UAV-Based VLC for Precision Agriculture

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***Abstract*—Visible-light communication (VLC) uses the light-emitting diode (LED) -based luminaires to provide simultaneous illumination and communication. It has been receiving an increasing interest for use in different use cases, due to the increasing deployment of LED-based luminaires in wide range of applications. Use of LED-based grow lights has been receiving an increasing interest in the area of agriculture, as it can provide flexibility in growing plants throughout the year. In this work, we present the use of LED-based grow lights for providing unmanned-aerial vehicle (UAV) -based VLC in the precision agriculture (PA) systems. The advantages include achieving efficient resource utilization by using the grow lights for supporting plants growth and communications simultaneously, while providing electromagnetic field (EMF) interference free communication between the user nodes considered in the PA systems such as those at unmanned ground vehicles, sensors, and other Internet-of-things (IoT) devices.**

I. Introduction

The concept of precision agriculture (PA) has been receiving an increasing interest in the last two decades [1]. It is based on considering farming management that uses information technology to increase crop yields. It relies mainly on using robots to do the farming tasks (e.g. sowing, spraying, and harvesting), while exploiting the massive data collected throughout the field to understand the temporal and spatial variability of the data. For such systems, use of unmanned aerial vehicles (UAVs) to support PA offers an interesting solution for providing data such as plants growth data and crops health data, given the ability of the UAVs to fly at high altitudes, and the possibility of equipping the UAVs with cameras [2]. Based on the collected data for PA, optimal farming decisions could be taken to maximize the farming outcomes while minimizing the used resources. Indeed, such approach requires integration between different devices such as UAVs, robots, sensors, and Internet-of-things (IoT) devices. Wireless connectivity offers flexible solutions to achieve such integration while supporting devices mobility.

Use of grow lights can help in providing the energy required for photosynthesis, which is essential for the growth of plants. Interest in use of light-emitting diode (LED) -based grow lights has been increasing, due to advantages that include high energy efficiency. Visible-light communication (VLC), which is based on use of LED-based lighting for simultaneous communication and illumination, has been receiving an increasing interest, due to advantages that include presence of wide unregulated spectrum, efficient resource utilization, and electromagnetic field (EMF) interference free communication.

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Fig. 1. An illustration for the proposed UAV-based VLC for PA system, where tethered UAVs are equipped with LED-based lighitngs for supporting plant growth needs and illumination needs, while satisfying the communication needs to connect the devices in the network such as the sensors, robots, and the IoT devices.

UAV-based VLC offers flexible solution for providing on-demand communications, which is essential for supporting wireless coverage in remote and hard-to-reach areas. The utilization of grow light -based VLC was proposed recently, where LED-based grow lights were used for supporting plants growth and communication [3]. In this work, we propose the use of LED-based grow lights as access points (APs) in the UAV-based VLC networks. In particular, by equipping the UAVs with LED-based grow lights, the grow lights can be used for helping in satisfying the plants growth needs in PA systems, while supporting the connectivity requirements for achieving PA using VLC.

II. System Architecture

To provide an overview on the proposed UAV-based VLC for PA systems, we show in Fig. 1 an illustration for the considered system, where UAVs are equipped with LED-based luminaries for providing illumination and LED-based grow lights for supporting plants growth. For satisfying the PA system data system needs, the UAVs are equipped with cameras and sensors for monitoring. Note that, due to the ability of rotary-wing UAVs to hover and to hold on to their location, they are considered, given the plant growth and the illumination needs. To support long operation times for the UAVs, and given the limitations on the battery size at the UAV, tethered UAVs are considered, which rely on wired connectivity for providing power and data [4]. The ensemble of the UAVs is connected to a central control unit, which coordinates between the UAVs and carries out the main processing and synchronization tasks in the network.

For carrying out the farming tasks needed for achieving the PA goals, reliable flow of information is needed between devices such as sensors, Unmanned-Ground Vehicles (UGVs), and IoT devices. The UGVs play important role in PA as they carry out physical tasks that require mobility such as seeding, irrigation, spraying, and harvesting. For carrying out such tasks, high data rate communication is needed for three kinds of cooperation. First cooperation is between UGVs for path optimization and spatial allocation [5], second cooperation is between humans and UGVs for critical tasks that require supervision and verification by a human operator, which usually requires video transmission, and third cooperation is between UAVs and UGVs, where the UAVs provide the data about the field and the UGVs operate accordingly. Sensors also play an important role, as they are responsible for collecting information such as received light intensity, moisture of the soil, and compaction of the soil.

Besides supporting wireless communications requirements in the PA systems, use of LEDs at the UAVs could help in satisfying the illumination requirements in the farming systems. By using LED-based grow lights at the UAVs, they can be used for plant growth by satisfying the photosynthesis needs [6]. Generally, to satisfy the plant growth needs, the light should satisfy three criteria [7]. First, received light intensity measured in Photosynthesis Plant Flux Density (PPFD) should be within the range of 250–600 μmol. Second, the frequency distribution of the transmitted light should be tuned to maximize the vegetative growth and flowering. Finally, duration of light exposure should be adapted to the light needs (e.g., long-day plants benefit from longer exposure to light compared to short-day plants). Figure 2 shows examples of the lighting needs of long-day and short-day plants.

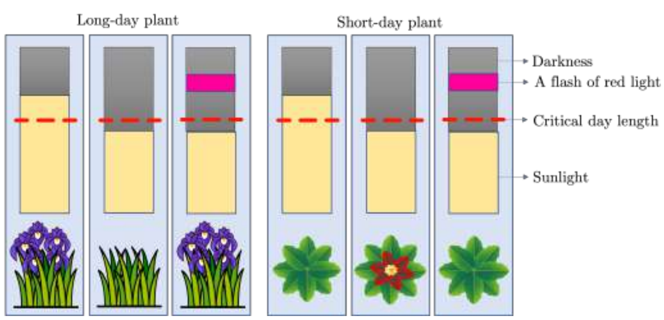

Fig. 2. Examples for the amount of light needed for growth of long-day and short-day plants.

In the proposed system, UAVs are used for providing light with a specified wavelength and intensity to compensate for any shortage in the light required for flowering, growth, or any other process done by the plants. Based on data collected by the sensors (e.g. light intensity), the UAVs can optimize their locations to maximize the PA system performance.

III. Conclusions

This work presented an overview on the use of LED-based grow lights for supporting UAV-based VLC in PA systems. It illustrated the needs of the PA systems, considering the use of sensors, UGVs, and IoT devices. In addition, it highlighted the system constraints with respect to the UAVs, illuminations, and communications requirements. Finally, it presented the constraints on the use of LED-based grow lights with respect to the plants vegetative growth and flowering.

References

[1] N. Zhang, M. Wang, and N. Wang, "Precision agriculture—a worldwide overview," *Computers and electronics in agriculture*, vol. 36, no. 2-3, pp. 113–132, 2002.

[2] D. C. Tsouros, S. Bibi, and P. G. Sarigiannidis, "A review on UAV-based applications for precision agriculture," *Information*, vol. 10, no. 11, p. 349, 2019.

[3] S. Javed, L. Issaoui, S. Cho, and H. Chun, "Utilization of LED grow lights for optical wireless communication-based RF-free smart-farming system," *Sensors*, vol. 21, no. 20, p. 6833, 2021.

[4] B. E. Y. Belmekki and M.-S. Alouini, "Unleashing the potential of networked tethered flying platforms: Prospects, challenges, and applications," *IEEE Open Journal of Vehicular Technology*, vol. 3, pp. 278–320, 2022.

[5] C. Lytridis, V. G. Kaburlasos, T. Pachidis, M. Manios, E. Vrochidou, T. Kalampokas, and S. Chatzistamatis, "An overview of cooperative robotics in agriculture," *Agronomy*, vol. 11, no. 9, p. 1818, 2021.

[6] J. B. Reece, L. A. Urry, M. L. Cain, S. A. Wasserman, P. V. Minorsky, R. B. Jackson *et al.*, *Campbell biology*. Pearson Boston, 2014, vol. 9.

[7] D. Singh, C. Basu, M. Meinhardt-Wollweber, and B. Roth, "LEDs for energy efficient greenhouse lighting," *Renewable and Sustainable Energy Reviews*, vol. 49, pp. 139–147, 2015.