such as subterranean mines and tunnels, different sensing modalities can become degraded in different parts of the environment due to the diversity of sensor perception challenges presented in terms of both nature and condition of the operational environment. Motivated by this fact, in this work a complementary multi-modal sensor fusion approach is presented that improves the reliability of the pose estimation process for aerial robots by fusing visual-inertial (VIO) and thermal-inertial (TIO) odometry estimates with a LiDAR odometry and mapping solution. In particular, VIO/TIO estimates are utilized for providing robust priors for LiDAR pose estimation as well as for selectively propagating the LiDAR pose estimates when LiDAR pose estimation process becomes degenerate. The proposed approach is experimentally verified in a variety of subterranean environments as well as utilized during the competition run of the tunnel circuit of the DARPA Subterranean Challenge.

ThC2 — Kozani

Fail-Safe Systems (Regular Session)

17:00-17:20 ThC2.1

A Fault-Tolerant Control Scheme for Fixed-Wing UAVs with Flight Envelope Integration, pp. 1030-1039

Zogopoulos Papaliakos, Georgios — National Technical University of Athens
Karras, George — University of Thessaly
Kyriakopoulos, Kostas J. — National Technical University of Athens

Fault-tolerant control is currently the most important step towards increased autonomy for Unmanned Aerial Vehicles (UAVs). In this work, we consider actuator and airframe faults in fixed-wing UAVs and show that an online Flight Envelope (FE) calculation can interpret their effect on the achievable trim trajectories. Subsequently, we design a fully integrated control scheme with an RRT-based planner and 3 Nonlinear Model Predictive Control (MPC) layers. The FE is provided at each control layer with the beneficial result that non-trimmable, unstable trajectories are avoided. Results from high-fidelity simulations are provided.

17:20-17:40 ThC2.2

Agent Fault-Tolerant Strategy in a Heterogeneous Triangular Formation, pp. 1040-1047

Vasconcelos, João Vítor — University Federal of Viçosa
Villa, Daniel Khede Dourado — Federal University of Espírito Santo
Gomes Caldeira, Alexandre — University Federal of Viçosa
Sarcinelli-Filho, Mário — Federal University of Espirito Santo

Brandao, Alexandre Santos — University Federal of Vicosa

Heterogeneous formations are widely used in cooperation between Unmanned Ground Vehicles (UGVs) and Unmanned Aerial Vehicles (UAVs), like object tracking, load transportation, path planning, and inspection missions. The focus of this work is inspection systems involving long distances, which are susceptible to failures, which may come from the environment, communication, robot infrastructure and so on. Aiming at the efficiency, stability, and security of an inspection involving UGVs and UAVs, we propose fault-tolerant strategies using a triangular-shaped virtual structure. Two specific types of failures are addressed: battery discharge of the UAV and communication or mechanical failure of the UGV. A fault-tolerant strategy is proposed for each type of fault and experiments were carried out to validate the methodology presented through cooperation among the robots: Pioneer3DX, AR.Drone 2.0 and Bebop 2.

17:40-18:00 — ThC2.3

UAV Mission Monitoring and Sequencing, pp. 1048-1055

Goudarzi, Hirad — University of Bristol
Richards, Arthur — University of Bristol

A method is proposed to enhance the automation of Unmanned Aerial Vehicle operations. Waypoint-based missions are augmented with safety monitoring of the UAV as a whole and execution monitoring and control of each mission leg. The monitoring and control are implemented using a Behavior Tree which is automatically generated from the waypoints. The approach exploits the modularity of Behavior Trees to populate a standard mission template with modules appropriate to each mission. The result is a highly flexible and reconfigurable framework that is easy to use for those overseeing the flight. Simulated flight results in a simple inspection scenario are provided.

18:00-18:20 — ThC2.4

Automated Emergency Landing System for Drones: SafeEYE Project, pp. 1056-1064

Bektash, O. — Aalborg University
Ramirez Gomez, Aitor — Aalborg University
Naundrup Pedersen, Jacob — Aalborg University
la Cour-Harbo, Anders — Aalborg University

Automated emergency response systems have been the focus for development of more reliable and robust safety systems, from simpler ones to the most complex. For drones, such systems can be designed to allow compliance standards, track safe places for landing and provide an easier development for operational process. Although many works have acknowledged a need for automated response to deal with the increasing drone safety concerns, the literature is still scarce on research incorporating drone operations. Given this outlook, this paper presents the SafeEYE project, which was initiated to develop and commercialize an automated emergency landing system for larger (> 7 kg) drones. The system consists of a small embedded computer, mounted on a drone, that keeps track of safe places to land, or even crash, as well as the health state of the drone. When there is a failure condition, the device can monitor and detect issues using vibration data, select potential landing zones via a convolutional neural network framework and terminate the flight with the least probability of fatalities. This means a significantly reduced risk for automated, typically Beyond Visual Line of Sight, operations. Therefore, SafeEYE has the potential to become a safety enabler for many applications, including farming, inspection, transportation, search and rescue. With the risk mitigation ability, the project aims at achieving formal approval of the Danish authorities and abroad. SafeEYE is planned to be manufactured as a standalone unit, provided first through drone technology suppliers and later to service providers and manufacturers of autopilots.

18:20-18:40 — ThC2.5

Fault-Tolerant Final Approach Navigation for a Fixed-Wing UAV by Using Long-Range Stereo Camera System, pp. 1065-1074

Watanabe, Yoko — ONERA
Manecy, Augustin — ONERA
Amiez, Alexandre — ONERA
Aoki, Shin — RICOH Co. Ltd
Nagai, Sho — RICOH Co. Ltd

This paper presents an onboard vision/GNSS-integrated fault tolerant navigation system for aircraft final approach. The world-first long-range stereo camera system which captures an object and measures its distance up to 1 km has been developed and implemented for runway feature detection. The navigation filter is designed based on time-delayed Error State Kalman filter for tightly coupling GNSS pseudo-range measurements with the stereo camera outputs. Then it is augmented with an integrity monitoring function for fault detection and protection level calculation. The whole navigation system has been evaluated on real sensor data sets, acquired on the ONERA experimental UAV, with GNSS fault emulation. The results show an improvement both in fault detectability and in navigation performance thanks to adding the stereo camera to the conventional GNSS navigation setup.

18:40-19:00 — ThC2.6

Distributed Fault Detection for UAV Formation Missions, pp. 1075-1084

Kladis, Georgios P. — Hellenic Army Academy
Tsourveloudis, Nikos — Technical University of Crete

A network of N uncertain aerial vehicle systems is connected via a Leader-Follower (L/F) configuration. These systems consist of control systems, sensors (proprioceptive/ exteroceptive), and monitoring systems. If unanticipated faults occur in sensors or actuators, then the objective is to design the monitoring systems such that the follower vehicles can timely detect faulty behavior. This can be achieved by the inclusion of a Distributed Fault Detection and Isolation (DFDI) module. The proposed architecture involves the design of a bank of monitoring systems which generate residuals of the proprioceptive and exteroceptive state that are compared against designed adaptive thresholds. Through such a procedure, it makes it possible to detect and infer on the faulty vehicle. The proposed methodology shows that the design of the architecture is decoupled from the size of the network, whilst decomposing the entire swarm into configurations of vehicles to be exploited. In particular, in the proposed design these configurations consist of two and three vehicles, respectively. The efficacy of the approach is shown through an example swarm scenario.

ThC3	Edessa
UAS Applications III (Regular Session)	

17:00-17:20	ThC3.1

RCPNet: Deep-Learning Based Relative Camera Pose Estimation for UAVs, pp. 1085-1092

Yang, Chenhao	University of Tübingen
Liu, Yuyi	Kyoto University
Zell, Andreas	University of Tübingen

In this paper, we propose a deep neural-network-based regression approach, combined with a 3D structure-based computer vision method, to solve the relative camera pose estimation problem for autonomous navigation of UAVs. Different from existing learning-based methods that train and test camera pose estimation in the same scene, our method succeeds in estimating relative camera poses across various urban scenes via a single trained model. We also built a Tuebingen Buildings database of RGB images collected by a drone in eight urban scenes. Over 10,000 images with corresponding 6DoF poses as well as 300,000 image pairs with their relative translational and rotational information are included in the dataset. We evaluate the accuracy of our method in the same scene and across scenes, using the Cambridge Landmarks dataset and the Tuebingen Buildings dataset. We compare the performance with existing learning-based pose regression methods PoseNet and RPNet on these two benchmark datasets.

17:20-17:40	ThC3.2

Aerial Following of a Non-Holonomic Mobile Robot Subject to Velocity Fields: A Case Study for Autonomous Vehicles Surveillance, pp. 1093-1102

Sanchez, Anand	CINVESTAV
Castillo, Pedro	Université De Technologie De Compiègne
Oliva-Palomo, Fatima	CINVESTAV
Betancourt Vera, Guillermo Julio Cesar	Université De Technologie De Compiègne
Parra-Vega, Vicente	CINVESTAV
Gallegos Bermúdez, Luis Eduardo	Centro De Investigación Y De Estudios Avanzados
Ruiz Sanchez, Francisco Jose	CINVESTAV

Surveillance is a major concern nowadays for the development of autonomous vehicles (AVs) technology, in particular during prototyping stage. However, it is unclear what an effective strategy is for aerial imagery with drones. On one hand, the dynamics of such autonomous vehicle is commonly subject to non-holonomic constraints, whose steering wheel is driven under the paradigm of look-ahead, i.e., users drive a car by looking forward, instead of minimizing the instantaneous position error as if navigating in a smooth velocity field. On the other hand, aerial footage is typically conducted with underactuated drones where admissible position trajectories are limited to a subset of paths. In this paper, a scheme for aerial visual servoing of a mobile ground robot tracking a smooth vector field is proposed. The scheme is based on structural properties and constraints of both systems, such as a non-holonomy, nonlinear dynamics and under actuation. The result is aerial surveillance of an autonomous vehicle mimicking how we drive a real vehicle by redefining locally smooth velocity field toward the next target through admissible paths. As a proof of concept, experiments are presented for a quadrotor tracking in the image plane a mobile robot, which in turn tracks admissible trajectories modelled with vector fields based on a given smooth contour chosen ahead in the field of view. Experiments show the feasibility of the proposed scheme by controlling the quadrotor's underactuated positions (x, y) from the velocity field, the altitude z to facilitate a monocular camera, and yaw angle ψ to recover the direction of the field.

17:40-18:00	ThC3.3

Improved Multi-Camera Coverage Control of Unmanned Multirotors, pp. 1103-1112

Huang, Sunan	National University of Singapore
Yang, Hong	National University of Singapore
Leong, Wai Lun	National University of Singapore
Teo, Rodney	National University of Singapore

Unmanned aerial vehicles (UAVs) are becoming one of the most versatile robots working with various sensors such as camera, Lidar and GPS. This trend comes from the numerous studies in the network of UAVs and the control domain. Currently, coverage control, the control of UAVs to cover a given region, is an important problem in the study of multi-UAV networks. In this paper, an existing coverage control algorithm has been significantly improved by maximizing the sensing field of view (SFOV) over the area of interest, making it much more efficient. The camera used in each UAV allows pan-tilt-zoom (PTZ) in the bottom hemisphere of the UAV. We propose two network coverage algorithms for multiple UAVs to make this improvement: one is the Voronoi based coverage control, and the other one is the constrained optimization coverage algorithm. Finally, the proposed schemes are tested in simulation and a real outdoor environment.

18:00-18:20 ThC3.4

An Approach for Multi-UAV System Navigation and Target Finding in Cluttered Environments, pp. 1113-1120

Zhu, Xiaolong — Queensland University of Technology
Vanegas Alvarez, Fernando — Queensland University of Technology
Gonzalez, Luis Felipe — Queensland University of Technology

The range of applications of unmanned aerial vehicles (UAVs) could be widened if a team of multiple UAVs are used. In this paper, we propose a framework of a team of UAVs with the aim of cooperatively finding a target in a real-world based environment with obstacles. Examples of such applications include search and rescue, remote sensing or infrastructure inspection, which can benefit from an efficient and cooperative multi-UAV system. The framework presented in this paper is modified and extended based on Partially Observable Markov Decision Processes (POMDP) to suit the decentralized multi-agent system while considering the necessary uncertainties of environments and localizations. In addition, the team can cooperate efficiently by sharing limited observation in the mission. We simulated the system in Gazebo simulator and tested the performances for an increased number of UAVs in a cluttered flying area. Results indicate that a POMDP formulation allows for uncertainty in observations and multi-agent navigation and target finding can be implemented in a real-time application in real-world based scenarios.

18:20-18:40 ThC3.5

An Adaptive Informative Path Planning Algorithm for Real-Time Air Quality Monitoring Using UAVs, pp. 1121-1130

Velasco, Omar — Wageningen University and Research
Valente, João — Wageningen University and Research
Mersha, Abeje Yenehun — Saxion University of Applied Sciences

Environmental monitoring is a heavily data driven task where data sample efficiency is paramount due to the shear volumes of gathered data. In particular, air monitoring strongly depends on sensor location. Since the recent past, Unmanned Aerial Vehicles (UAVs) present themselves as a prospective solution for flexible and better air quality data gathering. In this paper, we present a novel adaptive Informative Path Planning (IPP) approach that enables UAVs navigate through a sample utility map based on adaptive Statistical Gas Distribution Models (GDM) for efficient surveying. The presented adaptive IPP approach maximizes the amount of gathered information per mission within the system constraints in known and unknown environments with near optimal performance. The effectiveness of the algorithm is tested through extensive simulation. The results showed high quality sample collection, low computational costs and better model prediction metrics against other surveying strategies. Although framed in an air environmental monitoring context, the developed solution can be used for any generic IPP problem by adapting the sample utility map to the particular application.

18:40-19:00 ThC3.6

Towards an Integrated Low-Cost Agricultural Monitoring System with Unmanned Aircraft System, pp. 1131-1138

Karatzinis, Georgios — Democritus University of Thrace
Apostolidis, Savvas — Democritus University of Thrace
Kapoutsis, Athanasios — Democritus University of Thrace
Panagiotopoulou, Liza — GEOTOPOS S.A
Boutalis, Yiannis — Democritus University of Thrace
Kosmatopoulos, Elias — Democritus University of Thrace and CERTH

Over the last years, an intensified interest has been shown in many studies for precision agriculture. Unmanned Aircraft Systems (UASs) are capable of solving a plethora of surveying tasks due to their flexibility, independence and customization. The incorporation of UASs remote sensing in precision agriculture enhances the abilities of crop mapping, management and identification through vegetation indices. In addition to this, different image analysis and computer vision processes were adopted trying to facilitate field operations in cooperation with human intervention to enhance the overall performance. In this paper, we present a practically oriented application on vineyards towards an integrated low-cost system which utilizes Spiral-STC (Spanning Tree Coverage) algorithm as a Coverage Path Planning (CPP) method. Based on the resulted flight campaign, UAV images were collected, and the incorporated image analysis processes finally extract vegetation knowledge. Also, geo referenced orthophotos and computer vision applications complete the generated oversight of the field. These supportive tools provide farmers with useful information (crop health indicators, weather predictions) letting them extrapolate knowledge and identify crop irregularities.

ThC4 Naousa

Micro and Mini UAS II (Regular Session)

17:00-17:20 ThC4.1

Implementation of a Natural User Interface to Command a Drone, pp. 1139-1144

Yam-Viramontes, Brandon Alberto — Instituto Tecnológico Superior De Jerez

Mercado Ravell, Diego Alberto — Center for Research in Mathematics CIMAT

In this work, we propose the use of a Natural User Interface (NUI) through body gestures, using the open source library OpenPose, looking for a more dynamic and intuitive way to control a drone. For the implementation, we use the Robotic Operative System (ROS) to control and manage the different components of the project. Wrapped inside ROS, OpenPose (OP) processes the video obtained in real-time by a commercial drone, allowing to obtain the user's pose. Finally, the key points provided by OpenPose are processed and translated, using geometric constraints, to specify high-level commands to the drone. The proposed strategy was implemented in real-time experiments and validated with different human users through a standard User Experience Questionnaire (UEQ), showing good results in usability and user experience.

17:20-17:40 ThC4.2

Aerial Interaction Control in Outdoor Environments for a Micro Aerial Vehicle Equipped with a Robotic Arm, pp. 1145-1153

Lopez Luna, Aaron — INAOE

Cruz, Israel — INAOE

Martinez-Carranza, Jose — Instituto Nacional De Astrofisica Optica Y Electronica

Physical contact with the surrounding environment is an essential and challenging task for unmanned aerial vehicles (UAV) to perform complex missions in the aerial manipulation field. Steady flight of an aerial manipulator is compromised due to the disturbance forces induced by the actuators of the manipulator, and the conditions of the indoor/outdoor environment. This paper focuses on the pose control performance of the aerial manipulator composed of an UAV and a 2-DOF arm for full contact of the system with a vertical surface in an outdoor scenario. The control technique is based on the Gain Scheduling (GS) approach incorporated into a proportional-integral-derivative (PID) algorithm to reduce the offset of the instability produced by the movement of the robotic arm, the wall effect and the external conditions like wind gusts. The visual simultaneous location and mapping (SLAM) method is implemented, exploiting the onboard sensing capabilities of the UAV without using another external caption motion method to estimate the pose of the system in the outdoor environment. The control design was implemented through extensive outdoor flight experiments to analyzed the behavior of the system in such conditions and obtained the gain value for the set of controllers. Experimental results of aerial contact with a surface show that the controller can suppress the disturbance mentioned above effectively and make the system hover steadily with sufficient accuracy to complete aerial contact mission in an outdoor environment.

17:40-18:00 ThC4.3

A Lightweight Waterproof Casing for an Aquatic UAV Using Rapid Prototyping, pp. 1154-1161

Tan, Yu Herng — National University of Singapore

Chen, Ben M. — Chinese University of Hong Kong

Aquatic unmanned aerial vehicles (UAVs) are a unique type of UAVs which have the ability to operate in both air and water. However, the vastly different medium properties of air and water pose significant challenges to the design of such vehicles. One of these is the contradicting requirement of minimizing weight in air while ensuring that the vehicle is sufficiently dense to obtain near neutral buoyancy in water. In addition, being submerged requires the vehicle to be adequately waterproof, which will inevitably contribute to a significant portion of the vehicle's weight and volume. Here, we look into the design and manufacturing of such a waterproof casing for a proposed aquatic UAV design. Rapid prototyping using low cost desktop 3D printers was used to develop and produce a customized hull casing with complex geometry for the vehicle. Through the use of different materials, printing methods, and hardware design to seal the access openings, a small lightweight casing can create a waterproof hull while achieving the desired vehicle dynamics in both mediums.

18:00-18:20 ThC4.4

Characterization of Ground-To-Air Emissions with sUAS Using a Digital Twin Framework, pp. 1162-1166

Hollenbeck, Derek — MESA Lab at UC Merced

Chen, YangQuan — University of California, Merced

Environmental sensing using small unmanned aircraft systems (sUAS) has become more and more desirable due to the spatial temporal resolution and frequency of sampling. In the oil and gas industry, the process of detecting, quantifying, and localizing leaks are of utmost concern. Emission leaks that go undetected are potentially hazardous and can be costly to companies. In this work we extend a digital twin framework to a controlled release experiment using sUAS. The digital twin model is tuned heuristically and compared using a mass balance method to estimate the source rate. The results show qualitative agreement with the temporal and spatial behavior of the experimental data.

18:20-18:40 ThC4.5

A Generalized Framework Designing Monopulse Tracking of OFDM-Aided Aircraft Communication, pp. 1167-1174

Yan, Chaoxing — Beijing Research Institute of Telemetry

Fu, Lingang — Beijing Research Institute of Telemetry

Liu, Tongling — Beijing Research Institute of Telemetry

Chen, Ming — Beijing Research Institute of Telemetry

The upcoming non-terrestrial network communication system will comprise unmanned aerial vehicles (UAVs) and satellites as platforms providing broadband communication service in the future. The conventional UAV monopulse tracking technique at ground station tracking receiver requires dedicated signals which suffer from multipath effect in air-to-ground (A2G) link with low elevation angles. As an essential physical layer technique in 5G wireless networks, the orthogonal frequency division multiplexing (OFDM) under fading channel was not yet investigated well for target tracking in the UAV A2G link. In this paper, we propose a generalized nonlinearity-based angle detection method in tracking receiver of single-channel mono pulse tracking (SCMT) system using OFDM signals. Then, we design a generalized framework of monopulse tracking system and evaluate the nonlinearity functions in terms of angle detection S-curve and detection range. Simulations results show that, the logarithmic nonlinearity detection functions exhibit smaller angle estimation root mean squared errors (RMSEs) than square- and absolute-nonlinearity detection functions by 0.03 degree under fading channels as well as additive white Gaussian noise (AWGN) channels.

18:40-19:00	ThC4.6

Situation Awareness and Routing Challenges in Unmanned HAPS/UAV Based Communications Networks, pp. 1175-1182

Anicho, Ogbonnaya	Liverpool Hope University
Charlesworth, Philip	Liverpool Hope University
Baicher, Gurvinder	Liverpool Hope University
Nagar, Atulya	Liverpool Hope University

This paper examines Situation Awareness (SA) as a factor in addressing routing challenges in HAPS/UAV based networks especially in multi-HAPS/UAV implementations. Routing in UAV-based networks is a critical element for successful transmission of data from source to destination node. However, in UAV based networks the concept of routing assumes a more challenging dimension mainly due to the mobility of the vehicles or platforms. This paper highlights how situation awareness can impact routing decisions and consequently improve network throughput. It is suggested that SA should be considered a factor in mitigating routing challenges in UAV based networks.

Friday September 4, 2020

FrA1	Macedonia Hall
Navigation (Regular Session)	

09:00-09:20	FrA1.1

Finite-Time Convergent Sliding-Mode Guidance Law for High-Speed Flight Vehicle with Bearings-Only Measurement, pp. 1183-1188

Qu, Yaohong	Northwestern Polytechnical University
Wang, Kai	Northwestern Polytechnical University
Yu, Ziquan	Nanjing University of Aeronautics and Astronautics

Aiming at the problem of a high-speed flight vehicle accurate tracking a target on the ground, a finite-time sliding-mode guidance law during the whole guidance period is proposed. Different from the traditional tracking guidance problem which believes that the acceleration of non-cooperative targets is known, this paper uses filtering method to obtain target motion parameters. First of all, the model of the vehicle-target tracking is established in the planar. Then, by combining the finite-time control and sliding-mode variable structure control methods, the finite-time sliding-mode guidance law is developed, and the designed guidance law's finite-time stability proved theoretically. Furthermore, the extended Kalman filter (EKF) is used to estimate vehicle-target relative range, relative velocity, and target acceleration involved in the guidance law during the whole guidance period, in which the vehicle equips a passive seeker that the bearings-only measurement (BOM) is available. Finally, numerical simulations demonstrate it can provide good performance for the filter.

09:20-09:40	FrA1.2

Leader-Follower Formation Feedback Control Composed of Turning Rate and Velocity Controllers, pp. 1189-1198

Milutinovic, Dejan	University of California at Santa Cruz
Casbeer, David	Air Force Research Laboratory

We study the leader-follower feedback formation control, including the feature that the follower can reach and maintain the formation starting from any initial relative position with respect to the leader. The follower uses only observable information, i.e., the distance and bearing angle towards the leader. The formation control is based on a turning rate controller for the follower to track the leader and a velocity controller which uses the bearing angle. The conditions for the tracking performance of the controller are provided and the formation keeping controller is illustrated by numerical simulations.

09:40-10:00	FrA1.3

3D Map Exploration Via Learning Submodular Functions in the Fourier Domain, pp. 1199-1205

Lu, Bing-Xian	National Central University
Tseng, Kuo-Shih	National Central University

3D map exploration is one of key technologies in robotics. However, finding an optimal exploration path is a challenge since the environment is unknown. This research proposed the submodular exploration (SE) algorithm to enable an unmanned aerial vehicle (UAV) to explore 3D environments. The algorithm learns the submodular function in the Fourier domain and reconstructs the submodular function in the spatial domain via the compressed sensing techniques. Since the objective function of spatial exploration is reformulated as a maximizing submodular function with path constraints, greedy algorithms can achieve 1/2 (1-e^{-1}) of the optimum. Experiments conducted with this algorithm demonstrate that the UAV can explore more voxels in the environments than the benchmark approach.

10:00-10:20 FrA1.4

Multi-Layer Map: Augmenting Semantic Visual Memory, pp. 1206-1212

Papapetros, Ioannis Tsampikos — Democritus University of Thrace
Balaska, Vasiliki — Democritus University of Thrace
Gasteratos, Antonios — Democritus University of Thrace

The modern view of things in the science of robotics imposes that when working in a human environment, understanding of its equivalent semantics is required. In this paper, we present a graph-based unsupervised semantic clustering method and a novel cluster matching technique, with a view to create a multi-layer semantic memory map robust to illumination changes. Using indoor data collected by an unmanned aerial robot (UAR) and a publicly available dataset, we apply a community detection algorithm (CDA) to find efficiently coherent visual data throughout the trajectory creating a semantic base map. Then, we optimize the formed communities using metric information by implementing an hierarchical agglomerative clustering algorithm. The multi-layer semantic map is created by constructing map instances for variant lighting conditions and matching the generated clusters to their base map correspondence. The proposed matching method relies on the graphs centrality indicators to identify central images of a region and utilize them to efficiently extract resemblances within the base map.

10:20-10:40 FrA1.5

Regions of Interest Segmentation from LiDAR Point Cloud for Multirotor Aerial Vehicles, pp. 1213-1220

Kulathunga, Geesara — Innopolis University
Fedorenko, Roman — Innopolis University
Klimchik, Alexandr — Innopolis University

We propose a novel filter for segmenting the regions of interest from LiDAR 3D point cloud for multirotor aerial vehicles. It is specially targeted for real-time applications and works on sparse LiDAR point clouds without preliminary mapping. We use this filter as a crucial component of fast obstacle avoidance system for agriculture drone operating at low altitude. As the first step, each point cloud is transformed into a depth image and then identify places near to the vehicle (local maxima) by locating areas with high pixel densities. Afterwards, we merge the original depth image with identified locations after maximizing intensities of pixels in which local maxima were obtained. Next step is to calculate the range angle image that represents angles between two consecutive laser beams based on the improved depth image. Once the corresponding range angle image is constructed, smoothing is applied to reduce the noise. Finally, we find out connected components within the improved depth image while incorporating smoothed range angle image. This allows separating the regions of interest. The filter has been tested on various simulated environments as well as an actual drone and provides real-time performance. Source code and dataset are available at https://github.com/GPrathap/hagen.git and real-world experiment results can be found at https://www.youtube.com/watch?v=iHd_ZkhKPjc.

10:40-11:00 FrA1.6

Multi-Agent Mapping and Navigation of Unknown GPS-Denied Environments Using a Relative Navigation Framework, pp. 1221-1230

Olson, Jacob — Brigham Young University
Toombs, Nathan — Brigham Young University
McLain, Tim — Brigham Young University

When generating 3D maps with unmanned aerial vehicles (UAVs) in GPS-denied environments, it is important to correctly handle path planning, estimation, and mapping techniques. Because multirotor UAVs are limited in flight time, using multiple UAVs to map an environment collaboratively can significantly improve the mapping efficiency. This paper addresses the following key issues required to enable mapping with multiple agents: Combining a reactive path planner with an obstacle avoidance algorithm to handle navigation in complex environments. Estimating the relative and global states of a UAV separately with a relative navigation framework to allow for loop closures in the mapping process without causing the estimation to diverge. Adapting a graph-based simultaneous localization and mapping (graph-SLAM) technique for multiple UAVs flying simultaneously and merging their maps in real- time. We were able to use these strategies to generate dense maps in complex GPS-denied environments with multiple UAVs.

FrA2 Kozani

Levels of Safety (Regular Session)

09:00-09:20 FrA2.1

Coordinated Coverage and Fault Tolerance Using Fixed-Wing Unmanned Aerial Vehicles, pp. 1231-1240

Shriwastav, Sachin — University of Hawaii at Manoa
Song, Zhuoyuan — University of Hawaii at Manoa

This paper presents an approach for deploying and maintaining a fleet of homogeneous fixed wing unmanned aerial vehicles (UAVs) for all-time coverage of an area. Two approaches for loiter circle packing have been presented: square and hexagon packing, and the benefits of hexagon packing for minimizing the number of deployed UAVs has been shown. Based on the number of UAVs available and the desired loitering altitude, the proposed algorithm solves an optimization problem to calculate the centers of the loitering circles and the loitering radius for that altitude. The algorithm also incorporates fault recovery capacity in case of simultaneous multiple UAV failures. These failures could form clusters of survivor (active) UAVs over the area with no overall survivor information. The algorithm deploys a super-agent with a larger communication capacity at a higher altitude to recover from the failure. The super-agent collects the information of survivors and updates the homogeneous radius and the locations of the loitering circles at the same altitude to restore the full coverage. The individual survivor UAVs are then informed and transit to the new loitering circles using Dubin's paths. The relationship with the extent of recoverable loss fractions of the deployed UAVs have been analyzed for varying the initial loiter radii. Simulation results have been presented to demonstrate the applicability of the approach and compare the two presented packing approaches.

09:20-09:40 FrA2.2

UAVs and Their Role in the Health Supply Chain: A Case Study from Malawi, pp. 1241-1248

Triche, Ryan — Chemonics in Support of USAID GHSC-PSM
Greve, Ashley — USAID GHSC-PSM
Dubin, Scott — USAID GHSC-PSM

Unmanned Aerial Vehicles (UAVs) have been captivating audiences for over a decade now; from their military, mapping, photography, and even more recently cargo carrying abilities – UAVs continue to innovate in ways to remove human error from logistics and provide services in ways never tenable previously. The USAID Global Health Supply Chain Program – Procurement and Supply Management project (GHSC-PSM) recently began delivering vital life-saving health services to remote locations in Africa via the use of UAVs. Through adaptation, these UAVs were able to embed themselves into the pre-existing supply chain in Malawi to greatly improve health service delivery in several remote villages. The lessons learned from this activity have a larger impact on the use of UAVs and the potential benefits to society, especially related to health outcomes. With this activity, we hope to continue to innovate on UAV health service delivery and seek new avenues for which to improve the lives of people across the globe.

09:40-10:00 FrA2.3

Estimation of Actuator Faults in Quadrotor Vehicles: From Theory to Validation with Experimental Flight Data, pp. 1249-1256

Baldini, Alessandro — Università Politecnica Delle Marche
Felicetti, Riccardo — Università Politecnica Delle Marche
Freddi, Alessandro — Università Politecnica Delle Marche
Monteriù, Andrea — Università Politecnica Delle Marche
Tempesta, Matteo — Università Politecnica Delle Marche

In this paper, we propose the experimental validation of a fault observer which allows to reconstruct the time behavior of an injected fault effect on a quadrotor actuator. The observer is firstly presented, designed, and its stability property analyzed for independent multiplicative faults/failures on each actuator. Then, the experimental setup is described, taking into consideration the adopted hardware and software implementation, both of them based on commercial and easy to plug-in components. Parameter estimation is also considered in order to obtain numerical evaluations of all the unknown constants of the actual physical system. For the considered experimental setup, the results confirm the validity of the proposed observer, within an acceptance tolerance.

10:00-10:20 FrA2.4

UAV Collision Avoidance with Varying Trigger Time, pp. 1257-1264

Lin, Zijie — University of Maryland, College Park
Castano, Lina — University of Maryland, College Park
Xu, Huan — University of Maryland, College Park

This paper examines the effect that the selection of the different collision avoidance trigger time has on UAV safety and avoidance efficiency and finds the optimal trigger time for different cases. The trigger time indicates when a collision avoidance maneuver begins. An earlier trigger time is safer for the UAV to avoid all the obstacles but causes the UAV to deviate away from its intended path, while a delayed avoidance trigger action reduces overall path deviation but entails a higher risk of collision. Thus, the balance between safety and avoidance efficiency is important. Simulations for different mission scenarios show that by selecting specific avoidance trigger times, missed waypoints which are a result of the avoidance maneuver, could be reduced by over 40%. In addition, avoidance time and space required by the avoidance maneuver are also reduced, as compared to always starting the avoidance maneuver when the obstacle is first detected. Hence, selecting the avoidance trigger time can improve the performance of the UAV's avoidance maneuver, especially for real-time applications.

10:20-10:40 FrA2.5

Cybersecurity of the Unmanned Aircraft System (UAS), pp. 1265-1269

Pyzynski, Mariusz — Lazarski University

In recent years, UASs have become more and more popular. There are many reasons for this; one of the most popular is the enhancement of drones' functionalities and improvement in battery life, stabilization, navigation, sensor technology, and much more.

The growth is driven by many benefits. However, as the number of drones is expanding and levels of their technological functionalities evolving, the use of drones brings a lot of concerns as well as challenges that should not be underestimated. This refers to issues in the area of cybersecurity, privacy, and public safety. UASs, under the international, regional, and national regime of aviation law, are considered aircraft. Since there is no existing cybersecurity framework for UASs, the civil aviation cybersecurity framework should apply to their operations. This paper will focus on the potential cyber threats against UASs, providing some examples of cyberattacks from the past. Further, the overview of the aviation cybersecurity framework will follow in order to determine the current status of maturity at the international and regional (European Union) levels. The conclusion of the paper will identify the necessary steps to be taken and potential solutions in terms of applying the aviation cybersecurity framework into the operation of UASs.

FrA3 Edessa

UAS Applications IV (Regular Session)

09:00-09:20 FrA3.1

Automatic Condition Monitoring of Railway Overhead Lines from Close-Range Aerial Images and Video Data, pp. 1270-1277

Andert, Franz — German Aerospace Center
Kornfeld, Nils — German Aerospace Center
Nikodem, Florian — Deutsches Zentrum Für Luft Und Raumfahrt
Li, Haiyan — Siemens Mobility GmbH
Kluckner, Stefan — Siemens Mobility GmbH
Gruber, Laura — Siemens Mobility GmbH
Kaiser, Christian — Copting GmbH

This paper is about automated condition monitoring of critical railway infrastructure using unmanned aircraft systems as flying sensors. As far as possible, automation shall include flight guidance and management as well as automated processing of large sensor data sets. Since a commercial solution must consider the regulatory framework on remotely piloted aircraft systems, the paper discusses legal issues to make allowance for flights beyond visual line of sight. The work described here is focused on Europe and Germany, however, the major principles are likely to be adaptable to other countries. Next to that, the paper presents a strategy for automated image and video data processing. It consists of a super-resolution approach where onboard video camera data from typical off-the-shelf drones can replace higher-resolution still imagery and thus avoid the necessity to use special flight systems, and a deep-learning approach where specific elements are to be detected in the images. With data from flight tests over railway overhead lines, the paper shows an automated detection of rod insulators. Moreover, it presents resolution improvements from video data so that off-the-shelf camera drones can be qualified for the detection of small defects.

09:20-09:40 FrA3.2

FDI Attack Detection for Formation Control of Quantized UAV Systems by Coding Sensor Outputs, pp. 1278-1285

Liu, Lin — Beihang University
Wu, Hanyuan — Beihang University
Xi, Zhiyu — Beihang University
Cui, Yucheng — Beihang University

False Data Injection (FDI) attack has been well studied in recent years. Due to its stealthiness and the possible severe damage to the attacked system, defense strategies against FDI attack are one of the most important research directions. Coding matrix method has been proposed several years ago which introduces a coding matrix to sensor outputs so that stealthy attack can be detected. However, its application to quantized systems has never been studied. In this paper, we consider the FDI detection strategy and its application to the formation control problem of quantized unmanned aerial vehicle (UAV) systems, where sensor outputs are transmitted via communication channels equipped with quantizers. The quantization process in the system has enforced different requirements to the design of coding matrix, and we have proposed sufficient conditions of effective coding matrix design under this condition. Simulation results have also proved the feasibility of our method in the detection of FDI attack.

09:40-10:00 FrA3.3

Reactive Mission Planning for UAV Based Crane Rail Inspection in an Automated Container Terminal, pp. 1286-1293

Bobbe, Markus — Technical University of Braunschweig
Khedar, Yogesh — Technical University of Braunschweig
Backhaus, Jan — Technical University of Braunschweig
Gerke, Markus — Technical University of Braunschweig
Ghassoun, Yahya — Technical University of Braunschweig
Plöger, Frank — HHLA

At the automated Container Terminal Altenwerder (CTA) Hamburg, Rail-mounted gantry cranes (RMGC) transfer the containers between the incoming ships and the customer container trucks. Due to the special geomorphological conditions of the soil at CTA and heavy load of the crane movement, the rail tracks move in horizontal and vertical plane. Currently, these rail tracks are bi-annually inspected using traditional surveying methods during which the container storage blocks need to be stopped to allow the

human surveyors to operate, leading to significant loss of operational capacity. In the AeroInspekt project we aim to inspect the rails using UAV based autonomous aerial photogrammetry without affecting the crane operations. In order to avoid the bad effect on the photogrammetry process from the images with crane occluding the rails, several intelligent drone mission planning strategies were designed and tested in a simulation environment in order to minimize the flying time. The optimized approach was implemented in the control station app on an Android tablet and tested in practice.

10:00-10:20 FrA3.4

Optimal Sensor Management for Multiple Target Tracking Using Cooperative Unmanned Aerial Vehicles, pp. 1294-1300

Baek, Stan — United States Air Force Academy
York, George — Academy Center for Unmanned Aircraft Systems Research

In this work, we consider collaborative unmanned aerial vehicles (UAVs) with a gimbaled sensor tracking multiple mobile surface targets, where the number of targets is greater than the number of UAVs. To this end, we have developed an efficient distributed software algorithm enabling a team of collaborative unmanned aerial vehicles to effectively detect and track multiple mobile ground targets. The software framework we present in this paper includes optimal sensor management technique to minimize the localization uncertainty of targets, efficient data association method, and a consensus decision-making algorithm to reach agreement on target assignments. Our novel strategy in this integrated framework of cooperative aerial robots effectively utilizes their sensing resources using the optimal sensor management technique as well as the consensus decision-making. Our results show that a team of n UAVs can effectively track more than 2n targets with practically acceptable localization uncertainties.

10:20-10:40 FrA3.5

UAV Vision-Based Nonlinear Formation Control Applied to Inspection of Electrical Power Lines, pp. 1301-1308

Uzakov, Timur — Czech Technical University in Prague
Saska, Martin — Czech Technical University in Prague
Nascimento, Tiago — Universidade Federal Da Paraiba

Cooperation of human workers and a team of UAV co-workers for inspection and maintenance of electrical power is the main motivation of research presented in this paper. Collaborative human-UAV works at height are beneficial from several reasons including providing images from the ideal point of view, monitoring of the safety of individual workers, and even aerial delivering of required tools. These tasks also involve cognitive capabilities in the monitoring of the workers and the detection of unsafe behaviors, transportation of tools or parts needed by the workers and collective manipulation with the workers. In general, interaction of humans and teams of UAVs becomes an important task as aerial robots are widely spread in various applications that require the presence of people in their workspace. To achieve such interaction, group control of multiple UAVs must take states of workers (e.g. position relative to aerial co-workers and prediction of worker's future behavior), maintaining an adaptable formation and maximizing the observation of the worker. Thus, we propose in this work, a distributed vision-based nonlinear formation control (DVNFC) approach that results in an adaptable formation where the controller minimizes the error in observation always maintaining the visualization of the human by the whole formation. We performed several numerical simulations using ROS/Gazebo with real-time visual feedback to validate our approach.

10:40-11:00 FrA3.6

Range Estimation and Visual Servoing of a Dynamic Target Using a Monocular Camera, pp. 1309-1316

Srivastava, Raunak — Indian Institute of Technology Bombay
Maity, Arnab — Indian Institute of Technology Bombay
Lima, Rolif — TCS Innovation Labs
Das, Kaushik — TATA Consultancy Service

This paper delves into the problem of tracking an unknown maneuvering target using only monocular visual feedback. It is usually difficult to perform target tracking using only monocular vision due to the absence of depth information. This restricts the use of commonly used Image and Position-based Visual Servoing methods. Hence, range estimation from monocular images has paramount importance if a conventional position-based path planning algorithm is to be utilized. In this paper, we circumvent this problem using the angle subtended by the target on the follower in both 3D and image coordinate systems. Also, an Extended Kalman Filter is used to filter and get accurate range estimates of the moving target. The proposed method is extensively validated on a simulated setup created in Gazebo. Also, a Proportional Derivative (PD) controller is used to maintain a fixed standoff distance from the moving target while following it.

FrA4 Naousa

Airspace Control (Regular Session)

09:00-09:20 FrA4.1

The Wild West of Drones: A Review on Autonomous-UAV Traffic-Management, pp. 1317-1322

Rumba, Rudolfs — Riga Technical University
Nikitenko, Agris — Riga Technical University

This paper presents a study on autonomous UAV traffic management. As the need for autonomous UAVs grows every year, there must be a system in place for controlling the vehicles. Modern methods of air traffic control may be found ineffective to cope with the expected density of vehicles. Research of UAV is growing rapidly, but methods of UAV traffic management (UTM) are yet to be kickstarted. There is no backbone of how the UTM system should be built and as of now, the solutions solve the problems of today, ignoring the ever so growing need for autonomy. In this paper, the current state-of-the-art of UTM was described including the problem statement and exposure of autonomous UTM (a-UTM) in the scientific literature. The main findings reveal that manufacturers of the UAV's are launching autonomous vehicles only in less developed airspaces, where due to lack of infrastructure benefits outweigh the risks. Developed airspaces without regulation and infrastructure to accommodate the autonomy are restricting any testing and trials of such systems. There is a demand for a scalable a-UTM solution for BVLOS and fully autonomous flight control in developed airspace.

09:20-09:40 FrA4.2

Aircraft Stall Recovery Using Sliding-Mode Based Pitch-Attitude and Altitude Control, pp. 1323-1328

Qazi, Salahudden — IIT Kanpur
Giri, Dipak Kumar — IIT Kanpur
Ghosh, A.K. Ghosh — IIT Kanpur

This paper presents the control law design for transferring the aircraft from stall flight to steady-straight-level flight using a sliding-mode based pitch attitude and altitude control. The exponential convergence of errors is discussed by invoking Barbalat's Lemma theorem. Thereafter, settling time expression, for commanded variables, to reach the sliding surface is obtained. Finite-time stability to reach sliding manifold is also proved. In the proposed control strategy, control inputs viz., elevator and throttle are obtained in a closed-loop form. The results of this research indicate the proposed controller first stops the aircraft pitching motion by controlling the aircraft pitch angle then reaches the commanded altitude to attain constant-altitude-level flight.

09:40-10:00 FrA4.3

Hover-To-Cruise Transition Control for High-Speed Level Flight of Ducted Fan UAV, pp. 1329-1337

Cheng, Zihuan — South China University of Technology
Pei, Hai-Long — South China University of Technology

In this paper, we address the hover-to-cruise transition control problem for high-speed level flight of a ducted fan UAV. Firstly, the nonlinear aircraft dynamic system is derived, and relevant key aerodynamic characteristics are presented. Then, we divide the dynamic system into known parts and uncertain parts. In order to track a reference system formed by the known parts, we propose a neural-network-based control strategy to learn the error dynamics and cancel the tracking error with proved stability. Finally, simulations and experiments are conducted to perform the transition process at fixed altitude and constant horizontal acceleration, with satisfactory results accomplishing the designed flight course.

10:00-10:20 FrA4.4

Observer Based Appointed-Finite-Time Nonsingular Sliding Mode Based Disturbance Attenuation Control for Quadrotor UAV, pp. 1338-1343

Gong, Wenquan — Shanghai Maritime University
LI, Bo — Shanghai Maritime University
Xiong, Hang — Shanghai Maritime University
Yang, Yongsheng — Shanghai Maritime University
Bing, Xiao — Northwestern Polytechnical University

This work investigates the appointed-finite-time trajectory tracking control problem for quadrotor unmanned aerial vehicles subject to external disturbances. More specifically, two nonsingular terminal sliding mode manifolds are first designed such that the singularity problem of the traditional sliding mode control is settled. And that, the appointed-finite-time stability of the proposed manifolds is proved by rigorous Lyapunov theory. Furthermore, two novel sliding mode control based appointed-finite-time controllers are developed to realize the trajectory tracking objective. The undesired chattering is alleviated by discontinuous control structure. Finally, numerical simulation results are presented to illustrate that the quadrotor can successfully accomplish the tracking task by utilizing the proposed controllers.

10:20-10:40 FrA4.5

Adaptive Finite-Time Tracking Control for Spacecraft Proximity Operations under Actuator Saturation, pp. 1344-1349

Liu, Kang — University of Science and Technology of China
Wang, Yu — University of Science and Technology of China
Ji, Haibo — University of Science and Technology of China

In this paper, we propose an adaptive finite-time control for spacecraft proximity operations (SPO) regarding to external disturbance, parametric uncertainty as well as actuator saturation. Firstly, a six degree of freedom model is constructed to describe the relative motion relationship between the target spacecraft and pursuer spacecraft. To address the challenge of external disturbance and parametric uncertainty, a finite-time controller based non-singular integral terminal sliding mode is designed. With the help of the adaptive technique, the prior knowledge of the upper bound on the compound disturbance is not required. Subsequently, to deal with the actuator saturation, a dead zone operator-based model is employed. Based on Lyapunov stability theorem, the developed controller can ensure that the tracking errors converge to the origin after finite time. Last but not least, simulations are made to intuitive verify the validity of the introduced control method.

10:40-11:00 FrA4.6

Wireless Longitudinal Motion Controller Design for Quadrotors, pp. 1350-1358

Kouvakas, Nikolaos — National and Kapodistrian University of Athens
KOUMBOULIS, FOTIOS — National and Kapodistrian University of Athens
Giannaris, Georgios — Sterea Ellada Institute of Technology
Vouyioukas, Demosthenes — University of the Aegean

In the present paper, the problem of remotely controlling a quadrotor in longitudinal motion and under atmospheric disturbances is studied. The disturbances are considered not to be measurable. The controller - communication system is enriched with a synchronization / signal reconstruction algorithm imposing constant delays. The design goal is to independently control the horizontal and vertical velocity of the quadrotor while simultaneously attenuating the influence of the disturbances to these two velocities. To this end, a linear dynamic time delay controller will be designed. The satisfactory performance of the proposed control scheme is illustrated through computational experiments for the case of a climbing maneuver.

FrB1 Macedonia Hall

Energy Efficient UAS (Regular Session)

11:30-11:50 FrB1.1

State-Of-Technology and Barriers for Adoption of Fuel Cell Powered Multirotor Drones, pp. 1359-1367

Apeland, Jørgen — University of Stavanger, Nordic Unmanned AS
Pavlou, Dimitrios — University of Stavanger
Hemmingsen, Tor — University of Stavanger

Industrial use of multirotor drones is gaining traction, and fuel cell-based power sources have been identified as a way of improving the flight endurance from what is possible to achieve with current lithium-based battery options. The state-of-technology and barriers for further adoption are presented. It is found that there are lightweight options commercially available and that the viability of powering multirotor drones for long-range and high endurance missions is demonstrated. The barriers mainly relate to the future required level of certification, technical improvements, and operational aspects. For advancing the state-of-technology, liquid-cooled fuel cells are identified as an attractive alternative that can expand the environmental flight envelope. However, a high system mass of these fuel cells remains a constraint. Hydrogen storage is a central challenge, and storage alternatives are investigated. To further improve the adoption of fuel cell-based power sources for multirotor drones, operational and financial rewards must be well proven for realistic operations and relevant operating conditions.

11:50-12:10 FrB1.2

Turn Decision-Making for Improved Autonomous Thermalling of Unmanned Aerial Gliders, pp. 1368-1375

El Tin, Fares — McGill University
Borowczyk, Alexandre — Notos Technologies
Sharf, Inna — McGill University
Nahon, Meyer — McGill University

Unmanned Aerial Vehicles (UAVs) are increasingly being proposed and used for a wide range of civilian applications. A subclass of fixed-wing UAVs, known as Unmanned Aerial Gliders (UAGs), are particularly well-suited to applications involving long endurance and range. An ongoing challenge to achieve full autonomy for these aircraft, is to improve the detection and exploitation of rising air masses (thermals). This paper proposes a turn decision-making algorithm for improved thermal exploitation with UAGs. The algorithm monitors netto-variometer data composed of vehicle states to identify the presence of thermal updraft. Following thermal detection, a turn decision into the thermal is made based on the induced roll effects on the UAG due to updraft wind gradients. Once inside the rising air mass, the thermal center location is estimated using the centroid method. The effects of turn decisions on thermalling performance are initially examined in a batch simulation involving various thermal properties and wind conditions, implemented in MATLAB/Simulink. The algorithm is subsequently integrated into the PX4 flight stack for flight testing and results demonstrate the performance of the algorithm and improved thermalling when making intelligent turn decisions to capture a thermal.

12:10-12:30 FrB1.3

Online ADP Based Oxygen Excess Ratio Control of the PEM Fuel Cell System Applying to UAVs, pp. 1376-1383

Zhu, Jing — Nanjing University of Aeronautics and Astronautics
Zhang, Peng — Nanjing University of Aeronautics and Astronautics
Jiang, Bin — Nanjing University of Aeronautics and Astronautics

The excess ratio control of PEM fuel cells systems is investigated in this paper with the use of double loop cascade control structure. In the outer loop, an improved supertwisting control algorithm is proposed which is robust against dynamics and disturbances in UAVs. As for the inner loop, the optimal tracking controller based upon adaptive dynamic programming (ADP) is exploited to adaptively approximate the optimal control policy, where the weights of neural networks are updated real-time. Simulation results are demonstrated with comparison between the traditional cascaded super twisting control scheme and the ADP based scheme.

12:50-13:10 FrB1.5

Energy Efficiency Improvement Potential of a Tactical BWB UAV Using Renewable Energy Sources, pp. 1384-1391

DIMITRIOU, STYLIANOS — Aristotle University of Thessaloniki
KAPSALIS, STAVROS — Aristotle University of Thessaloniki
Panagiotou, Pericles — Aristotle University of Thessaloniki
Yakinthos, Kyriakos — Aristotle University of Thessaloniki

The current study presents the energy efficiency improvement potential of a Blended-Wing-Body (BWB) Unmanned Aerial Vehicle (UAV) with the implementation of alternative energy sources. A fixed-wing, tactical BWB UAV experimental prototype, which operates on fossil fuel and has been developed for the aerial delivery of cargo and lifesaving supplies as well as surveillance missions, is used as a reference platform. Two alternative propulsion systems, a hybrid-electric and an all-electric, are investigated in this work, by taking into account the required modifications, additional equipment and auxiliary systems, on a conceptual design level. A solar irradiation estimation model is used to calculate the solar power available, whereas an aerodynamic analysis is conducted, using Computational Fluid Dynamics (CFD) modeling, to estimate the required power. The selection and sizing of the corresponding systems is then made, by assuming that the external configuration layout remains the same. Finally, the three configurations, i.e. the conventional, the hybrid-electric, and the all-electric, are compared in terms of Gross Takeoff Weight (GTOW) and power consumption, so that an assessment of the use of renewable energy sources can be carried out.

13:10-13:30 — FrB1.6

Aerial Worker for Skyscraper Fire Fighting Using a Water-Jetpack Inspired Approach, pp. 1392-1397

Chaikalis, Dimitris — New York University Abu Dhabi
Tzes, Anthony — New York University Abu Dhabi
Khorrami, Farshad — New York University

This article is concerned with the utilization of Unmanned Aerial Systems (UASs) for firefighting purposes in skyscrapers. The water is supplied to these systems through a hose using a water pump in a similar manner as in hydro flight sports. The UAS utilizes this hydro-propulsion to lift the water hose and the water present in it, thus extending its flight time. An adaptive backstepping controller is employed for controlling the water jet in the yaw axis, while considering as disturbance the forces acting along its roll and pitch axes. Simulation results highlighting the system's performance against forces acting on its center of mass are offered.

FrB2 — Kozani

Risk Analysis (Regular Session)

11:30-11:50 — FrB2.1

Efficient Generation of Ground Impact Probability Maps by Neural Networks for Risk Analysis of UAV Missions, pp. 1398-1406

Levasseur, Baptiste — ONERA
Bertrand, Sylvain — ONERA
Raballand, Nicolas — ONERA

This paper investigates the generation of ground impact probability maps of UAVs in case of failure during the flight. Such maps are of a huge interest for risk assessment of UAV operations and can be used both for offline mission preparation or analysis and online decision making. Two approaches are proposed in this paper to generate such maps, taking into account a dynamical model a fixed-wing UAV and wind conditions. The first one relies on the generation of a complete database by Monte Carlo simulations. The second one is based on neural network surrogate models obtained by supervised learning using this database. Computation time required by the second approach is very small and compatible with online use. The two approaches are presented and discussed, and examples of ground impact probability maps generated are provided.

11:50-12:10 — FrB2.2

Situational Risk Assessment within Safety-Driven Behavior Management in the Context of UAS, pp. 1407-1415

Hägele, Georg — Semcon Sweden AB
Sarkheyli-Hägele, Arezoo — Malmö University

This paper addresses the problem of hazard recognition and risk assessment in open and non-predictive environments to support decision making and action selection for UAS. Decision making and action selection incorporate decreasing situational risks and maintain safety as operational constraints. Commonly, neither existing safety standards nor the situation modeling, or knowledge representation is considered in that context. This contribution applies a novel approach denoted as a Safety-Driven Behavior Management for UAS focusing on situation modeling, and the problem of knowledge representation in the context of situational risks. It combines the safety standards-oriented hazards analysis and the risk assessment approach with the machine learning-based situation recognition. The illustrative scenario and first experimental results underline the feasibility of the novel approach.

12:10-12:30 — FrB2.3

A Sociotechnical Approach to UAV Safety for Search and Rescue Missions, pp. 1416-1424

Charalampidou, Stavroula — Democritus University of Thrace
Lygouras, Eleftherios — Democritus University of Thrace
Dokas, Ioannis — Democritus University of Thrace

Gasteratos, Antonios — Democritus University of Thrace
Zacharopoulou, Aikaterini — Democritus University of Thrace

Nowadays search and rescue teams are using Unmanned Aerial Vehicles (UAVs) to complete important tasks. Unfortunately, the safety aspect of UAVs during search and rescue missions from a sociotechnical point of view has not been excessively studied. In this paper, the Systems Theoretic Process Analysis (STPA) has been applied to a fully autonomous UAV system called ROLFER (Robotic Lifeguard for Emergency Rescue). ROLFER has two operational modes. The first one indicates the preparations that have to take place before the ROLFERs SAR missions, and the second mode indicates the actual SAR mission of the UAV. STPA was applied in both operational modes and identified new safety specifications between the technical components of the system and the human administration during the preparation phase, during the checks between each SAR mission and also on the interactions involving the human components of ROLFER which the developers of ROLFER have not initially considered.

12:30-12:50 FrB2.4

Preliminary Evaluation of Thrust Loss in Commercial Aircraft Engine Due to Airborne Collision with Unmanned Aerial Vehicles (UAVs), pp. 1425-1432

Che Man, Mohd Hasrizam — Nanyang Technological University
Liu, Hu — Nanyang Technological University
Ng, Bing Feng — Nanyang Technological University
Low, Kin Huat — Nanyang Technological University

This paper is devoted to investigating the influence of UAVs airborne collision with civil aircraft engine on the operation safety of commercial aircraft. The damage levels of the civil aircraft fan blades and compressor blades during the UAVs airborne collision are both evaluated based on the Finite Element Method (FEM) simulation. Besides, the percentage of the engine thrust loss can be estimated by the reduction of pressure ratio throughout the engine using Computational Fluid Dynamics (CFD) simulation. In our study, it is found that UAVs ingestion at approach flight phase has the highest UAVs debris weight of 80g which can cause most severe damage to aircraft Inlet Guide Vane (IGV) Low Pressure Compressor (LPC) blades. This thrust loss can reach up to 75% when the damage of High Pressure Compressor (HPC) blades is included in the analysis. More simulations are will be carefully carried out to check the reliability of this conclusion, in which the influence of secondary level of damage especially IGV blades debris impact on HPC blades are considered.

12:50-13:10 FrB2.5

Toward Cybersecurity of Unmanned Aircraft System Operations under "Specific" Category, pp. 1433-1441

Tran, Trung Duc — SOGILIS Company and University Grenoble Alpes, CNRS
Thiriet, Jean-Marc — GIPSA-Lab, University Grenoble Alpes
Marchand, Nicolas — GIPSA-Lab CNRS
El Mrabti, Amin — SOGILIS Company

Nowadays, the increasing number of Unmanned Aircraft System (UAS) operations raises public concerns on cybersecurity issues. Therefore, it requires a methodology to address these issues during the UAS development. The Specific Operation Risk Assessment (SORA) is a risk assessment methodology developed by Joint Authorities for Rulemaking on Unmanned Aircraft System (JARUS). This methodology is endorsed by the European Union Aviation Safety Agency (EASA) as an acceptable means to fulfill the requirements of EU regulation related to UAS operations under the Specific category. The original SORA methodology focuses on Safety risk scenarios only, which relate to unintentional threats and the harms to people's life. In this paper, we introduce our solution to extend the methodology toward cybersecurity aspects. The extended methodology concerns risk scenarios relating to intentional digital threats and some other harms (e.g privacy violation, damage to critical infrastructure). A part of this solution is developed and is presented in this paper.

13:10-13:30 FrB2.6

Ground Impact Probability Distribution for Small Unmanned Aircraft in Ballistic Descent, pp. 1442-1451

la Cour-Harbo, Anders — Aalborg University

Safety is a key factor in all aviation, and while years of development has made manned aviation relatively safe, the same has yet to happen for unmanned aircraft. However, the rapid development of unmanned aircraft technology means that the range of commercial and scientific applications is growing equally rapid. At the same time the trend in national and international regulations for unmanned aircraft is to take a risk-based approach, effectively requiring risk assessment for every flight operation. This work addresses the growing need for methods for quantitatively evaluating individual flights by modelling the consequences of a ballistic descent of an unmanned aircraft as a result of a major in-flight incident. The presented model is a probability density function for the ground impact area based on a second order drag model with probabilistic assumptions on the least well-known parameters of the flight and includes the effect of wind. The model has low computational complexity and is well-suited for high fidelity simulations for longer flights over populated areas and with changing trajectory parameters.

FrB3 Edessa

UAS Applications V (Regular Session)

11:30-11:50 FrB3.1

Surface-Condition Detection System of Drone-Landing Space Using Ultrasonic Waves and Deep Learning, pp. 1452-

1459

Hamanaka, Masatoshi — RIKEN
Nakano, Fujio — Kyoto University

We propose a system for detecting the surface conditions of a landing space using ultrasonic sensors mounted on a drone. The advantage of ultrasonic sensors is that they are extremely low cost, are much lighter and smaller than cameras, have millimeter-wave lasers, and use LiDAR. However, normal ultrasonic sensors can only measure the distance from the nearest object, so the amount of information is insufficient to estimate the conditions of a landing space. Therefore, we propose installing an ultrasonic sensor on each arm of the drone and estimating the condition of the landing space from the time series of reflected waves for very short ultrasonic waves. In the measurement results, reflected waves were small and changed irregularly for each sensor where a space was not suitable for landing. In a simulation experiment using deep learning, our system was able to determine whether a condition was suitable for landing with an accuracy of 98%.

11:50-12:10 FrB3.2

Dense Crowds Detection and Surveillance with Drones Using Density Maps, pp. 1460-1467

Gonzalez-Trejo, Javier — CIMAT Zacatecas
Mercado Ravell, Diego Alberto — Center for Research in Mathematics CIMAT

Detecting and Counting people in a human crowd from a moving drone present challenging problems that arise from the constant changing in the image perspective and camera angle. In this paper, we test two different state-of-the-art approaches, density map generation with VGG19 trained with the Bayes loss function and detect-then-count with Faster R-CNN with ResNet50-FPN as backbone, in order to compare their accuracy at counting and detecting people in different scenarios taken from a drone in flight. We show empirically that both proposed methodologies perform well for detecting and counting people in sparse crowds when the drone is near the ground. Nevertheless, Bayes Loss provides better accuracy on both tasks while also being lighter than Faster R-CNN. Furthermore, Bayes Loss outperforms Faster R-CNN when dealing with dense crowds, proving to be more robust to scale variations and strong occlusions, hence being more suitable for surveillance applications using drones.

12:10-12:30 FrB3.3

UAS Based Methodology for Measuring Glide Slope Angles of Airport Precision Approach Path Indicators (PAPI), pp. 1468-1474

Lin, Yi-Chun — Purdue University
Hasheminasab, Seyyed Meghdad — Purdue University
Bullock, John — Purdue University
Horton, Deborah — Purdue University
Baxmeyer, Adam — Purdue University
Habib, Ayman — Purdue University
Bullock, Darcy — Purdue University

This paper reports on a methodology for using an Unmanned Aircraft System (UAS) to measure angles where Precision Approach Path Indicator (PAPI) lights transition from white to red to assess compliance with the US Federal Aviation Administration (FAA) Order JO6850.2B. Precise location of each image was obtained by mounting a survey prism on the UAS and using ground-based surveying total stations to record the x, y, z location of the UAS. Two 15-minute UAS missions collected 70 images that were synchronized with total station readings. UAS images were classified by the number of white and red PAPI lights visible. A logit model was used to estimate the transition angle of the four PAPI Light Housing Assemblies, which were compared with the angle and tolerance of transition angles defined in FAA Order JO6850.2B. A second independent robotic total station measured the location of the UAS when images were taken. Comparing the two independent total station measurements, the root mean squared error of the UAS position on the glide slope was 1.3 arc-min. The paper concludes that low cost UAS with a total station can quickly and accurately evaluate PAPI lights to determine if they are aimed within the prescribed FAA tolerance.

12:30-12:50 FrB3.4

Coordinated CRLB-Based Control for Tracking Multiple First Responders in 3D Environments, pp. 1475-1484

Papaioannou, Savvas — University of Cyprus
Kim, Sungjin — Hanyang University
Laoudias, Christos — University of Cyprus
Kolios, Panayiotis — University of Cyprus
Kim, Sunwoo — Hanyang University
Theocharides, Theocharis — University of Cyprus
Panayiotou, Christos — University of Cyprus
Polycarpou, Marios M. — University of Cyprus

In this paper we study the problem of tracking a team of first responders with a fleet of autonomous mobile flying agents, operating in 3D environments. We assume that the first responders exhibit stochastic dynamics and evolve inside challenging environments with obstacles and occlusions. As a result, the mobile agents probabilistically receive noisy line-of-sight (LoS), as well as non-line-

of-sight (NLoS) range measurements from the first responders. In this work, we propose a novel estimation (i.e., estimating the position of multiple first responders over time) and control (i.e., controlling the movement of the agents) framework based on the Cramer-Rao lower bound (CRLB). More specifically, we analytically derive the CRLB of the measurement likelihood function which we use as a control criterion to select the optimal joint control actions over all agents, thus achieving optimized tracking performance. The effectiveness of the proposed multi-agent multi-target estimation and control framework is demonstrated through an extensive simulation analysis.

12:50-13:10	FrB3.5

Estimating Crop Coefficients Using Linear and Deep Stochastic Configuration Networks Models and UAV-Based Normalized Difference Vegetation Index (NDVI), pp. 1485-1490

Niu, Haoyu	UC, Merced
Wang, Dong	USDA ARS Parlier
Chen, YangQuan	University of California, Merced

Crop coefficient K_c methods have been commonly used for evapotranspiration estimation. Researchers estimate K_c as a function of the vegetation index because of similarities between the K_c curve and the vegetation index curve. A linear regression model is usually developed between the K_c and the normalized difference vegetation index (NDVI) derived from satellite imagery. However, the spatial resolution of satellite imagery is in the range of meters or greater, which is often not enough for crops with clumped canopy structures, such as trees, and vines. In this study, the Unmanned Aerial Vehicles (UAVs) were used to collect high-resolution images in an experimental pomegranate orchard located at the USDA-ARS, San Joaquin Valley Agricultural Sciences Center, Parlier, CA. The NDVI values were derived from UAV images. The K_c values were measured from a weighing lysimeter in the pomegranate field. The relationship between the NDVI and K_c was established by using both a linear regression model and a deep stochastic configuration networks (DeepSCNs) model. Results show that the linear regression model has an R^2 and RMSE value of 0.975 and 0.05, respectively. The DeepSCNs regression model has an R^2 and RMSE value of 0.999 and 0.046, respectively. The DeepSCNs model showed improved performance than the linear regression model in predicting K_c from NDVI.

13:10-13:30	FrB3.6

UAV-Assisted Aerial Survey of Railways Using Deep Learning, pp. 1491-1500

Kafetzis, Dimitrios	Athens University of Economics and Business
Fourfouris, Ioannis	Athens University of Economics and Business
Argyropoulos, Savvas	StreamOwl
Koutsopoulos, Iordanis	Athens University of Economics and Business

Unmanned Air Vehicles (UAVs) are currently in use for diverse applications such as critical infrastructure monitoring. Monitoring is based on video capture by a video camera and subsequent use of Deep Learning (DL) techniques to perform image recognition. In this paper we do a proof-of-concept validation of DL and UAV-assisted monitoring for vegetation and object detection on railways. The large diversity of vegetation, terrain and railway settings increases the challenges for object detection and classification. Moreover, the creation of an appropriate dataset for the training of a classifier is a nontrivial task per se. We show the related challenges in this setting, and we create from scratch a dedicated dataset with manual annotation for vegetation management on railways, based on publicly available video clips and our own video recordings at a railway. To the best of our knowledge this is the first dedicated dataset for this application. Next, we develop a DL pipeline on this dataset and evaluate its performance for different classes of vegetation and obstacles on the railways. Our approach leads to satisfactory detection accuracy, especially given the diversity of obstacles and the fact that most objects to be detected appear at the background of the frame image. Also, we test our classifier models in the NVIDIA Jetson Nano platform, which is the on-board computing system of a UAV that we used for on-site testing. The classifier may operate on the Jetson Nano board presenting a good and viable performance.

FrB4	Naousa
Airspace Management (Regular Session)	

11:30-11:50	FrB4.1

Cooperative Robust Line-Of-Sight Guidance Law for Aerial Target Defense, pp. 1501-1507

Luo, Hongbing	University of Science and Technology of China
Ji, Haibo	University of Science and Technology of China
Wang, Xinghu	University of Science and Technology of China
Qu, Xinyu	University of Science and Technology of China

We consider a three-body conflict problem in which an aerial target is pursued by a homing missile, and the target launches a defense missile to intercept the homing missile. Under the assumption that the homing missile adopts a proportional guidance law with more maneuverability than aerial target and defense missile, we propose a cooperative robust line of sight guidance law based on a nonlinear control method. Simulations are carried out for the different levels of cooperation and compared with the traditional proportional guidance law, showing the better performance of proposed guidance law.

11:50-12:10	FrB4.2

Imitation Learning for Neural Network Autopilot in Fixed-Wing Unmanned Aerial Systems, pp. 1508-1517

Shukla, Daksh	The University of Kansas

Keshmiri, Shawn — University of Kansas
Beckage, Nicole — Intel Labs

This research identifies the feasibility of training an artificial neural network (ANN) autopilot, using supervised learning techniques, including an imitation learning framework known as the data aggregation set (DAgger) algorithm. The ANN autopilot aims to mimic a unified guidance, navigation & control (GNC) system to fly a fixed-wing UAS. Utilizing high-fidelity nonlinear 6-DOF aircraft simulations, it is shown that several modifications in existing imitation learning techniques must be considered. DAgger algorithm when applied sequentially to augment data along the desired flight trajectory to train the ANN autopilot is unable to generalize across turning and straight-line maneuvers, and hence cannot learn to fly stably, eventually terminating the simulation. Monte-Carlo methods when incorporated into the DAgger algorithm allow for sampling of random data along the desired flight trajectory, proved to be effective to train the ANN autopilot to fly indefinitely with acceptable tracking errors, however undesirable low frequency oscillations were observed in control input and aircraft states. The oscillatory behavior is dealt with by introducing a time-based moving window along the trajectory for data addition in conjunction with the standard DAgger algorithm. Different variations of DAgger algorithms are tested and compared using closed-loop 6-DOF flight simulations. 3D trajectory tracking and stability in aircraft states are evaluated with evidence supporting the idea that an ANN autopilot can behave as a unified GNC system and fly a fixed-wing UAS.

12:10-12:30 — FrB4.3

Variable L1 Guidance Strategy for Path Following of UAVs, pp. 1518-1524

R, Saurav — IIT Madras
Laad, Dhruv — IIT Madras
Ghosh, Satadal — IIT Madras

In this paper the problem of path following or trajectory tracking by an unmanned aerial vehicle (UAV) is considered. Several guidance laws have been presented in literature to this end. Among them, L_1 guidance strategy, which has similarity with proportional navigation guidance, has received most attention. However, the constant value of look-ahead distance L_1 considered in that guidance algorithm poses a drawback that leads to degraded performance in path following for varied range of radius of curvature of paths. To obviate this drawback, this paper presents a variable L_1 path-following guidance strategy, which relies on the consideration of a pre-fixed allowable settling time and a pre-fixed allowable peak overshoot, related to allowable maximum cross-track error, in path following performance of the UAV. Simulation studies are presented to validate the better performance of the presented variable L_1 guidance algorithm over the existing constant L_1 algorithm in following reference paths containing segments with varied radii of curvature.

12:30-12:50 — FrB4.4

Gradient-Based Augmentation to Maxima Turn Switching Strategy for Source-Seeking Using Sensor-Equipped UAVs, pp. 1525-1532

Kamthe, Aniket — IIT Madras
Ghosh, Satadal — IIT Madras

Localization of an unknown source emanating a radial monotonically varying scalar field in a planar environment by sensor-equipped unmanned aerial vehicles (UAVs) is considered in this paper. The source may be stationary, moving or maneuvering, but of constant signal strength. The only available information is the scalar measurements of the signal field taken by the on-board sensor of the UAV at each time instant. No range or bearing angle information is available to the UAV. Several methodologies have been explored for source seeking in the literature. Among them, a recently proposed algorithm leveraging an inter-loop switched-turn strategy, named 'Maxima Turn Strategy' (MTS), has been found to outperform several other strategies in terms of localization time-efficiency. However, the MTS strategy has a drawback in the sense that between two turn switching points the UAV traverses an entire circular arc, the radius of which corresponds to a pre-fixed nominal turn rate of the UAV. Thus, the MTS could be further improved upon by leveraging information about the gradient estimate updated at the end of the previous loop. Such a gradient-augmented MTS strategy that further reduces the intra-loop traversed path length with quite low memory storage requirement is presented in this paper. Effectiveness of the presented gradient-augmented MTS in terms of source localization time is validated by simulation studies with varied initial geometries for stationary, moving and maneuvering sources.

12:50-13:10 — FrB4.5

Online Hybrid Motion Planning for Unmanned Aerial Vehicles in Planar Environments, pp. 1533-1540

Lapasi, Manikandan — IIT Madras
Ghosh, Satadal — IIT Madras

Motion planning for unmanned aerial vehicles (UAVs) in an obstacle-cluttered environment for target interception/rendezvous has been a problem of growing importance. Several offline deterministic and sampling-based planners have been presented in literature to address this issue. However, online motion planners gained paramount importance due to their inherent feedback mechanism. Following this, several guidance algorithms and collision avoidance algorithms have been presented in literature. But very few literature have merged them to come up with a holistic online motion planner. Even among them, realistic turn capabilities of UAVs have been largely ignored. Also, they rely on the near-collision-course geometry between the UAV and the target. To obviate these limitations, this paper presents an online hybrid motion planner for a constant-speed UAV in a 2-D obstacle-cluttered environment that combines a global planner with local planners for online collision avoidance with obstacles. Specifically, this paper investigates the performance of combinations of the most widely studied guidance, proportional navigation, as global planner with three seminal local planners for collision avoidance based on the potential field, velocity obstacle and collision cone concepts. Extensive simulation

studies help elucidate the performance comparison of these three hybrid motion planning algorithms in terms of four crucial measures of effectiveness (MOEs) - target interception time, minimum obstacle distance, overall control effort and computational cycle time. Discussion about the effectiveness of these three online hybrid algorithms under different considerations of these MOEs exhibits their potential in real-time motion planning and control for real-life UAV applications.

13:10-13:30 FrB4.6

Lateral Fractional Order Controller Design and Tuning for a Flying-Wing UAS, pp. 1541-1545

Flanagan, Harold — University of Kansas
Chao, Haiyang — University of Kansas
Chen, YangQuan — University of California, Merced

It is very challenging to develop stable and robust controllers to support Unmanned Aerial System (UAS) flight in turbulent Atmospheric Boundary Layer (ABL). This paper introduces a new fractional order controller for roll tracking of a flying-wing UAS. The proposed factional order proportional derivative (FOPD) controller is compared with the classical PD controller, and both controllers were determined using a genetic algorithm optimization method. The paper also introduces a genetic algorithm cost function that takes into account aircraft stability margins. The FOPD controller performance for turbulence rejection is significantly better than the classical PD controller, while also providing a lower disturbance rejection peak (DRP) value. These results show the usefulness of the FOPD controller over the classical PD controller.

FrC1 Macedonia Hall

Technology Challenges (Regular Session)

14:30-14:50 FrC1.1

Wind Field Estimation by Small UAVs for Rapid Response to Contaminant Leaks, pp. 1546-1552

Ayala-Alfaro, Victor — University of Guanajuato
Torres del Carmen, Felipe de Jesus — University of Guanajuato
Ramirez Paredes, Juan Pablo — University of Guanajuato

We present a system based on a quadrotor Unmanned Aerial Vehicle for wind field estimation and prediction of contaminant spread, aiming to provide valuable information to first responders and containment crews. In our method, the wind field is estimated based on quadrotor scans over the contaminated area that leverage the onboard sensors of the aerial platform. A dispersion model is computed based on the wind field estimation, and finite element analysis is performed to find the steady state contaminant concentration map. The proposed system enables emergency workers to have a fast response to contaminant leaks in low-wind conditions by estimating the pollutant concentration map over a predetermined area. Simulation results are provided to compare and validate the estimated values obtained by our system when sensor noise is considered.

14:50-15:10 FrC1.2

Development of an Automated Monitoring Platform for Invasive Plants in a Rare Great Lakes Ecosystem Using Uncrewed Aerial Systems and Convolutional Neural Networks, pp. 1553-1564

Cohen, Joshua — Michigan Natural Features Inventory, Michigan State University
Lewis, Matthew — Michigan Aerospace Corporation

We present a novel method for rapidly and precisely monitoring invasive plant species within rare and Great Lakes endemic coastal ecosystems. Our monitoring platform comprises: 1) an Uncrewed Aerial System capable of collecting high-resolution imagery in a precise and repeatable manner; 2) software enabling ecologists to annotate this imagery to identify invasive plant species of interest; 3) neural network–based algorithms for identifying targeted invasive plant species in the images; and 4) software for generating georeferenced probability maps of invasive plant species infestations. We applied our monitoring platform to two lake plain prairie remnants in southeastern Michigan and classifier performance was high for both invasive reed (Phragmites australis subsp. australis) and glossy buckthorn (Frangula alnus) (AUC values of 96.5% and 99.4%, respectively). We present invasive species probability maps generated by deep Convolutional Neural Networks. These site-specific georeferenced maps quantify invasive plant species density and distribution and provide resource managers with actionable insight to gauge risk to the site, plan biodiversity restoration, and evaluate the efficacy of control efforts.

15:10-15:30 FrC1.3

Modeling and Multimode Analysis of Electrically Driven Flying Car, pp. 1565-1571

Ai, Tianfu — Beijing Institute of Technology
Xu, Bin — Beijing Institute of Technology
Xiang, Changle — Beijing Institute of Technology
Fan, Wei — Beijing Institute of Technology
Zhang, Yibo — Beijing Institute of Technology

Aiming at a flying car which can be used for land-air amphibious, the dynamic models of its land drive module and air flight module are built respectively to obtain the simulation model under different working conditions. In order to ensure that the simulation model can stably track the driving speed and other indicators, different controllers are designed for the land and air modules as the nominal control structures, respectively. A series of simulations of different working conditions for flying car are presented, such as straight-line driving on the ground to fly in the air. The results show that the vehicle can track the speed well under the straight-line driving condition, and it can track the height well under the hovering condition. The vehicle wheel vertical load and lateral load will decrease to zero during switching driving on ground to fly in the air. When it takes off completely, it will experience an oscillation process and finally stabilize.

15:30-15:50	FrC1.4

Capability Caution in UAV Design, pp. 1572-1581

Cawthorne, Dylan	University of Southern Denmark
Devos, Arne	Southern University of Denmark

Concerns about the impact unmanned aerial vehicles (UAVs) will have on society is growing, making the consideration of ethics in UAV design urgent. Privacy, safety, and security are widely discussed, but engineers have few tools to address these and other ethical issues in their designs. This paper contributes by helping to bridge the gap between ethical theory and design practice. To do so, the concept of capability caution in UAV design is introduced. Capability caution in UAV design is the need for setting well-reasoned limits to the technology's capabilities during the design phase, both to limit risks of misuse, but also to enhance performance within the specified application. Five capability caution design principles are developed which should be considered: 1. context of use 2. privacy 3. jobs and human skills 4. safety, security, and misuse, and 5. the future. A Danish healthcare UAV that has been designed using the capability caution design principles is presented to illustrate the approach.

15:50-16:10	FrC1.5

A Genetic Algorithm Based Method for the Airfoil Optimization of a Tactical Blended-Wing-Body UAV, pp. 1582-1589

Mathioudakis, Nikolaos	Aristotle University of Thessaloniki
Panagiotou, Pericles	Aristotle University of Thessaloniki
Kaparos, Pavlos	Aristotle University of Thessaloniki
Yakinthos, Kyriakos	Aristotle University of Thessaloniki

The current study presents the development of an in-house, low-fidelity optimization methodology, suitable for generating optimized airfoil shapes with respect to predefined goals and constrains, for Unmanned Aerial Vehicle (UAV) applications. The aim is to optimize the airfoil selection phase during the UAV preliminary design phase. The optimization method is that of a Genetic Algorithm (GA) and the aerodynamic analysis is conducted using the low-fidelity, panel-method-based XFOIL. To facilitate the calculations of the methodology, an in-house software is developed on MATLAB and the optimization of the center-body airfoil profile of a tactical, fixed-wing, Blended-Wing-Body (BWB) Unmanned Aerial Vehicle (UAV) experimental prototype is solved as a case study. The results of the study indicate that the current methodology can be successfully utilized for the optimization of the BWB UAV layout by providing all-round optimized airfoils.

16:10-16:30	FrC1.6

LS-SVM for LPV-ARX Identification: Efficient Online Update by Low-Rank Matrix Approximation, pp. 1590-1595

Cavanini, Luca	Università Politecnica Delle Marche
Ferracuti, Francesco	Università Politecnica Delle Marche
Longhi, Sauro	Università Politecnica Delle Marche
Monteriù, Andrea	Università Politecnica Delle Marche

Least-Squares Support Vector Machine (LS-SVM) is a promising approach to data-driven identification of Linear Parameter-Varying (LPV) models. As for other data-driven methods, the performance of the LS-SVM model identification method is strictly related to data available off-line for training the algorithm. Further, this method does not consider the possibility to learn from on-line data, or at least this is not possible in a computationally efficient way. These aspects limit the possibility to exploit the features of the algorithm in real- world applications. This paper presents an online updating procedure of LPV-ARX (AutoRegressive with eXogenous input) model based on the Low-Rank (LR) matrix approximation aided to overcome these limits. The proposed method permits to improve the base of knowledge of the provided LS-SVM by introducing the possibility to learn from on-line data, neglecting to perform the time-expensive training phase, such that the proposed approach is suitable for on-line execution. In order to further limit the computational cost and the storage memory related to the on-line learning feature, the proposed approach permits to maintain the original algorithm requirements by introducing a forgetting method able to neglect less important data. The performance of the proposed solution has been evaluate considering as case study a Spark-Ignited (SI) aircraft engine system identification.

FrC2	Kozani
Biologically Inspired and Energy Efficient UAS (Regular Session)	

14:30-14:50	FrC2.1

Effects of Unsteady Aerodynamics on Gliding Stability of a Bio-Inspired UAV, pp. 1596-1604

Sanchez-Laulhe, Ernesto	University of Seville
Fernandez-Feria, Ramón	University of Málaga
Acosta, Jose Angel	University of Seville
Ollero, Anibal	University of Seville

This paper presents a longitudinal dynamic model to be used in the control of new animal flight bio-inspired UAVs designed to achieve better performance in terms of energy consumption, flight endurance, and safety when comparing with conventional multi-rotors. In order to control these UAVs, simple models are needed to predict its dynamics in real time by the on-board autopilots, which are very limited in term of computational resources. To that end, the model presented considers transitional aerodynamic unsteady effects, which change significantly the evolution of the system. The physical relevance of these aerodynamic unsteady terms in gliding flight is validated by comparing with results when these new terms are neglected. Finally, an analysis of dynamic stability is proposed in order to characterize the transitional phases of gliding flight.

14:50-15:10 FrC2.2

Fault Recognition of Electric Servo Steering Gear Based on Long and Short-Term Memory Neural Network, pp. 1605-1613

Xu, Yixiang — Zhejiang University
Yang, Chunning — Zhejiang University

In order to recognize different kinds of faults of helicopters' three types of electric servos, this paper proposes a fault state recognition algorithm of electric steering gears based on long short-term memory(LSTM) neural network. Firstly, the original three types of electric servo data are preprocessed, the data set is transformed into a supervised learning problem, and the input variables are normalized. Secondly, different optimization algorithms are introduced to the LSTM neural network model to optimize the parameters. Finally, the number of different hidden layer neural network and the time step are set for comparison experiments, and the optimal neural network configuration is selected from them. The test results show that this model can effectively identify single and multiple faults. The training results show that the model can effectively identify single and multiple faults, and the recognition rate of pitch and left roll is high and has good practicability.

15:10-15:30 FrC2.3

Internal Combustion Engine Control System Design Suitable for Hybrid Propulsion Applications, pp. 1614-1619

Pavkovic, Danijel — University of Zagreb
Krznar, Matija — University of Zagreb
Cipek, Mihael — University of Zagreb
Zorc, Davor — University of Zagreb
Trstenjak, Maja — University of Zagreb

This paper presents a generator set speed control system within a hybrid propulsion based on an internal combustion engine (ICE) as primary energy source for a hypothetical multi-rotor unmanned aerial vehicle (UAV). The engine-generator set rotational speed is estimated based on rotor position sensing from embedded Hall sensors and armature current/voltage measurements within the framework of Kalman filtering. Based on these speed estimators, ICE speed control systems featuring proportional-integral (PI) and proportional-integral-derivative (PID) feedback controllers are designed utilizing damping optimum criterion, and the resulting control systems are validated by means of simulations within MATLAB/Simulink environment.

15:30-15:50 FrC2.4

Control of a Passively Coupled Hybrid Aircraft, pp. 1620-1627

Patience, Christian — McGill University
Nahon, Meyer — McGill University

Unmanned aerial vehicles have gained popularity in applications such as farming and package delivery, due to their low cost and versatility. The two traditional existing aircraft architectures are fixed wing and rotorcraft, each with distinct advantages. Tilt-rotor hybrid aircraft blend the two architectures and retain the advantages of each. However, their complex dynamics and broader flight envelope make them more difficult to control. The Vogi UAV can be classified as a tilt-rotor aircraft and comprises a fixed-wing body with a passively hinged quadrotor frame. In this paper, we present a single controller that seamlessly handles the transition from vertical to forward flight. The controller is evaluated in a comprehensive MATLAB/Simulink flight simulation. The test trajectory used covers all flight modes that a hybrid aircraft would undergo, including vertical take-off, forward flight with turns, and vertical landing. Since the proposed control strategy is largely platform-independent, it can be generalized to other tilt-rotor aircraft with modifications to the control allocation.

15:50-16:10 FrC2.5

Design and Fabrication of a Nomadic Solar-Powered Quad-Rotor, pp. 1628-1635

Henderson, Travis — University of Minnesota
Jenson, Devon — University of Minnesota
D'Sa, Ruben — University of Minnesota
Kilian, Jack — University of Minnesota
Papanikolopoulos, Nikos — University of Minnesota

The recent advancements and accessibility of unmanned aerial vehicles (UAV), particularly hover-capable rotorcraft, have captured the attention of companies, media, and the general public. As a result, rotorcraft UAVs are performing tasks of increasing sophistication and difficulty. Though key advancements in battery technology and electric motor efficiency in just the last decade have enabled great strides in platform utility, hovering UAVs are still severely limited in their usefulness due to their short flight time.

This aspect of rotorcraft makes their deployment dependent upon regular human intervention to replenish energy. However, the addition of passive energy collection has the potential to relax both the flight time constraint and the dependence of rotorcraft on direct human intervention for replenishing energy reserves. This paper demonstrates the addition of solar power collection to a prototype of the Solar UAV Quad (SUAV-Q) at the University of Minnesota and shows significant potential for performing long-term autonomous missions without the intervention of any third party.

16:10-16:30 FrC2.6

A Methodology for Preliminary Performance Estimation of a Hybrid-Electric Tilt-Wing Aircraft for Emergency Medical Services, pp. 1636-1643

Barra, Federico — Politecnico Di Torino
Capone, Pierluigi — Zurich University of Applied Sciences
Guglieri, Giorgio — Politecnico Di Torino

This paper aims to provide a simple methodology to preliminary size a hybrid-electric propulsion system for large scale piloted, optionally piloted or unmanned tilt-wing aircraft. In this work, the author refers to three mission profile representative of an Emergency Medical Service (EMS) operation and estimate the performance of the aircraft along the mission. Thus, based on some assumptions on battery technology, architecture of the hybrid system and mission safety requirements, a methodology for preliminary performance estimation is described and results for a baseline architecture are presented. Based on present and near future battery technology (in terms of charge/discharge rates and energy density), the present study shows how safety requirements can strongly affect the overall size of the power-plant system and impact the feasibility of hybrid-electric technology in aeronautical applications.

FrC3 Edessa

Manned/Unmanned Aviation (Regular Session)

14:30-14:50 FrC3.1

Rotor Performance Analysis and Modeling of Multirotor Using Wind-Tunnel Test, pp. 1644-1649

Ye, Jianchuan — Beijing Institute of Technology
Jiang, Wang — Beijing Institute of Technology
He, Shaoming — Cranfield University
Song, Tao — Beijing Institute of Technology

In this study, the performance characteristics of a rotor used for multirotor are investigated through wind-tunnel tests. The rotor is tested at several flow speeds and angles to approximate the actual flying condition. A high resolution six-axis force/moment sensor is utilized to record the forces and moments in three directions. Wind tunnel results show the changes in the rotor performance with the variation in flying speed, flying angle, and rotor revolution. The results also demonstrate that the aerodynamic characteristics of the rotor quite differ from those in the hovering state when the vehicle is flying forward. Finally, aerodynamic models of the rotor in forward state are provided.

14:50-15:10 FrC3.2

Flight Dynamics and Control of a New VTOL Aircraft in Fixed-Wing Mode, pp. 1650-1657

Gao, Honggang — Northwestern Polytechnical University
Liu, Zhenbao — Northwestern Polytechnical University
Wang, Ban — Northwestern Polytechnical University
pang, chao — Northwestern Polytechnical University

The aerodynamic layout of the fixed-wing mode of Canard Rotor/Wing (CRW) aircraft is quite different from that of the conventional fixed-wing aircraft. This study will focus on the flight dynamics characteristics and control in the fixed-wing mode of the CRW aircraft. First, aiming at the complicated aerodynamic interference in the fixed-wing mode of CRW aircraft, the flight dynamics model of the fixed-wing mode is established by combining CFD and engineering estimation. Then, by trimming at the different forward flight speeds, it is found that the minimum thrust is required when only the canard control surface is operated for longitudinal control. The linearized results show that the stability of most modes are good, and nevertheless only the Dutch roll mode diverges. It is found that the Dutch roll mode divergence is results from the unique three-wing aerodynamic layout of CRW aircraft. Finally, an explicit model tracking control system is designed to enhance the stability of the fixed-wing mode of CRW aircraft, which contributes for the future engineering application.

15:10-15:30 FrC3.3

Reporting UAS Related Incidents under Aviation Occurrence Reporting Legislation, pp. 1819-1827

Kasprzyk, Piotr — Lazarski University in Warsaw
Konert, Anna — Lazarski University in Warsaw

The paper is analyzing the regulations on reporting of UAS related incidents other than accidents or serious incidents. Regulations are discussed in the context of available statistics and its analyses from European and national perspective. Finally, the goal of the paper is to provide some recommendations with regards to the reporting and analyzing UAS incidents in order to improve the safety integration of unmanned UAS.

15:50-16:10 FrC3.5

Autonomous Teammates for Squad Tactics, pp. 1658-1663

Tyler, James — Northeastern University
Arnold, Ross — Department of Defense
Abruzzo, Benjamin — US Department of Defense
Korpela, Christopher — United States Military Academy

The United States Department of Defense seeks to integrate small unmanned aerial systems (UAS) into infantry squads and develop tactics, techniques, and procedures using unmanned systems. Through an iterative design process consisting of live-fly tactical exercises, this research investigates the teaming of humans with unmanned aerial systems. Exercises involve force on force engagements to encourage the development of tactics and procedures for the future operating environment. Three successful mission tactics for leveraging UAS in missions are defined. In addition to autonomy, teams leverage convolutional and artificial deep neural networks running real time on aerial video feeds to identify and classify combatants and friendly forces.

16:10-16:30 FrC3.6

Operator Controlled, Reactive UAV Behaviors in Manned-Unmanned Teaming Scenarios with Selective Datalink Availability, pp. 1664-1670

Meyer, Carsten — University of the Bundeswehr Munich
Schulte, Axel — University of the Bundeswehr Munich

This article discusses a way to increase controllability of an unmanned aerial vehicles (UAV) when data link is not or only temporarily available, by providing user-adaptable reactive behaviors of a UAV to events, and user-adaptable constraints of how to execute a task. Effective use of current unmanned systems in manned military missions is dependent on a continuous datalink. An interrupted datalink makes it impossible to issue or alter commands, having a negative impact on controllability of the UAV. We aim to increase controllability during datalink outages by allowing the pilot to define automatic behaviors as reactions to events as well as constraints defining how to execute tasks and reactions. The occurrence and time of these events is uncertain while the datalink is still available, hence a direct and explicit formulation of a reaction is impossible. This contribution describes a functioning implementation of automation functions and an interface for user-adaptable behaviors in a full mission, Manned-Unmanned Teaming helicopter simulator. Automation functions have been integrated by extending an existing planning agent, the user interface has been fully integrated into a tactical command interface. Preliminary tests during testing and development of the automation functions and interface suggest the desired increase in operational capabilities and controllability by the pilot. The possibility to define reactions to events can greatly improve contingency planning capabilities and resilience towards datalink interruptions. User-adaptable behaviors can contribute to a safe and effective integration of UAV into non-segregated civilian air space by enabling situation adapted reactions to system failures.

FrC4 — Naousa

Air Vehicle Operations (Regular Session)

14:30-14:50 FrC4.1

UTM System Operational Implementation As a Way for U-Space Deployment on Basis of Polish National Law, pp. 1671-1678

Kotlinski, Mateusz — Polish Air Navigation Services Agency

UAVs have become one of the common users of the airspace. The rising number of UAVs' operations resulted in the interest of numerous States, entities and international organizations and agencies to work on the safe integration of manned and unmanned operations. There are many projects and demonstrations which are tasked to tackle the task of U-space concept implementation. Between different approaches to the same goal there are few which involves the UTM (Unmanned Traffic Management) system as a core of U-space deployment. One of the examples of such deployment is the operational implementation of the UTM system called PansaUTM in Poland. This paper is focused to show how important is the proper legislation and cooperation of different stakeholders in order to implement such a complex concept as U-space.

14:50-15:10 FrC4.2

A New Method to Combine Detection and Tracking Algorithms for Fast and Accurate Human Localization in UAV-Based SAR Operations, pp. 1679-1687

Lygouras, Eleftherios — Democritus University of Thrace
Gasteratos, Antonios — Democritus University of Thrace

This paper presents the study and the evaluation of GPS/GNSS techniques combined with advanced image processing algorithms for the precise detection, positioning and tracking of distressed humans. In particular, the issue of human detection on both terrestrial and marine environments, as the human silhouette in a marine environment may differ substantially from a land one, is addressed. A robust approach, including an adaptive distressed human detection algorithm running every N input image frames combined with a much faster human tracking algorithm, is proposed. Real time or near-real-time distressed human detection rates, under several illumination and background conditions, can be achieved using a single, low cost day/night NIR camera. It is mounted onboard a fully autonomous UAV for Search and Rescue (SAR) missions. Moreover, the collection of a novel dataset, suitable for training the computer vision algorithms is also presented. Details about both hardware and software configuration as well as the assessment of the proposed approach performance are discussed. Last, a comparison of the proposed approach to other human detection methods

used in the literature is presented.

15:10-15:30 FrC4.3

Perching Upside down with Bi-Directional Thrust Quadrotor, pp. 1688-1694

Yu, Pengfei	The University of Sydney
Chamitoff, Gregory	The University of Sydney
Wong, KC	The University of Sydney

In this paper, we utilized a bi-directional thrust quadrotor with manipulators to mimic a bat's upside-down perching maneuver. This "perch and watch" capability could be beneficial to some specific mission involved extended endurance, such as monitoring wild animals in a natural reserve. This capability also avoids the downwash effect that commonly encountered during an upright perching. The bi-directional thrust is achieved by the dedicated Electric Speed Controller (ESC) firmware which could drive motor bi-directionally during the flight and with nearly symmetric fixed pitch propeller. This method of generating bi-directional thrust has a noticeable delay compared to a variable pitch propeller mechanism, thus a compensation strategy is adopted to minimize the delay in the process of reversing the propeller. So the altitude loss is minimized when a half flip maneuver is conducted. We also noticed that an inverted quadrotor generates more thrust compared to the upright configuration due to frame obstruction, thus controller gains also need to be compensated for accurate trajectory tracking. A customized offboard control method is developed to achieve this perching upside maneuvers with a motion capture system. Finally, a feasible perching trajectory is generated, and the test result is presented.

15:30-15:50 FrC4.4

Fuzzy Model Predictive Control of a Quadrotor Unmanned Aerial Vehicle, pp. 1695-1704

Hossny, Mohamed	German University in Cairo
El-Badawy, Ayman	German University in Cairo
Hassan, Ragi	German University in Cairo

This paper proposes a new design of a Fuzzy Model Predictive Control (FMPC) algorithm for controlling a quadrotor unmanned aerial vehicle. The quadrotor's nonlinear model is represented by a Takagi-Sugeno (T-S) fuzzy model, where the nonlinear model is approximated by multiple linear models, and the fuzzy combination of these linear models constructs the overall fuzzy model of the nonlinear system. The performance of the proposed FMPC algorithm is compared with Linear Model Predictive Control (LMPC), and Nonlinear Model Predictive Control (NMPC) applied on the nonlinear model of the quadrotor system. Simulation results show that FMPC yields better performance and a wider flight range than LMPC. FMPC also proved to have almost similar results to NMPC in trajectory tracking but with less computational time. Finally, the control invariant sets are calculated, and the results are analyzed.

15:50-16:10 FrC4.5

Dynamic Modeling of a Transformable Quadrotor, pp. 1705-1710

Derrouaoui, Saddam Hocine	Ecole Militaire Polytechnique
Guiatni, Mohamed	Ecole Militaire Polytechnique
Bouzid, Yasser	Ecole Militaire Polytechnique
Islam, Dib	Ecole Militaire Polytechnique
Nour Eddine, Moudjari	Ecole Militaire Polytechnique

This paper proposes a new design of the well-known quadrotor UAV. This design is based on a variable morphology that can be modified instantaneously during the flight, according to the tasks and the followed trajectory. It is able to change the rotation and the extension of its arms independently. This quadrotor exploits simple mechanisms i.e. extendable arms and rotating arms. The modeling of this category of quadrotors is not obvious compared to the conventional ones because of its asymmetry. So, a detailed generic model that takes into account the variation of the center of gravity and the inertia is presented. The first prototype platform with rotating arms and some possible configurations will be shown.

16:10-16:30 FrC4.6

Robust Immersion and Invariance Adaptive Control with Disturbance Observer for a Quadrotor UAV, pp. 1711-1716

Han, Qi	Beijing Jiao Tong University
Liu, Xiangbin	Beijing Jiao Tong University
Zou, Lang	Beijing Jiao Tong University

In this paper, a robust immersion and invariance(I&I) adaptive control with disturbance observer(DO) is proposed for an uncertain quadrotor unmanned aerial vehicle(UAV) subjected to disturbance. The parametric uncertainties in both position loop and attitude loop of a quadrotor are compensated by I&I adaptation laws, while the disturbances in the attitude loop are attenuated by a constructed disturbance observer. The ultimate boundedness of the attitude tracking errors, and the satisfying trajectory tracking performance of the quadrotor are guaranteed by the presented control law with stringent proof. Physical experiment results are carried out to illustrate the effectiveness of the proposed control law.

FrD1 Macedonia Hall

UAS Testbeds (Regular Session)

16:30-16:50	FrD1.1

Joint Virtual and Physical Prototype Design and Testing of a Sensor Fusion Workbench for Fixed-Wing UAVs, pp. 1717-1723

Huang, Peng	Technische Universität Dresden
Meyr, Heinrich	Barkhausen Institut
Fettweis, Gerhard	Technische Universität Dresden

Unmanned aerial vehicles (UAVs) require cost-efficient on board multi-sensor fusion to achieve accurate and reliable flight state estimation. The challenges behind the implementation of sensor fusion algorithms from scratch towards in-flight testing on microcontroller-based hardware are, however, demanding, since it requires not only understanding and implementing complex sensor fusion algorithms but also developing embedded software in a microcontroller. Those challenges make the process of prototyping onboard sensor fusion algorithms time-consuming, expensive, and inefficient. We present fast prototyping of a sensor fusion workbench based on extended Kalman filtering (EKF) for fixed-wing UAVs. The workbench incorporates multiple sensors, including an inertial measurement unit, a GPS receiver, and static and dynamic pressure sensors. The multi-sensor fusion algorithm has been tested under virtual flight data, as well as measured flight data including challenging environments with thermals and gusts. After performance evaluation, we transferred the algorithm from MATLAB code to C code and integrated it into an avionics device LXNAV S10. The implemented sensor fusion algorithm has been successfully tested on a manned glider under windy and turbulent environment.

16:50-17:10	FrD1.2

Bebop 2 Quadrotor As a Platform for Research and Education in Robotics and Control Engineering, pp. 1724-1732

Giernacki, Wojciech	Poznan University of Technology
Kozierski, Piotr	Poznan University of Technology
Michalski, Jacek	Poznan University of Technology
Retinger, Marek	Poznan University of Poznan
Madonski, Rafal	Jinan University
Campoy, Pascual	Universidad Politecnica Madrid

In conducting research and teaching in fields related to unmanned aerial vehicles (UAVs), it is particularly important to select a universal, safe, open research platform and tools for rapid prototyping. Ready-to-use, low-cost micro-class UAVs such as Bebop 2 are successfully used. This article presents how to use the potential of this flying robot with Robot Operating System (ROS). The most important software solutions for the developed experimental testbed FlyBebop are characterized. Their capabilities in research and education are exemplified here using three distinct cases: 1) research results on the method of optimal, in-flight, iterative self-tuning of UAV position controller parameters (which based only on current measurements), 2) the use of the reinforcement learning method in the autonomous landing of a single drone on a moving vehicle, 3) planning the movement of UAVs for autonomous video recording along the planned path in the arrangement: "cameraman drone" and "lighting technician drones".

17:10-17:30	FrD1.3

Omnibot: A Small Versatile Robotic Platform Capable of Air, Ground, and Underwater Operation, pp. 1733-1738

Canelon-Suarez, Dario	University of Minnesota
Wang, Youbing	University of Minnesota
Papanikolopoulos, Nikos	University of Minnesota

Autonomous systems are increasingly sought after and most available ones are designed to operate in a limited environment. Complementary to available systems, by combining different mechanisms into one design, a new kind of universal robotic platform called the Omnibot is proposed, which can fly, move on the ground, swim and dive into the water at the same time. To achieve this goal, a quadrotor configuration, screwdrive drivetrain, and a bladder-based buoyancy unit are proposed as a robotic design and a proof-of-concept platform is developed. Preliminary results demonstrate that the system is lightweight, cost-effective, versatile and able to navigate in the four kinds of environments and switch between them seamlessly without changing its hardware. This proposed design would enable a robotic system to switch among its methods for locomotion and choose the best mode according to the current goal, environment and the internal power supply conditions thus making it especially suited to carry out complex missions in changing and unpredictable environments.

17:30-17:50	FrD1.4

Modeling and Control of an Overactuated Aerial Vehicle with Four Tiltable Quadrotors Attached by Means of Passive Universal Joints, pp. 1739-1747

Iriarte, Imanol	Tecnalia
Otaola, Erlantz	Tecnalia
Culla, David	Tecnalia
Iglesias, Iñaki	Tecnalia
Lasa, Joseba	Tecnalia
Sierra, Basi	University of Basque Country

We present a novel over-actuated aerial vehicle based on four quadrotors connected to an airframe by means of passive universal

joints. The proposed architecture allows to independently control the six degrees of freedom of the airframe without having fixed propellers at inefficient configurations or making use of dedicated rotor tilting actuators. After deriving the dynamic equations that describe its motion, we propose a linear control strategy that is able to successfully decouple rotation and translation, relying exclusively on on-board sensors. A prototype is built and preliminary experimental results demonstrate that the concept is feasible.

17:50-18:10 FrD1.5

UAS Testing in Low Pressure and Temperature Conditions, pp. 1748-1756

Scanavino, Matteo — Politecnico Di Torino
Avi, Arrigo — Eurac Research
Vilardi, Andrea — Eurac Research
Guglieri, Giorgio — Politecnico Di Torino

The increasing demand of UAS has generated interest in the scientific community to understand how the environmental parameters affect performance of these emerging vehicles. A bias in the existing tests has been the nonreproducibility of the same climatic conditions. Therefore, UAS have not been fully exploited by the marker so far. Standard protocols for UAS testing in unconventional weather conditions have not been investigated from both industry and academic research. Temperature and pressure are environmental parameters that affect the aerodynamics of Unmanned Aircraft Systems (UAS). Low Reynolds numbers are common for small scale UAS and have a strongly influence on propeller and vehicle capabilities. In the past years, experimental studies on the effects of low Reynolds numbers have been carried out in wind tunnel facilities in conventional atmospheres (ambient temperature and pressure). Moreover, the complexity of the aerodynamic field results in propeller and full vehicle performance prediction methods with limited accuracy. In this paper an experimental setup inside a climatic and hypobaric laboratory is used to highlight temperature and pressure influence on single propeller and full vehicle performance in static conditions (hover). Test results are discussed and provided to the reader, highlighting the complexities of the measurements when extreme temperature and low pressure are set. The main contribution of this study is a set of experimental data to pave the way for a deep investigation on harsh environmental conditions on UAS propulsion system. Index Terms—Propeller and UAS Performance, Harsh Environmental Conditions, Test Stand

17:50-18:10 FrD1.6

EuroDRONE, a European UTM Testbed for U-Space, pp. 1757-1765

Lappas, Vaios — University of Patras
Shin, Hyo-Sang — Cranfield University
Tsourdos, Antonios — Cranfield University

EuroDRONE is an Unmanned Traffic Management (UTM) demonstration project, funded by the EU's SESAR organization and its aim is to test and validate key UTM technologies for Europe's 'U-Space' UTM program. The EuroDRONE UTM architecture is made of cloud software (DroNav) and hardware (transponder) to be installed on drones. The proposed EuroDRONE system is a Highly Automated Air Traffic Management System for Small UAVs Operating at Low Altitudes. It is a sophisticated self-learning system based on software and hardware elements, operating in distributed computing environment, offering multiple levels of redundancy, fail-safe algorithms for conflict prevention/resolution and assets management. EuroDRONE focuses its work on functionalities which involve use of new communication links, use of V2I and V2V technology to communicate information and drones for safe and effective UTM functionality. Practical demonstrations taken place in Patras / Messolonghi in 2019 are presented and show the benefits and shortcomings for near term UTM implementation in Europe.

FrD2 Kozani

Simulation (Regular Session)

16:30-16:50 FrD2.1

The Simulator-In-Hardware: A Low Cost and Hard Real-Time Hardware-In-The-Loop Simulator for Flying Vehicles, pp. 1766-1772

Chiappinelli, Romain — McGill University
Nahon, Meyer — McGill University
Apkarian, Jacob — Coriolis G, Toronto, Canada

Hardware-In-The-Loop simulation is nowadays widely used to validate the control and estimation algorithms of autonomous flying vehicles before attempting the first flight. It avoids the time and cost of a real flight while ensuring testing the algorithms in a safe and controlled environment. However, this technology can be cost-prohibitive when implemented with a computer capable of real-time response. An alternative approach, proposed here, is to implement the simulator in the hardware autopilot. This ensures the simulator is running on a real-time operating system on the autopilot board itself. The obtained results demonstrate that this simulator shows performances similar to conventional hardware-in-the-loop approaches while ensuring a very accurate sampling time.

16:50-17:10 FrD2.2

Flight Control Simulation and Battery Performance Analysis of a Quadrotor under Wind Gust, pp. 1773-1782

Kim, Hyeongseok — Seoul National University
Lim, Daejin — Seoul National University
Yee, Kwanjung — Seoul National University

Quadrotors are utilized in various applications, such as industrial and public services. Despite their various applications, the operation of quadrotors is restricted by wind disturbances due to their small size and multiple propellers. The wind disturbances cause additional thrusts of the propeller, resulting in more battery energy. To consider the additional battery energy, this study developed a multidisciplinary simulation tool that can estimate the control performances changed by the wind disturbances and corresponding battery capacity. The simulation tool was validated by comparing analysis results with those of flight test data. Then, the impact of wind disturbances on the required battery energy was investigated in various wind conditions. As a result, the remarkable difference of 13% total battery capacity caused by the wind disturbances was revealed. It was concluded that the conceptual design process should consider the ambient air environment.

17:10-17:30 FrD2.3

Simulating GPS-Denied Autonomous UAV Navigation for Detection of Surface Water Bodies, pp. 1783-1791

Singh, Arnav Deo — Queensland University of Technology
Vanegas Alvarez, Fernando — Queensland University of Technology

The aim to colonize extra-terrestrial planets has been of great interest in recent years. For Mars, or other planets to sustain human life, it is essential that water is present and accessible. Mars may contain or provide signs of the possibility of near surface water, but this work will only focus on surface water for the purposes of simulation. In this paper, we present a method for autonomous navigation and detection of surface water bodies in the GPS denied environments of Mars via a fully autonomous UAV. A combination of existing state-of-the-art tools and techniques have been utilized to enable the development of this system. Additionally, we create a modular framework to simulate the mission using the AirSim simulation environment and the Robot Operating System (ROS). The simulation environment is leveraged by using the Unreal game engine running in Windows OS, interfacing with an open source software for simultaneous localization and mapping (SLAM), running on ROS and Linux OS. A simulated mission was successfully implemented and demonstrated using the framework. Results obtained indicate that the framework enables the navigation of a UAV in the simulated Mars environment and allows the UAV to detect surface water bodies. The developed simulation framework, along with the knowledge and techniques attained in this research, could accelerate the development, testing and deployment of missions for a real-world Mars UAV, for the detection of surface water bodies. Additionally, this research aims to support and build upon prior work to further aid the search for water on other planets, as well as assisting humans in becoming a multi-planet species.

17:30-17:50 FrD2.4

Modelling and Simulation of a Tethered UAS, pp. 1792-1799

Dicembrini, Emilio — Politecnico Di Torino
Scanavino, Matteo — Politecnico Di Torino
Dabbene, Fabrizio — Politecnico Di Torino
Guglieri, Giorgio — Politecnico Di Torino

Battery lifetime is one of the most challenging problems for Unmanned Aircraft System (UAS) applications. Multi-rotor platforms usually suffer limited payload capabilities and flight time. To overcome this problem, tethered vehicle solutions have been developed. In this paper, we propose a mathematical model able to describe the dynamic behaviour of a tethered UAS. The approach is based on the Finite Element Method and Lagrange's Equation of motion. The cable is divided into segments linked to each other by spherical joints. An additional virtual element is used to represent the vehicle dynamics. Compared to other works, a variable cable length is implemented as well as wind effects on overall system are included. Simulation results corroborate that the proposed approach is able to simulate how the cable and UAS work in different operating conditions, such as take-off and hovering in both still air and wind scenario.

17:50-18:10 FrD2.5

Model-In-The-Loop Testing of Control Systems and Path Planner Algorithms for QuadRotor UAVs, pp. 1800-1809

David Du Mutel de Pierrepont Franzetti, Iris — Universidad Politécnica De Cataluña
Carminati, Davide — Politecnico Di Torino
Scanavino, Matteo — Politecnico Di Torino
Capello, Elisa — Politecnico Di Torino

Real systems, as Unmanned Aerial Vehicles (UAVs), are usually subject to disturbances and parametric uncertainties, which could compromise the mission accomplishment, considering in particular harsh environment or challenges applications. For this reason, the main idea proposed in this research is the design of the on-board software, as autopilot software candidate, for a multirotor UAV. In detail, the inner loop of the autopilot system is designed with a variable structure control system, based on sliding mode theory, able to handle external disturbances and uncertainties. This controller is compared with a simple Proportional-Integral-Derivative controller, usually implemented on the on-board software. The key aspects of the proposed methodology are the robustness to bounded disturbances and parametric uncertainties of the proposed combination of guidance and control algorithms. A path-following algorithm is designated for the guidance task, which provides the desired waypoints to the control algorithm. Model-in-the-loop simulations have been performed to validate the proposed approaches. Computational efficient algorithms are proposed, as combination of a robust control system and path planner. Extensive simulations are performed to show the effectiveness of the proposed methodologies, considering both disturbances and uncertainties.

17:50-18:10 FrD2.6

A Gazebo/ROS-Based Communication-Realistic Simulator for Networked SUAS, pp. 1810-1818

Moon, Sangwoo	University of Colorado Boulder
Bird, John	University of Colorado Boulder
Borenstein, Steve	University of Colorado
Frew, Eric W.	University of Colorado, Boulder

Although communication is a critical factor of situational awareness and performance on networked sUAS, most simulators do not provide realistic wireless communication modules. It prevents realizing communication among multiple UA and information sharing, which yields significantly different results compared with actual results in the real world. This paper presents a communication-realistic simulator to improve more realistic results from coordination or cooperative planning/control of networked sUAS. The simulator in this paper is based on Gazebo/ROS with ArduPilot, where ArduPilot-Socket-API (APS) which generates aircraft data to be usable in ROS from ArduPilot is implemented. The wireless transceiver plugin in Gazebo is used to mimic the wireless communication between two UA with aids of the Hata-Okumura model for wireless radio propagation and quadrature phase-shift keying (QPSK) for data package modulation. Simulation results describe how realistic communication in the presented simulator affects data delivery concerning different communication-related parameters. This paper also gives how well the presented simulator emulates communication status realistically by comparing it with communication data gathered in real flight tests.

FrD3 Edessa

Manned/Unmanned Aviation and Testbeds (Regular Session)

16:50-17:10 FrD3.1

A Prescribed Performance Adaptive Optimal Control Scheme for Flying-Wing Aircraft, pp. 1828-1833

Huang, Chenyu	Nanjing University of Aeronautics and Astronautics
Zhang, Shaojie	Nanjing University of Aeronautics and Astronautics

A model-free adaptive control scheme combining the incremental control, recursive least squares identification, approximate dynamic programming algorithm and prescribed performance control theory is proposed for a kind of flying-wing aircrafts to improve dynamic performance for issue of regulation control. In this work, prescribed performance bound function is introduced to help simplify the adaptive controller design process so as to reduce dependence on human experience when designing and choosing certain parameters, at the meantime, the boundness and convergence of state are both guaranteed. Finally, the effectiveness of the presented approach is validated by several simulations.

17:10-17:30 FrD3.2

A Systematic Modelling Framework for Commercial Unmanned Hexacopter Considering Fractional Order System Theory, pp. 1834-1843

Sridhar, Nithya	TCS Research and Innovation
N S, Abhinay	Tata Consultancy Services
Bodduluri, Chaithanya Krishna	Tata Consultancy Services
Das, Kaushik	TATA Consultancy Service
Maity, Arnab	Indian Institute of Technology Bombay

This research work proposes a systematic methodology to model Commercial-Off-The-Shelf Unmanned Aerial Vehicle (UAVs) that belong to the class of multicopters. The modelling framework consists of meticulous analysis of frequency domain and time domain data acquired from the hexacopter. The aim of this work is to model a commercially available UAV to enable the development of an efficient outer loop controller, specific to the intended application. This framework makes use of sine and step response data of the hexacopter's velocities in all the three planar axes corresponding to the global frame of reference. The framework considers the fractional-order model as a potential candidate for the UAV. Hence, it consists of a systematic method to determine the order of the model in integers or fractions, and its parameters. In the modelling process, control theory and fractional order theory have been sufficiently used to best correlate theoretical proposition with experimental outcomes. Also, real world factors and system constraints have been explicated and considered appropriately. The model obtained using the proposed framework has an average error of less than 5% when compared to the real system's response. Additionally, the ill effect of considering a near integer order model for a fractional order system is demonstrated to show the importance of this modelling framework. Further, a linear controller is implemented for the system using the estimated model and corroborated with real world results.

17:30-17:50 FrD3.3

UAS, Data and Privacy Protection within the European Union: The Case of Greece, pp. 1844-1851

Sansaridis, Serafeim	Attorney at Law, DUTH & University of Macedonia

The paper at hand analyzes briefly how data protection and privacy issues are being regulated within the European Union (EU), as fast as the field of unmanned aviation is concerned. It presents how the EU institutions comprehended the above-mentioned issues during the effect of Directive 95/45/EC and how the Greek authorities handled relevant cases within their territory, so that the reader can understand the challenges that will arise after the introduction of GDPR and the newly introduced regulations of the EU about UAS.

17:50-18:10 FrD3.4

Wake Interactions of a Tetrahedron Quadcopter, pp. 1852-1859

Epps, Jeremy	Georgia Institute of Technology
Garanger, Kevin	Georgia Institute of Technology
Feron, Eric	King Abdullah University of Science and Technology

This paper studies the influence of the placement of a quadcopter's rotors with a tetrahedron shape on its produced thrust. A tetrahedron quadcopter is a rotorcraft with four horizontal rotors, including an upper rotor and three lower rotors placed equidistant around the upper rotor on a lower plane. The goal of this aircraft design is to create an airframe that is structurally rigid in 3-dimensions while being as efficient as an aircraft that has its rotors on the same vertical plane. Due to the wake interaction between the top and bottom propellers, a reduction of thrust is expected compared to a placement of the rotors on the same plane when rotors are close enough. The results presented in this paper illustrate how the wake interactions impact the performance of several configurations of the tetrahedron quadcopter.

17:50-18:10 FrD3.5

A 4D Trajectory Follower Based on the 'Carrot Chasing' Algorithm for UAS within the U-Space Context, pp. 1860-1867

Perez-Leon, Hector	University of Seville
Acevedo, José Joaquín	AICIA
Maza, Ivan	University of Seville
Ollero, Anibal	University of Seville

This paper is focused on the trajectory following problem for unmanned aerial systems in the context of the U-space and the 4D trajectory-based operations (4D-TBO). A trajectory follower implementation for UASs, based on the carrot chasing algorithm, is presented with the twofold objective of minimizing the mean normal distance to the user-defined path and the mean difference with respect to the defined arrival times through the whole flight. The paper presents simulated, and real flights carried out under the ROS (Robotic Operating System) framework that allow us to compare and analyze the behavior of the proposed solution for different policies.

18:10-18:30 FrD3.6

Safe Flyable and Energy Efficient UAV Missions Via Biologically Inspired Methods, pp. 1868-1877

Platanitis, Konstantinos	Technical University of Crete
Kladis, Georgios P.	Hellenic Army Academy
Tsourveloudis, Nikos	Technical University of Crete

In this article the offline Unmanned Aerial Vehicle (UAV) path planning problem is addressed for real environments whilst enhancing energy requirements. In particular, a two-step procedure is adopted for the determination of the energy efficient safe flyable path that satisfies a-priori defined criteria. By the former step, via principles of mechanics, safe flyable candidate paths are designed meeting functional/physical limitations of the aerial vehicle. By the latter step, those paths are fed in the Genetic Algorithm (GA) setup, and the best path that fulfils mission's objectives and satisfies constraints is determined. The efficacy of the approach is shown via simulation examples, where a UAV is deployed to safely navigate with the least energy demand in an a priori known environment whilst meeting mission objectives.

ICUAS '20 Key Word Index

Thank You