Open Source-Based UAVs for STEAM Education: Some Case Studies

Koh Sueda
Smart Systems Institute, National University of Singapore, Singapore
Email: idmks@nus.edu.sg

Atsuko K. Yamazaki
Department of Information & Communication Engineering, Shibaura Institute of Technology, Japan
Email: atsuko@sic.shibaura-it.ac.jp

Makoto Nomura, Masayuki Sakamoto, Yasuhiro Kato, and Masanori Hosaka
Japan Aviation Academy, Ishikawa, Japan
Email: m-nomura@jaaw.ac.jp; ma-sakamoto@jaaw.ac.jp; y-kato@jaaw.ac.jp; m-hosaka@jaaw.ac.jp

***Abstract*— The importance of Science Technology, Engineering, Arts, and Mathematics (STEAM) education has been strongly recognized over the last few years. STEAM education requires an approach to integrate these disciples, and robots and unmanned aerial vehicles (UAVs) are often utilized as ideal tools for hands-on STEAM education. Over the past few years, open source-based fully autonomous UAVs have been priced below $100. This fact also has allowed UAV Research and Development (R&D) to bring reverse innovation in education. This paper introduces our projects contributing to local communities, including R&D and STEAM educational programs that exploit open-source UAV platforms. We describe three examples of STEAM educational programs using UAV technologies: a three-day scratch-build UAV workshop at the Kirirom Institute of Technologies in Cambodia, a sailing robot development project at a private STEAM education and fabrication lab for children, VIVISTOP Kashiwanoha in Chiba, Japan, and an ongoing project of UAV R&D at Japan Aviation Academy whose framework is going to be extended to a workshop for local children in Ishikawa, Japan, with a local board of education.**

***Index Terms*—STEAM education, UAVs, open-source technology, team learning, self-learning**

I. Introduction

The importance of Science Technology, Engineering, Arts, and Mathematics (STEAM) education has been emphasized over the last few years due to rapid progress in such technologies as robotics and AI. Within a decade, the technologies are likely to reshape jobs to require not only education in science, technology, and mathematics (STEM) but also transversal skills for decision making, working well with others, independence, and communication [1]. Such jobs are often called STEM/STEAM jobs as a success career in the jobs depends on background in STEM disciplines and on "artistic" skills. The art here includes liberal arts, fine arts, music, design-thinking, and language arts, which are considered to be critical components to help create innovation [2]. According to the U.S. Bureau of Labor Statistics, a total of 6.2% of U.S. employment used to be STEAM jobs in May 2015. However, the U.S. Department of Education has reported that the number of STEAM jobs in the U.S. will grow by 14% from 2010 to 2020. This figure is 5%–8% higher on average than all the other job sectors [3].

Many STEAM education programs today are composed of courses in digital engineering, robotics, design fabrication, and computer programming. They often use robots as tools for hands-on education as building and controlling a robot contain all the elements of STEM skills. In addition, designing a robot and working in a team for building a robot is coupled with the art components of STEAM education. Building a moving object like a robot and maneuvering it can elicit interests and a feeling of accomplishment [4], [5] from students. UAVs can be utilized in the same context of practical STEAM education because they are often called flying robots; therefore, they are also ideal teaching and learning tools for STEAM education.

II. UAVs for STEAM Education

UAVs have been attracting considerable attention from engineers and researchers because they are expected to play an important role for innovative research projects and commercial applications. At the same time, they have been recognized as ideal educational tools to enhance STEM skills at any levels of education. UAVs used to be too expensive for an educational program and instructions, and necessary programming for them were too difficult even for university students [6]. Moreover, maneuvering UAVs often required skills that were difficult for children. However, thanks to the spreading of open source-based UAV technologies, including Ardupilot, developers and

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researchers are now able to create add-value applications using UAVs. Simultaneously, open-source hardware has been rapidly developing, penetrating, and becoming cheaper in recent years due to an increase of Chinese suppliers in the manufacturing ecosystem and the update and improvement of their products quickly [7]. Consequently, cheap and high-quality open source-based flight controllers (that meet the needs of UAV developers and the drone racing community) spread widely today.

Over the past few years, open source-based fully autonomous UAVs have been priced below $100, such as selfie digital toys and disposal UAVs. These UAVs are not in the traditional aerospace markets [8]. Furthermore, many programs for young students now prove that recent maneuvering and coding systems for UAVs have been made much easier for them to handle. These changes have allowed UAV research and development (R&D) to bring reverse innovation in education [9], [10].

Using an UAV as an educational tool includes other components than programming and mechanical designing. Basic aerodynamics, which is a branch of physics that deals with the motion of air, is definitely an important part of UAV mechanisms. This is an advantage of using an UAV for STEAM education over using a robot. Moreover, the utility of UAVs can give an opportunity to have students consider non-technical factors related to the application of UAVs in society. UAV applications in such industries as agriculture and logistics can give students an opportunity to associate technology learned in class with their daily lives and future careers. The applications of UAVs have been drawing considerable attention from various stakeholders and actors, such as governmental authorities including military, commercial operators, scientific institutions, and individuals. This also raises the issues of laws and regulations associated with UAV utilization [11]. These factors of UAV applications can be effectively integrated into practical STEAM education as its "art" component by directing students to utilize their knowledge of social science and enhance their communication skills in the discussion and presentation of these issues.

This paper introduces three examples of STEAM educational programs using UAV technologies: a three-day scratch-build UAV workshop at the Kirirom Institute of Technologies in Cambodia, a sailing robot development workshop at a private STEAM education and fabrication lab for children, VIVISTOP Kashiwanoha in Chiba, Japan, and an ongoing project of UAV R&D at Japan Aviation Academy whose framework is going to be extended to a workshop for local children and their parents in Noto Region in Japan.

III. Case Studies

One of the features of open-source software (OSS) is that learning and problem-solving expertise can be shared quickly in the user community. In other words, this sharing of knowledge and skills can be called "teaching or learning without teachers." We have been working on R&D and education by taking advantage of the characteristics of OSS and utilizing the benefits of an open source-based UAV as a teaching and learning material as described in the previous section. In our three STEAM educational projects with UAVs in the OSS framework, participants were given an opportunity to do the following:

- Leverage existing OSS resources and know-how to save implementation time and focus on issues to solve,
- Learn not only through programming and implementation work but also how to become a problem solver (how to access effective solutions), and
- Practically learn how to apply modern knowledge and know-how by understanding the benefits and significance of OSS.

This section introduces UAV development workshops and the cases of UAV R&D that exploit these OSS advantages.

A. Scratch Build UAV Intensive Workshop at the Kirirom Institute of Technologies in Cambodia

Figure 1. Cambodian students working together in a team to build a DIY UAV

The first one is a three-day scratch-build UAV workshop at the Kirirom Institute of Technologies in Cambodia, which was held from 11 May 2019 to 12 May 2019. Forty-eight students in Information Communication Technology majors attended the workshop, and most of them were approximately 20 years old (1st and 2nd year students). The technical goal of the workshop was to create scratch-build UAVs and to learn Ardupilot to develop mission-specific drones for the region facing rapid aging and depopulation. These social issues also gave the students an opportunity to pay attention to the local problems and to enhance their problem-solving skills by using open source-based technology. The coordinator of the workshop provided a set of a fixed-wing drone kit for aircraft using Ardupilot. The students were divided into three groups: aerodynamics, flight avionics, and piloting. From one to two hours after the introduction of open-source UAVs, the students developed/assembled a DIY drone by themselves by looking up information including official documents on the Internet. The students worked through repeated trial-and-error attempts, sharing troubles with other participants. They completed an Ardupilot-controlled UAV in 3 days and succeeded in the test flight on the 4th day. Through these team activities, the students also had a chance to improve their team-working skills. Fig. 1 shows a picture of the participants of the workshop working in a team.

B. Sailing Robot Development Workshop in Kashiwa, Japan

The second example is a sailing robot development project at a private STEAM education and fabrication lab for children, VIVISTOP Kashiwanoha in Chiba, Japan. A workshop was held by the lab from 11 May 2019 to 12 May 2019, and six elementary school students and eight adults (engineers and directors from startup companies and educators) attended the workshop. The goal of this workshop was to complete an Ardupilot-controlled quadcopter in 3 days. In this workshop, the members of a startup company aiming to develop a sailing drone and three elementary school children were grouped in a team. The participants worked together to build open source-based quadcopters to learn Ardupilot and to extend the know-how to the development of an autonomous sailing drone. As with the case of the workshop in Cambodia, the participants developed/assembled a DIY drone by themselves. The participants obtained information not only from official documents but also from users' demo video on YouTube when they encountered troubles. A month after the workshop, the startup company held a regatta by applying Ardupilot control know-how to sailing drones. Fig. 2 shows adult participants and children working together to build an open source-based UAV.

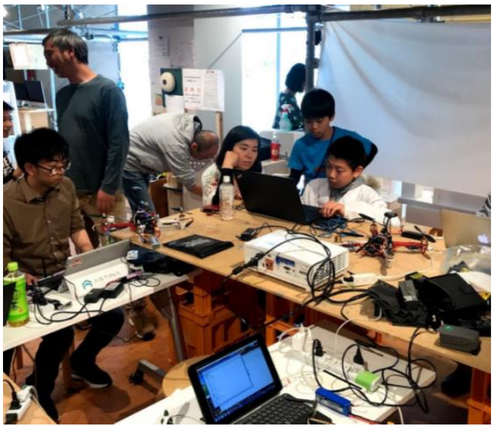

Figure 2. Adult and child participants working together to build an open source-based UAV in the Kashiwa workshop

IV. UAV Project and Workshop for Region Community and Social Implementation in Noto

The third example is a project in Noto Region, Ishikawa, Japan, which aims the research and development of UAV's UI/UX and its applications for the stimulation of region community/social implementation. This on-going project started in April 2018, and more than 20 participants, mainly teachers and researchers working with Japan Aviation Academy (JAA) in Ishikawa, have been participating in this project. This project aimed to advance joint research among several institutions and to give an example of reverse innovation using UAVs, as well as to develop mission-specific drones for the aging and depopulation problems that Noto Region is facing. We have been utilizing OSSUAV to develop issue-driven mission-specific drones and working with local stakeholders to develop bird-sweep UAVs for airports, open source-based UAVs optimized for agriculture, tourism promotion, culture enhancement, and engineering education. Fig. 3 shows the pictures of the bird-sweep UAVs for airports in Noto Project.

To extend the benefits of this UAV development to education for local community, we are going to hold a workshop for junior high and elementary school students, their parents, and other local adults who are novice at UAVs. The workshop will be held with help from the Board of Education of Suzu City in Noto. In the workshop, the participants will learn basic knowledge associated with UAVs, such as basic aerodynamics, programming, and mechanical designing. In addition, they will work together to fly mini UAVs to experience UAV technology and to discuss the utility of UAVs to solve such local problems as rapid aging, depopulation, activating, and creating industries in the region. These activities are expected to give an opportunity to the participants to learn about the technological aspects of UAVs and social issues and teamwork skills.

Figure 3. Pictures of the bird-sweep UAVs for airports in Noto Project

V. Insights

Our case studies imply that the open-source advantages can enhance STEAM education and drive reverse innovation as the aspects of the following:

- With the maturation of UAV's open-source platform, the participants can learn about technology to solve problems and improve their work easily on the basis of the know-how and knowledge accumulated in the community.
- In the case studies, the participants directly searched for the situation of a problem and an error code when the problem was encountered and found a suitable solution not only by text but also by video and image instructions.
- The case studies confirmed the effectiveness of the method of directly searching for error messages as queries and teaching the procedure for solving problems as mentioned in [12]. In the case studies, the videos made the solving of the problems visually and intuitively possible (Fig. 4).
- Many of these videos can be automatically translated to display subtitles in any language. Therefore, language barriers can be reduced (Fig. 4).

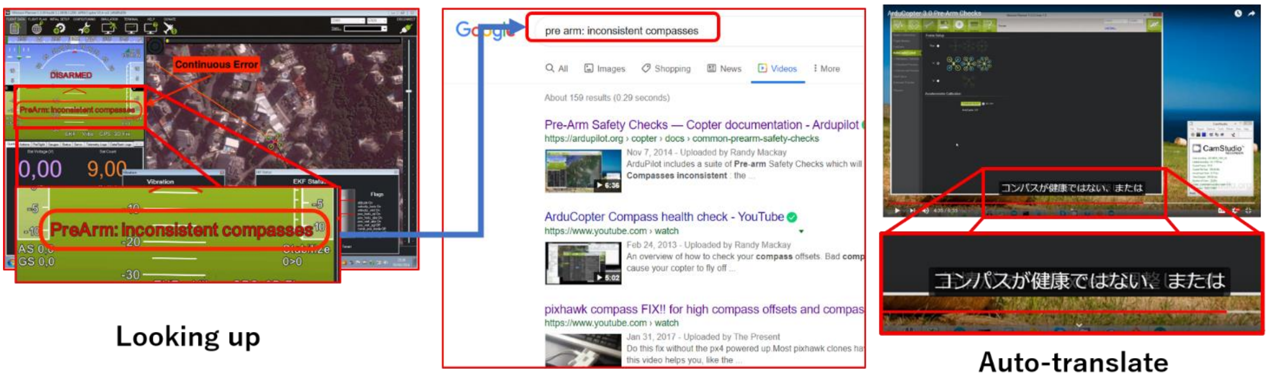

Figure 4. Example of problem solving by using Google, YouTube, and Auto-translate

VI. Conclusion

This paper discusses the use of UAVs for STEAM education by giving the integrated aspects of its educational utilities. Moreover, this paper introduces three STEAM educational programs as examples using UAVs in Cambodia and Japan. By the time today's primary and secondary students start to look for a job, over half of the available jobs will be in the STEAM field, and a large portion of job market will require employees to have some STEAM skills. Many studies have asserted that over the next 10 years, millions of jobs will be lost to such technology as AI and robotic technology, while millions of new jobs will emerge. These studies also note that these future jobs require creativity, innovation, and leadership in addition to technological knowledge and skills [13]. STEAM education using UAVs can integrate science knowledge, technological subjects, and liberal arts to foster the competency of students in engineering and give practical educational opportunities for young students to cope with changes in their careers in the future.

Conflict of Interest

The authors declare no conflict of interest.

Authors Contributions

Sueda conducted all workshops described in this paper and analyzed their educational implications from feedbacks from the participants of the workshops. Yamazaki mainly conducted literature reviews for the paper and analyzed the workshop activities from the aspect of their implications for engineering education. Nomura, Kato, and Hosaka built open source-based UAVs to develop prototype UAVs for regional stakeholders at JAA. Sakamoto also participated in the UAV development at JAA and applied the STEAM method described in this paper to their students' final-year projects.

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Koh Sueda is Senior Research Fellow at National University of Singapore. Sueda received his B.A. in architecture from Musashino Art University in 2000, an M.Sc. in information and telecommunication from Waseda University in 2003, and a Ph.D. in Information Studies from the Graduate School of Interdisciplinary Information Studies of the University of Tokyo in 2013. Sueda works in multiple areas of computer-human interfacing (CHI): Media art/design, ubiquitous computing, sports IoT, designing UAV's UI/UX, and architecture. He has presented his own works at a variety of academic, industrial design, and media art venues including ACM SIGGRAPH and ArsElectronica.

Atsuko K. Yamazaki is Professor at Shibaura Institute of Technology, where she teaches and conducts research in systems engineering, human communication studies and global education. Her current projects include studies of human cognitive activities for communication from neurological aspects, and the development of ICT & IoT systems to assist small and medium farming operations. She obtained a B.S. in Chemistry from Ibaraki University, M.S. in Computer Science from University of Maryland, M.A. in TESOL from Monterey Institute of International Studies and Ph. D. in Systems Engineering from Wakayama University. She has held leadership positions in IEEE and KES, such as the Associate Editor of IEEE Transactions of Education.

Makoto Nomura is a part-time lecturer at Japan Aviation Academy and a freelance engineer. He has been involved in aeronautical engineering education and research as well as the development of UAVs for corporates. He obtained a B.E. in Electrical Engineering from Kanazawa Institute of Technology in 1973 and graduated from the Graduate School of National Defense Academy in 1978. He worked as a research engineer at Japan Air Defense Force from 1978 to 1987. He also worked at Institute of Defense Agency for technical research and development during the period. He was involved in a business jet development project for Honda Jet as an aeronautical engineer at Honda R&D until 1987.

Masayuki Sakamoto is Lecture at Japan Aviation Academy. He graduated from Kanazawa Gakuin University in 2002. He engaged in video shooting and editing for over 10 years. He has been teaching aerial photography and editing skills to students at Aviation Maintenance Division in JAA based on his experience since 2015. In 2017, he won the "Drone Business Challenge Grand Prix" at the "Japan Drone", which is the largest drone exhibition in Japan. He is currently engaged in the cultivation of industrial drone developers, and his students joined many leading companies in related fields.

Yasuhiro Kato includes is Lecturer at Japan Aviation Academy(JAA). He graduated from Japan Aviation Technical College in 2004 and joined Japan Aviation Academy in April 2004. His main research fields include general aircraft operations, flight management, and drone education businesses. In recent years, he has been conducting studies in the development of DIY UAVs using the open-source framework "Adulpilot", and the implementation of information visualization using aerial images for agricultural fields.

Masanori Hosaka is Lecturer at Japan Aviation Academy(JAA) He graduated from Japan Aviation College in 2006. He joined Mitsubishi Heavy Industries, Ltd. and was engaged in functional testing on the new Boeing 787 Dreamliner. He has been at his current position at JAA since 2014 and taught aviation engineering based on his experience at Mitsubishi. Recently, he has been involved in the development of open-source-based fixed wing aircrafts using Ardupilot as a builder and a test pilot.