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DRON MONITORUJĄCY ROŚLINNOŚĆ PRZY POMOCY TELEDETEKCJI

Streszczenie: Artykuł ten opisuje projekt drona wyposażonego w aparaturę badawczą, którego misją jest ocenienie stanu zdrowia i rozwoju roślinności. W tym celu aparatura badawcza drona wykonuje zdjęcia powierzchni Ziemi, na podstawie których wyznaczany jest Znormalizowany Wskaźnik Wegetacji Roślin (NDVI).

Słowa kluczowe: dron, teledetekcja, NDVI, monitorowanie roślinności

A QUADCOPTER MONITORING THE VEGETATION USING REMOTE SENSING

Summary: This article explains the project of a drone equipped with a research device, which mission is to assess the health and development of vegetation. For this purpose, the drone's research device takes pictures of the Earth's surface, based on which the Normalized Differential Vegetation Index (NDVI) is calculated.

Keywords: drone, remote sensing, NDVI, monitoring of vegetation

1. Introduction

The advances in remote sensing have enabled assessing the health and development of vegetation using cameras and other sensors. For this purpose, the quadcopter described in this paper has been built.

The main goal of the project was to build a reliable and low-cost device that can be used in remote sensing. In this project, focus was placed on monitoring the condition

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of vegetation. To monitor the plants, a Python code calculating Normalized Differential Vegetation Index (NDVI) was written.

2. Project description

The design of the drone is based on two parts: the frame and the landing gear to which all other components are attached. Both of these parts are made out of durable materials (Nylon frame and ABS chassis).

2.1. Mechanical design

The research device and its attachment to the drone frame were designed, manufactured, and programmed entirely independently. Their detailed description can be found in the further part of this paper.

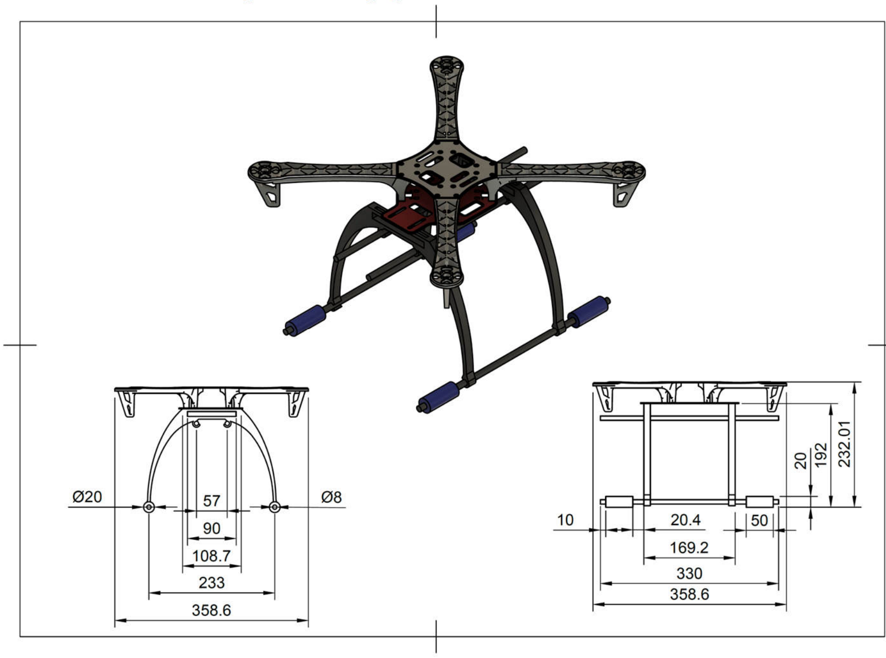

Figure 1. The mechanical drawing of the frame and the chassis

The following components are attached to the frame and chassis:
- **Pixhawk 2.4.8** – the flight controller of the drone. Onboard of the Pixhawk there is a gyroscope, an accelerometer, a magnetometer, and a pressure sensor. The controller is responsible for stable and safe flight. It is located on the top of the quadcopter,
- **GPS module with compass** – this module is responsible for the correct execution of the autonomous flight that was pre-planned. It is mounted on an extension arm on the top of the quadcopter,
- **electronic speed controllers (ESC)** – the ESCs are responsible for controlling and adjusting the speed of the aircraft's motors. Located on the arms of the frame,

- **Racerstar BR2212 1000kV motors** – the motors that allow the quadcopter to fly. Located on the ends of the frame's arms,
- **FS-iA6B receiver** – radio receiver responsible for receiving commands from the transmitter. Located on the top of the drone,
- **1047 propellers** – mounted on the motors. The propellers allow the motors to create thrust that lifts the drone.
- **Redox 3S 4400mAh LiPo battery** – the battery that powers the electronic elements and the motors.

The constructed drone is a quadcopter. Its total weight is 15N. Each of the motors produces a maximum thrust of 8.85N (35.4N in total). The attained thrust allows lifting of the drone together with the research device.

Figure 2. The constructed quadcopter

2.2. Electrical design

All electronic components are connected directly to the drone's flight controller via jumper wires. The flight controller takes readings from the gyroscopes, accelerometers, magnetometer, barometer, and GPS module, processes them, and then gives commands to the ESCs. The connection of sensors and motors ensures a stable and safe flight.

Pixhawk provides each of the components with the power necessary for its proper operation. The motors are connected in series via electronic speed controllers to the battery.

The battery capacity is 4400 mAh at 11.1V. Assuming 80% battery efficiency, we get 38.72Wh. The motors need 173W to generate 17.5N of thrust, giving a maximum flight time of approximately 13.5 minutes.

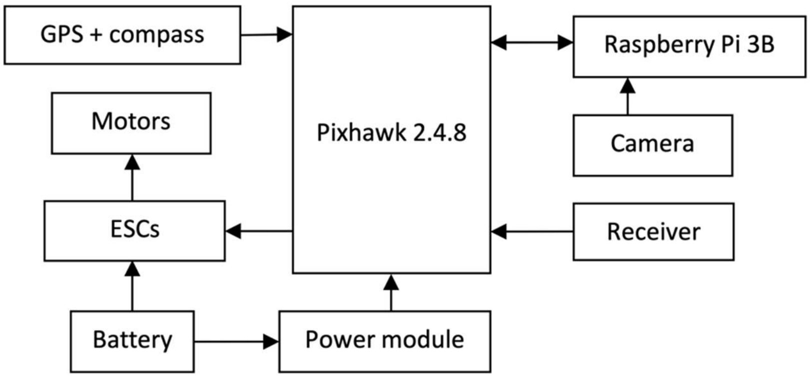

Figure 3. The electronic diagram

2.3. Software design

The software used to control the drone is the open source ArduPilot, which ensures safe and stable flight. ArduPilot allows to carry out autonomous flights using the GPS module and compass, as well as standard flights using the control apparatus.

ArduPilot also allows to save flight data (GPS coordinates and readings from the barometer, accelerometer, compass, and gyroscope) on the Pixhawk SD card for later analysis.

2.4. The research device

The research device consists of the following components:
- **Raspberry Pi 3B** – an on-board computer responsible for taking and storing images on the SD card. It runs on a Linux distribution adapted for the Raspberry Pi. Using the Mission Planner software, Raspberry Pi can control the flight of the drone using the MAVLink protocol,
- **Raspberry Pi Camera Module 3 NoIR Wide** – a wide-angle camera sensitive to infrared light. It is responsible for taking photos in the red and near-infrared bands (blue and green bands are blocked by the **MidOpt DB660/850 Dual Bandpass Red + 850nm NIR** optical filter). The camera uses a Sony IMX708 sensor with a resolution of 12Mpx.

In order to place these components on board of the drone, a special mount was designed and manufactured. During its design, efforts were made to maintain the highest possible mechanical strength of the mount with the lowest possible weight.

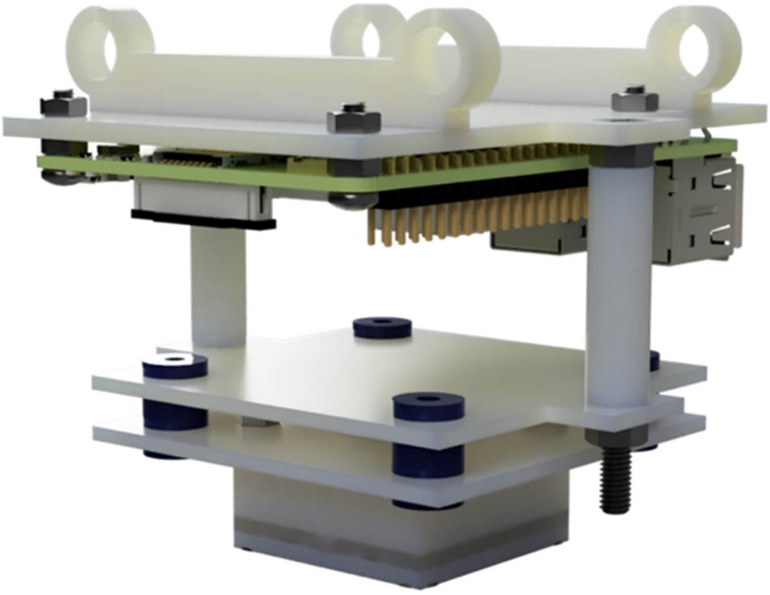

Figure 4. A render of the research device

To eliminate vibrations caused by the drone's motors, an anti-vibration system has been designed. The camera module is attached to the rest of the mount with cylindrical vibration dampers that dampen the vibrations generated by the drone's motors. The test device can be attached to the drone’s chassis with hooks.

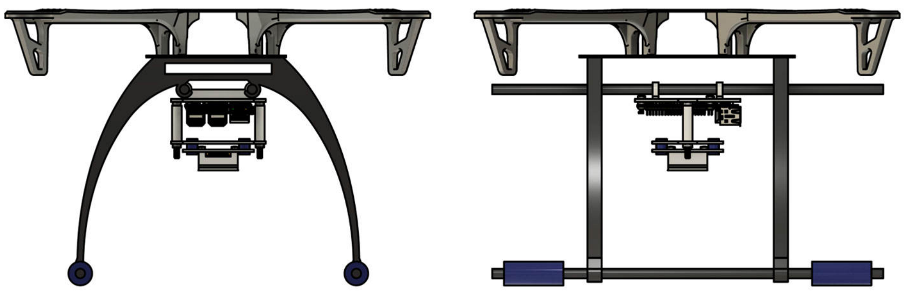

Figure 5. The research device attached to the drone's chassis

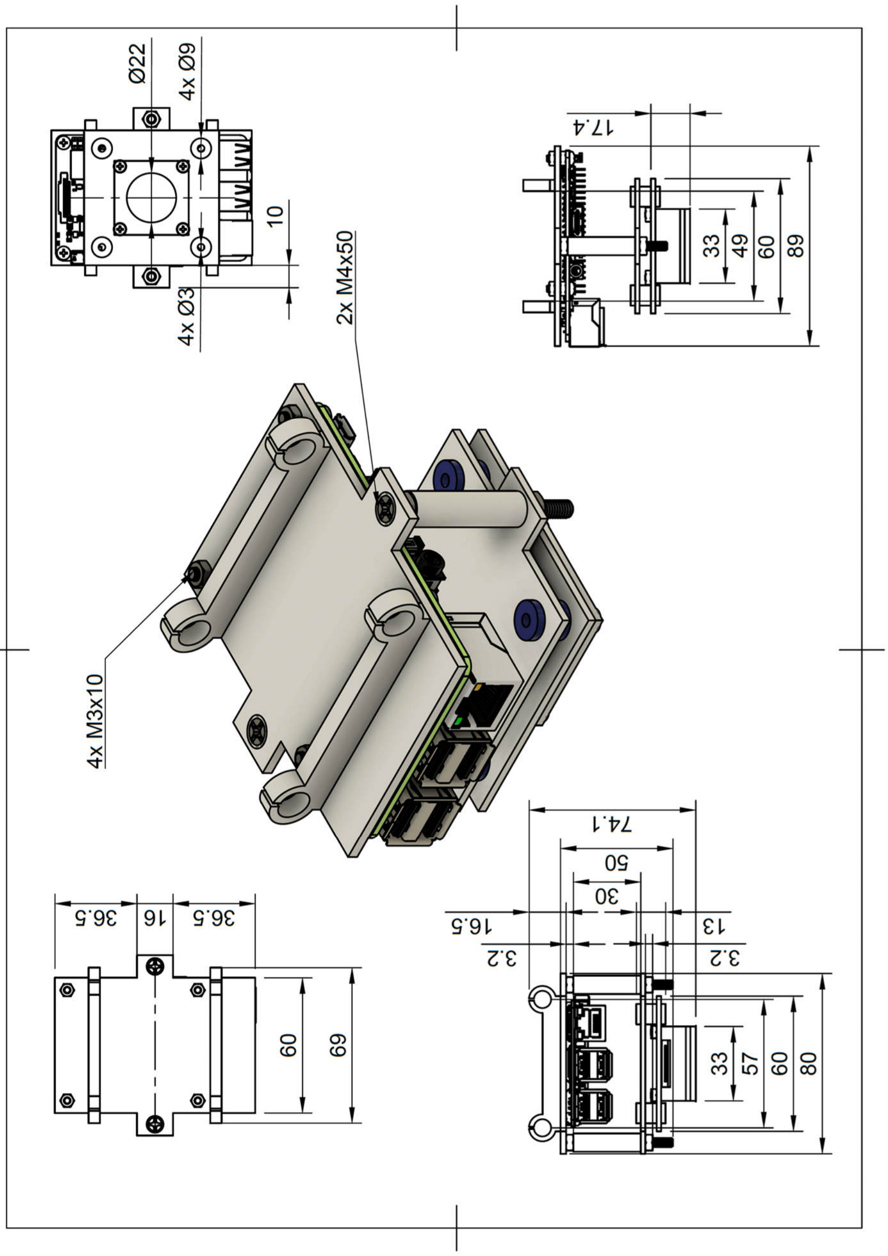

Figure 6. The mechanical drawing of the research device

3. Quadcopter's mission

The task of the constructed drone is to monitor the health of vegetation using remote sensing. For this purpose, the device takes pictures of the earth's surface using a specialized camera described in the previous chapter, and then, using a computer program, the Normalized Vegetation Index (NDVI) is determined on its basis.

3.1. Normalized Differential Vegetation Index (NDVI)

The Normalized Differential Vegetation Index is a graphical indicator that is used in assessing the level of vegetation and the health of plants, developed by J. W. Rouse. It is expressed with the following formula:

$$NDVI = \frac{NIR-Red}{NIR+Red} \tag{1}$$

where *NIR* stands for reflection in near-infrared spectrum of light (radiation with a wavelength of 850nm) and *Red* is the reflection in the red spectrum of light (radiation with a wavelength of 660nm). The indicator takes values from -1 to 1. The higher its value is, the healthier and more lush vegetation is in the assessed area.

3.2. The software determining the Normalized Differential Vegetation Index

The Normalized Differential Vegetation Index is determined using proprietary code written in Python. First, the program loads the photo and converts it into a table of RGN (Red, Green, Near-Infrared) color values. The contrast of the image is then increased, making it easier to calculate the NDVI.

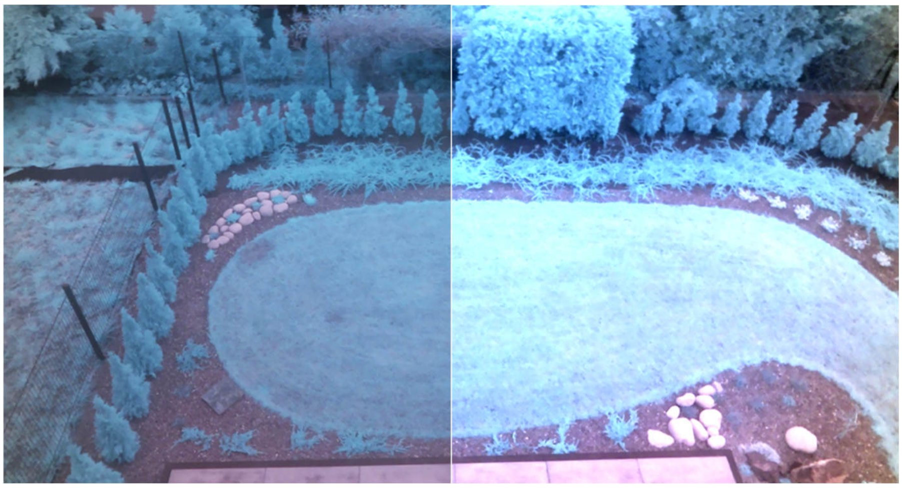

Figure 7. The original image (on the left), image with the increased contrast (on the right)

After increasing the contrast of the image, the NDVI index can be calculated. The code divides the RGN color table into three tables. Each of them contains one of the three color values of each pixel. Then the denominator of the NDVI index is calculated according to the formula. To avoid the division by 0 error, denominator values equal to 0 are converted to 0.01. Then the numerator value is calculated and the NDVI index is determined. As a result of this action, we get a photo with the calculated grayscale indicator. The brighter the color of a pixel is, the higher the value of the indicator is.

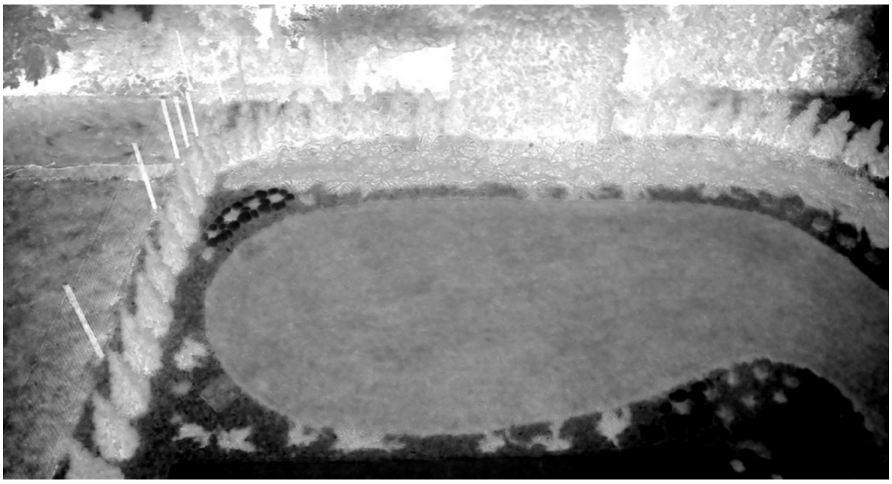

Figure 8. An image with determined NDVI in greyscale

In order to improve the readability of the indicator, the code applies *RdYlGn* colormap to the image (see Figure 10).

3.3. Analysis of a sample image

The sample image was taken on 20th March 2023. There is fragment of the garden with grass, a rim made of stones and thujas.

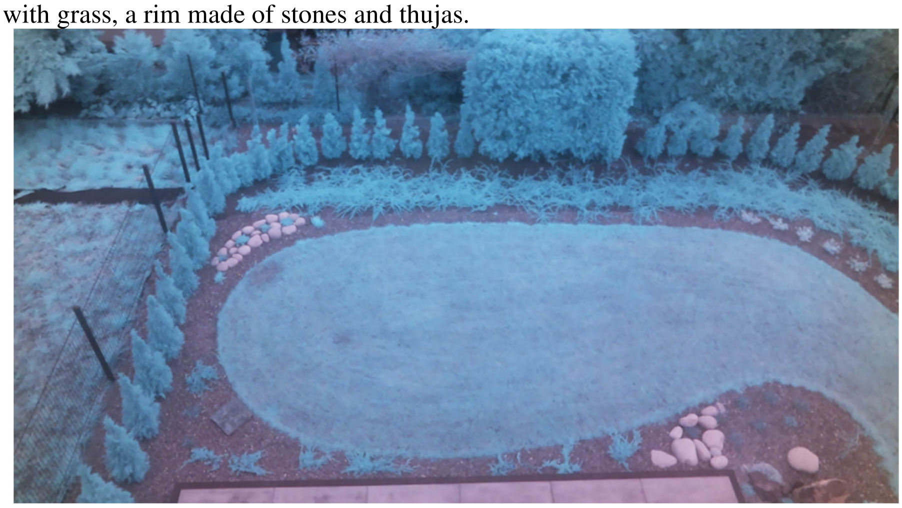

Figure 9. The sample image

The Normalized Differential Vegetation Index was determined based on this image.

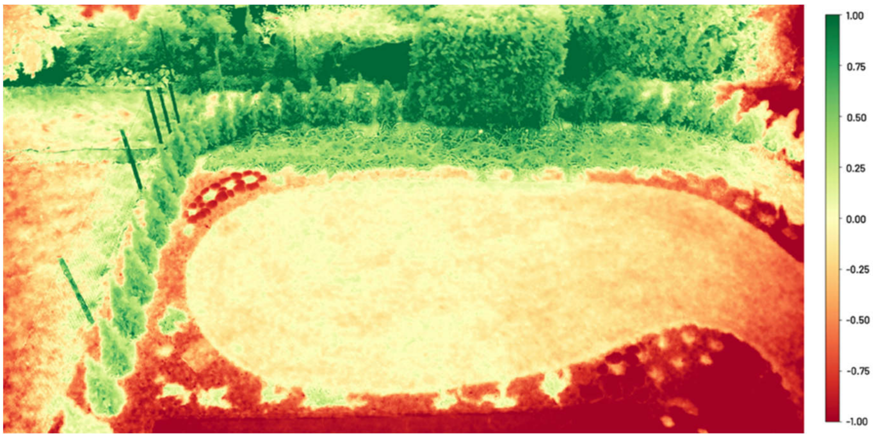

Figure 10. An image with determined NDVI and applied colormap

NDVI takes the highest values for thujas located in the upper part of the image, because they absorb the most radiation in the red band. Values in the range (0; 0.33) are taken by grass and low shrubs, which indicates that they are less healthy and less lush compared to the area where thujas occur. The thujas on the left of the image have lower NDVI values compared to those in the upper part of the image, which indicates that they are growing worse or are drying out and intervention (e.g. fertilization) is needed. The lowest values of the indicator are on the stones located in the lawn's rim and on the grass located in the lower right part of the picture. The reason for its low NDVI value is that it has dried up over the winter and no fertilizer has been used.

3.4. Practical applications of the quadcopter

The constructed drone has a chance to be widely used in research in the field of ecology and environmental protection. The drone can be used to monitor the health of vegetation in a predetermined area (e.g. in a national park), which will allow a quick detection of areas where diseases or pests have appeared among protected vegetation. Monitoring vegetation using a drone is much faster, more effective, cheaper and more accurate than checking a set area by humans.

The device can also be used in agriculture to monitor the condition of crops. With its help, the state of vegetation development can be determined, as well as places where plants do not develop well enough can be found. The use of a drone will improve the fertilization process by indicating places where more fertilizer needs to be applied.

4. Conclusions

The main goal of the project was to independently construct a low-cost, reliable, and multi-task system (drone + software) that can be used in remote sensing projects. Such a device has been constructed. A code, that calculates Normalized Differential Vegetation Index (NDVI) was also written. Further development of the project is planned in the future. It is planned to add an additional camera that will allow the drone to be used in more remote sensing studies and to extend the flight time of the device by constructing a device that is a hybrid of a multirotor and a fixed wing aircraft.

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