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ICUAS MAGAZINE

State-of-the-art
and recent developments
in unmanned aviation

In This Issue

EDITORIAL

Dear Readers:

First, we wish you a Happy New Year, with health, happiness, and prosperity. Next, we welcome you to the inaugural issue of the ICUAS eMagazine. The eMagazine is the logical transition from the initial Newsletter, which served its purpose, to a more substantial and informative publication.

The aim of the eMagazine is multifold: i) It will publish invited and submitted peer reviewed papers on selected topics (referring to technical advances and applications) in unmanned aircraft systems: ii) It will publish select papers on unmanned aviation regulations, legal, privacy, ethical and other regulatory issues, and challenges we face before complete integration into the national airspace: iii) It will serve as an information depository for our regular readers and followers, but also for practitioners and end-users who simply want to 'find out' and 'learn' about unmanned aviation in general, and iv) It will serve as the backbone for the annual International Conference on UAS.

The eMagazine is managed by a small Editorial Board. Its members, their credentials and professional experience are presented below. The plan is to enhance the Board as needed.

This issue includes three invited articles:

- UAS Regulations in Europe, authored by Dr. Anna Konert and Dr. Piotr Kasprzyk, summarizes the current state-of-the-art in regulations and regulatory frameworks (mostly within the EU), it presents steps that need to be followed by operators to fly drones, and offers information about what comes / should come next. The article includes website references for quick access to information on drones and details for the registration process.
- Smart Big Data in Precision Agriculture Applications: Acquisition, Advanced Analytics, and Plant Physiology-informed Machine Learning, authored by Haoyu Niu and Dr. YangQuan Chen, focuses on the use of UAV technology, where the aerial platform is also seen as a data acquisition device, but also serves as the eye-in-the-sky that dictates what needs to be done to optimize productivity.
- Challenges and Strategies for UAV-based Cargo Transportation, authored by Dr. Alexandre Santos Brandao, deals with aerial manipulation (stated differently with payload transportation using UAVs equipped with grippers and/or manipulators). It discusses challenges that need to be overcome and the stages that need to be followed to complete tasks.

We also provide the most recent update about the 2023 ICUAS that will take place on June 6-9 in Warsaw, Poland, while in the Latest News section we highlight selected events, announcements, and other useful information.

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EDITORIAL BOARD **INTRODUCTION**

EDITOR-IN-CHIEF

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Dr. Kimon P. Valavanis is currently John Evans Professor, D. F. Ritchie School of Engineering and Computer Science, University of Denver. He has been Guest Professor in the Faculty of Electrical Engineering and Computing, University of Zagreb; Visiting Professor at Politecnico di Torino, Dipartimento di Ingegneria Meccanica e Aerospaziale; and Professeur Invité, Université de Lorraine - Polytech Nancy. Dr. Valavanis' research interests focus on the areas of Unmanned Systems, Distributed Intelligence Systems, Robotics and Automation. He has published more than 450 book chapters, technical journal, and transaction papers, referred conference papers, invited papers and technical reports. He has authored, co-authored, and edited 19 books. He also holds several patents in unmanned aerial vehicles.

He was Editor-in-chief of the IEEE Robotics and Automation Magazine for ten years (1996-2005), and since 2006 he serves as Editor-in-chief of the Journal of Intelligent and Robotic Systems. He serves as Co-chair of the Aerial Robotics and Unmanned Aerial Vehicles Technical Committee since 2008.

Dr. Valavanis has served as a Technical Expert of the NATO Science and Technology Organization (STO). He was appointed in 2021 to the NATO STO Technical Team of SAS-ET-EX on "Integration of Unmanned Systems into Operational Units" for the duration of the Program of Work. He is Fellow of the American Association for the Advancement of Science, Fellow of the U.K. Institute of Measurement and Control, IEEE Senior Member, and a Fulbright Scholar (Senior Lecturing & Research Award).

ELECTRONIC SERVICES MANAGER

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Panos Valavanis is a Software Engineer working for Lockheed Martin. He has received BS and MS degrees in Computer Science from the University of South Florida (USF) in 2017 and 2019, respectively.

His MS thesis focused on vision-based quadrotor autonomous obstacle detection and avoidance in cluttered environments. While at USF, he was a member of the Herd of Thunder Marching Band Drumline, and then, Drum Captain of the ensemble.

His work at Lockheed Martin Missiles and Fire Control division focuses on embedded software development, real-time operating systems, software-hardware integration, testing, debugging, and system validation and verification. In his free time, he enjoys playing guitar and percussion, photography and scuba diving.

ART, PRODUCTION & MEDIA MANAGER

NADIA DANEZOU

Nadia Danezou studied Graphic Design in Akto Art and Design College in Athens, Greece. She has 25+ years of experience in visual communication and art direction, editorial and publication designs, brand identity, web design, packaging and advertising. She has organized several cultural events, exhibitions, musicals, art shows, and has managed and coordinated art and fashion publications and magazines. She has worked for more than 10 years in TV stations. She has been a lead member of the ICUAS Newsletter team and she now manages the eMagazine. Besides work, her passion is travelling, as any journey "expresses an attempt to turn the dream into reality".

ALEJANDRO SUAREZ

Alejandro Suarez is post-doctoral researcher in aerial robotics and assistant professor at the University of Seville (Spain). He received the degree in telecommunication engineering and the M.Sc. degree in automation and robotics from the University of Seville in 2012 and 2014, respectively, and the Ph.D. degree in robotics in 2019. Since 2012, he has been with the GRVC Robotics Laboratory, working in the FP7 EC-SAFEMOBIL and H2020 HYFLIERS projects, the PERIGEO and CLEAR Spanish projects, and other transfer projects with companies. In 2014, he obtained a FPU Grant from the Spanish Ministry of Education, Culture and Sport for supporting his research activity as a Ph.D. student in the frame of the AEROARMS H2020 Project, receiving the AIRBUS Chair Award and the SEIDROB-SPR Award for his PhD Thesis in 2019. For three months he stayed at the Robotics and Mechatronics Institute at DLR (Oberpfaffenhofen, Germany). He is currently working on the AERIAL-CORE H2020 Project, the ERC Advanced GRIFFIN Project, and euROBIN, the European RObotics and AI Network. He is author of more than 35 articles in international conferences and journals, including a survey paper in aerial robotic manipulation on the Transactions on Robotics. He was editor of the "Aerial Robotics for Inspection and Maintenance" book, participating as Program Chair in the ICUAS 2022 conference and serving as reviewer for IROS and ICRA conferences as well as for several journals in robotics. His research interests include aerial and space robotic manipulation, and the development of anthropomorphic, compliant, and lightweight robotic arms (LiCAS).

ELIZABETH J. KAISER

Elizabeth J. Kaiser is a Law Clerk of the firm LaFollette, Johnson, DeHaas, Fesler & Ames, which primarily specializes in defending healthcare providers in medical malpractice actions. She is a JD candidate at LMU Loyola Law School in Los Angeles, California, USA. Prior thereto, she received her BA in Political Science and Criminology from the University of Denver, Colorado, USA in 2020. Her research history is centered around astronomical studies. In 2015, she joined an infrared survey of Venusian climate, made possible by NASA. In 2016, she joined the Center for Gravitational Wave Astronomy, utilizing millisecond pulsars to identify gravitational waves. Leading to her legal studies, Elizabeth worked with Judicial Arbiter Group in Denver, Colorado, USA. In 2021, she joined The Atticus Project—a team of law students, attorneys, and artificial intelligence experts—where she contributed to the development contract-analyzing software. She served as a co-author for the forthcoming Handbook of Unmanned Aerial Vehicles, Second Edition, writing chapters explaining the various regulatory requirements and airspace considerations for UAS/UAV operation. She continues to research and author in this field.

BENJAMYN I. SCOTT

Benjamyn I. Scott is an Assistant Professor at Leiden University working at both the International Institute for Air and Space Law (IIASL), and Center for Law and Digital Technologies (eLaw). Dr. Scott holds an LLB (Hons) in Law with the EU Legal Studies from the University of Kent and the University of Amsterdam, an LLM in International Commercial Law with a focus on space law from the University of Kent (Distinction), an LLM (Adv.) in Air and Space Law from Leiden University (cum laude), and a PhD in Law from the University of Cologne (magna cum laude). Dr. Scott's PhD thesis explored the regulatory approach taken at a European and international level to aviation cybersecurity. The thesis was later published under the title Aviation Cybersecurity: Regulatory Approach in the European Union (Eleven, 2019). Dr. Scott has a strong background in developing and emerging technologies, where he has concentrated on unmanned aircraft systems (remotely piloted and autonomously flown), urban air mobility (eVTOL, societal acceptance and multimodality), cybersecurity, artificial intelligence, and unmanned traffic management. Dr. Scott has supported different stakeholder groups, presented at conferences, published journal articles and books, and lectured at different universities around the world. Of note, is his 2022 edited book titled 'The Law of Unmanned Aircraft Systems', which comprises of 43 chapters written by 44 different contributors from around the world. Finally, he is also a member of the Board of Editors of the Air & Space Law journal, and Aviation & Space Journal.

LUIS MEJIAS ALVAREZ

Luis Mejias studied electronic engineering at UNEXPO (Venezuela) obtaining the degree of Electronic Engineer in November 1999. In 2000, he joined the master program at ETSIT-Universidad Politécnica de Madrid obtaining a MSc. in Networks and Telecommunication Systems in 2001. After completing his master's degree, he moved to DISAM (ETSII) Universidad Politécnica de Madrid where he obtained his doctorate in Robotics and Automation. While completing his PhD he gained extensive experience with Unmanned Aerial Vehicles (UAVs) and Autonomous Helicopters investigating computer vision techniques for Guidance, Navigation and Control (GNC) of UAVs. He is currently an Associate Professor and Researcher at Queensland University of Technology, Australia.

HAO LIU

Hao Liu received a B.E. degree in control science and engineering from Northwestern Polytechnical University, Xi'an, China, in 2008, and the PhD degree in automatic control from Tsinghua University, Beijing, China, in 2013. In 2012, he was a visiting student in the Research School of Engineering, Australian National University. From 2013 to 2020, he was with the School of Astronautics, Beihang University, Beijing, China, where he is currently an Associate Professor. In 2020, he also joined the Institute of Artificial Intelligence, Beihang University, Beijing, China. Dr. Liu was also a visiting scholar at the University of Texas at Arlington, Automation and Robotics Research Institute in 2017-2018. His research interests include formation control, reinforcement learning, robust control, nonlinear control, unmanned aerial vehicles, unmanned underwater vehicles, and multi-agent systems. He serves as an associate editor of the Transactions of the Institute of Measurement and Control and Advanced Control for Applications: Engineering and Industrial Systems, and as Editor of the Journal of Intelligent and Robotic Systems. He is the recipient of the best paper award in IEEE ICCA 2018.

LAZARSKI.AVIATION

UAS REGULATIONS IN EUROPE

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Technological developments in the aviation industry are ahead of legal regulations; this is not unusual as we deal with this challenge in almost every other area in real life.

Several studies and published reports state that drones will gradually replace “traditional” (manned) aviation in diverse fields such as aerial photography, infrastructure monitoring or search and rescue operations. The cost of using unmanned aviation systems for such applications is incomparable to the cost incurred when using manned aviation systems and platforms. Services may be provided by the unmanned platform both remotely, i.e. with an operator (pilot) remotely controlling the platform, or autonomously in a pre-programmed way without an operator’s (pilot’s) intervention, or with the operator role simply limited to system supervision. It is a belief that unmanned aircraft systems will contribute to creating completely new types of services, which will stem from their ability to fly at very low altitudes and in urban areas. Transmission network monitoring or precise aerial application activities are just two examples of such new “aerial services”.

Public law defines a UAV/UAS as an aircraft that falls within the scope of aviation law, and only in certain cases do we need new, special regulations, which go beyond the framework of traditional aviation law. However, the rate of progress and of development of UAS technology in recent years, rightly gives grounds to state that we now deal with disruptive technology, which, is also disruptive for regulators.

It is possible to base UAS regulations on certain approaches that have been developed over the years for manned aviation safety regulations. These regulations should, above all, be proportionate. They can and should be differentiated depending on the risk associated with a given operation. However, unlike traditional safety regulations where an aircraft has always been the starting point, UAS safety regulations focus more on operations themselves. Currently, there are no commonly accepted standards for designing and manufacturing UAS/UAVs. An unmanned aircraft is more of a system in which the aircraft (understood as a device capable of sustained flight) is just one of its components. The aircraft maintains flight despite lacking crew on board and, therefore, – as a system – it must consist of other critical components such as a remote-control system or traffic detection and avoidance systems. These components also need to be subject to strict safety requirements. Determining these requirements is not the only challenge. It is also necessary to develop rules for UAS traffic organization and to review the principles of manned aviation traffic and airspace organization. Unfortunately, legal regulations are always one step behind when it comes to novel technology.

Effective January 1, 2021, the European Union (EU) Aviation Safety Agency (EASA) has standardized drone regulations throughout its member states. The new regulatory framework replaces existing regulations that were previously passed into law by individual member states. In addition to the 27-member states, Iceland, Switzerland, Lichtenstein, and Norway have also adopted the new EASA drone regulations. The EU and EASA also have set the framework in the field of unmanned control, but it is also necessary to analyze what is happening in other countries in Europe. Moreover, on April 22, 2021, the European Commission adopted the U-Space Regulation, which paves the way towards the widespread use of drones. This Regulation creates the conditions necessary for both drones and manned aircraft to operate safely in sections of the airspace known as the U-space. This Regulation will enter into force in January 2023, and it will enhance further the European drone services market. In addition, as part of preparing a regulatory framework, EASA conducted the "Study on the Societal Acceptance of Urban Air Mobility (UAM) in Europe" between November 2020 and April 2021 with a focus on the societal acceptance of UAM operations across the European Union. Based on research, literature review, local market analysis, surveys and interviews, the study examined the attitude, expectations, and concerns of EU citizens with respect to UAM.

EASA has also developed common European rules to ensure free movement of drones and a level playing field for all UAS operators in the EU. Thanks to these regulations, drone pilots can seamlessly perform drone operations while traveling within the EU or while developing their drone business in Europe. The principles described are based on an operational risk assessment and strike a balance between the responsibilities of drone manufacturers and operators in terms of safety, privacy, the environment, and noise protection. These regulations make it easier to fly a drone under the same conditions across most of Europe.

A drone operator needs to register once in their country of residence or main place of business. The unique drone operator registration ID can be used in all EASA Member States. If a drone operator wants to take a drone to another EASA Member State, all is needed is to ensure that the operator registration ID, obtained in the country of residence or place of business, is clearly visible on the drone.

Under the new European Drone regulation, all drone pilot certificates issued by any of the EASA Member States are recognized by, and in, all other EASA Member State countries. EASA itself does not issue pilot certificates. Therefore, if an operator has completed the necessary online training, has passed a drone's pilot exam and has gotten a remote pilot competency certificate in any EASA Member State, the operator can fly a drone in any other EASA Member State.

Non-EU individuals (including UK citizens) wishing to fly a drone in one of the EU Member States should register with the National Aviation Authority in the first EU country where they intend to fly a drone. If, for example, this country is Poland, an operator needs to register at drony.ulc.gov.pl, set up an operator profile and pilot profile, and then put the operator number on the drone. If operations are performed using a drone with a camera and weight up to 250 gr, registration alone is enough. If the drone weighs more than 250 gr, it is necessary to complete the online training and pass the online test. Training is free and includes getting acquainted with and understanding information describing the applicable regulations and flight rules. Each UAV operation within Polish airspace must take place after informing the Polish Air Navigation Service Agency (PANSA) about the intention to perform the flight via the ICT system specified by the Agency. This means that each UAV flight must be preceded by a check-in in the DroneRadar application. The UAS operator is fully responsible for the performed operation; before performing it, the operator must check the availability of airspace using the DroneRadar application or the PANSA website.

EASA provides a list with website references by country, as supplied by the respective National Aviation Authority (NAA) to ensure quick access to information on drones and details for the registration process (see: https://www.easa.europa.eu/en/domains/civil-drones/naa).

It is true that COVID-19 pandemic has affected commercial manned aviation, but it also has created an opportunity for unmanned aviation. There is considerable support for the idea to allow drones to fly in an automated way over longer distances, thus, reducing cost and making services more attractive. Scholars, scientists, engineers, researchers, and academics must have an independent view of existing unmanned aircraft regulations. To date, only regulators, stakeholders and drone users are familiar with EASA regulations (third party assessment). These are technical regulations, and it is necessary to analyze their impact on legal issues. Examples include the relation between the use of drones and property right; protection of the right to privacy; civil liability; criminal liability; insurance; trespass and nuisance; negligence, liability issues while using autonomous drones; liability for damages caused in U-space/UAM, and restrictions on operating drones in congested areas.

Smart Big Data in Precision Agriculture Applications: Acquisition, Advanced Analytics, and Plant Physiology-informed Machine Learning

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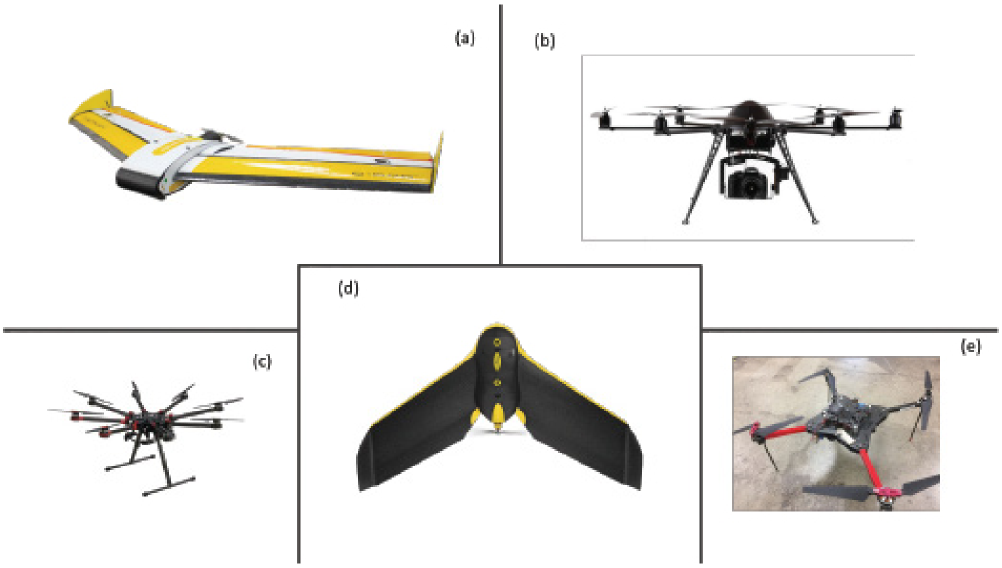
Big data acquisition platforms, such as small unmanned aerial vehicles (UAVs), unmanned ground vehicles (UGVs), and proximate sensors for precision agriculture, especially for heterogeneous crops, such as vineyards and orchards, are gaining interest from both researchers and growers. Typically, there are two types of UAV platforms, fixed-wing UAVs and multirotor (Figure 1). Fixed-wing UAVs can usually fly longer with a larger payload. It can usually fly for about 2 hours, which is suitable for a large scale of field. Multirotor can fly about 30 minutes with payload, which is suitable for short flight missions. For example, lightweight sensors mounted on UAVs, such as multispectral and thermal infrared cameras (Figure 2), can be used to collect high-resolution images. The higher temporal and spatial resolutions of the images, relatively low operational costs, and nearly real-time image acquisition make the UAVs an ideal platform for mapping and monitoring the variability of crops over large acreage [1].

Figure 1



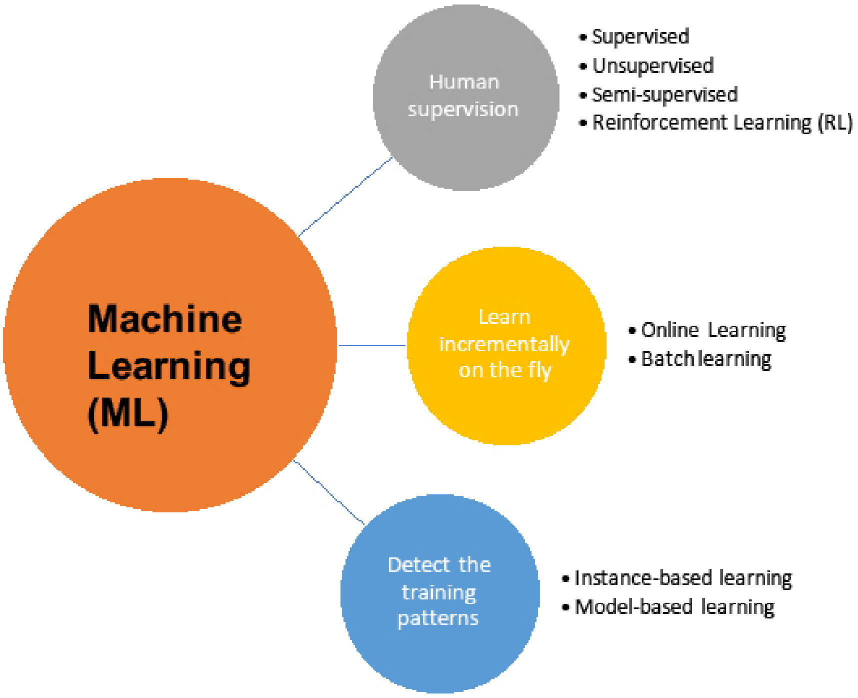
(a) The QuestUAV 200 UAV (b) The MK Okto XL 6S12 (c) The DJI S1000 (d) The eBee Classic (e) The Hover

The data acquisition platforms and analytics can create big data and demand fractional order thinking due to the "complexity" and, thus, variability inherent in the process. Much hope is placed on machine learning (ML) (Figure 3). How can an ML model learn from big data efficiently (optimally) and make the big data "smart" is important in agricultural research. The key to the learning process is the plant physiology and optimization method [2]. Designing an efficient optimization method poses three questions: 1.) What is the best way to optimize? 2.) What is the more optimal way to optimize? 3.) Can we demand "more optimal machine learning," for example, deep learning with the minimum or smallest labeled data for agriculture?

Figure 2 *(a) The multispectral camera, Rededge M (b) The ICI thermal camera (c) The MAPIR RGB or NIR camera (d) The SWIR camera*

Figure 3

The ML can be classified as supervised, unsupervised, semi supervised, and Reinforcement Learning (RL) based on whether human supervision is included. According to whether the ML algorithms can learn incrementally on the fly, they can be classified into online and batch learning. Based on whether the ML algorithms detect the training data patterns and create a predictive model, the ML can be classified into instance-based and model-based learning.



Therefore, the authors investigated the foundations of the plant physiology-informed machine learning (PPIML) and the principle of tail matching (POTM) framework. They elucidated their role in modeling, analyzing, designing, and managing complex systems based on the big data in precision agriculture. Plant physiology entails the complexity of growth. The complex system has both deterministic and stochastic dynamic processes with external driving processes characterized and modeled using fractional calculus-based models, which will better inform the complexity-informed machine learning (CIML) algorithms. Data acquisition platforms, such as low-cost UAVs, UGVs, and edge-AI sensors, were designed and built to demonstrate their reliability and robustness for remote and proximate sensing in agricultural applications.

For example, In the authors' research, "Individual Tree-level Water Status Inference Using High-resolution UAV Thermal Imagery and Complexity-informed Machine Learning [3]", the aim of this work was for irrigation treatment levels inference in the pomegranate field at the individual tree level by using UAV-based thermal images and machine learning algorithms. The authors collected the midday infrared canopy to air temperature difference by using a UAV-based high-resolution thermal camera (Figure 4). Then, CIML algorithms were adopted for

Figure 4

The IRT sensor was installed 4.5 m above the soil surface, with a FOV of 20 degrees. A quadcopter was used as the low-cost UAV platform (less than $1000)to collect high-resolution thermal images at the height of 60 m.

the tree-level irrigation treatment classification problem.

The author developed a reliable tree-level irrigation treatment inference method using UAV-based high-resolution thermal images. The research results showed that the best classification accuracy of irrigation treatment levels was 90% when the "Naive Bayes" method was adopted (Figure 5). The results of this research supported the idea that a significant increase in the midday infrared canopy to air temperature difference will indicate stomata closure and water stress conditions. The authors also proposed the concept of CIML and proved its performance on the classification of tree-level irrigation treatments. CIML models have great potential for future agriculture research. With more complex information, it will benefit the training and testing process of machine learning algorithms (Figure 6).

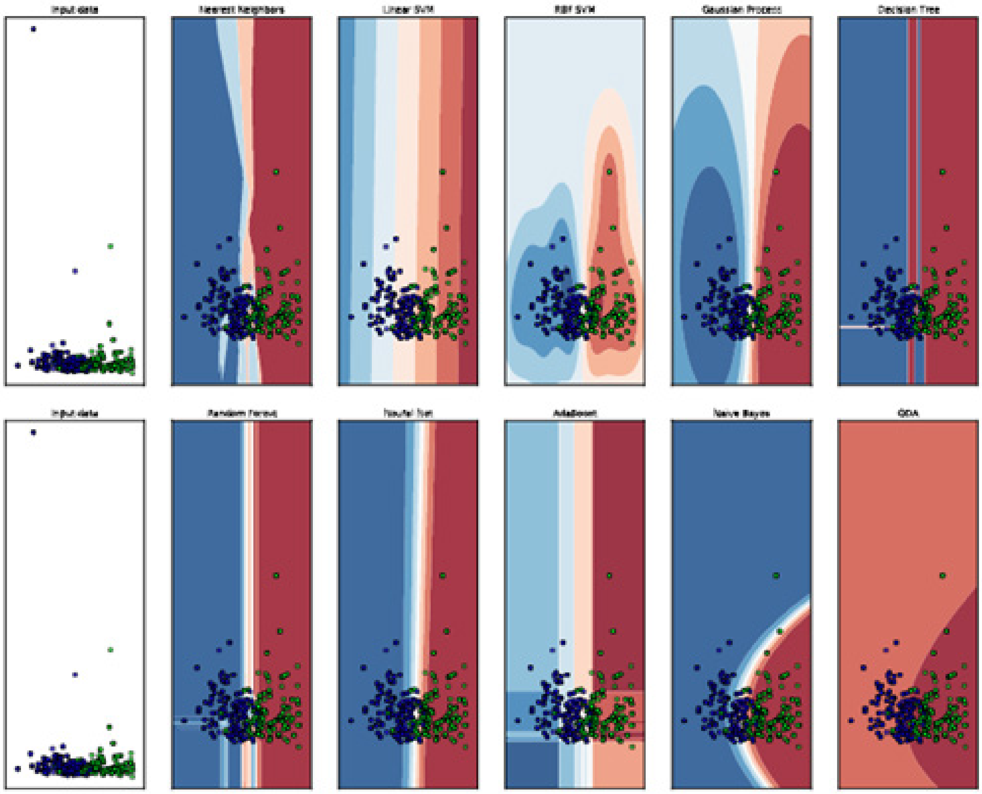


Figure 5

The test performance for the histogram dataset. The t-distributed stochastic neighbor embedding (TSNE) method was used for data visualization, which learned the most critical axes between the classes. The axes were then used to define the hyperplane to project the high-dimensional training data into two dimensions, which gained important insight by visually detecting patterns. The x-axis and y-axis had no scale because of hyperplane projection. The irrigation treatment levels were successfully clustered into low-level (blue) and high-level (green).

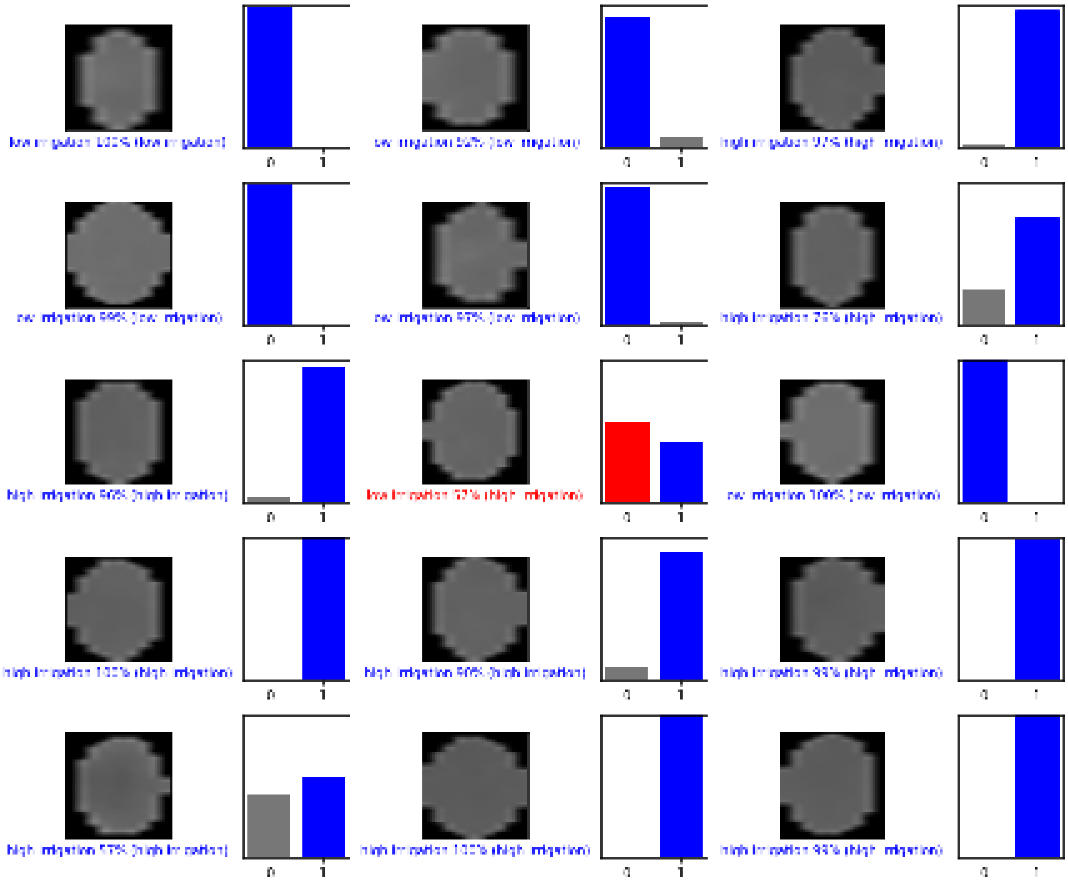


Figure 6 *To visualize the trained model performance, the authors made predictions about some images in the test dataset. Correct prediction labels are blue and incorrect prediction labels are red. The number gives the percentage (out of 100) for the predicted label.*

In another research, "Scale-aware Pomegranate Yield Prediction Using UAV Imagery and Machine Learning [4]", the aim of this work was for individual tree level yield prediction in the pomegranate field (Figure 7) using a UAV-based remote sensing method. The authors collected the yield data and calculated the vegetation indices derived from the high-resolution UAV imagery. Then, machine learning algorithms were adopted for the yield prediction classification (Figure 8). The research results showed that the best classification accuracy of yield was 85% when the "Decision Trees" method was being adopted (Figure 9). For the other ML models' test performance, the accuracy of the k-nearest neighbor was 0.8. "Support Vector Classification (SVC)" had an accuracy of 0.7. The "Random Forest" had a test accuracy of 0.65. The "AdaBoost", "Gaussian Process", and "Gaussian Naive Bayes" had an accuracy of 0.8, 0.75, and 0.6, respectively. The "QDA" also had a prediction accuracy of 0.8. The pomegranate yield information could be reflected by vegetation index data. The research results supported the idea that vegetation indices could be used for yield estimation. Furthermore, the findings of this research provided insights for the scale-aware yield prediction using phenotyping and machine learning technology.

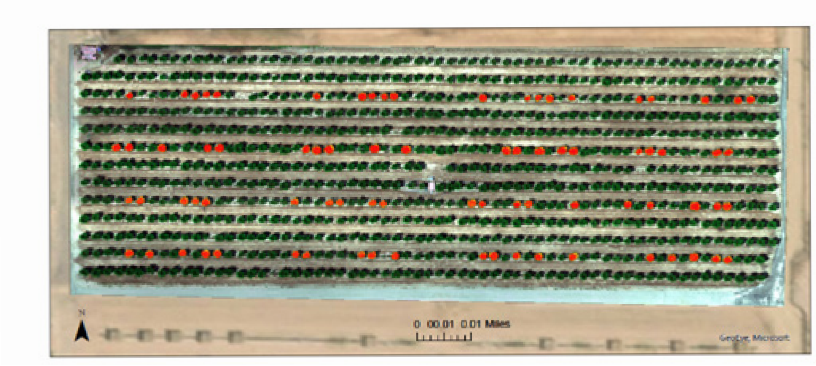


Figure 7

There were five sampling trees in each block, 80 sampling trees in total, marked with red labels.

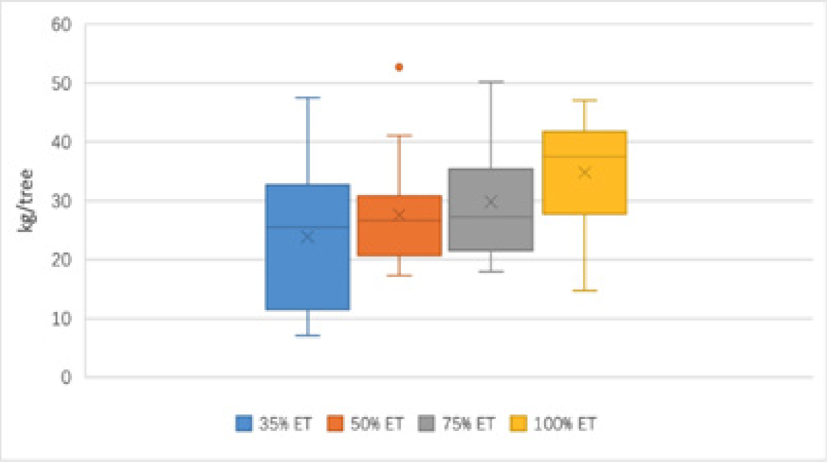


Figure 8

The pomegranate yield performance at the individual tree level in 2019. For the 35% irrigation treatment, the total fruit weight per tree was 23.92 kg, which produced the lowest yield. For the 50% irrigation treatment, the total fruit weight per tree was 27.63 kg. For 75% and 100% irrigation treatment, the total fruit weight per tree was 29.84 kg and 34.85 kg, respectively.

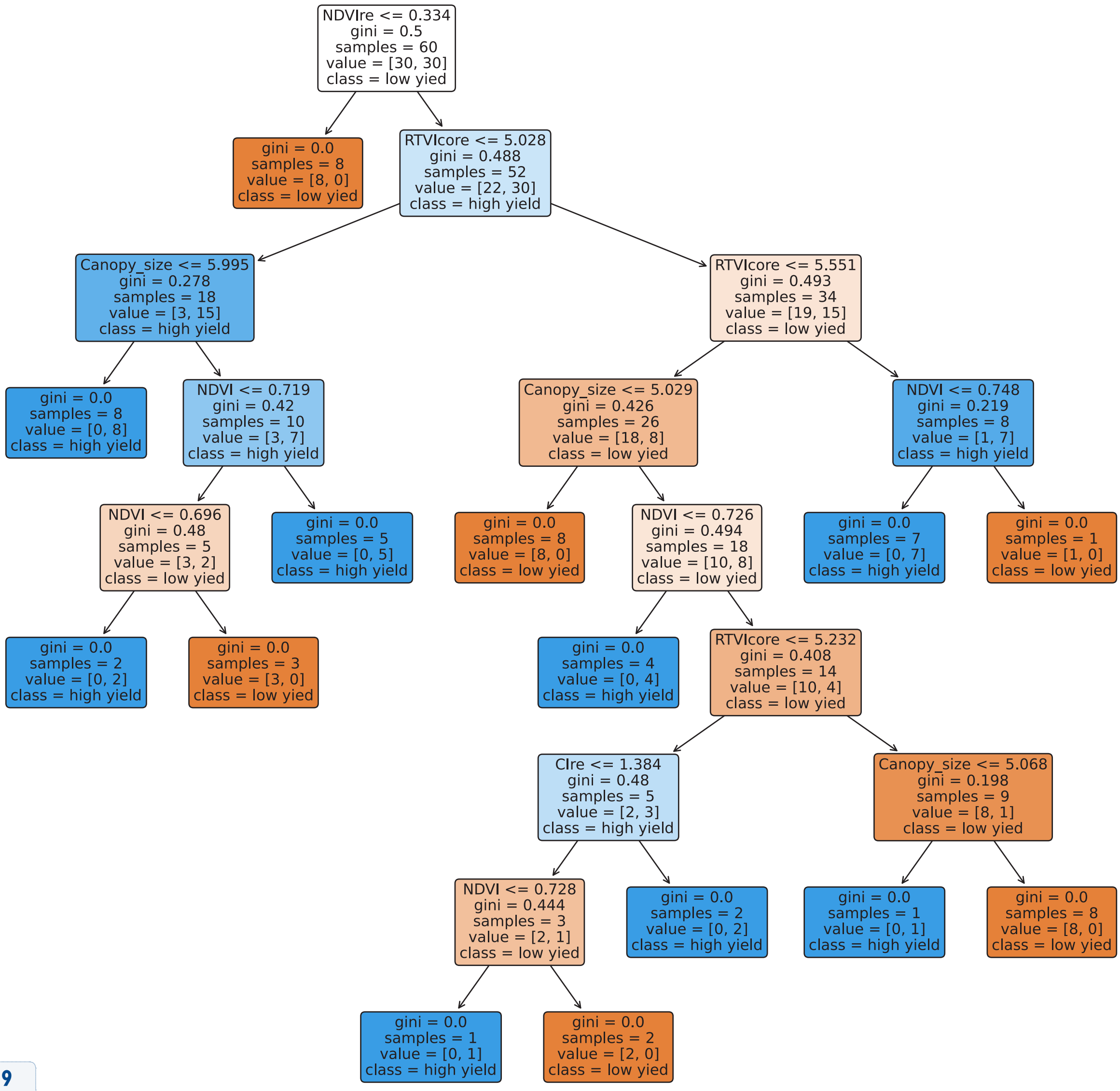


Figure 9

The "Decision Trees" method training process. The "Decision Trees" usually uses a white box model, which means the explanation for the condition is easily explained by Boolean logic if a given situation is observable in a model. As shown here, the "Decision Trees" ML model started at the root node, if the NDVIre value were less than 0.334, the prediction process would move to the leaf child node. In this case, the model would predict that the input was a low-yield pomegranate tree. A node's gini attribute measures its impurity: a node is "pure (gini = 0)" if all the training instances it applies are from the same class.

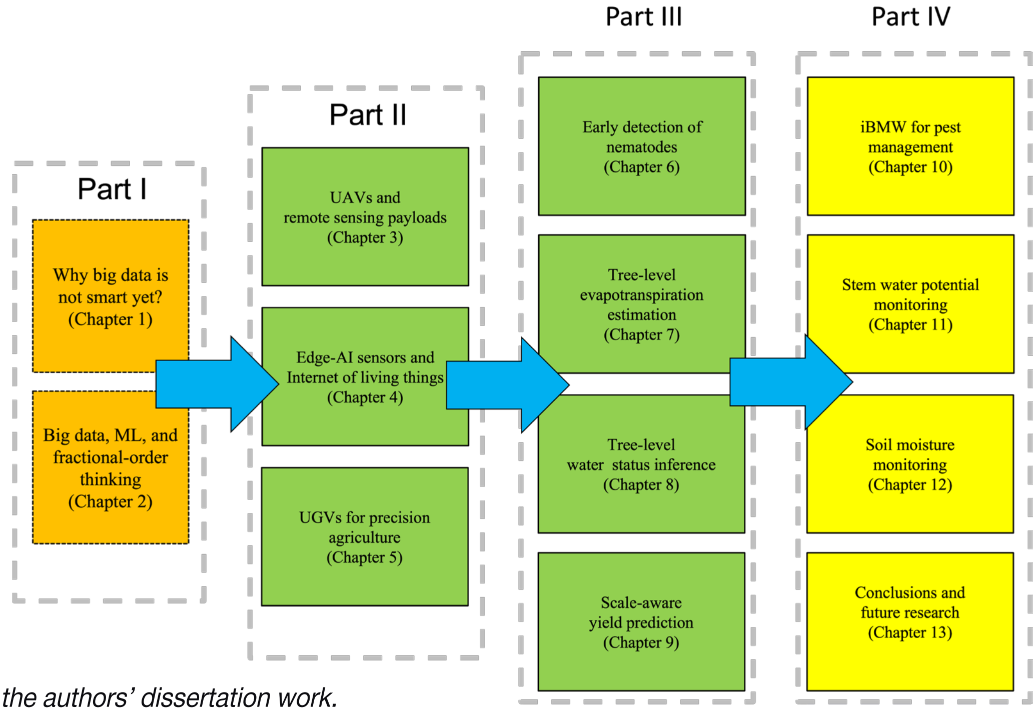


Figure 10

The outline of the authors' dissertation work.

In general, research results showed that the PPIML, POTM, CIML, and the data acquisition platforms were reliable, robust, and smart tools for precision agricultural research in varying situations, such as water stress detection, early detection of nematodes, yield estimation, and evapotranspiration (ET) estimation. The application of these tools has the potential to assist stakeholders in their crop management decisions. Figure 10 shows the outline of the authors' dissertation work and all the ideas discussed here can be found in more details [1].

Smart big data is the use of various methods, such as ML algorithms and artificial intelligence, to analyze and transform the agricultural data into information from which valuable insight can be drawn. It incorporates advanced analytics to enhance plant physiology-informed machine learning. The application of smart big data can help researchers and stakeholders develop a better understanding of the data with the goal of developing better precision agriculture. So far, these are still the initial steps for the development of the smart big data applications in precision agriculture. More explicit definition of the steps of the smart big data framework integrated with advanced analytics, ML algorithms, and AI is required to demonstrate the capabilities of this innovative methodology.

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CHALLENGES AND STRATEGIES FOR UAV-BASED CARGO TRANSPORTATION

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Multi-rotor UAVs already are a reality for aerial operations, synchronized artistic choreography, and even for entertainment of roboticists and aviation enthusiasts. What we recently observe is also the change from remotely controlled UAVs, widely known as drones, to fully autonomous aircraft.

Due to this 'autonomy', we increasingly envision UAVs delivering packages to our doorsteps, carrying medicine and supplies to disaster or conflict zones, transporting organs and other hospital necessities, spraying pesticides in crop fields located in rough terrains, among other applications, all of which have 'cargo transportation' as common task. From this point of view, in this paper, the focus is to present some challenges, strategies and applications related to the aerial transportation of objects using UAVs.

To begin with, it is agreed within the scientific community that the main advantages of multi-rotor UAVs, when compared to other aerial platforms, are related to their ability to hover in the air and to rapidly change their flight direction. In addition, it is also a point of common agreement that applications with electrically powered UAVs are still limited by their 'energy autonomy'. After all, although energy storage sources have improved considerably, the amount of energy required during flight is substantial when compared to fixed-wing or lighter-than-air vehicles. Moreover, this requirement becomes more challenging when the objective is to carry a load. Therefore, an area to be investigated is implementation of control strategies focused on energy management to reduce the «cost of flying».

Due to the continuously expanding range of applications, the need to develop increasingly sophisticated UAVs has grown considerably. Because of this trend, the need to ensure reliability and safety of these flying robots has also increased, particularly when such aerial platforms fly and operate close to humans, i.e., in urban areas.

As such, recent work centers around fault diagnosis, involving fault detection, identification, isolation and, when possible, fault accommodation. Assuming the occurrence of faults only in electromechanical components (not related to the UAV physical structure or control software), the main sensor-based faults are bias, drift, loss of accuracy, freezing, calibration error, while those related to actuators are lock-in-place, float, and loss of effectiveness. To mitigate such issues and their consequence, researchers and companies invest in redundant hardware apparatus as well as implementation of computational strategies to improve data analysis and to stabilize the UAV (i.e., multi-rotor) in case of minor damages (such as actuator failures). Despite understanding the importance of this topic, further discussion is beyond the scope of this article.

Focusing on cargo transportation using UAVs, companies around the world are investing in strategies for capturing and delivering packages and on optimizing logistics operations. Based on all possible commercial solutions and on those published in existing literature, it is true that loads are generally transported using grippers, robotic arms, and suspended cables.

When using grippers for load transportation, see Figure 1, the load is carried, preferably and when possible, close to the center of gravity of the rotorcraft. The UAV-plus-cargo combination becomes a 'new body' with a higher moment of inertia, thus reducing the UAV agility and maneuverability. In this case, the UAV becomes less responsive to attitude maneuvers. However, in terms of control, the degrees of freedom (DOF) are identical to those required to control only the UAV.

When the ensemble of Figure 1 cannot pick up and carry an object, a solution is to equip the multi-rotor with a robotic arm, as shown in Figure 2. Under this configuration, called a mobile manipulator, the UAV may still hover while the manipulator approaches the object to perform the grasp task. However, this 'add on flexibility' is acquired at the cost

Figure 1 *Multi-rotor UAV equipped with a gripper.*

of solving the manipulator inverse kinematics and control, on top of the UAV stabilization. Candidate control strategies based on this approach must address the operation of the robotic arm in its region of greatest manipulability. To be specific, the UAV stabilization and control are connected to the manipulator's extension or contraction movement. It is also worth noting that a UAV maneuver directly reflects on the manipulator and, consequently, on the transported load. Therefore, it is up to the manipulator to mitigate or attenuate oscillations or unwanted movements in the load.

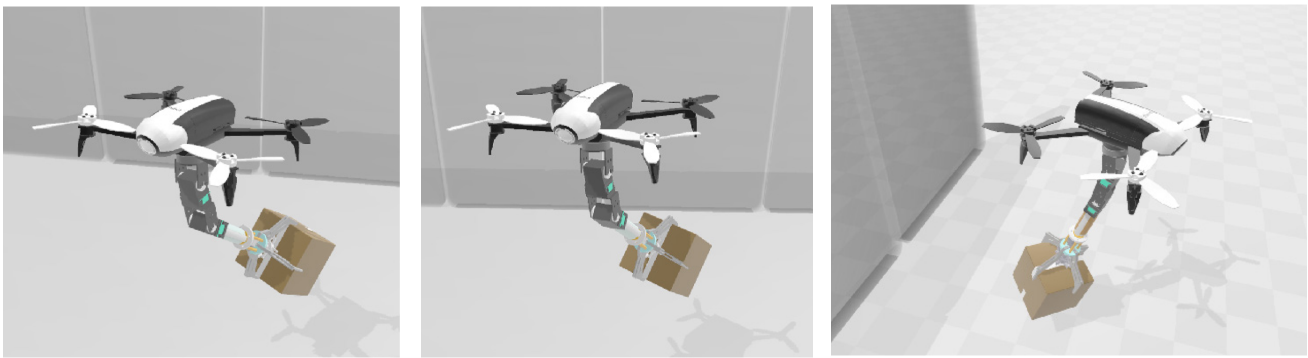

Figure 2 *Aerial manipulation: UAV with a robotic arm.*

When following suspended cable transportation, the UAV is more flexible to move. In this case, the UAV motion coordination is due to the additional connected mass, mostly near/close to its center of mass, see Figure 3. A negative consequence is the increase of the number of non-actuated DOFs. Hence, suppression of the oscillatory motions of the cable and of the payload itself dominate UAV controller(s) design – this is similar to the problem of stabilizing a conical pendulum.

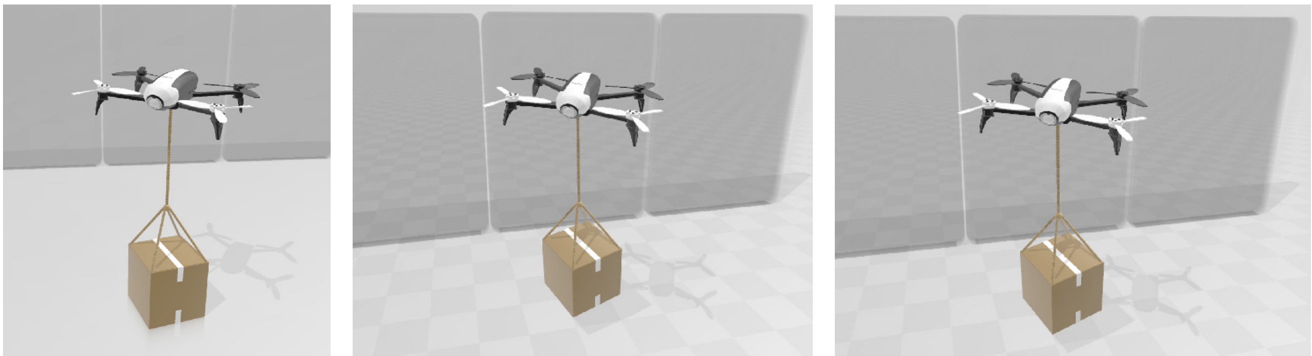

Figure 3 *UAV transporting a load by a suspended cable.*

Regardless, there is no best approach to load transportation. Each of the three strategies has advantages and disadvantages. It is up to the designer to evaluate, based on the specifics of load transportation, which strategy meets and best solves the problem at hand.

The task of transporting/moving a load from the starting to the destination location involves lifting, effective transportation, and delivery. Consider for example a load transportation using suspended cables and follow the stages as shown in Figure 4.

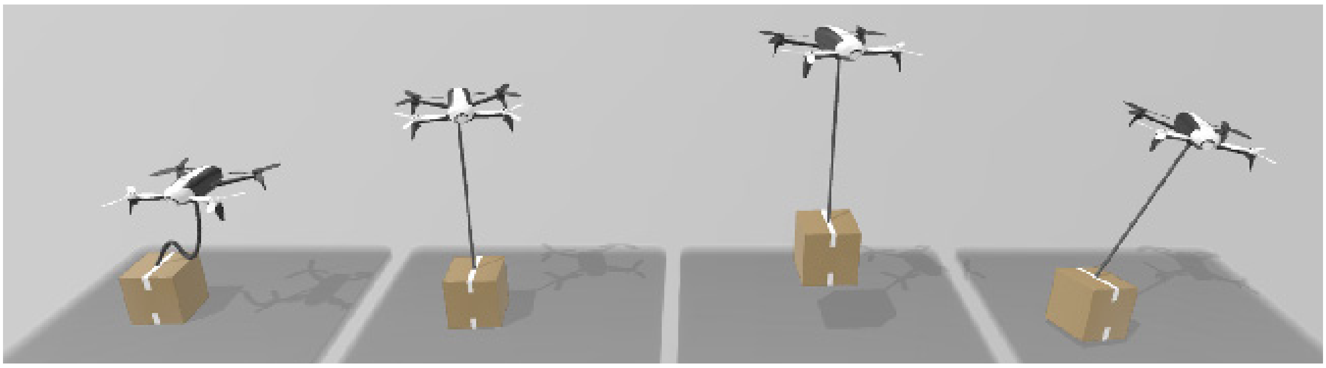

Figure 4 *Stage of load transportation. From left to right: Setup, Pull, Raise and Side-Pull.*

The UAV starts the mission by approaching the object to be lifted and by performing a hovering maneuver over it. This stage is labeled as Setup; it aims to analyze the conditions of the environment before starting the lift. The cable connecting the UAV and the load remains relaxed. In other words, the distance between the UAV and the load is less than the length of the cable.

Next, the UAV starts the preparation for lifting; it ascends to an altitude equivalent to the length of the cable in such a way that the cable is kept taut. While the load is still on the ground, it is possible to estimate its mass before lifting, if load cells are available at one end of the cable. Otherwise, the load mass may be estimated in the Raise stage. At this stage, the load is taken off the ground and the propulsion required to lift it to a predetermined height is observed on the UAV. The difference between the propulsion required at the Pull and Raise stages can then be used to estimate the mass of the payload.

If the UAV cannot reach the preset altitude, or even get the payload off the ground, this is, most likely, because its payload capacity is less than the weight of the load to be transported. In such cases, the literature suggests returning to the previous stages and aborting the mission to preserve the integrity of the UAV. This is because the UAV actuators will probably be saturated and, consequently, the controllability and stability of the system will no longer be guaranteed.

If there are no restrictions to dragging the load over a/the surface, a possible alternative is to perform the Side-Pull maneuver. This translates to moving the load while still in contact with the surface. Thus, the propulsion previously required to lift the load off the ground, is now converted into a lateral drag force.

It is important to emphasize that these stages may be used as the basis to formalize strategies for the other two forms of load transportation.

Next, considering situations where a single UAV propulsion is not sufficient to lift the payload, or when the payload shape makes it difficult, or even impossible, to lift it, the Side-Pull approach appears to be a viable alternative if the load can be pulled along the surface. Figure 5 illustrates a load transportation, with or without their heading control, individually or collectively.

An application with ecological appeal is depicted in Figure 6. It reflects the hypothetical situation where a group of UAVs, after identifying floating objects, execute the removal task without lifting them. In this scenario, UAVs work collaboratively to transport the loads by suspended cables and by using a trawl. As seen in the illustration, the UAVs may lift objects or move them over the surface. The latter approach reflects a better energy-saving solution. Regardless, the goal is to transport the objects to a location where they can be conditioned or picked up.

In summary, one may safely conclude that the use of multi-rotors for load transportation is growing; this is also supported by published research on this topic. It is also up to scientists, engineers, researchers, and practitioners to: propose, implement and test the best navigation strategies; analyze and choose the most efficient actuators; decide on the best approach to solve the challenge at hand. Therefore, this contribution serves as a provocation for future research in this field, given the presented challenges.

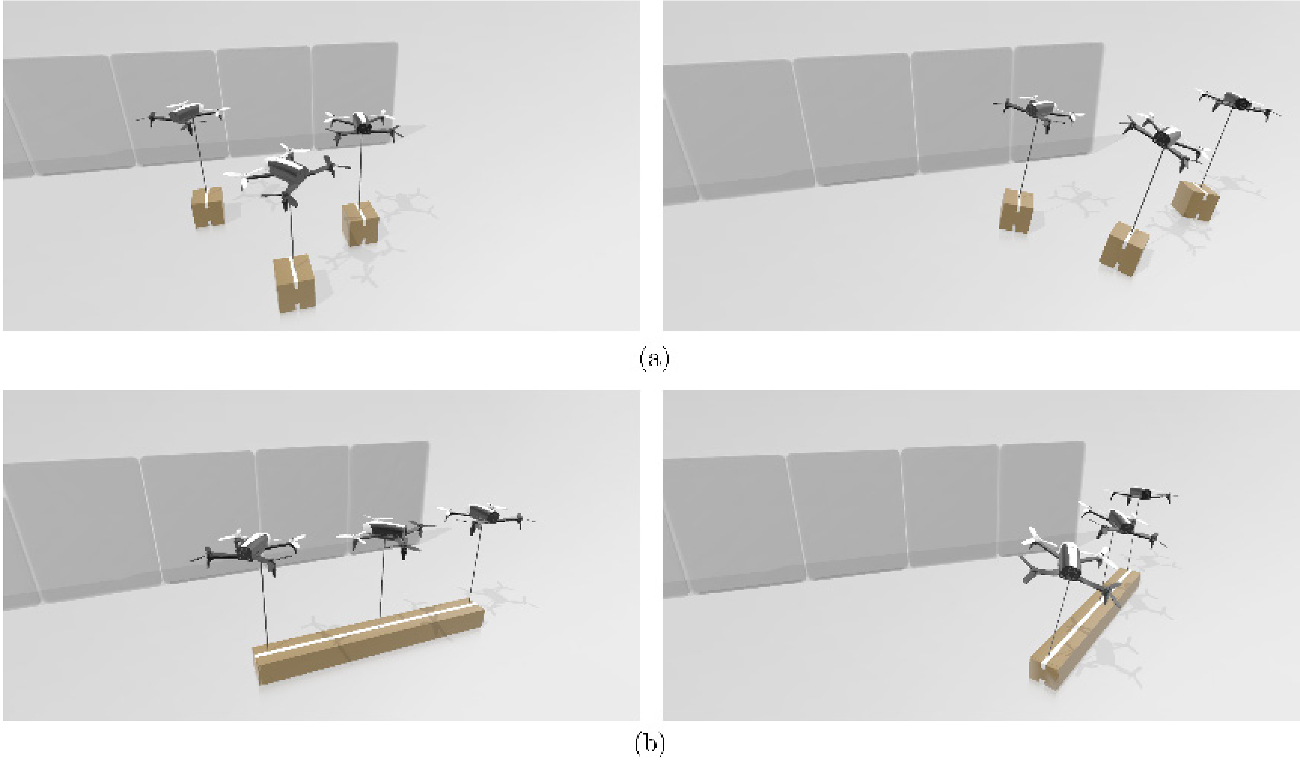

Figure 5 *Side-Pull maneuver considering a) multi-UAV system, each one responsible for its load, and b) multi-UAV system controlling and moving a single load.*

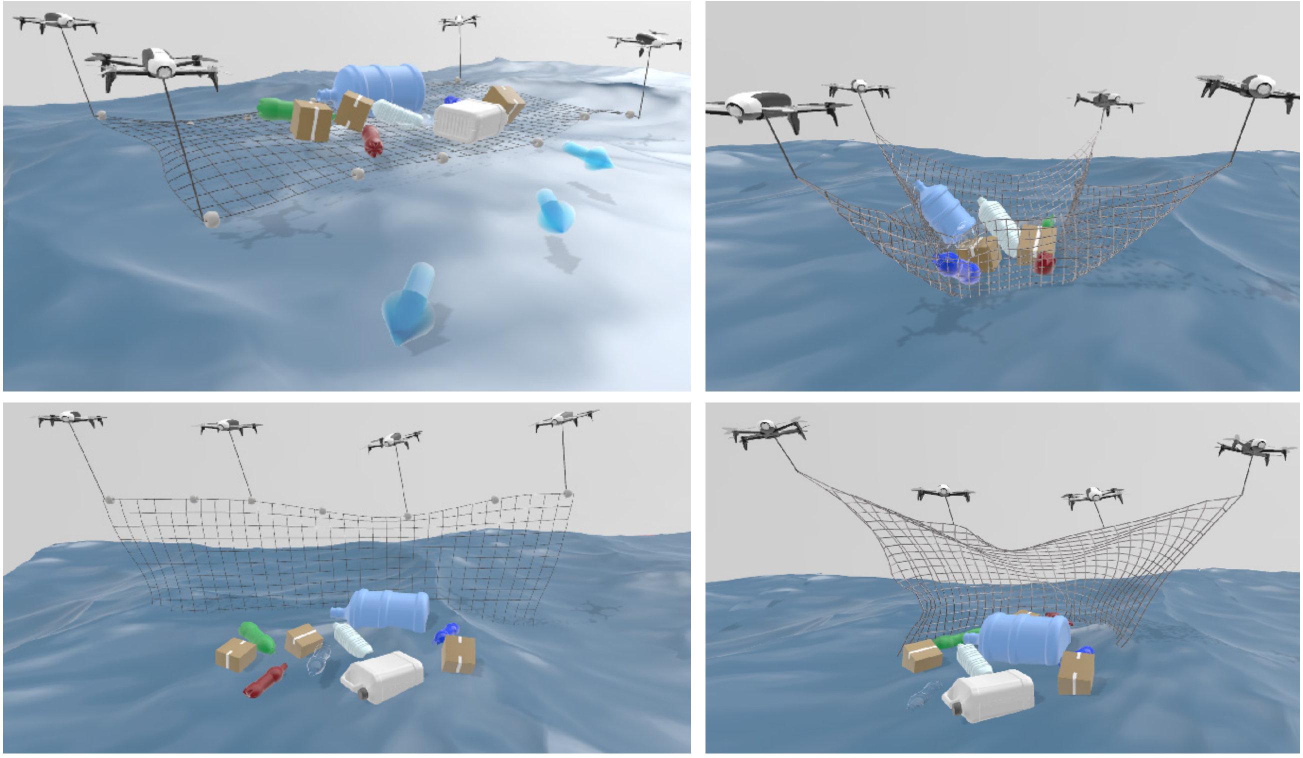

Figure 6 *UAVs removing debris from the sea surface.*

UPDATE ON ICUAS 2023

THE 2023 CONFERENCE WILL BE HYBRID, ALLOWING FOR VIRTUAL AND PHYSICAL PARTICIPATION AND PAPER PRESENTATIONS.

The following has been finalized, and all details regarding the conference have been uploaded on the web, **www.uasconferences.com.**

1. Keynote addresses have been confirmed.
2. As of now, three Workshops have been scheduled.
3. UAV Competition details, Theme and Timeline, Rules and Software, and Preliminary Registration are available on the conference web.
4. The updated list of (preferred) hotels recommended to conference participants along with the room rates is provided. Note that to better serve you, there will be a bus to transfer you to/from the venue from/to your hotel during the four-day conference.

Moreover, starting with this year's conference, it has been decided to announce the best paper during the Awards Dinner. All submitted papers will be peer-reviewed by at least three external reviewers. The Committee, composed of the Program Chairs and Vice-Chairs and the Awards Committee Chair, Prof. Fulvia Quagliotti, will re-evaluate all papers and will rank the best papers, also considering Associate Editor (handling editor) recommendations and the reviewer comments. The best 6 papers will be grouped together, and they will be presented in one session (same session) for final ranking, which will consider the (physical or virtual) presentation, too.

We will continue informing you on a regular basis you about the latest conference developments. In the meantime, just in case you wish to register early (virtual or physical presence), you may do so using the **www.icuas.com** website. The direct link is **https://icuas.com/registration-%26-fees**; click on it and follow the steps.

Note that as in previous years, we will issue invitation letters to those who request them, and every registered attendee will receive a conference attendance / participation certificate.

LATEST NEWS IN UNMANNED AVIATION AND SYSTEMS

UNMANNED AVIATION CONTINUES TO ADVANCE ON ALL FRONTS.

For the latest information on regulations and all aspects concerning UAS, visit **https://www.faa.gov/uas**.
Selected information items from the UAS Magazine, **uasmagazine.com**, are:

- Northrop and NASA have announced a collaborative effort with the aim to develop and test viable solutions for the integration of large UAS into the National Airspace System (NAS).
- Lockheed Martin has been awarded a 10-year contract by the UK Ministry of Defence, which centers on using the most advanced AI technology to develop ISR systems for UAS.
- General Atomics Aeronautical Systems, Inc. completed three test missions in which their Avenger® UAS was paired with "digital twin" aircraft to conduct multi-objective collaborative combat missions, autonomously.

Moreover:

- The US and European (EU) countries now consider using drones and sensors to secure ocean floors against threats. This initiative is the aftermath of September's underwater explosion in Nord Stream pipelines.
- 2023 also marks the launching of the first-ever surface drone fleet.

For details see **https://www.defensenews.com**

- National Geographic reports on efforts by Explorer Ved Chirayath who uses a drone that can carry high-tech instruments to image underwater features. The aim is to mapping oceans with software on drones.

See for details, **https://www.nationalgeographic.com/impact/article/scientist-ved-chirayat-maps-seafloors-fluidcam-midar?cmpid=org=ngp::mc=social::src=linkedin::cmp=editorial::add=li20230113impact-vedchirayat&linkId=196877067**