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Proceedings of 15th International Conference on Electromechanics and Robotics “Zavalishin’s Readings”

ER(ZR) 2020, Ufa, Russia, 15–18 April 2020
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Foreword

Dmitry Aleksandrovich Zavalishin (1900–1968)—a Russian scientist, corresponding member of the USSR Academy of Sciences, founder of the school of valve energy converters based on electric machines and valve converters energy. The first conference was organized by the Institute of Innovative Technologies in Electromechanics and Robotics of the St. Petersburg State University of Aerospace Instrumentation in 2006.

The purpose of the conference is the exchange of information and progressive results of scientific research work of scientific and pedagogical workers, young scientists, graduate students, applicants and students in the field of: automatic control systems, electromechanics, electric power engineering and electrical engineering, mechatronics, robotics, automation, technical physics and management in the electric power industry.

We express our deepest gratitude to all participants for their valuable contribution to the successful organization of ER(ZR)-2020, hope for and look forward to your attention to the next International Conference on Electromechanics and Robotics “Zavalishin’s Readings” in 2021. The conference website is located at: http://suai.edu.ru/conference/zav-read/.

St. Petersburg, Russia
May 2020

Prof. Yulia A. Antokhina
General Chair of 15th International Conference on Electromechanics and Robotics “Zavalishin’s Readings”—2020
Rector of the St. Petersburg State University of Aerospace Instrumentation
This year, the conference The 15th International Conference on Electromechanics and Robotics “Zavalishin’s Readings”—2020, ER(ZR)-2020 was organized with XIV International Conference “Vibration-2020. Vibration technologies, mechatronics and controlled machines” and V International Conference “Electric drive, electrical technology and electrical equipment of enterprises” during April 15–18, 2020 in Ufa, Russia. The conferences were organized by St. Petersburg State University of Aerospace Instrumentation (SUAI, St. Petersburg, Russia), St. Petersburg Institute for Informatics and Automation of the Russian Academy of Sciences (SPIIRAS, St. Petersburg, Russia), Southwest State University (SWSU, Kursk, Russia) and Ufa State Petroleum Technical University (USPTU, Ufa, Russia). The conference is held with the financial support of the Russian Foundation for Basic Research, project No. 20–08–20030.

Due to the COVID–19 pandemic in the world, for the first time ER(ZR)-2020 was organized as a virtual conference. The virtual conference in the online format via Zoom service also had a number of advantages including: an increased number of participants, and no costs for travel and accommodation, comfortable home conditions, etc.

During the conference the invited talks were given by Prof. Jesus Savage (National Autonomous University of Mexico, Mexico), Assoc. prof. Lingfei Xiao (Nanjing University of Aeronautics and Astronautics, China), Ilshat Mamaev (Karlsruhe Institute of Technology, Germany), Prof. Oleg Darintsev (Ufa State Aviation Technical University Russia), Prof. Vladimir Fetisov (Ufa State Aviation Technical University, Russia), Assoc. prof. Sergey Konesev (Ufa State Oil Technical University, Russia), Prof Robert Sattarov (Ufa State Aviation University, Russia). More then 173 papers of authors from China, Czech Republic, Mexico, Russia, Taiwan, Turkey, Uzbekistan, Viet Nam and Japan were submitted to the conference and each paper was reviewed by several scientists. Around 30% of the best papers were published in English proceedings by Springer in series Smart Innovation, Systems and Technologies indexed in SCOPUS, Thomson Reuters (Web of Science), Inspec, etc. Due to great efforts of reviewers this book was carefully prepared and consists of 44 contributions.
Special thanks are due to the members of the Local Organizing Committee for their tireless effort and enthusiasm during the conference organization. Hope for and look forward to your attention to the ER(ZR)-2021. The conference website is located at: http://suai.edu.ru/conference/zav-read/.

St. Petersburg, Russia  Prof. Andrey L. Ronzhin
May 2020  Chair of Program Committee
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  on Electromechanics and Robotics
  “Zavalishin’s Readings”—2020
  Director of St. Petersburg Institute for Informatics
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Part I
Keynote Lectures
Chapter 1
Aerial Robots and Infrastructure of Their Working Environment

Vladimir Fetisov

Abstract  Aerial robots (also known as UAVs—unmanned aerial vehicles) are increasingly being introduced into our life. Today, we can see aerial robots in agriculture, building industry, delivery services, security and monitoring systems and so on. More frequently not single UAVs but their groups are used. And it would be reasonable to control such groups at all functioning stages, including on-ground maintenance, in automatic mode. Development of infrastructure for automatic service and maintenance of aerial robots has appeared on the agenda of many companies specializing in unmanned aerial systems. Some aspects of such infrastructure creation are discussed in this paper with special emphasis on charging stations for UAVs with electrical propulsion system.

1.1 Introduction: What Is AR, UAV, UAS

In robotics the term “aerial robot” (AR) is known from 1998, when Michelson [1] described a new class of highly intelligent, small flying machines. Now the sense covered under the term AR extends much further. In the field of aviation, robotic flying machines are referred to as “unmanned aerial vehicles” (UAVs), or drones, by simply saying.

Unmanned aerial vehicle (UAV) is defined as a pilotless aircraft, which is flown without a pilot-in-command on-board and is either remotely and fully controlled from another place (ground, another aircraft, ship, space) or programmed and fully autonomous [2].

On the other hand, it is known for the following definition of AR: “An aerial robot is a system capable of sustained flight with no direct human control and able to perform a specific task” [3]. According to this definition, any contemporary UAV is AR because UAV’s on-board flight controller with embedded navigation equipment...
provides sustainable flight without an operator’s participation. Such minimal on-board intelligence of the robot allows to sustain itself in the air with no human intervention.

So notions of UAV and AR are often considered as equivalent. But in recent years, a new trend has appeared to consider AR as an UAV designed to perform special operations in autonomous mode.

In other words, AR is a big class of mobile robots based on UAV for special tasks that can be performed with different degree of autonomy, i.e., AR has a lot of intelligence and self-sufficiency for its special function implementation. However, the UAV operator, as a rule, can control the AR remotely, switching from automatic to manual mode if the situation requires it.

There are many types of UAVs based on different flight principles. This work deals primarily with the rotary-wing type of aerial vehicles (helicopters, multicopters) and other aircraft (convertiplanes and other hybrids) capable of vertical takeoff and landing (VTOL). VTOL UAVs are the closest to common notion of “robots” because of their capability of hovering, which has huge advantages, in comparison with fixed-wing aircrafts, for general versatility. For example, VTOL UAVs can implement various repairs and building-up operations under the object by means of on-board manipulators. VTOL UAVs are capable of hovering and agile at the same time. Their rich sensory and motor abilities allow them to move and work in very different environments: open skies, confined environments, on the ground, on vertical surfaces, in swarms and near humans [4].

ARs are designed for various useful functions: aerial photography, monitoring, construction operations, agricultural works, delivery of small packages and so on. More and more frequently not single UAVs but their groups are used. And it would be reasonable to control such groups at all functioning stages, including on-ground maintenance, in automatic mode. Development of infrastructure for automatic service and maintenance of ARs have appeared on the agenda of many companies specializing in UAS—unmanned aerial systems (or unmanned aircraft systems). UAS is a widely used notion, which is a more complex term than UAV [5, 6]. UAS comprises one or more UAVs, along with the technical equipment necessary to operate them and other components. Full composition of UAS is shown in Fig. 1.1. When UAVs are considered as ARs, UAS provides an infrastructure for working environment of ARs. Let us take a detailed look at all components of UAS.

1.2 Components of Unmanned Aerial System

1.2.1 Main Functional Means

Main functional means of UAS include all components that are closely connected with flights: UAVs, control station (CS), start and landing equipment, means of transportation, navigation and communication equipment and service stations.
UAVs (ARs). One AR is the minimal number of vehicles in the system. The only UAV in UAS is becoming a rarity. In recent times, groups of ARs are used more and more. Various concepts of UAV group control are known, from centralized control of each vehicle to concepts based on artificial intelligence (AI). Among them, swarm intelligence (SI) occupies a special place. The term was introduced by Beni [7], in the context of cellular robotic systems (CRS). A CRS consists of a large number of robots and operates in n-dimensional cellular space under distributed control. Wide centralized mechanism and synchronous clock are not assumed. Limited communication exists only between adjacent robots. On the one hand, these robots operate autonomously; on the other hand, they cooperate to perform predefined global tasks [8]. SI systems consist of simple agents (ARs) interacting locally with one another and with their environment (Fig. 1.2). SI aerial systems are similar to biological systems. The ARs follow very simple rules, and their operations are local and to a certain degree random. There is no centralized control structure defining how individual agents should behave, but interactions between such agents lead to the appearance of smart global swarm behavior, unknown to the individual agents. Examples of SI in natural systems are ant colonies, bird flocking, hawks hunting, animal herding and