Unmanned Aircraft Systems - Education Activities in Finland, UCNDrone Perspective

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***Abstract*—This paper is the initial attempt to revise the activities of Finnish universities relevant to education in the field of Unmanned Aircraft Systems. The contributors are members of the UAS (Drone) University Collaboration Network project funded by the Ministry of Education, Science and Culture of Finland. The project is a national collaboration of three universities, Oulu, Helsinki, Turku, and seven Universities of Applied Sciences, Centria, Metropolia, Savonia, XAMK, Tampere, Turku and Oulu. The aim of the network is to identify national and international development targets in the field of UAS and raise Finland to the forefront of education and research in the domain of UAS and co-develop these together.**

I. Introduction

Unmanned Aircraft Systems (UAS), somewhat known as Unmanned Aircraft Vehicles (UAV), or drones, is one of the most rapidly developed technology fields. Its application areas are widely spread across the different public and industry sectors. The global UAS market is expected to reach 501,4 billion USD by 2028 from 13,44 billion USD in 2020 [1].

The majority of UAS applications are driven by high demand from the business world. The UAS application areas widen and getting more sophisticated and unique along with the development of technologies. That exposes an increased need for professionals that have the required skill set. Currently, the demand for skilful professionals in the UAS field is much higher than the labour market offer. Nevertheless, the general public, particularly the young generation, are not always aware of how UAS is changing our lives, how people can be involved, and what they can do with UAS. UAS-related education is already offered: the challenge for high education organisations is to provide up-to-date education and raise awareness about the opportunities. There is a lot of knowledge in the field of UAS in Finland and worldwide. Still, currently, the expertise is scattered, and no systematic network has been created to improve UAS related education.

The UAS (Drone) University Collaboration Network (UCNDrone) project [2] takes those challenges into account and contributes to the field of UAS demand and supply from the academic side. UCNDrone is a national project to create a network of Finnish high educational institutions focusing on education, research, development, and innovation (RDI) related to UAS technologies and applications.

Each member of the network participates in the project according to its own strategic priorities, while all together partners are to identify the genuine gaps in education and RDI in the field of UAS.

The rest of this paper is organised as follows. Section II describes the overview of the educational activities of the

current UCNDrone project partners. The discussion and conclusion are given in sections III and IV.

II. Overview of the education activities

The overview of the educational activities is formed from the input of UCNDrone project participants and does not cover all education activities relevant to the UAS domain in Finland. One of the missions of the UCNDrone network is to explore all such activities and communicate those to UAS stakeholders inside and outside Finland.

A. University of Oulu

The Biomimetics and Intelligent Systems Group (BISG) at the University of Oulu (UOULU) is a fusion of expertise from the fields of computer science and biology. In BISG, our research areas include data mining, machine learning, robotics, and information security. More precise research topics vary from data mining algorithm development and optimisation of industrial manufacturing processes all the way to environmental monitoring with mobile robots. In addition to the group's long-term research strands, it also aims to provide concrete new openings for the purpose of reacting to fundamentals and novelties to integrate better ICT and biotechnology/biomedicine. BISG has conducted research in national and international research projects funded by the Academy of Finland, the Finnish Funding Agency for Innovation TEKES, also as an international collaboration with the Japan Society for the Promotion of Science JSPS and the USA National Science Foundation NSF, and the European Union, e.g. Flying Forward 2020 project [3]. The group has participated in many robotic EU framework projects and has been granted funded research from TEKES and the Academy of Finland for more than ten million euros. Robotics research activity at BISG includes collaboration with, e.g. processing industry. The group's research activity has spun off more than ten several enterprises, e.g. Codenomicon, Clarified Networks, Atomia, Probot, IndoorAtlas.

DroneMaster project [4] is a collaborative project by the University of Oulu, Oulu University of Applied Sciences and Centria University of Applied Science to provide a course for applying UAVs for professional use. It will be modular and free training to learn the skills of a professional drone pilot.

Finnish industry and research groups have a great demand for professional drone pilots. Drones have applications in various industries like waste management, energy sector, smart traffic and construction. Professional drone piloting is a complex profession, and at least a bachelor's degree level of technical understanding is required.

For a drone pilot to be successful, he needs to understand different camera and measurement devices and be capable of analysing the data they produce. Additionally, the pilot must know the legislation related to drones. The training courses created will give drone operators the skills to react correctly to different situations they may face when operating a drone. Skilled drone operators will decrease the risk of accidents that may have juridical consequences in the worst case. The content of the training will be defined in the project. That will cover, e.g. laws, regulations, arctic weather conditions and application-specific requirements. Additionally, a professional drone pilot requires also technical knowledge. The project will study the latest drone technology to create the content of the training.

B. University of Helsinki

The Department of Computer Science at the University of Helsinki is a leading teaching and research unit in its area in Finland. Its research groups address significant research challenges, such as data analytics, AI, and security and privacy. The Department has extensive international collaboration with companies and universities. The Department is a member of the Helsinki Institute for Information Technology (HIIT) and Finnish Centre for Artificial Intelligence (FCAI). HIIT is a joint research institute of Aalto University and the University of Helsinki for basic and applied research on information technology. FCAI is a community of experts that brings together top talents in academia with industry and the public sector to solve real-life problems using both existing and novel AI. The Department of Computer Science has two masters' programs, Computer Science and Data Science. Both programs teach courses critical also for the drone ecosystem, such as machine learning, computer vision, cyber security, algorithm and software development.

Spatiotemporal Data Analysis (SDA) research group at the Department of Computer Science at UH does research on ML for accurate and reliable navigation and situational awareness. SDA's research goals are to provide novel AI solutions based on computer vision, machine learning, Global Navigation Satellite Signals (GNSS) and 5G signals, and traffic modelling to benefit the development of autonomous systems [5],[6],[7] and sustainable smart cities. SDA is taking an active part in the Helsinki Institute of Sustainability Science (HELSUS) activities to secure the sustainability focus on all research.

C. University of Turku

The Turku Intelligent Embedded and Robotic Systems (TIERS) group emphasis are on the multi-robot system, autonomous robots and edge AI. The core technical development concentrates on localisation and mapping in dense urban environments, mapping of unstructured environments, computational offloading techniques, and hardware accelerators for ROS. By shifting computing near to the source of data allows us to decentralised control in collaborative and heterogeneous multi-robot systems. Heterogeneous robotic collaboration is integrated within the Blockchain and estimated at all robots equally without explicitly sharing information about the robots' hardware or sensors.

Our communication and cyber security engineering research group is operating in three application domains where we also develop their key technologies. Those core domains are 1) autonomous systems, b) smart city and cyber society, and c) health and well-being. Relating to UAS, our research activities are focused on autonomous systems design, security and communication engineering, including a) smart controller, sensor fusion and communication design, b) low latency cyber security technology, Intruder Detection System (IDS), fall-back

mechanism, the concept of trust, GDPR, and c) IoT communication and security, secure mobile platforms, cryptography for light-weight applications.

Both research groups have their own master programmes in EIT digital, and they have been active in education digitalisation and transnational education [8],[9]. They have actively developed MOOCs and virtual laboratories to support their versatile educational activities. TIERS is putting research in education through 3 courses that build the core competencies in the field: 1) Perception and Navigation in Robotics, 2) Hardware Accelerators for Robotics and AI and 3) Robotics and Autonomous Systems. In the first one, students will use different types of sensors in autonomous mobile robots (drones) and other types of autonomous systems. In the second one, students will have a deep understanding of the performance and suitability of the different platforms for training and inference of advanced AI models tailored to robotics. In the last one taking the earlier course's learnings to the next level, students design and develop complex projects using ROS and will have the ability to write modular and reusable libraries for robotic perception, control, motion and planning. In addition, students get to use advanced sensors such as cameras, lidar, ultra-wideband (UWB) wireless nodes, depth cameras, and others.

D. Centria University of Applied Sciences

Centria University of Applied Sciences strong UAS expertise has been utilised in various RDI (Research, Development and Innovation) projects, experiments by authorities and companies since 2014. The pioneering experience of the researchers with UAS' is also utilised in teaching. Centria uses a wide range of commercial equipment and custom UAS' in their research activities. Centria has the ability to design and manufacture customised drone solutions for a variety of tests and applications. Centria's Drone Lab is involved in several collaborative ecosystems, such as RAAS (Rethinking Autonomy And Safety), FUAVE (Finnish UAV Ecosystem) and RPAS (Remotely Piloted Aircraft Systems) Finland.

Currently, Centria has UAS activities in different domains, such as developing different measurement methods for RF (Radio Frequency) & 5G needs [10], [11], [12] logistics, agriculture, industry and enhancing situational awareness for authorities and utilising UAS control and communication link in a mobile network. Centria's aim is to invent new types of solutions for company and authority needs with different drone equipment.

Centria contributes to several UAS-related projects at the national and international levels. These are Arctic Airborne 3D and RoboSol, funded by Interreg Nord, UCNDrone [2] funded by the Finnish Ministry of Education, Science, and Culture, DroneMaster [4] funded by European Social Fund, AfarCloud and TRINITY, which are funded under Horizon 2020, Business Finland funded PRIORITY project and others.

E. Metropolia University of Applied Sciences

Metropolia University of Applied Sciences UAS expertise has been utilised in various RDI (Research, Development and Innovation) projects. For example, in the Digi-Lightning project Aiforsite part explored the possibilities of collecting data by photographing the interiors of construction sites by drones. The assembly is built with the Finnish Meteorological Institute, which has a solution for predictive building automation that can be designed for optimal heating based on independent outdoor weather and weather forecasts.

Metropolia University of Applied Sciences has supervised a bachelor thesis in energy engineering where was tested how aerial filming by a drone can be used in property maintenance measuring heat leaks with a thermal camera.

Metropolia's building technology engineering and land Surveying departments are using drones for laser scanning, photogrammetry and mapping.

In the near future, Metropolia has plans to start running RPAS & UAV club activities.

F. Savonia University of Applied Sciences

Savonia University of Applied Sciences has been conducting four years of bachelor's degree programs in the Internet of Things, where several activities and students project related to Unmanned Aircraft Systems are being carried out. One of the crucial activities related to unmanned aircraft systems is measuring snow-depth using frequency modulated continuous wave (FMCW) radar sensors [13]. In this work, the DJI-Phantom 4 Pro unmanned aerial quadcopter and silicon Radar (122 GHz) ST Nucleo 64 microcontroller board were utilised to measure the snow-depth.

One of the significant challenges was storing the measurement data on the cloud as the FMCW kit has limited ability to connect and disconnect to the sensors and provide instant visualisations. This challenge was sorted out by employing Savonia's own cloud systems (Sami Cloud) and a novel graphical user interface where measurement data were stored and analysed in real-time. The article can be read online here [13]. We are currently conducting several courses in which unmanned aerial vehicles and robots have been utilised as vehicles where several sensors, microcontrollers and communication devices are connected together to solve some of the problems.

G. South-Eastern Finland University of Applied Sciences

South-Eastern Finland University of Applied Sciences (Xamk) has started working with an open mind in communities utilising drone technology all over Finland - and at the same time, we are up to date on what is happening in our international networks. We have already organised in previous years, e.g. workshops devising drone services for different kinds of needs, and we have introduced our staff to various aerial and thermal imaging tasks as well as rescue drone opportunities. This year we have developed our expertise in even more precisely defined areas. In the summer of 2021, Xamk, together with its partners, tested two fixed-wing drone aircraft at Pyhtää Airport. Two Insta360 ONE cameras were installed as an operational load. In the tests, we studied the energy consumption of flying operations and, at the same time, learned how to handle fixed-wing drones.

As we continue to work with companies interested in drone technology, we are pooling expertise resources on issues needed by government organisations. The Defence Forces, the Emergency Services and the Border Guard are actively using drone technology. An excellent example of this cooperation is the oil spill response, in which Xamk has already been actively engaged in developing new methods. Drones bring completely new efficiency and speed to these issues as well.

H. Tampere University of Applied Sciences

Aeronautical Engineering has been one of the important teaching areas at TAMK for tens of years. In addition to the theory of flying, the focus of education has also been on practical projects, including upgrades of aeroplanes' avionics and engines.

During the last few years, drone technology research and flight training has drawn more attention in TAMK. Research focus areas include drone technology development [14], air quality measurements with drones [15], drones in forestry and farming [16], how to apply drones in surveillance [17], how to fly a drone in urban areas and apply in infra development [18], new business creation using drones [19], and drones in logistics [20].

TAMK has applied and developed Unmanned Aerial Vehicles (UAV), drones in multiple bachelor's and master's level degree programs for several years. The UAVs are used both in education and in various RDI projects. Students in TAMK's School of Built Environment and Bioeconomy have courses and hands-on training on how to use UAS as a 3D reality capture tool to produce information for digital workflows. The use cases in the domains of Building Information Modelling (BIM) and Geographic Information Systems (GIS) include, for example, mapping, site management and 3D model creation based on photogrammetry [21]. The data acquired locally by the UAVs is combined with other data sources to enable simulations and implementation of digital twins of the real environment.

TAMK is an active educational member of the UAS community in Finland and has been leading and participating in many different RDI projects. In those projects, TAMK has trained and developed together with enterprises the processes related to the commercial use of UAS technologies. Projects like ProDigiOUs [22], Drone Expert [23]. and New Solutions in City Logistics have enhanced enterprises' knowledge of drones with real-life experiments and pilot projects. TAMK is also cooperating with public organisations and authorities in improving the UAS related regulation and safety issues [24].

I. Turku University of Applied Science

The Computational Analysis and Engineering group (COMEA) is focusing on modelling, simulation and optimisation of complex systems, virtual prototypes and digital twins, and developing intelligent controllers for autonomous systems, e.g., drones. Recently, an open-source software architecture for digital twins (MCX) [25] was developed and validated on a MATLAB/SIMULINK based drone model to detect the state of the drone and to communicate the corresponding control commands and controller parameters to the drone in real-time. Furthermore, it works as a recovery control system for drones in case of failure detection. This work is contributed to ADAFI: Adaptive Fidelity Digital Twins for Robust and Intelligent Control Systems, which is funded by the Academy of Finland. The platform is currently under development to integrate with a physical drone system.

Moreover, we aim to resolve one of the most critical problems which occur during a task; the short operation time of the drone. This work is based on [26], where an intelligent control system is developed to ensure a safe landing of a drone by overcoming the ground effect outdoor. This work is extended so that a wireless charging station [27] is added in different locations, and when the drone battery charge reaches a specific threshold, it flies to the nearest station using a GPS, and once it is close to the station, it will start its safe landing technique based on the vision data, then continue its task after charging. This method can be used especially for the applications that require long flight time, e.g., using a drone for parcel delivery.

Finally, we are currently conducting a drone modelling and simulation course, which will focus on studying the drone control system, and how it can be used to develop different autonomous applications.

J. Oulu University of Applied Sciences

To bring close business and education activities, in 2017, Oulu University of Applied Sciences (Oamk) established the Arctic Drone Labs (ADL) [28], one of the Finnish innovation ecosystems contributing to the development of UAS. The ecosystem unites about a hundred members that discuss ideas, develop and exchange knowledge, and plan and develop joint research, development and innovation projects.

Among the services that Oamk provides together with ADL, members are consultation on different matters regarding UAS enabling technologies and applications, or regulatory matters, access to technical expertise and facilities for experiments, lab testing and validation, proof of concepts and prototype development and testing, demonstrations. A fair and largest in the Northern Finland fleet of UAS and the mission-specific payload in the region is available for lending, and ADL members offer a broad range of commercially available services. One of the examples is the availability of EFD682 OULU-HAILUOTO temporary danger area for certain UAS operations in Oulu.

Oamk yet does not have dedicated to UAS subject education. Nevertheless, at Oamk are established procedures of helping the students and staff to study how to pilot a UA and grow in qualification. Also, many UAS-relevant matters are integrated into education and project activities. Among the research interests is the application of UAS in different branches of economy, autonomous systems, robotics, augmented and virtual reality, internet of things, future networks, data analytics, printed intelligence, UAS legislation and standardisation, the Nordic challenges for UAS, and Urban Air Mobility (UAM) [7],[29],[30],[31],[32],[33],[34],[35],[36].

UAM is currently a very intensively developed in Europe concept. Here, air brings a third dimension to the traditional

transportation modalities, such as those based on ground and water. But the concept of UAM is much broader than just transportation. It covers all the operations of UAS in the urban environment and therefore exposes the environment of enormous complexity. To face future challenges and contribute to the development of Urban Aur Mobility, Oamk established Urban Air Mobility Oulu strategic initiative [37]. The initiative is driven by the City of Oulu represented by Business Oulu, both universities from the City of Oulu and VTT Technical Research Centre of Finland.

Oamk contributes to the number of UAS-related projects, which include Flying Forward 2020 [3] funded by the European Commission under the Horizon 2020 programme; UAS (Drone) University Collaboration Network, or UCNDrone [2] funded by the Finnish Ministry of Education, Science and Culture; Finnish UAV Ecosystem, or FUAVE [38], funded by Academy of Finland; DroneMaster [4] funded through the European Social Fund, and several other.

III. DISCUSSION

The UAS domain is among the domains of the highest complexity. Since all the universities have their own focus and strength, the resources that the current members of the UCNDrone network have are not sufficient to cover all the subjects of the domain. Moreover, UAS education is rapidly evolving domain-specific topics that need wide expertise in ICT. Those kinds of topics are very challenging to handle for a single research group to gain overall competence and keep the courses up to date. For this purpose, we need strong cooperation and a multidisciplinary network of expertise.

The aim of the UCNDrone network is to unite all Finnish universities to co-develop the education and research related to UAS. There are several important activities that need to be conducted in the near future. The most important activity is to produce a national survey on UAS education needs. This survey provides information on what kind of education is needed to meet the requirements of different domains. The survey is to be accomplished by the end of 2021. A national survey on UAS research needs is also important to, for example, increase the business possibilities of any cooperation company related to UAS or create joint international projects. This survey is planned to be accomplished in 2022.

Both of these surveys will help to identify the key elements of the UAS domain in Finland. The elements will be compared with the UAS taxonomy obtained from international standards, and the process will be concluded into the map of UAS expertise. The map will help to discover gaps and grey fields in Finnish research and education within the UAS domain. By comparing the map of Finnish UAS expertise with the future trends of the UAS domain anticipated together with leading research organisations in the field, it will be possible to form the demand for expertise that will help to facilitate fruitful international collaboration.

UCNDrone network unites universities that have own strength and different interests, employ UAS domain experts and conduct a broad range of educational activities with major and minor regarding the UAS domain as well as pre-requirements, generic ICT and associated knowledge domains. Co-developing courses together can improve knowledge exchange, increase expertise and improve the scope and quality of the provided courses in each organisation. There can be major topic courses for drone specific professionals and minor topic courses for the other ICT educational programmes allowing the students to have other ICT competence such as Artificial Intelligence, cyber security, communication technology, programming, data science and data analytics, and sensor technology, focusing their expertise to the UAS domain.

Joining the effort with other Finnish universities, ongoing communication with industry and key stakeholders of the UAS domain and knowledge exchange within and outside the UCNDrone network is vital. Also, it is essential to collaborate with other Finnish networks contributing to the development of the UAS domain, such as Finnish UAV Ecosystem (FUAVE) [38], and Rethinking Autonomy and Safety innovation ecosystem and service platform for autonomous systems R&D (RAAS) [39], and other networks and ecosystems.

The UCNDrone network proposes establishing the Finnish UAS Portal [2] where all the relevant to UAS ecosystems, networks and stakeholders in Finland would be able to share information about their activities, knowledge and practical experiences. That kind of portal may serve as a communication hub presenting Finnish UAS expertise to national and international stakeholders.

IV. CONCLUSION

The members of the UCNDrone network have their own strengths, which has been gained, for example, through national and international RDI projects. With this, it is possible to identify national and international development targets and raise Finland to the forefront of education and research in the field of UAS. In education, this means identifying the skill needs of companies and developing teaching according to the needs, taking into account the ability of students to create new business. In research, strengthening network and stakeholder activities creates the possibility for joint projects and more effective research in Finland and the EU.

The current UCNDrone network is not intended to be a closed network. The network welcomes the other Finish universities to explore the opportunity to collaborate as a single network of academic partners in the domain of UAS to explore and develop or acquire the missing expertise and fulfil the demand for education with education offer. That can be done together as a collaborative effort of all Finnish UAS stakeholders together with international partners.

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