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EXPERIENCE OF CONNECTING SENSORS TO THE CONTROLLER BASED ON THE ARDUINO BOARD FOR USE ON MULTICOPTERS

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ABSTRACT

The possibility of obtaining data on areal humidity based on unmanned aerial vehicles is being investigated. Modern humidity sensors are mostly stationary and provide point measurements. With the advent of mobile hardware and software tools that make it possible to automate the process of obtaining data, the problem of obtaining information distributed over a given area is being solved. And also there is the possibility of recording and saving data to the hard disk. One of the advanced areas in which multicopters are used is the creation of electronic field maps, as well as maps of vegetative NDVI indices. This paper discusses DHTxx temperature and humidity sensors. The small dimensions of the sensors, a sufficient number of I / O ports (data transfer, control of peripheral devices) made it possible to assemble many devices based on Arduino. The use of unmanned aerial vehicles greatly simplifies the collection of the necessary information about the state of crops. Unlike spacecraft, an unmanned aerial vehicle, in our case multicopters, is more mobile, with more detailed data (the ability to obtain images with a resolution of up to 1 cm). Due to the fact that the flight altitude of a multicopter is usually within 1 to 200 meters above the ground, it is possible to use various sensors (temperature, humidity, etc.), which were previously used by agronomists (farmers) for ground weather stations. The temperature and humidity sensors of the DHTxx family can be attributed to such sensors, which are necessary in terms of monitoring agricultural lands. The temperature and humidity sensors DHT11 and DTH22 include two measuring instruments useful for agriculture - a thermometer and a hygrometer. The progress of modern society cannot be imagined without the development of science and technology, without the introduction of technological innovations, in particular controllers and sensors with different functionality. The results of this study can be applied both to the design of multirotors in general and to the arrangement of sensors and actuators.

Keywords: *Unmanned Aerial Vehicles, Multicopter, Arduino, Temperature and Humidity Sensor, NDVI, Monitoring, GIS*

1. INTRODUCTION

Agriculture is one of the most promising sectors of the economy, given the constantly growing population of our planet. Therefore, any innovation in this industry is welcome. One such innovation is multicopters for agriculture [1, 2].

One of the leading directions in which multicopters are used is the creation of electronic maps of fields, as well as maps of normalized difference vegetation index [3, 4]. The technology of unmanned aerial vehicles makes it possible to record and monitor the state of agricultural land: it is the optimization of water consumption, the calculation of the optimal amount of fertilizers and chemicals applied, the creation of an electronic map of the fields, the forecast of crop yields, planning the laying of drainage systems, etc. terrain, size of fields, boundaries of water bodies (lakes, rivers, swamps) and roads [5, 6]. Using this technology, you can get photographs to analyze the state of the sowing, its density and uniformity. Using spectral sensors installed on unmanned aerial vehicles, information can be obtained not only in the visible spectrum, but also in various spectral ranges. All data can be presented with precise coordinates with the possibility of detailed study and analysis.

Unmanned aerial vehicles used in agriculture can be divided into 2 types: 1. Helicopter type aircraft (multicopter); 2. Flying aircraft type devices (flying wing).

These 2 classes are distinguished by size, functionality, flight range, and other characteristics.

Currently, home weather stations based on the Arduino hardware computing platform with the use of DHT 11 and DHT 22 temperature and humidity sensors have become widespread. many devices, and one of them is a home weather station. Figure 1 shows home weather station [7].

As discussed above, technology can help you move to the next level. Easily programmable and relatively small, both in size and weight, the sensors can be used not only at home (smart home), but also to introduce in an unmanned aerial vehicle.

Figure 1: Home weather station

To obtain data on the moisture and temperature of the underlying soil cover, which is so necessary for the development of agriculture. Crop health monitoring is a laborious process. It takes a lot of time, and the lack of information is costly. It is very difficult for a farmer walking around the fields with measuring instruments in his hands to see the full picture on a huge farmland scattered over a huge territory. The use of unmanned aerial vehicles greatly simplifies the collection of the necessary information about the state of crops. Unlike spacecraft, unmanned aerial vehicles, in our case multicopters, are more mobile, with greater data detail (the ability to obtain images with a resolution of up to 1 cm). Due to the fact that the flight altitude of a multicopter is usually in the range from 50 to 500 meters above the earth's surface, it is possible to use various sensors (temperature, humidity, etc.), which were previously used by agronomists (farmers) for ground-based weather stations.

Temperature and humidity sensors of the DHTxx family can be classified as such sensors necessary in terms of monitoring farmland.

DHT11 and DTH22 temperature and humidity sensors include two measuring devices useful for agriculture at once - a thermometer and a hygrometer (Figure 2):

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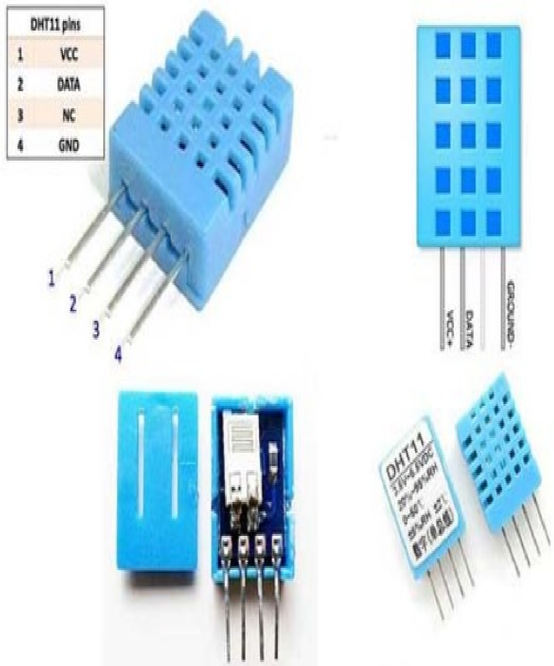

Figure 2: DTH11 sensor in plastic housing

But there are sensors that are soldered on a small board (Figure 3).

Figure 3: DTH11 sensor soldered on a small board

2. SPECIFICATIONS DHT11 AND DHT22

DHT11 [8]: Number of pins: 4; Consumption current - 2.5 mA (maximum value during data conversion); Measures humidity in the range from 20% to 95%. The error can be up to 5%; It is used when measuring temperature in the range from 0 to 50 degrees (accuracy - 2%). Overall dimensions: 15.5 mm length; 12mm width; 5.5mm height; Power supply - 3.3-5 Volts; One measurement per second. That is, the frequency is 1 Hz.

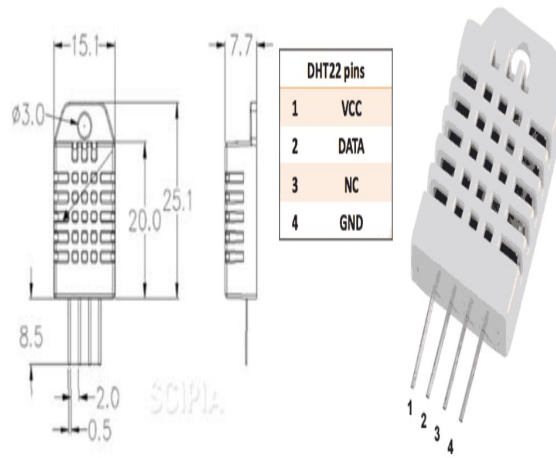

Figure 4: DHT22

DHT22 [9] (Figure 4): Number of pins: 4; Consumption current - 2.5 mA (maximum value during data conversion); Measures humidity in the range from 0% to 100%. Humidity measurement accuracy: ± 2% RH; It is used when measuring temperature in the range from -40 to 80 degrees (accuracy ± 0.5); Overall dimensions: 15.1 mm length; 25mm width; 7.7mm height; Power supply - 3.3 - 6 Volts; One measurement in 2 seconds. That is, the frequency is 0.5 Hz.

DHT22 is more accurate and has a wider measuring range. The applicators have one digital output each. Requests to them can be sent no more than in 1-2 seconds.

Inside DHTxx sensors there is a chip that performs analog-to-digital conversions and also separates the digital signal into temperature and humidity data. This data is very easily read by a microcontroller - a microcircuit designed to control electronic devices, in our case - a microcontroller based on Arduino UNO, ATmega328 (Figure 5):

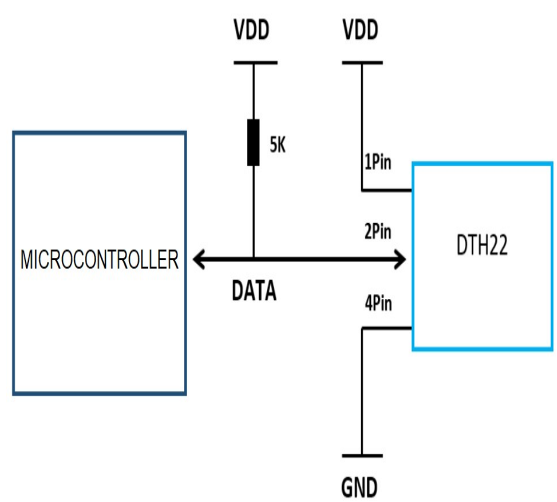

Figure 5: Schematic diagram

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3. EXPERIENCE CONNECTING DHT22 SENSOR TO ARDUINO

Required parts: Arduino UNO R3 x 1 pc.; DuPont wires; USB 2.0 A-B cable x 1 pc.; DHT22 temperature and humidity sensor x 1 piece; 10K ohm resistor x 1 pc; Development board MB-102 (Breadboard) x 1 pc.

Software: FLProg (visual programming) [10]; IDE Arduino [11]; DHT library (Github) [12].

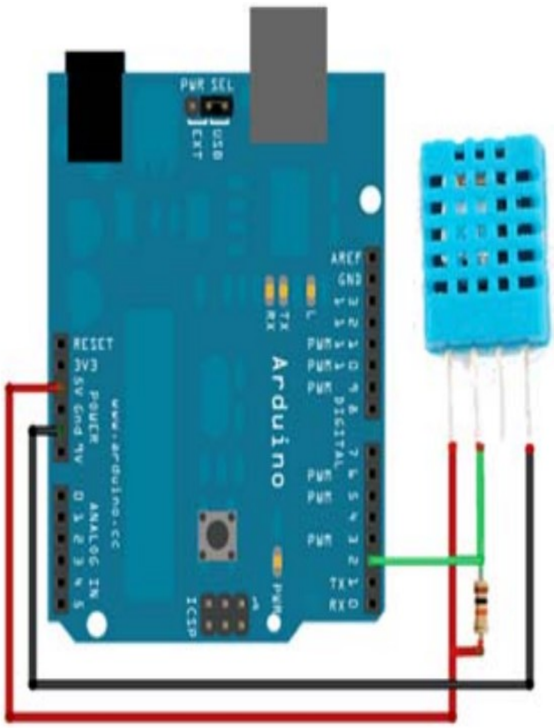

Figure 6: Connecting DHT22 sensor to Arduino

When connected to an ATmega328 microcontroller based on the Arduino UNO board (Figure 6), a 10 kΩ pull-up resistor should be placed between the VDD and Data pins. The Arduino board has built-in pull-ups, however, they are very weak - about 100 kOhm.

Figure 7 shows the wiring diagram for connecting the DHT22 sensor to the Arduino Uno board.

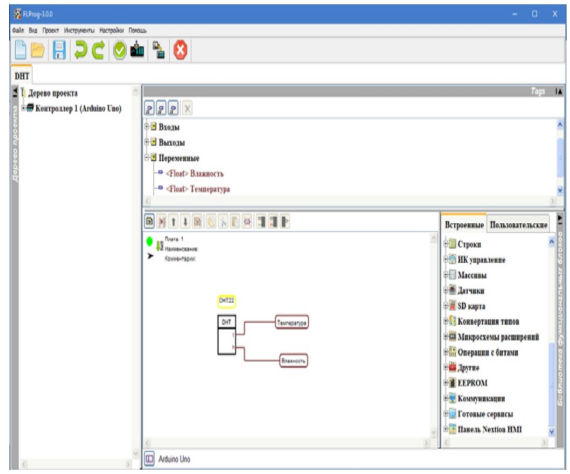

Figure 7: Wiring diagram and visual programming of DHT22 sensor for Arduino Uno board

To connect the sensor, you need to use the DHT.h library, created specifically for DHT sensors. It can be downloaded from the largest web service for hosting IT projects and their joint development GitHub.

We include the library: # inlude "DHT.h"

When using DHT11 sensor, it is necessary to comment out the DHT22 sensor line: DHT dht (DHTPIN, DHT22);

and uncomment the line DHT11: // DHT dht (DHTPIN, DHT11);

Next comes the setup block (baud rate, data output / transfer):

```
Serial.begin (9600);
Serial.println ("DHT22 test");
dht.begin ();
```

Determine the baud rate: Serial.begin (9600);

The following is a description of the main loop:

```
delay(2000);
        float h = dht.readHumidity();
        float t = dht.readTemperature();
        if (isnan(h) || isnan(t))
                {
                        Serial.println("Read
                error DHT22");
                        return;
                }
        Serial.print("Humidity: ");
        Serial.print(h);
        Serial.print(" %\t");
        Serial.print("Temperature: ");
        Serial.print(t);
        Serial.println(" *C ");
```

Where the values from the sensor are placed in the corresponding variables of the real type (Figure 8, 9):

```
float h = dht.readHumidity();
float t = dht.readTemperature();
```

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To display the required values of humidity and temperature, use the code:

```
Serial.print("Humidity: ");
Serial.print(h);
Serial.print(" %\t");
Serial.print("Temperature: ");
Serial.print(t);
Serial.println(" *C ");
```

Example program for working with DHT22 sensor:

```
#include "DHT.h"
#define DHTPIN 2
//#define DHTTYPE DHT11
#define DHTTYPE DHT22
DHT dht(DHTPIN, DHTTYPE);
void setup()
{
 Serial.begin(9600);
 Serial.println("DHT22 тестовый");
 dht.begin();
}
void loop()
{
 delay(2000);
 float h = dht.readHumidity();
 float t = dht.readTemperature();
 if (isnan(h) || isnan(t))
 {
 Serial.println("Ошибка чтения DHT22");
 return;
 }
 Serial.print("Влажность: ");
 Serial.print(h);
 Serial.print(" %\t");
 Serial.print("Температура: ");
 Serial.print(t);
 Serial.println(" *C ");
}
```

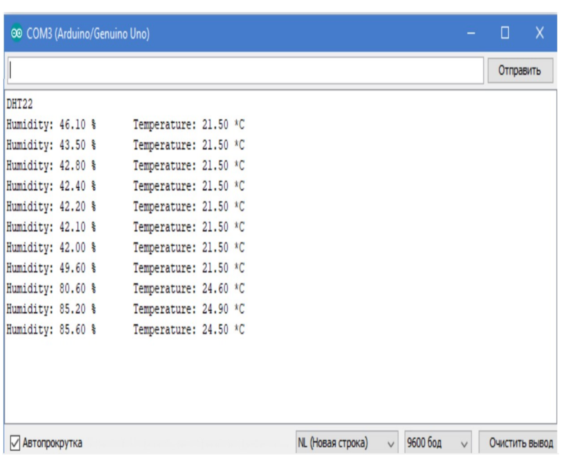

Figure 8: Outputting data to the COM port monitor

An example of a program for displaying a heat index:

```
#include "DHT.h"
#define DHTPIN 2
//#define DHTTYPE DHT11 // DHT 11
#define DHTTYPE DHT22 // DHT 22 (AM2302), AM2321
//#define DHTTYPE DHT21 // DHT 21 (AM2301)
DHT dht(DHTPIN, DHTTYPE);
void setup()
{
 Serial.begin(9600);
 Serial.println("DHTxx test!");
 dht.begin();
}
void loop()
{
 delay(2000);
 float h = dht.readHumidity();
float t = dht.readTemperature();
float f = dht.readTemperature(true);
if (isnan(h) || isnan(t) || isnan(f)) {
 Serial.println("Failed to read from DHT sensor!");
 return;
 }
 float hif = dht.computeHeatIndex(f, h);
 float hic = dht.computeHeatIndex(t, h, false);
 Serial.print("Humidity: ");
 Serial.print(h);
 Serial.print(" %\t");
 Serial.print("Temperature: ");
 Serial.print(t);
 Serial.print(" *C ");
 Serial.print(f);
 Serial.print(" *F\t");
 Serial.print("Heat index: ");
 Serial.print(hic);
 Serial.print(" *C ");
 Serial.print(hif);
 Serial.println(" *F");
}
```

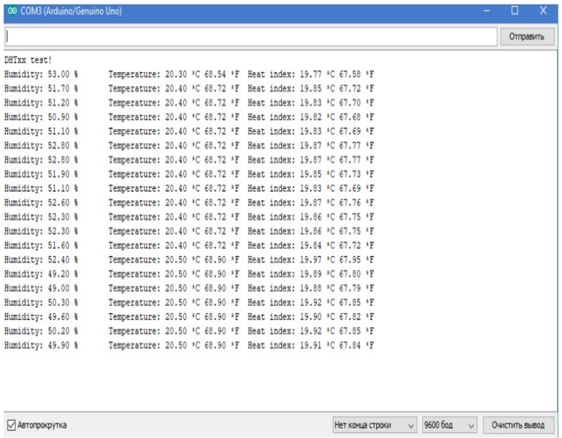

Figure 9: Outputting data to the COM port monitor

The heat index is a measure of how much it actually feels when relative humidity is factored in with actual air temperature [13, 14].

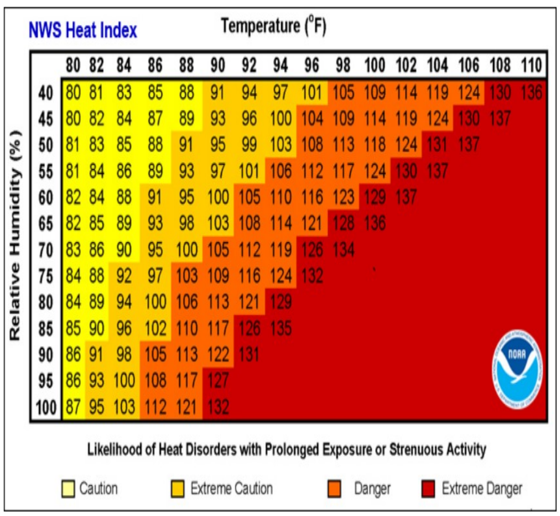

Figure 10: Heat index

The above table (Figure 10) is taken from the server of the National Weather Service (USA). Outdoors in open conditions, as the relative humidity increases, the first haze appears and eventually a thicker cloud cover, reducing the amount of direct sunlight reaching the surface. Thus, there is an inverse relationship between the maximum potential temperature and the maximum potential relative humidity.

4. EXPERIENCE IN WRITING TEMPERATURE AND HUMIDITY DATA TO A FILE ON AN SD CARD

Parts needed: Arduino UNO R3 x 1pc; DuPont wires; USB 2.0 A-B cable x 1 pc.; DHT22 temperature and humidity sensor x 1 piece; 10K ohm resistor x 1 pc; SD card module; Development board MB-102 (Breadboard) x 1 pc.

Software (Figure 11, 12): FLProg (visual programming); IDE Arduino; DHT library (Github).

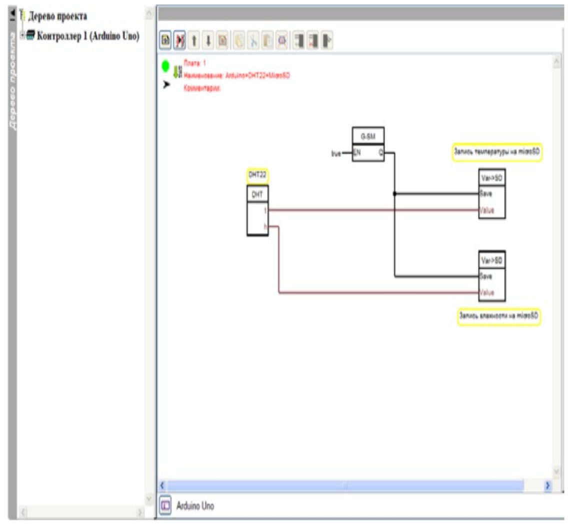

Figure 11: Wiring diagram and visual programming of the DHT22 sensor to the Arduino Uno board and writing data (temperature and humidity) to the microSD

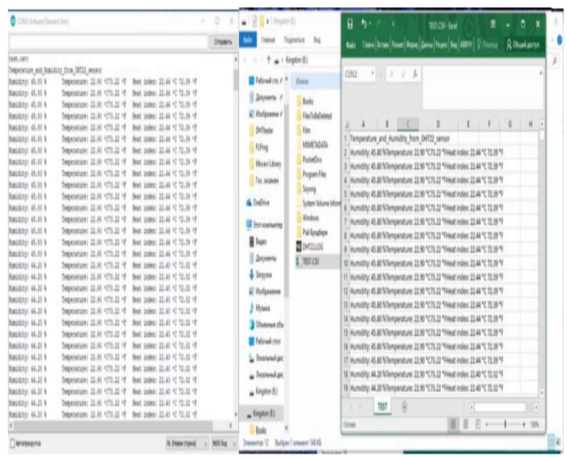

Figure 12: Data output and recording to micro SD

5. EXPERIENCE IN WRITING TEMPERATURE AND HUMIDITY DATA TO SD CARD USING DS1307 REAL-TIME MODULE

Required parts: Arduino UNO R3 x 1 pc.; DuPont wires; USB 2.0 A-B cable x 1 pc.; DHT22 temperature and humidity sensor x 1 piece; 10K ohm resistor x 1 pc; SD card module; Real time clock module DS1307 x 1 pc.; Development board MB-102 (Breadboard) x 1 pc.

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Software (Figure 13): FLProg (visual programming); IDE Arduino; DHT library (Github).

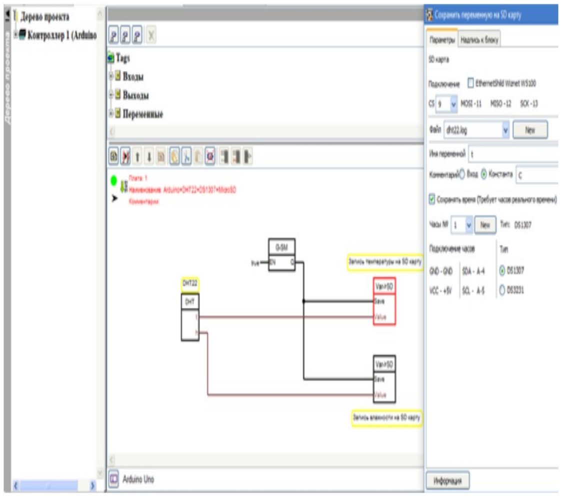

Figure 13: Wiring diagram and visual programming of the DHT22 sensor to the Arduino Uno board and recording data (temperature and humidity) on a micro SD with a DS1307 real-time clock module connected

Unmanned aerial vehicles are used in various fields related to environmental monitoring, for example, in obtaining meteorological information [15, 16]; measurement of greenhouse gases in the atmosphere, which primarily include carbon dioxide, methane and water vapor [17]; observation of clouds of polluting gases resulting from human activities [18].

Multi-rotors with temperature and humidity sensors installed on them can be integrated into the agricultural monitoring system. Similar work has already been carried out by French and Spanish scientists [19, 20] in relation to greenhouse agriculture (Figure 14).

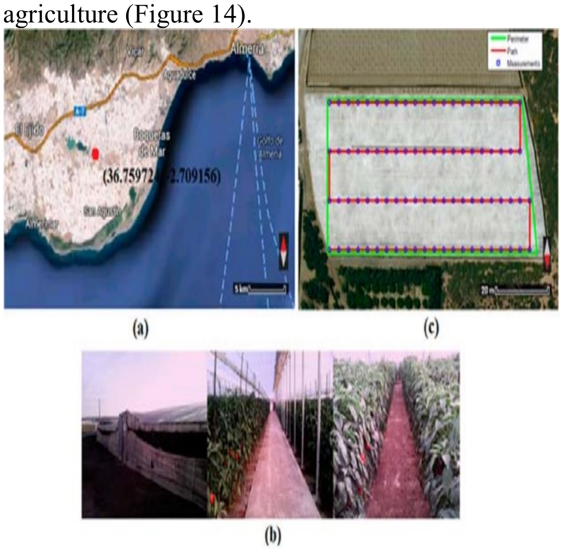

Figure 14: (a) The "sea of plastics" in Almería (Andalucía, Spain). (b) Inside and outside of the greenhouse; (c) Top view of the greenhouse. [19].

The location of sensors on multi-rotors is perhaps one of the most difficult decisions. The air currents produced by the rotors can greatly distort the measurements from the sensors. In [19], the aerodynamics of a multicopter was simulated in order to determine the optimal place for the installation of measuring equipment (Figure 15, 16).

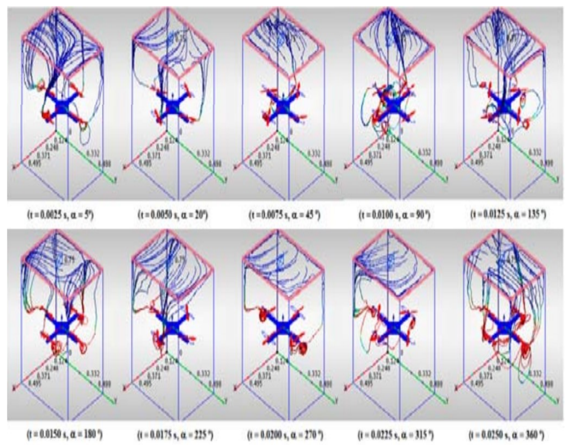

Figure 15: Air currents over the multicopter

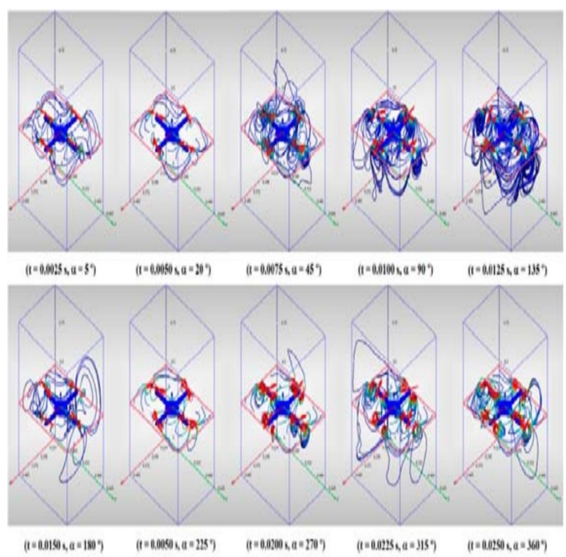

Figure 16: Air currents under the multicopter

As a result of modeling and testing the multicopter in the greenhouse, the optimal location of the sensors, the upper central part of the multicopter, was determined (Figure 17).

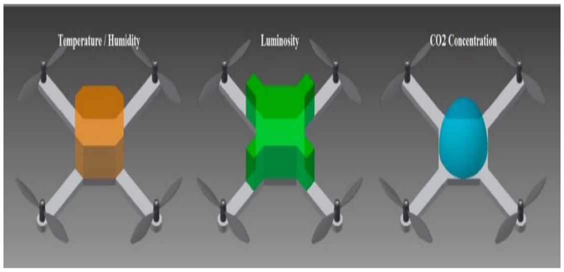

Figure 17: Optimal sensor placement

6. CONCLUSION

So, summing up, we can state the following: The progress of modern society cannot be imagined without the development of science and technology, without the introduction of technological innovations, in particular controllers and sensors with different functionality. The results of this study can be applied both to the design of multirotors in general and to the arrangement of sensors and actuators. The use of UAVs greatly simplifies the collection of necessary information about the state of crops. Unlike spacecraft, UAVs, in our case, multicopters, are more mobile, with more detailed data (the ability to obtain images with a resolution of up to one centimeter). Due to the fact that the flight altitude of a multicopter is usually within 1 to 200 meters above the ground, it is possible to use various sensors (temperature, humidity, etc.), which were previously used by agronomists (farmers) for ground weather stations. It is to such sensors, necessary in terms of monitoring farmland, that the temperature and humidity sensors of the DHTxx family can be attributed. The temperature and humidity sensors DHT11 and DTH22 include two measuring instruments useful for agriculture - a thermometer and a hygrometer. The progress of modern society cannot be imagined without the development of science and technology, without the introduction of technological innovations, in particular controllers and sensors with different functionality. The results of this study can be applied both to the design of multirotors in general and to the arrangement of sensors and actuators.

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