Measurement of light pollution by using BSP

Andrzej Szczepańczyk[1*], *Marek* Macko[1], and *Jakub* Lewandowski[1]

[1]Faculty of Mechatronics, Kazimierz Wielki University, Bydgoszcz, Poland

Abstract. Light pollution is a common problem, especially in large agglomerations, where something still shines: lanterns, lights from windows, car lights, neon lights, advertisements, shop windows, there is no such important darkness anymore. The lack of blackout has a negative impact on all living organisms, from plants, through animals, and ending on humans (e.g. it affects the quality of sleep, disrupts the hormonal balance). The proposed solution concerns the measurement of the intensity of the so-called light-smog (light pollution), using an unmanned aerial vehicle (UAV / drone). This project is to help determine the scale of the problem, present it in numbers and provide the basis for improving the quality of life and health by reducing light smog.

1 Introduction

In modern world, the more attention is paid on a problem of excessive artificial lighting. Multi-track research allows on measuring degree of pollution of the so-called light smog and qualitative and quantitative interpretation of the obtained results. Electric lighting may cause that lunar rhythms will be omitted, which extends human working time until late night hours. The effects of this include, among others: disruption to the well-being of people, fauna and flora. In humans, it may take a form of depression, obesity and even cancer [3]. Among tools for quantitative and qualitative assessment of the degree of light pollution which is emitted directly into the sky and reflected there are included those that enable on acquisition of data from measurement sensors mounted on unmanned aerial vehicles (UAV) [4]. However, the inability to fly at high altitudes, as well as the low payload of drones, mean that these methods have not been widely disseminated to monitor the degree of darkening of the night sky. The maps available on Internet are based on satellite images, data from which may be distorted due to part of emitted light being obscured by the infrastructure, especially in urban agglomerations [3,4]. Moreover, this method is ineffective when the sky is covered with clouds [6]. The authors of article [4] presented data from a digital camera and a sky quality meter to define the relationship between indicators determined on the basis of night sky photos and results of measurements from optical devices directed towards the ground. A linear regression model based on the light intensity index was used to analyze images taken at a height of 70 and 100 m [4]. Image analysis to determine the luminance for each pixel was also carried out in [6], based on a series of photos taken in various locations using an UAV. In the vast majority of studies on environmental factors, unmanned aerial vehicles are used to measure degree of air pollution with suspended dust [5]. Air quality monitoring and forecasting is carried out by correlating the analysis of haze images taken using UAVs and data collected via a terrestrial three-dimensional wireless network [5]. A holistic approach to assessing the effectiveness of lighting installations is provided by use of UAVs with several types of sensors and the ability to reprogram control applications, making it possible to collect measurement data from several different angle positions and heights, ensuring quick, easy, accurate and repeatable measurement [2]. Bouroussis et al. [2] proposed a combination of a drone and a goniophotometer (DGPM), which can be placed anywhere in three-dimensional space when measuring a sample. The benefits of using DGPM include: flexible measurements, high repeatability, the ability to perform static measurements, program the

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

measurement path and low operating costs [2]. The disadvantages include, among others, limited flight time, limited total weight of drone, and need to have licenses and permits to perform flights [2]. The proposal to measure light intensity using drones or balloons was also proposed by Bettanini et al. [1], where a commercial camera was used to monitor the main sources of ground light with an accuracy of several meters and a calibrated photodiode was used to simultaneously recognize the evolution of sky brightness [1]. Proper control of the flight trajectory allows to track changes in light intensity over time, even for several hours at night [1]. Unfortunately, as in case of previously mentioned measurement proposals, it is impossible to take into account, for example, the saturation of blue color coming from ubiquitous LEDs. Also a comprehensive review of available methods for measuring light pollution in Mander et al. [3] indicates possibility of using unmanned aircraft, however, with the flight altitude limited to 50-70 m and with use of commercial digital cameras, which provide only basic information and do not allow on preparation of an accurate map of intensity of the light emitted and reflected. The authors also mention other, currently most frequently used methods: photos from satellites and space stations as well as ground-based photosensors, and various smartphone applications based on infrared sensors. The subject of the invention is the concept of system to measurement light pollution with using UAV (drone).

2 Materials and Methods

The proposed system includes the concept of an electronic system incorporating light intensity sensor(s) to measure the degree of pollution caused by excessive light emissions (light pollution). The electronic system will be part of the overall system, including data acquisition and initial analysis. Ultimately, the system will also include a mechanical part, allowing the complete device to be mounted on an unmanned aerial vehicle (drone) and dedicated software to handle the data stream. Figure 1 shows the design of the measurement system.

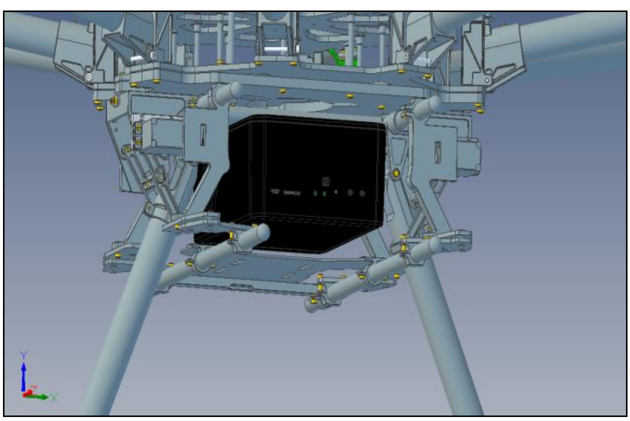

Fig. 1. Measurement system mounted under the unmanned aerial vehicle.

The measurement system consists of electronics components, firmware, software and mechanical components. The complete set of components will be mounted on an unmanned aerial vehicle.

A large part of the project will be realised using 3D printing technology, which will optimise the design in terms of weight, which is extremely important for unmanned aerial platforms. In addition, 3D printing will allow the optimisation of the landing gear to take place - keeping the various electronics modules separate. Each measurement will be tagged with data such as date, time, GPS location, humidity, pressure, temperature. This way of recording data will make it possible, for example, to collect data over longer periods of time and analyse their history, or to compare smog pollution in different areas. It will also be possible to create a map of light pollution and identify problem areas and provide arguments, for example, for the possible upgrading of street lighting.

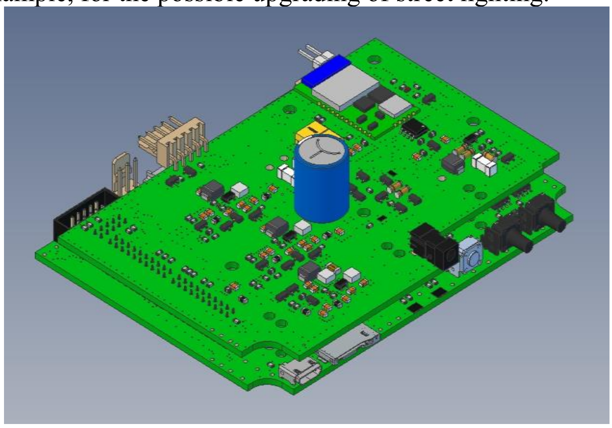

Fig. 2. Design of the module PWR and CPU.

The collected data will be saved on the internal memory card and also sent to the operator The data collected will be stored on an internal memory card and also transmitted to the operator on the ground. The whole system will be modular so as to maximise the simplicity of configuration changes and extend the functionality of the system. Measurements will be taken after sunset (mainly at night)

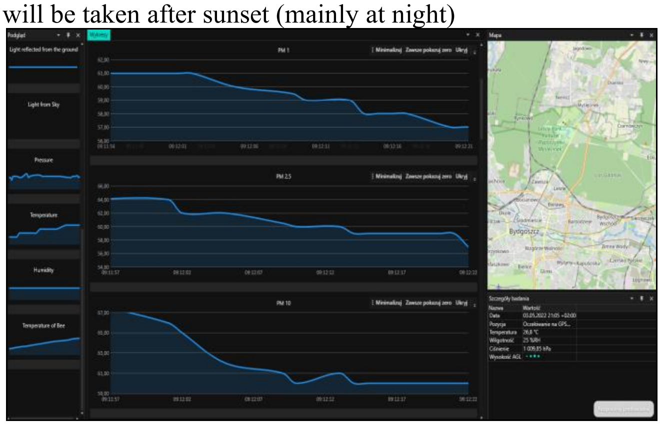

Fig. 3. Graphical interface of the software for data acquisition from the measurement system.

3 Results

The results of the measurements and their analysis can provide guidance to street lighting manufacturers (e.g. regarding the shape of street lamp shades - for example, a spherical lamp wastes most of the light shining into the sky). The judicious use of knowledge from the collection and careful analysis of measurement data can translate into real savings. Presenting information on energy losses (in the form of light emitted - completely unnecessarily - towards the sky), backed up by concrete figures, will allow, for example, the mayors of large cities to look at the problem and make adjustments to their public lighting systems.

People's health will also be improved: thanks to better production of melatonin, the sleep hormone, which is normally achieved in darkness. The conscious use of light is used, for example, in mares (influencing oestrus by regulating the light day). Light affects hormones: lack of darkness disrupts the human hormonal balance, which can result, for example, in female cycle disorders, very often leading to serious fertility problems. This is why it is so important to take a look at resting places (bedrooms) and answer the question: is it dark in there, or are laptop chargers, phones, computer screens, smartphones or televisions constantly on? All these inconspicuous lights can cause great havoc in the body.

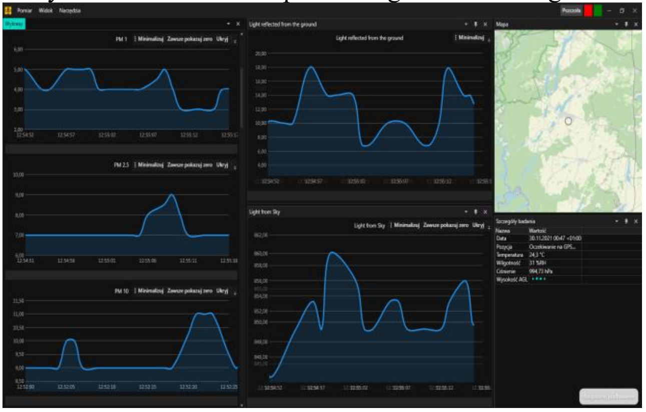

Fig. 4. Software window.

Fig.5. The authorial prototype of the measurement system, mounted on UAV.

4 Discussion

The proposed solution could find application in industries such as energy, health care, environmental protection, etc. After initial concept presentations to a group of industry audiences, there was very positive feedback on the project. Potential customers for the product include, for example, road managers, dark sky reserves, town halls, lighting retrofit companies; companies responsible for proper lighting; institutions related to Natural Family Planning. The advantage of this solution is the relatively low cost and small size of the system. And its mobility and applicability virtually anywhere. Another important advantage is the very short measurement time. In the next stages of the work, the authors intend to develop the concept of the presented system.

References

1. C. Bettanini, M. Bartolomei, A. Aboudan, G. Colombatti, L. Olivieri, *Flight test of an autonomous payload for measuring sky brightness and ground light pollution using a stratospheric sounding baloon*, Acta Astronautica, **191**, pp. 11–21 (2022)
2. C., A. Bouroussis, F., V. Topalis, *Assessment of outdoor lighting installations and their impact on light pollution using unmanned aircraft systems - The concept of the drone-gonio-photometer*, Journal of Quantitative Spectroscopy & Radiative Transfer, **253** (2020)
3. S. Mander, F. Alam, R. Lovreglio, M. Ooi, *How to measure light pollution – A systematic review of methods and applications*, Sustainable Cities and Society, **92** (2023)
4. L. Massetti, M. Paterni, S. Merlino, *Monitoring light pollution with an unmanned aerial vehicle: A case study Comparing RGB images and night ground brightness*, Remote Sens., **14**, 2052 (2022)
5. G. Rohi, O. Ejofodomi, G. Ofualagba, *Autonomous monitoring, analysis and countering of air pollution using environmental drones*, Heliyon, **6**, (2020)
6. P. Tabaka, *Pilot measurement of illuminance in the context of light pollution performerd with an unmanned aerial vehicle*, Remote Sens. 2020, **12**, 2124 (2020)