STEAM4ALL

2020-1-DE03-KA201-077538

IO2-A2: STEAM4ALL INTER-DISCIPLINARY EDUCATIONAL TOOL KIT: TEACHING AND LEARNING MATERIAL

Module: Drone Piloting

Co-funded by the European Union

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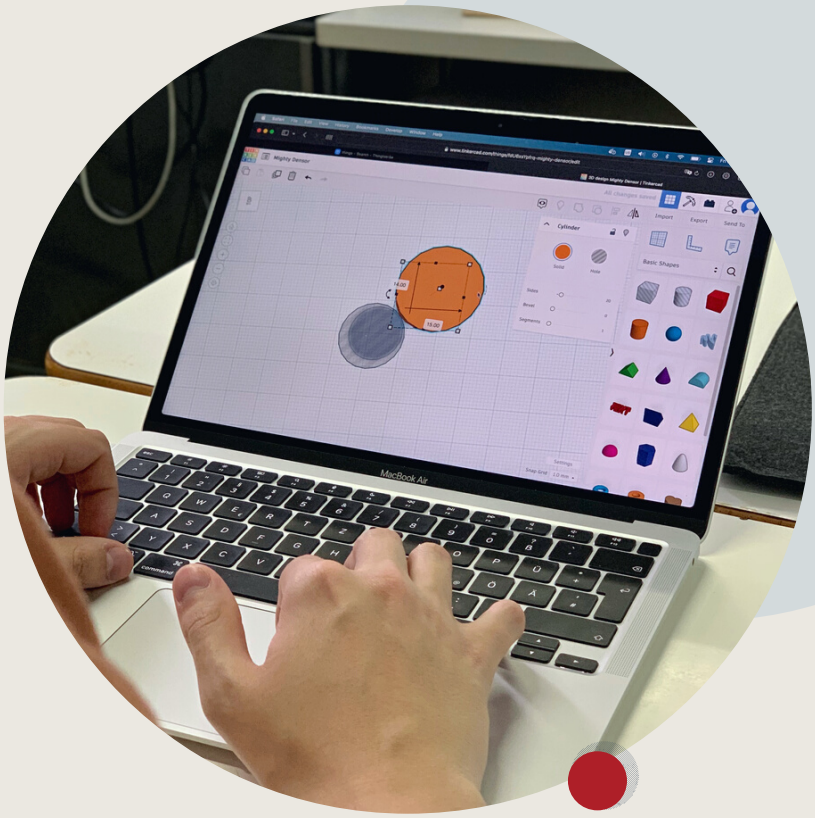

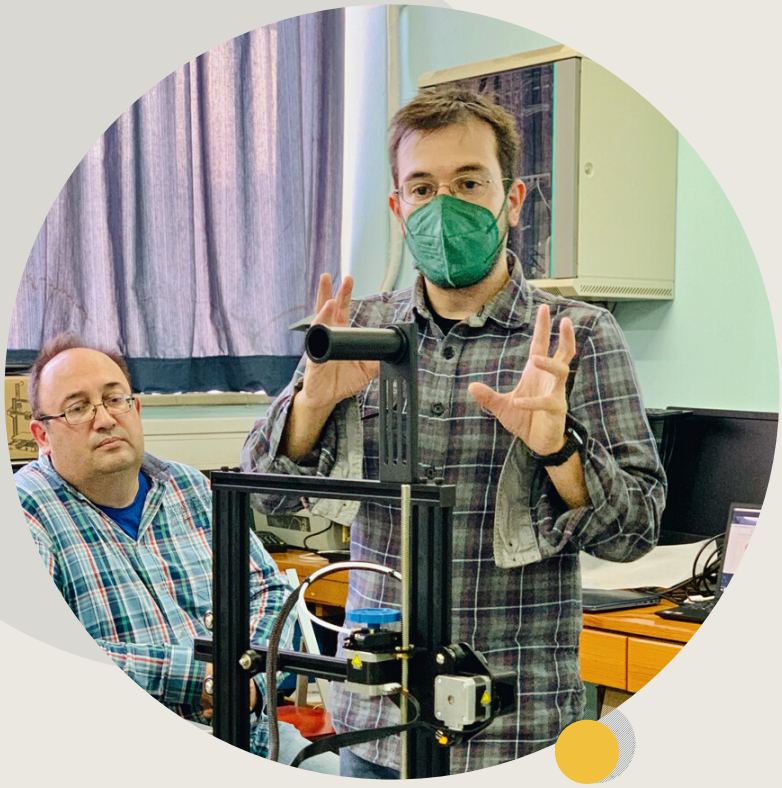

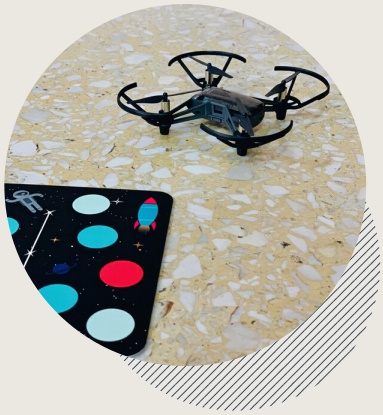

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STEAM4ALL: Supporting the Digital Inclusion of all Students Through an Inter-Disciplinary Programme for a Sustainable Future

IO2-A2: STEAM4ALL INTERDISCIPLINARY EDUCATIONAL TOOL KIT: TEACHING AND LEARNING MATERIAL

Module Name: Drone Piloting

Organisations: Dlearn, CGE Erfurt e.V., Emphasys Centre

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Topic 1 – Introduction to Drone Piloting

Description

A drone is an unmanned aerial vehicle capable of rising above the ground and moving through the air. This is the benefit of using a drone. The most important and most valuable thing about a drone is one or more cameras on board. Why the most important thing? Because it is the drone's vision, and without it, it is virtually useless.

What are the benefits of drones and why are they so popular?

Let's list the main scenarios for using drones in everyday life:

- Aerial photography (drones allow amateurs and professionals to get beautiful pictures and videos from a bird's-eye view);
- Search operations and research (search for missing people, things, objects in difficult areas);
- Security and monitoring;
- Delivery of goods.

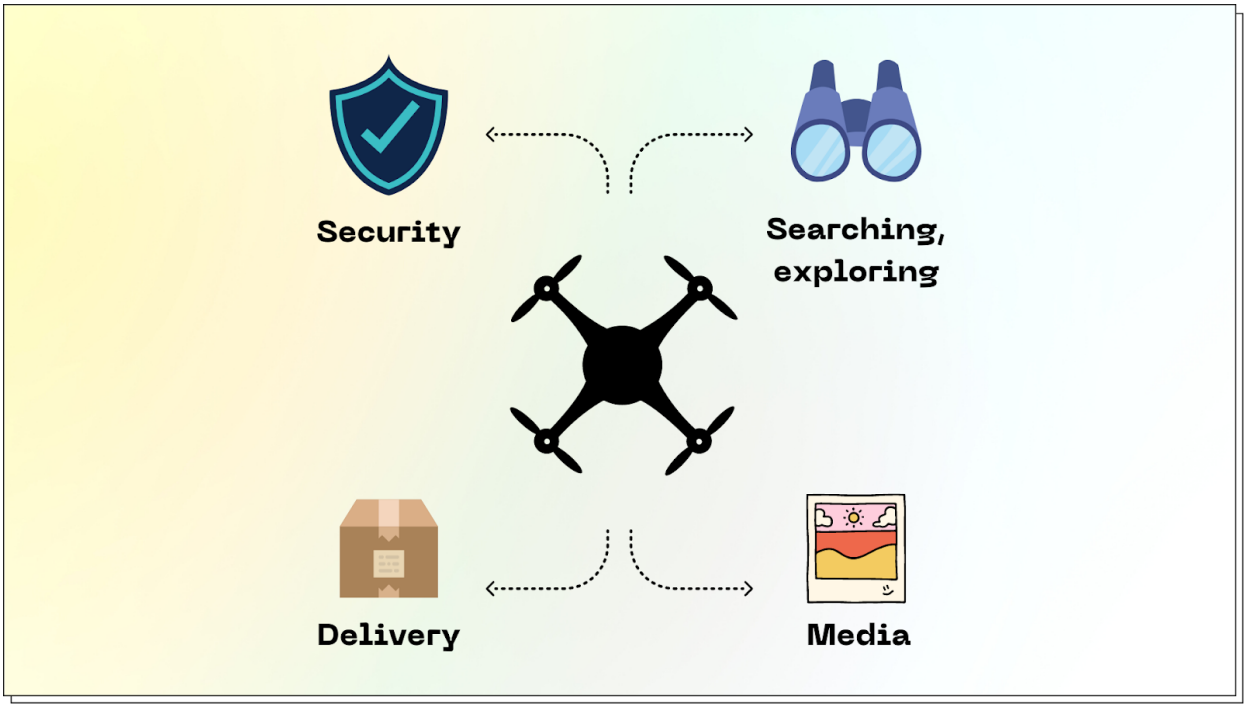

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Figure 1.1 – Drone operation capabilities

It is possible to implement such operations in several ways.

Ways of control

Three ways of controlling drones can be defined.

The first is manual control with a remote control. This remote control can be a joystick or a smartphone. In this case, the manipulation of the device is usually accompanied by monitoring the picture from the surveillance camera. The image is transmitted to the operator on the remote control, which in turn sends commands depending on what is seen.

The second way to control the drone is programming. This method allows to create an algorithm of control of the UAV, which will analyze the received information from CCTV cameras and automatically make decisions on the control of the drone.

The third method is hybrid, which combines automated control and manual control. The drone commands the program, and the observer can adjust some.

The components of drones

Main components:

- body;
- motors with paddles;
- battery;
- microcontroller;
- transmitter;
- video camera;
- sensors.

Drones are equipped with various sensors that help them navigate in space and maintain their integrity. These sensors include:

- proximity sensor;
- barometer;
- altitude hold sensor;
- lidar;

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- visual positioning sensor;
- gyrostabilizer;
- GPS.

Drone actions

The drone can perform several different basic actions that allow it to move in space along a given route.

State change actions:

- takeoff (launching the drone and raising it to a safe altitude);
- landing (lowering the drone to ground level and shutting down).

Move Actions:

- hover;
- changing the height (Z-axis);
- movement on different sides (X and Y axis);
- turning by a given angle α°;
- somersault.

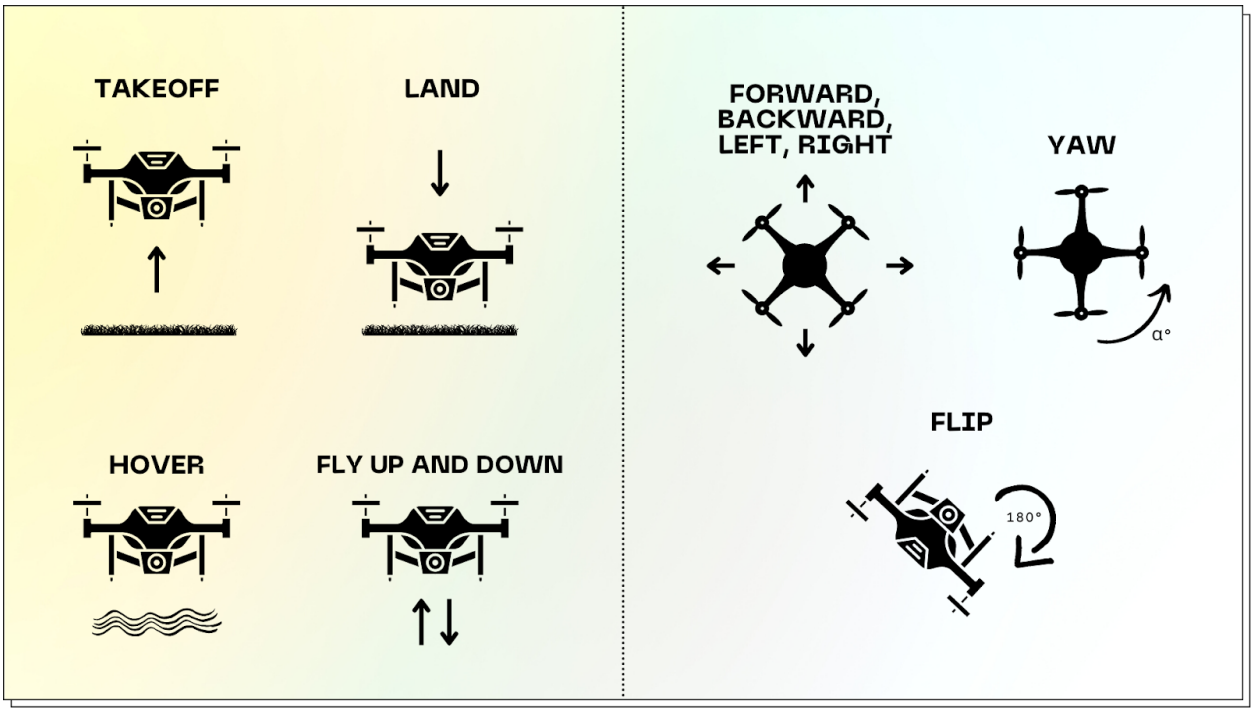

Figure 1.2 – Possible drone actions

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The actions shown are programmatically available. This means that you can write a program for the drone using this list of actions and extend its capabilities.

You can use the program to make the drone fly to a selected point with coordinates (X, Y, Z). To do this, you need to use simultaneous movement on three axes - altitude, longitude and latitude, i.e., to use 2 commands at one time.

To program the drone to fly on a curve, you need to use 3 commands at the same time: rotation, movement by altitude, longitude and latitude.

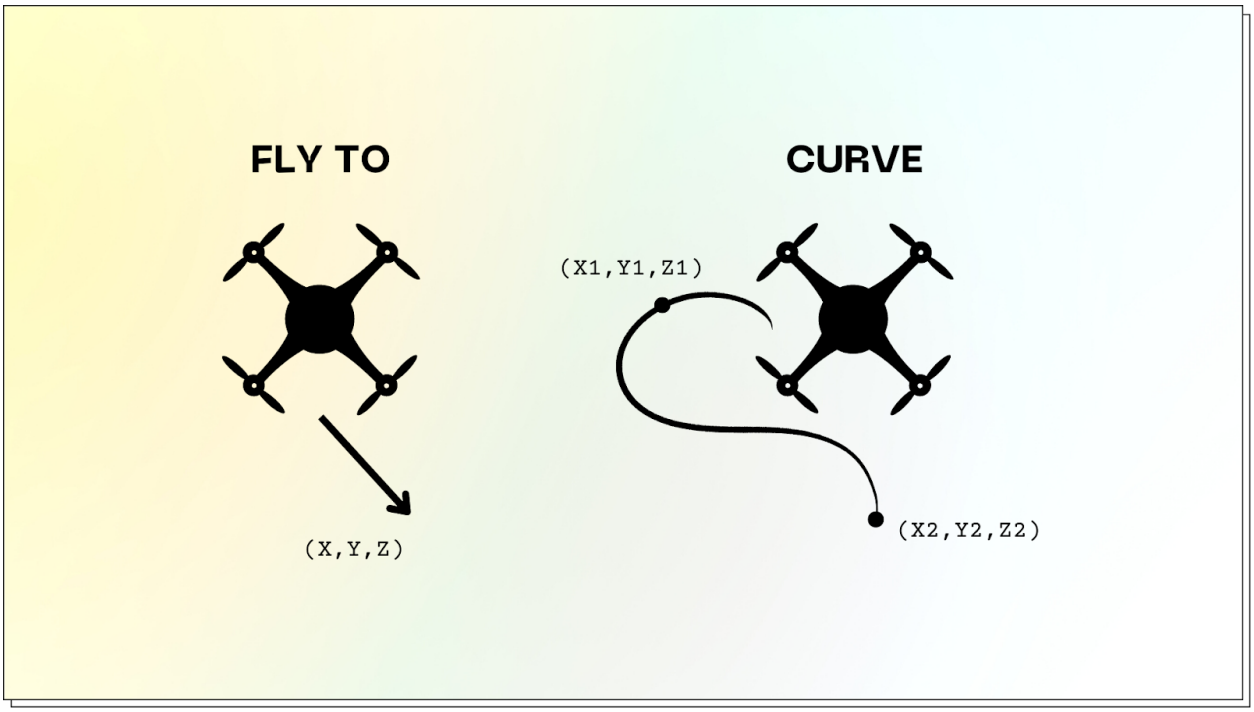

Figure 1.3 – Enhancing drone control capabilities

It is also possible to distinguish actions that are not related to movement:

- creating snapshots and video recordings;
- transmitting and receiving data from the control panel.

How does the drone execute commands?

Drones use propeller engines for propulsion and control. In Figure 1.4 they are marked with numbers 1, 2, 3, 4. The principle of drone flight is simple - the engines create rotation

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of the blades, which in turn blow air downwards, which creates a pressure difference between the propellers. This creates a lifting force, which pushes the drone upwards. And in order to set the direction of movement, it is necessary to adjust the speed of the engines.

It is important to clarify that the drone's engines must rotate in different directions. The first pair in one direction and the second pair in the opposite direction. This is shown in Figure 1.4. Motor blades 1 and 3 rotate clockwise and motors 2 and 4 rotate counterclockwise. Only with this arrangement of motors can the quadcopter be stabilized. Otherwise, when all motors rotate in one direction, the drone will rotate in the same direction and cannot be controlled.

We can divide the drone actions listed above into 2 types: vertical and horizontal. Vertical actions are hovering and moving up and down (Z-axis). Horizontal actions are turning and moving forward, backward, left and right (XY-axis).

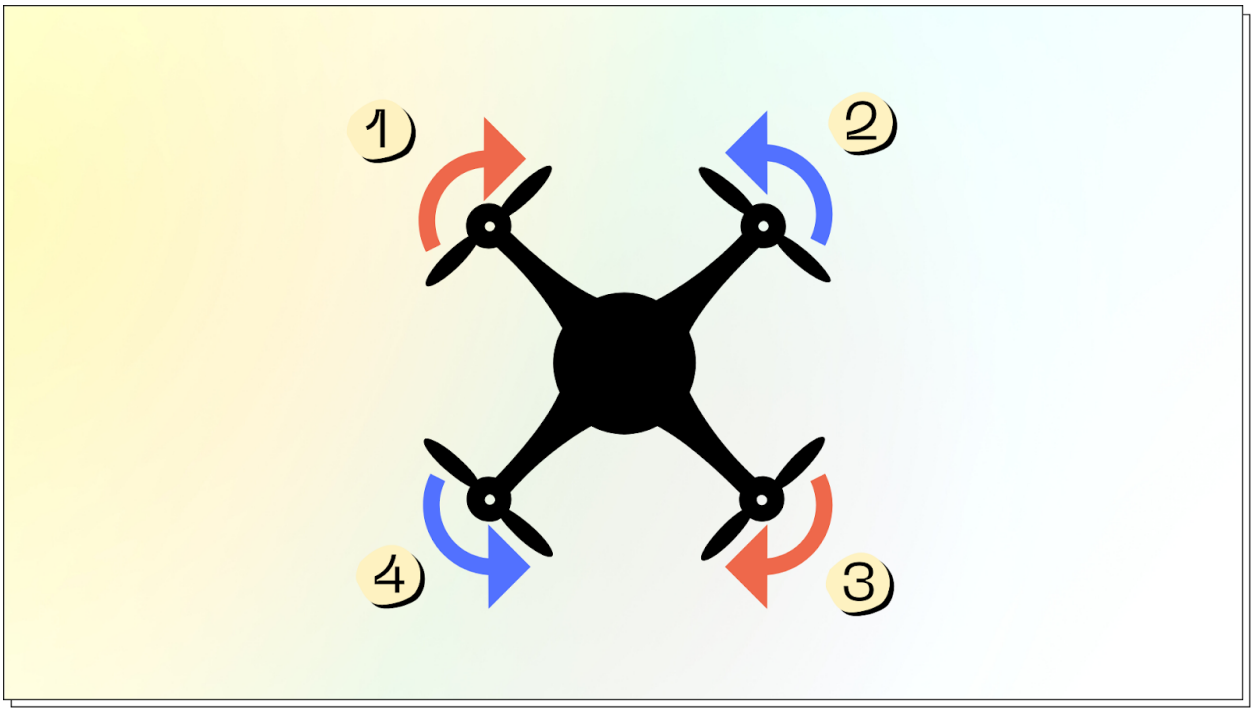

Figure 1.4 - Direction of rotation of the drone engines

Vertical movement

For vertical movements, the speed of all propellers must be the same, otherwise the drone will drift sideways.

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For a drone to hover over the surface means to stay at one specific point above the surface without moving. In order to a drone to hover, the combined thrust of all four motors that lift the drone must be equal to the force of gravity that pulls it down.

To move the drone up and down, you need to increase and decrease the rotational speed accordingly.

Horizontal movement

Horizontal movement requires different rotation speeds of the motors.

As already mentioned, the motors rotate in different directions to keep the quadcopter stable in the air. To turn or move the drone, you need to disrupt this stability.

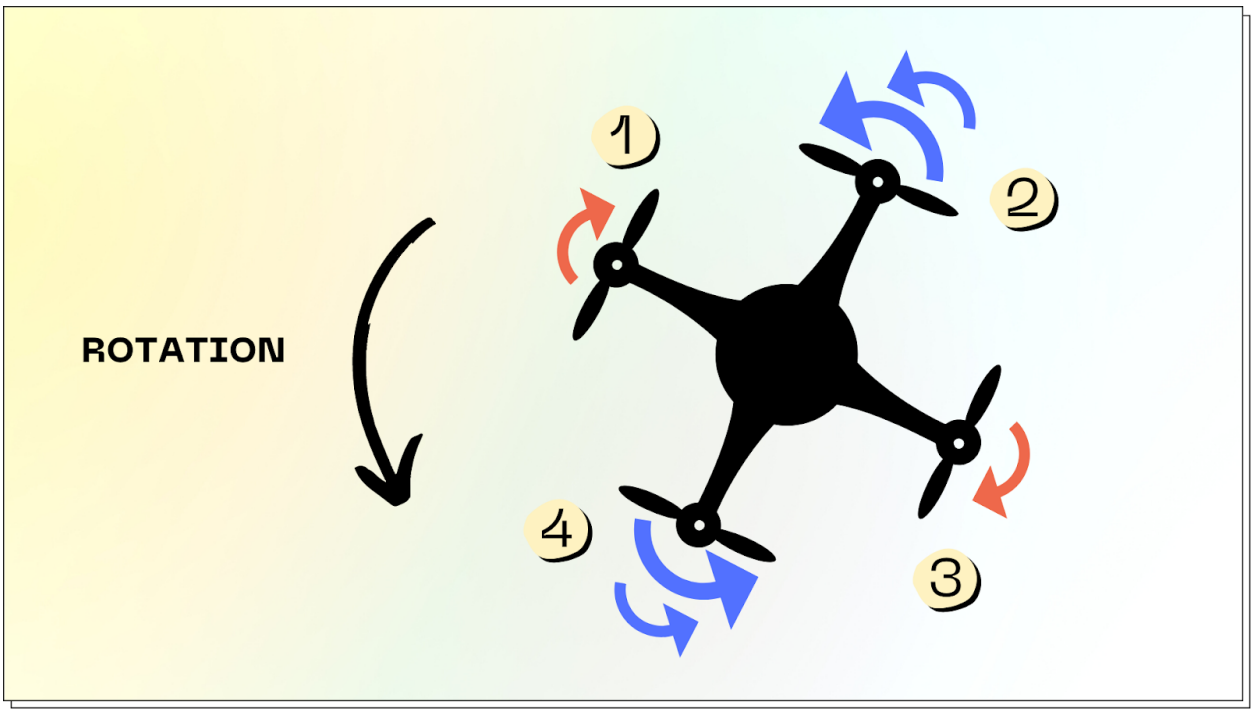

Figure 1.5 – Turning the Quadcopter

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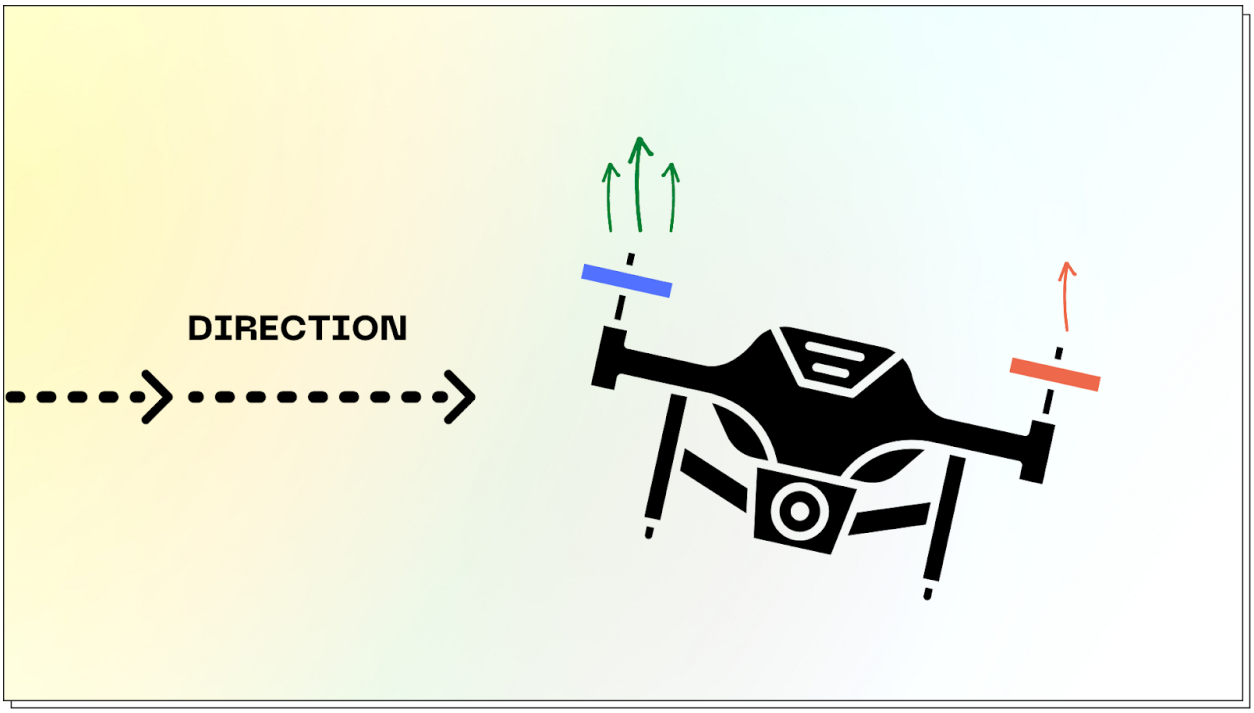

Figure 1.6 – Moving the quadcopter

To turn, one pair of motors on one side of the rotation must decrease the rotation speed, while the other pair must increase it at the same time to maintain altitude. In the example (Figure 1.5), to turn the copter drone counterclockwise, you need to decrease the thrust of motors 1, 3 and at the same time you need to increase the rotation for motors 2, 4.

Flying the drone sideways is the same process of redistributing the thrust of the engines. In this case, you need to increase the speed of the engines in the direction of travel and decrease the speed of the other two (Figure 1.6).

Topic 2 – Basic Drone Programming: Block-based coding

Introduction to drone programming

This module covers the programming of DJI TELLO drones. The quadcopters in this series allow you to load programs written in Scratch and Python onto them. Scratch is a visual-block event-driven programming environment for beginners. It does not require training in developing applications and setting up the environment for programming. In turn, creating programs in Python requires training in application development, installation and configuration of the relevant programs, in which you need to understand. Therefore, for

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the first steps in programming and getting acquainted with the work of programs a good start is to use block programming languages.

Block-based coding

Block coding is essentially a constructor in the world of application development in which the pieces are various functions and operators from programming languages. These pieces are represented as puzzles with different names and colours. To write a program is to assemble a constructor in which the pieces come together correctly. At the same time, there is flexibility and variability during the assembly of the code. This means that the programmer has a large field for experimentation and can create an application in different ways without following a certain pattern.

It is very easy to get acquainted with block programming. There are many resources that allow you to quickly immerse yourself in the environment of experimenting with basic application development.

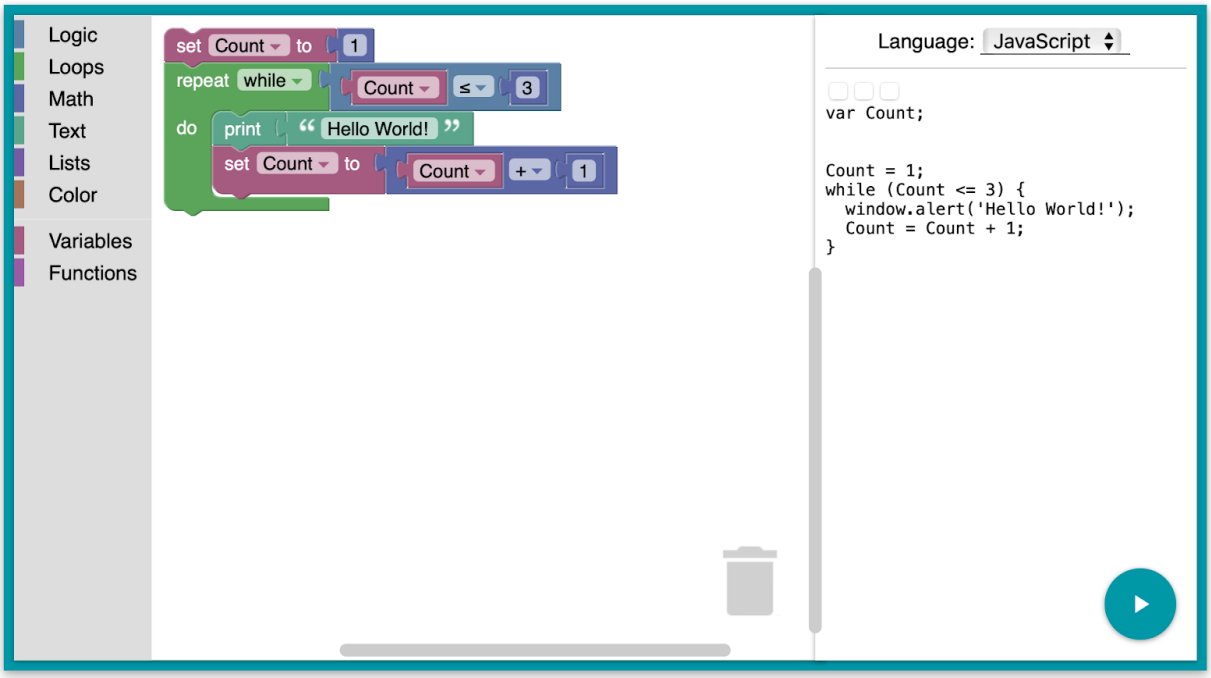

Figure 2.1 – Interface of the Blocky web service

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For PC users, the easiest way is to use web sites that provide a block coding interface. Examples of such services:

- Google Blockly — https://developers.google.com/blockly — a page that provides a library and a simple interface to block programming;
- Blockly Games — https://blockly.games — a website with game-like challenges that gradually immerses the user in algorithms and teaches new application development techniques;
- Scratch Online — https://scratch.mit.edu/projects/editor/?tutorial=getStarted — an advanced block programming application in which the control object is a character with different sensors and controls; the character and environment can be customized, which is more appealing to young students;
- Hour of Code Activities — https://code.org/hourofcode/overview — a platform with interactive games on various topics that challenge the player to learn new skills in programming.

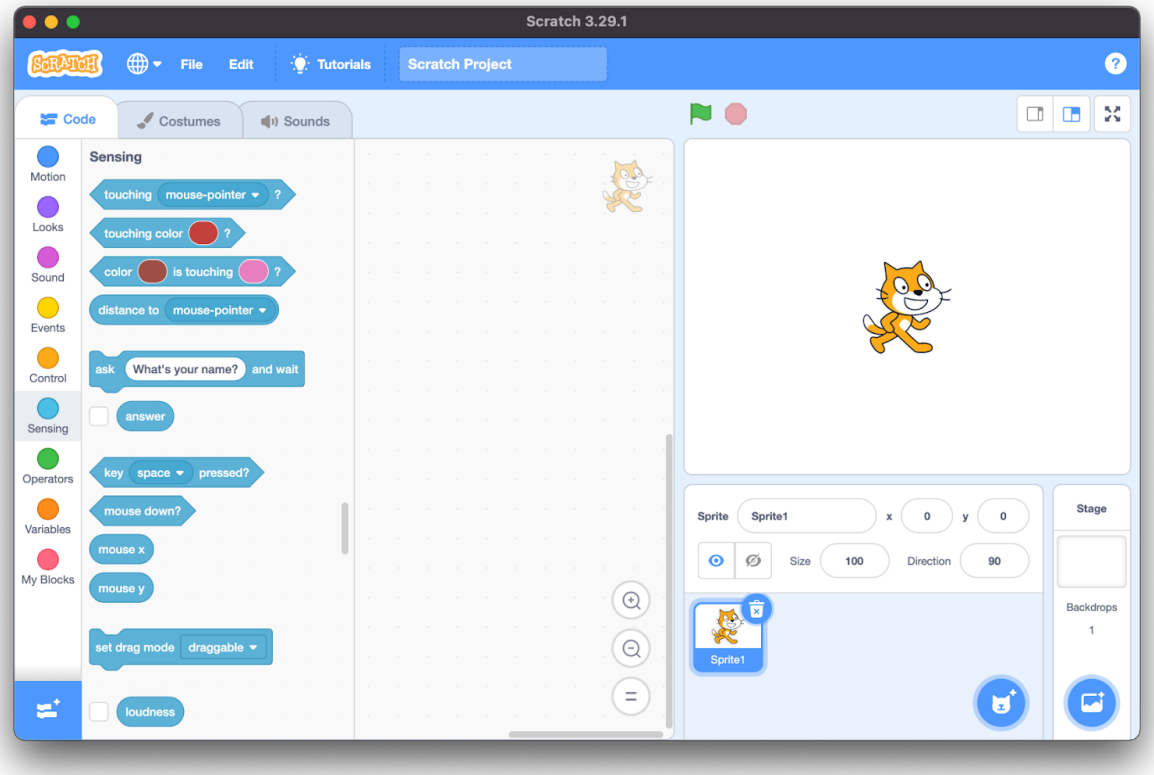

Figure 2.2 – Scratch 3 application window

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Applications to install:

- Scratch 3 — https://scratch.mit.edu/download (MacOS, Windows, Linux, Android, iOS) — block coding application, works the same way as the online version described above;
- Tello EDU — https://www.ryzerobotics.com/tello-edu/downloads (Android, iOS) — the original tutorial app for Tello drones, which contains several functions for learning. In it you can perform tasks in game mode, tasks are related to the movement of the drone on the map. The application can be used as a remote control for DJI Tello quadcopters. But most importantly, this application is a development environment using block programming.

Benefits as a teaching tool

Visual programming is a way to develop computer software without having to write code. Programs can be created and edited using only the mouse cursor or the touchscreen on a smart device, combining elements into one. This gives a big advantage over non-visual programming languages in the form of a low entry threshold for writing programs. This means that you need to spend a very small amount of time to start to understand how to create block code on your own.

By combining visual blocks together, you don't have to worry about spelling errors and misspellings of keywords like in written languages, because you almost don't have to enter anything from the keyboard.

When creating a visual program, there is no need to focus on the syntax of the language and it is impossible to make mistakes when creating a program because the code blocks are predefined. This allows the developer to concentrate on the logical part of his code without being distracted by possible mistakes.

Thus, because of the simple principle of program development, visual coding is a great way to demonstrate and present programming for beginners. Because it does not require keyboard input, it gives children the opportunity to immerse themselves in programming from a young age.

Use in real life

Visual programming is mostly used for training purposes. Simple language helps only to get acquainted with the construction of application logic and greatly limits the possibilities of written programming languages. That is why practically block coding is not used for

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professional purposes. However, it is quite a useful tool for application tasks. Such tasks may include writing scripts for various robots, often for quadcopters.

How to set up a development environment for block programming

Let's take a look at block coding in the Scratch development environment, which is aimed at gaining general skills in building program logic. And then we'll take a look at the Tello EDU application. It is less flexible, but it can be used to create scripts for Tello drones.

The Scratch development environment is quite popular and is available on different platforms in the form of applications on different platforms (Android, Windows, MacOS, ChromeOS). You can also use the online application in your browser.

The corresponding links are available on the official website: https://scratch.mit.edu/download.

On MacOS, the application is installed through the AppStore.

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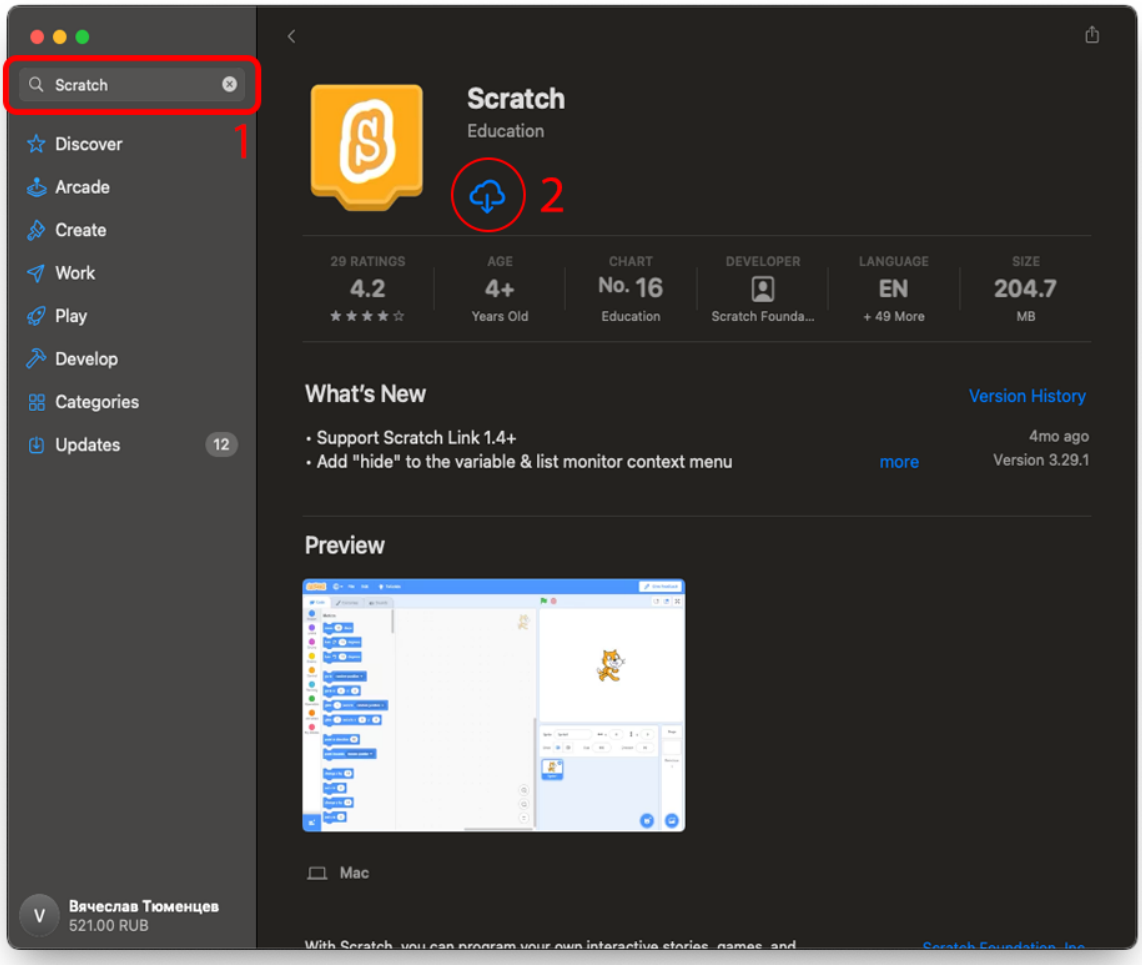

Figure 2.3 – AppStore window with the Scratch app

In the AppStore, search for Scratch to find the corresponding application and download it to your computer. After that, it will be ready to work.

Installing Scratch on other platforms through the app stores looks similar.

The first program written with block coding

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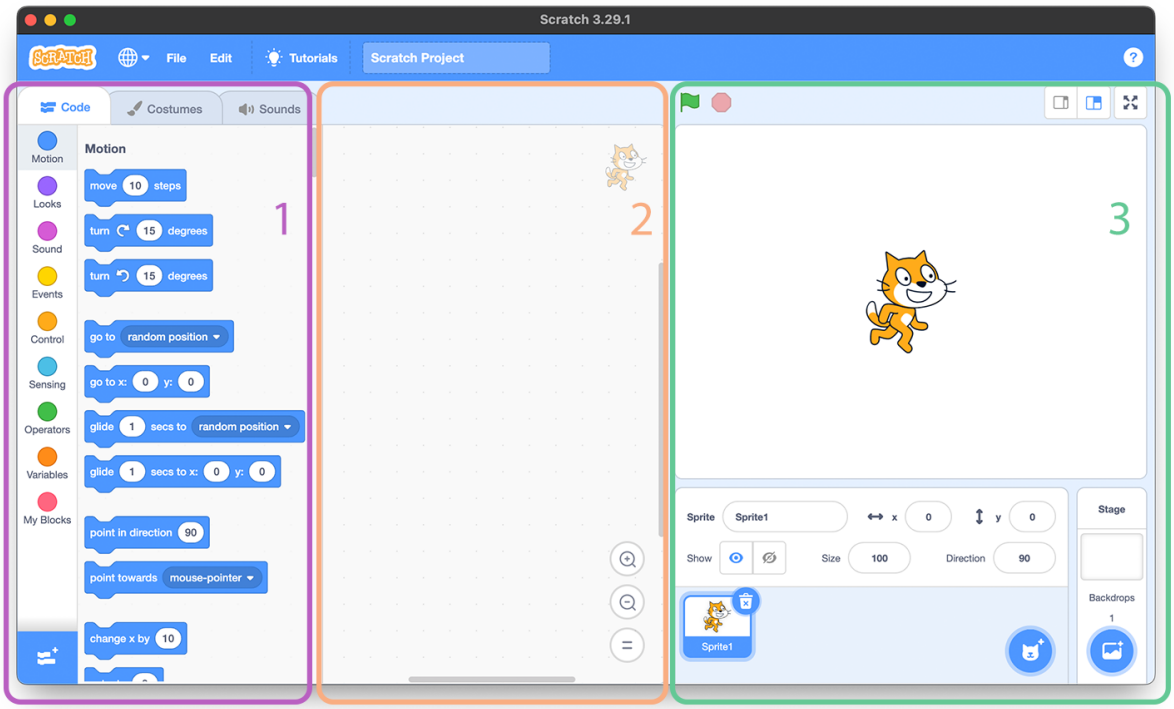

Figure 2.4 – Scratch program window

The Scratch application window is divided into three areas. The first one is the library of elements. The second area is the place to assemble the constructor from these elements. Each block must be taken and dragged from the first area to the second. The third zone, in turn, is the place where the result of the assembled code is displayed. The character does all the actions described in the second zone.

Let's write a simple program that moves the character to the right a few steps, sends him the phrase "Hello World!", turns him around and tells him to go back.

The program is started by pressing the green checkbox button. There is a block in the library that reacts to this event and runs the written program. It is signed "when ⚑ started" and is located in the Events tab. It should be placed at the very top. Placement is done by dragging items from the library into the code area.

You can attach other events below the button press event. They are connected like puzzles and can be placed in any order and quantity.

You can make a character move in a given direction in several ways. The easiest is the "move X steps" command. It moves the object by X steps in a certain direction. The

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direction is set in degrees and is 90 by default. This can be seen in the command execution area in the lower section. The field is called "Direction".

90 degrees corresponds to the direction to the right, -90 to the left, 0 and 180 up and down respectively. To change the direction the command "point in direction α" is used, where α is the direction angle.

And to output some text let's take the command "say A for X seconds".

From this you can assemble a simple program by assembling the elements as a whole.

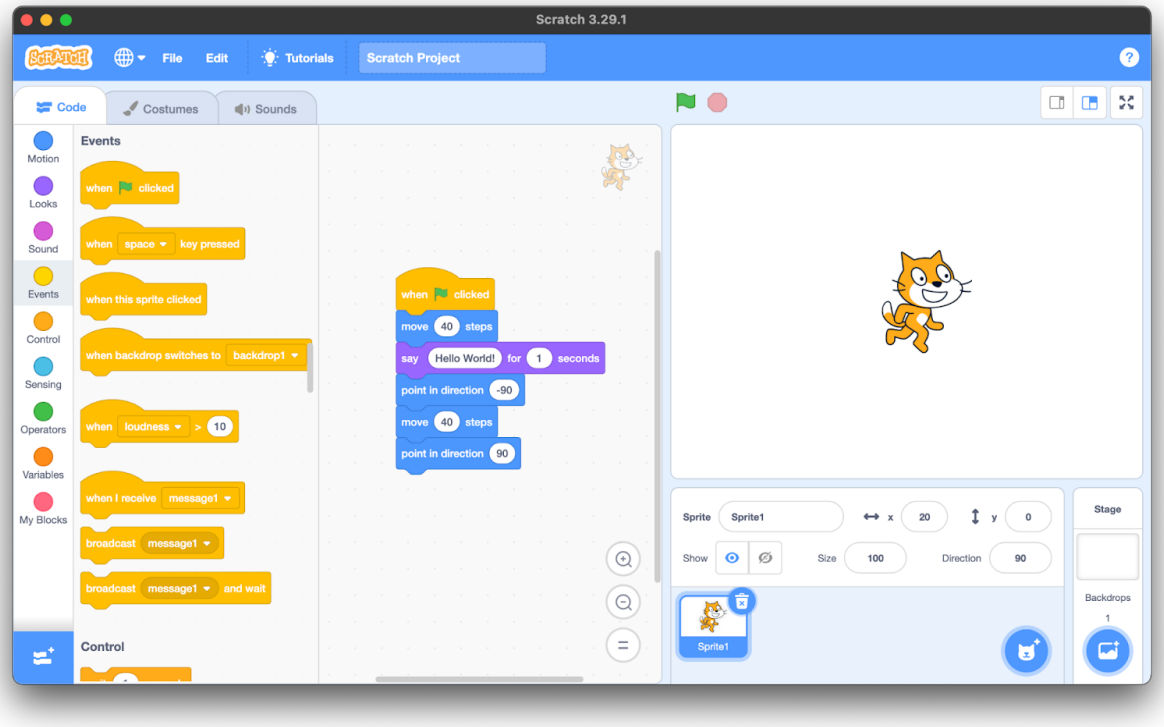

Figure 2.5 – The Hello World program in Scratch

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The first drone program

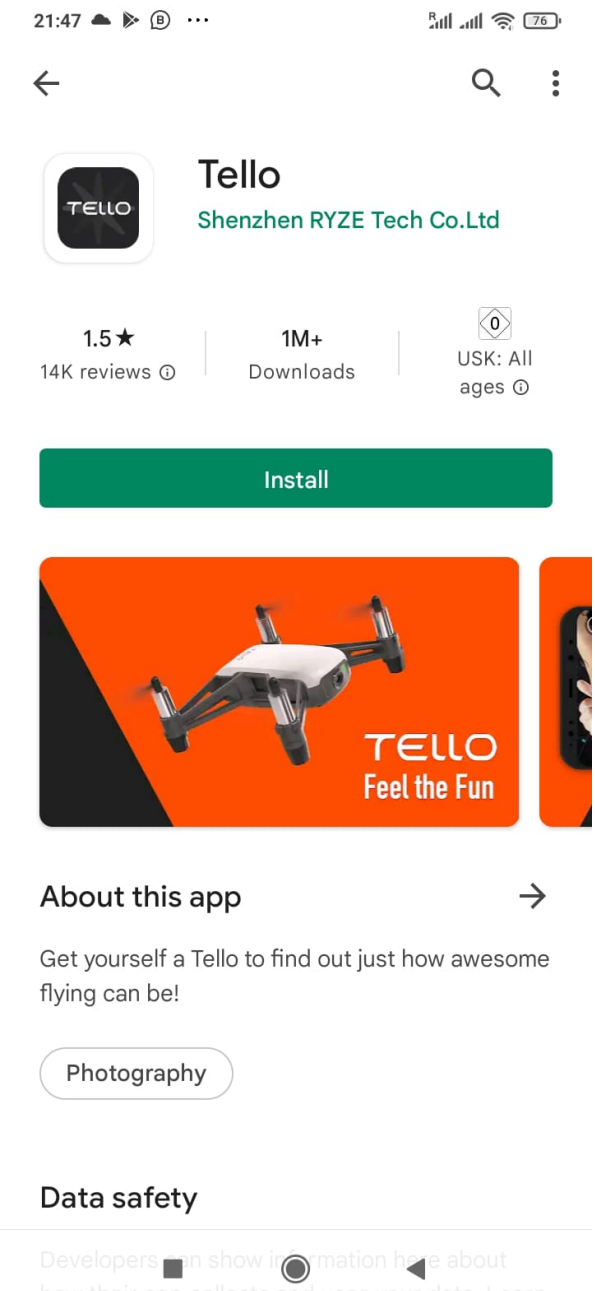

Figure 2.6 – The Tello app on Google Play

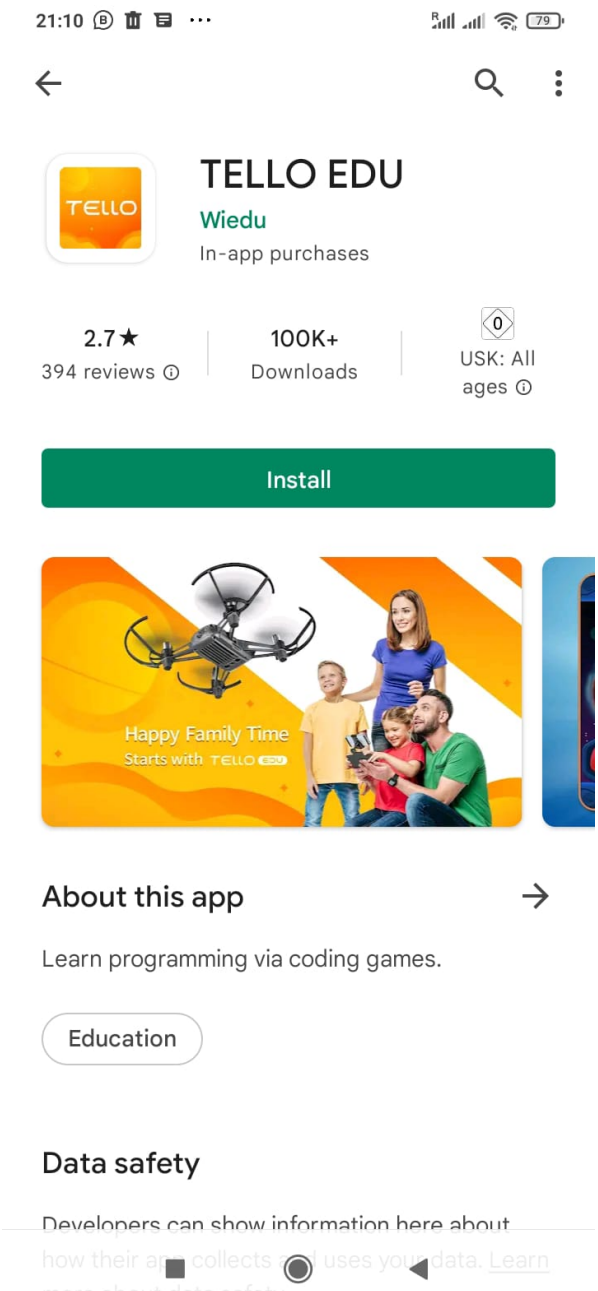

Figure 2.7 – The Tello EDU app on Google Play

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Preparing the development environment

Before you start controlling Tello drones, it is recommended that you check and update their firmware. This can be done through the official Tello app: https://www.dji.com/de/downloads/djiapp/tello.

During startup, the app will ask for access to the camera and geo position. These permissions are only needed to save images and videos to your smartphone's gallery, so they are not necessary for the app to work and can be disabled.

The app will then ask you to accept the agreement and then ask for new firmware for the drone. It will be downloaded to the mobile device first, and then it can be sent to the quadcopter.

Connecting a Tello drone to a smartphone

You now need a Tello drone with a charged battery to operate. Tello quadcopters connect to your smartphone via Wi-Fi. It is enough to press the only power button on it to turn it on. After that, the LED on the front should start flashing yellow, which is a signal that the Wi-Fi connection is ready.

Next, go to the Wi-Fi settings on the smartphone. A network named TELLO-****** will appear in the list of available networks. You can connect to it. By default, there should be no password. Therefore, the connection should be quick. At the same time, the LED should keep flashing.

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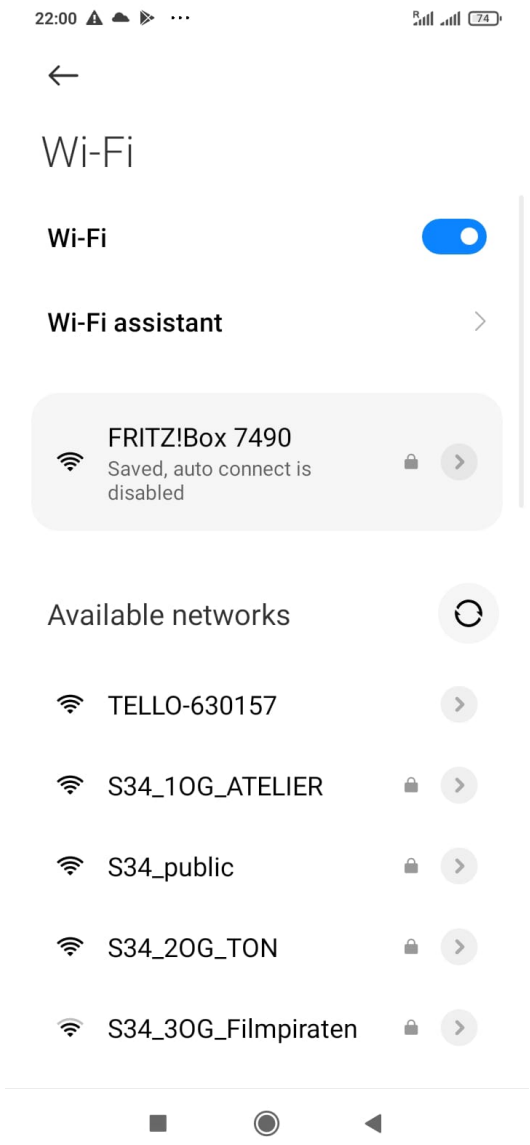

Figure 2.8 – Drone TELLO-630157 in the list of available networks to connect

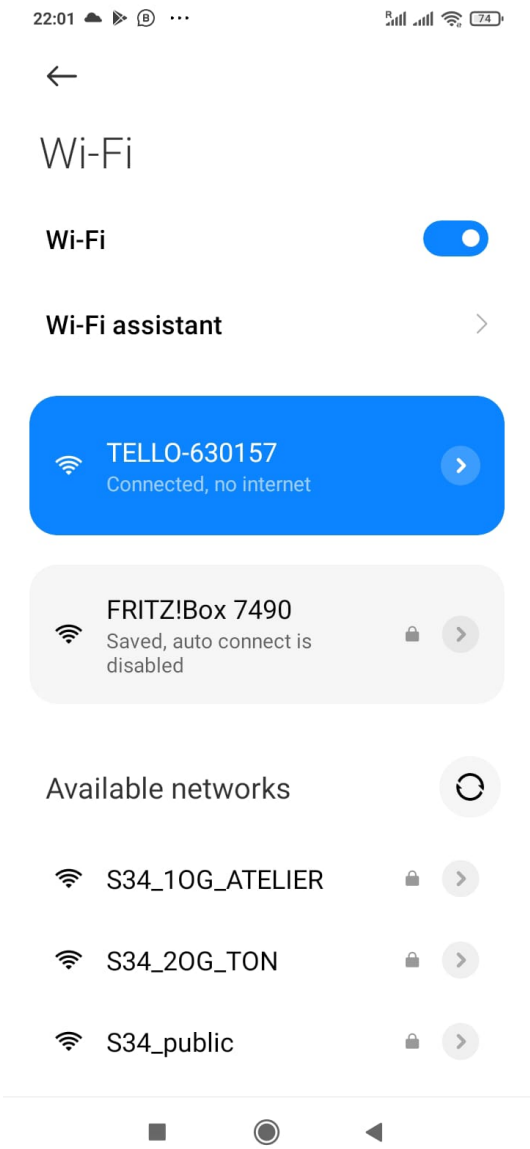

Figure 2.9 – Tello drone connected to Wi-Fi

When connected, the Tello app will allow you to control the drone with a video image in the background, which is streamed from the drone's camera.

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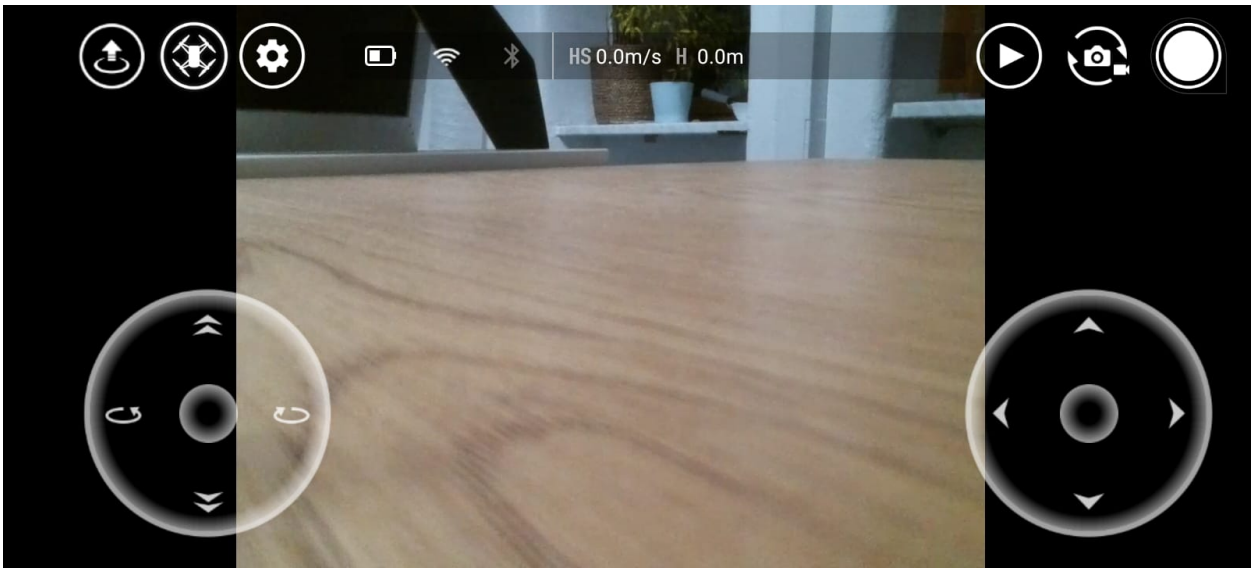

Figure 2.10 – Tello app interface

Now you should update the firmware. To do this, open the settings (the gear icon in the upper left corner). In the opened menu select "More", then in the line Firmware Version click on the button "Update". The battery charge must be more than half, otherwise the update will not be loaded.

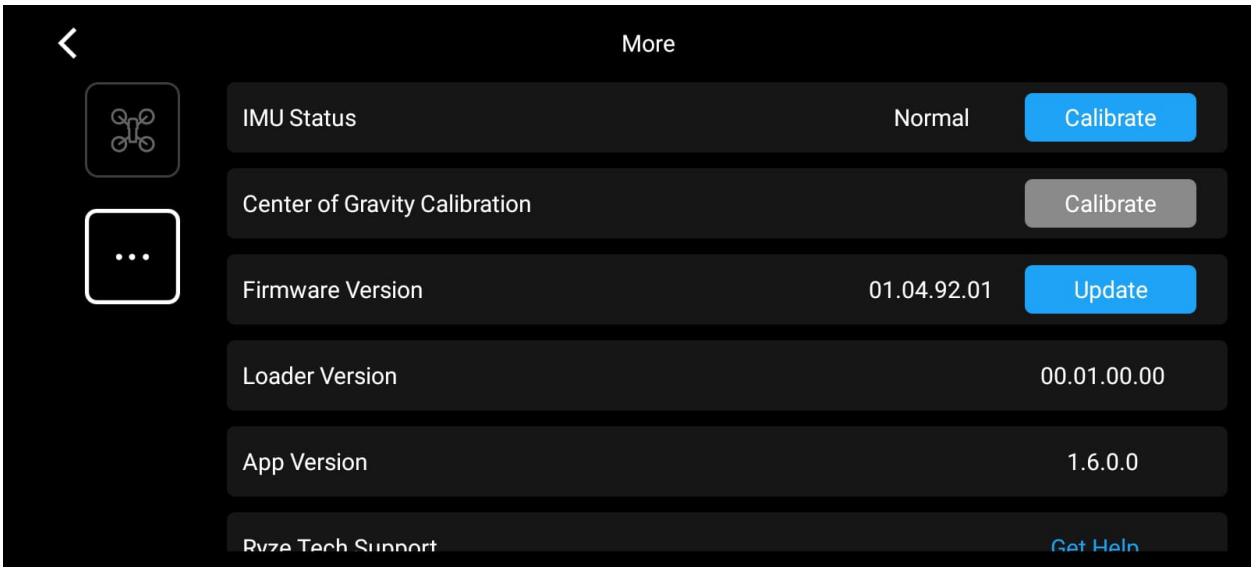

Figure 2.11 – Tello app settings interface

When the update is downloaded and installed, you can go to the Tello EDU app.

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Setting up the Tello EDU application

The universal drone app Tello EDU is only available on iOS and Android mobile devices. Links to the app stores can be found on the Tello website: https://www.ryzerobotics.com/de/tello/downloads.

The first time you run the app, it will ask for permission to use the camera and geo position. These items are not critical for the operation of the app, but they are not used against the user either. Camera permissions are needed to save pictures taken from drones to the device's gallery, so they can be enabled at will.

The first time you run the app, it will ask for permission to use the camera and geo position. These items are not critical for the operation of the app, but they are not used against the user either. Camera permissions are needed to save pictures taken from drones to the device's gallery, so they can be enabled at will.

Figure 2.12 – Tello EDU Home Screen

To create block code on the main screen, go to "Blocks" (the second icon at the bottom left).

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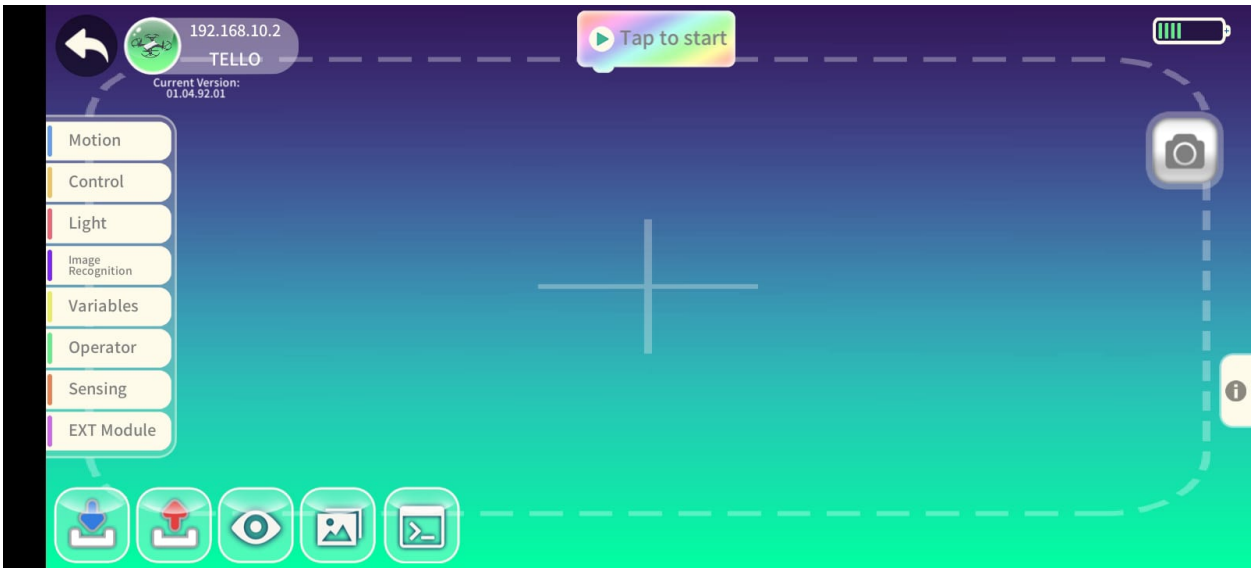

Figure 2.13 – Interface of the Blocks section of the Tello EDU application

Also, as in the Scratch application, the block library is available on the left side of the workspace, and in the center is the builder's gathering area. The block "Tap to Start" application start event is always attached at the top. All of the following commands to be executed by the drone must be connected to it.

As a simple code demonstration, the drone's takeoff and landing scenario is set. It is recommended to add an Exit command at the end, to automatically terminate the program after the commands are executed.

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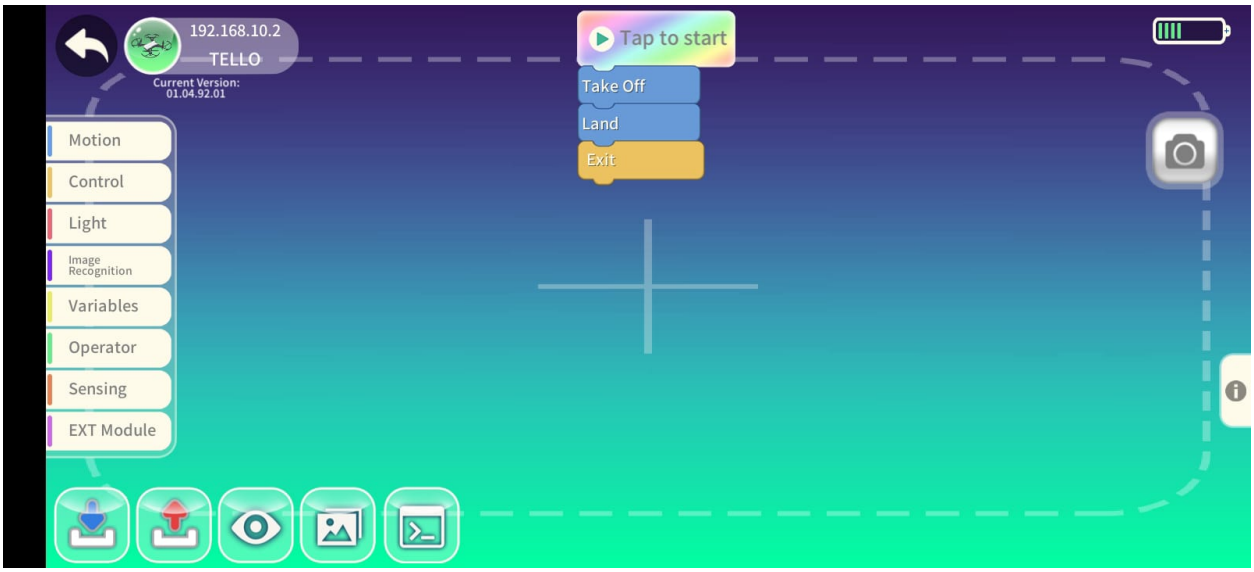

Figure 2.14 – Block coding in the Tello EDU application

The result of the code can be downloaded to the drone when it is connected via Wi-Fi to a smartphone, and you can also see the result of the program inside the application in the simulator. To go to the simulator, you should press the "eye" button on the bottom left.

Figure 2.15 – Simulation in the Tello EDU app

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Topic 3 – Visual Programming

The Tello EDU application allows you to program the drone to work with its camera for image recognition. In this mode, the drone's camera constantly captures an image and simultaneously analyzes the objects in it. Using this mechanism, you can teach the drone to perform certain actions at the moment it detects a given target.

In total, 2 tools are available in the Tello EDU program: target recognition by properties and QR code text recognition (Figure 3.1).

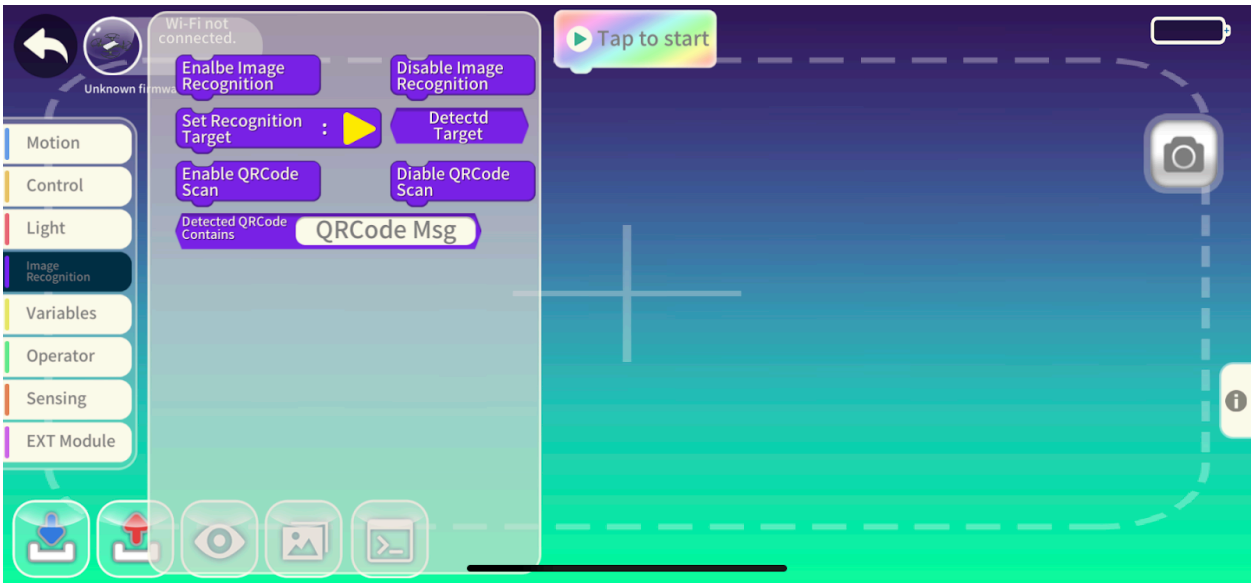

Figure 3.1 – Blocks for working with image recognition

In this section, the possibility of defining a goal will be considered.

Recognition is not enabled by default when the program starts. The “Enable Image Recognition” and “Disable Image Recognition” blocks, respectively, are responsible for its activation and deactivation. All other recognition-related blocks must only be placed after the “Enable Image Recognition” block and before “Disable Image Recognition”. Otherwise, the nested functionality will not work.

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A target can be recognized by just two properties: the shape of the object and its colour. The “Set Recognition Target” block is responsible for this. The setting is made after it is placed on the block programming field.

In the property selection menu (figure 3.2) the following shapes are available: triangle and square. Colours: red, green, blue, yellow.

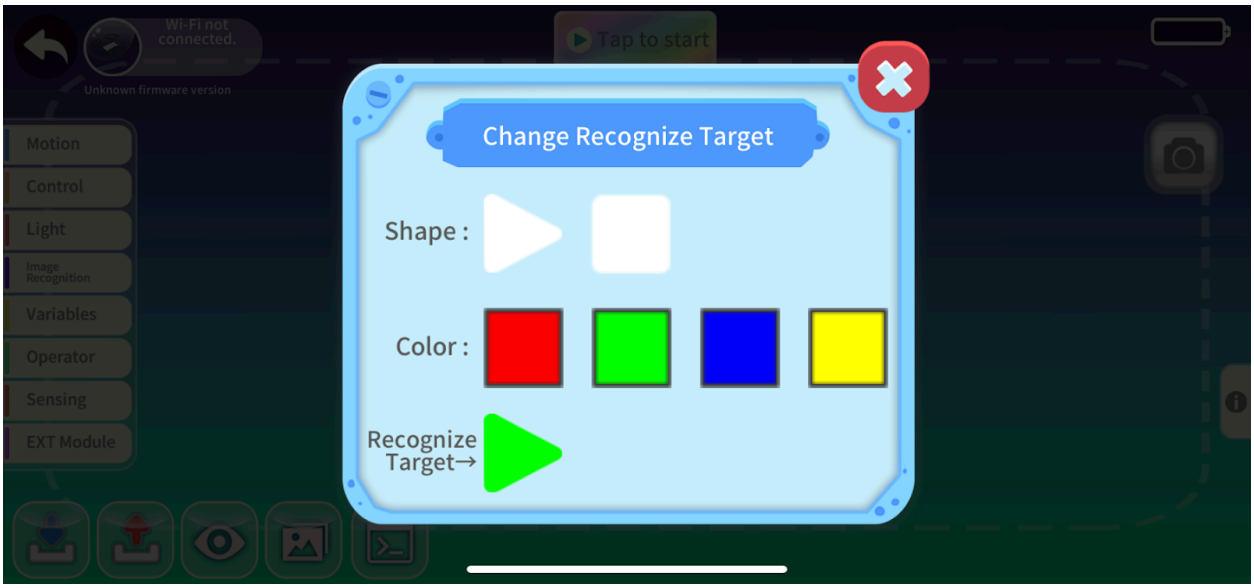

Figure 3.2 – Panel for selecting the properties of the object being defined

After configuring the “Set Recognition Target” block, the drone program will be configured to search for an object by the specified properties. To determine if an object was recognized by the specified properties through the drone's camera, you need to check the “Detected Target” block inside the blocks with the “IF” conditions checked.

Let's create a Scratch program in the Tello EDU application. Her tasks will include launching a drone and landing it if it detects a red square.

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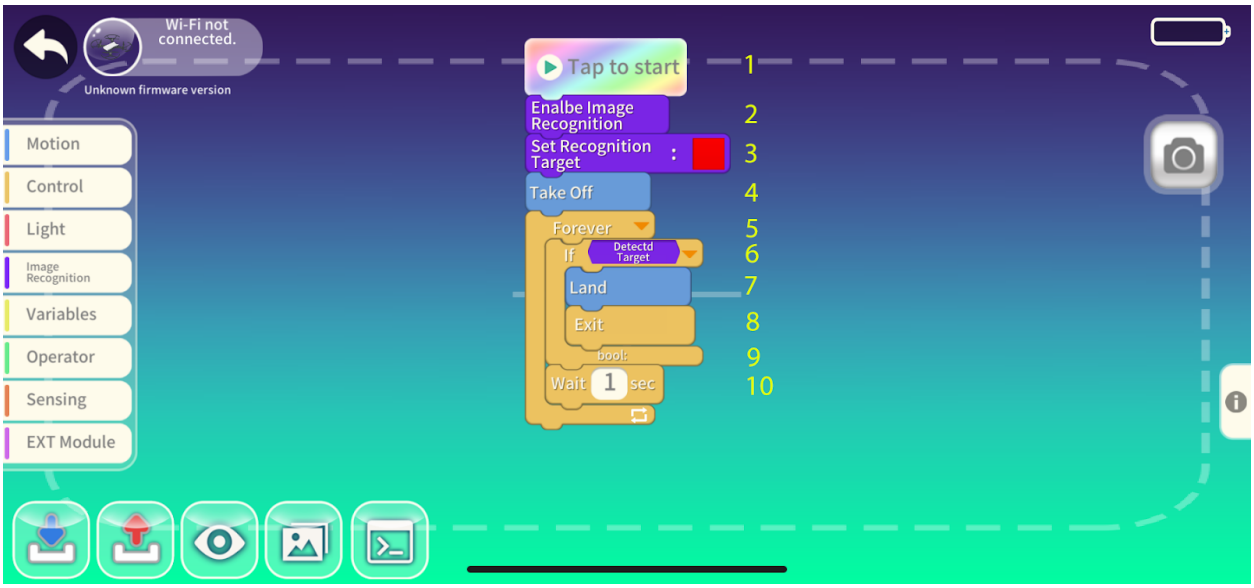

Figure 3.3 – An example of an object recognition program

Figure 3.3 shows a program that performs the task. For the convenience of explaining the code, each line with a block was marked with its serial number on the right.

So, it works according to the following algorithm:

1. Starting the program;
2. Activating recognition mode;
3. Setting the properties by which the object should be recognized;
4. Drone launch;
5. Setting the cycle for the permanent operation of the program, in the body of which the following blocks with numbers 6, 7, 8, 9 are placed;
6. Sets a condition that checks to see if the object you are looking for has been found. If this condition was met during one of the checks, the following blocks with numbers 7, 8 will work;
7. Drone landing (triggered if an object is found (line 6));
8. Exit from the program (works if the object is found (line 6));
9. Completion of the condition check;
10. 1 second timer (to reduce the frequency of checking and increase the efficiency of the drone).

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Quiz

1. Single Choice: What is unnecessary component of a drone?
    a. Propellers
    b. Battery
    c. Video Camera
    d. Body

2. True / False: All drone propellers can rotate in the same direction while remaining steerable
    a. True
    b. False

3. Single Choice: How drones gain altitude?
    a. By increasing the speed of rotation of all screws
    b. By increasing the speed of rotation of one of the screws
    c. By increasing the speed of rotation of the pair of the screws
    d. All options above are possible

4. Single Choice: How Tello EDU drone can be connected to control devices for transferring programs?
    a. By Wi-Fi
    b. By Bluetooth
    c. By Tello Network
    d. All options above are possible

5. Single Choice: How to determine if a drone is ready to connect to a device
    a. The LED on the front of the drone should be turned off
    b. The LED on the front of the drone should be glowing yellow
    c. The LED on the front of the drone should flashing yellow
    d. The LED on the front of the drone should flashing green

6. True / False: Block based coding can be used for professional purposes
    a. True
    b. False

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7. True / False: There is no necessary to think about the syntax in block-based programs
    a. True
    b. False

8. True / False: It's crucial for TELLO EDU Application to use geolocation
    a. True
    b. False

9. Multiple Choice: What motion commands are available for TELLO EDU Drones?
    a. Take off
    b. Curve
    c. Hover
    d. Back Flip
    e. Jump
    f. Wait

10. Single Choice: How to upload a program in TELLO EDU Application to a drone?
    a. By hitting the button "Export the program"
    b. By hitting the button "Upload the program"
    c. By hitting the button "Tap to Start"
    d. By using the command /upload in the console of the app

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Topic 4 - Drone Coding with Python

The material provided bellow includes a walkthrough for the installation of Python 3 and an IDE (Integrated Development Environment) called PyCharm. It covers the areas of basic Python Coding Principles with some example programs. The last part includes the installation of the necessary libraries for programming the DJI Tello Drone, how to connect the drone through the WIFI connection and finally how to program the drone with various example code, including the use of the on-board camera and the accompanied mission pads.

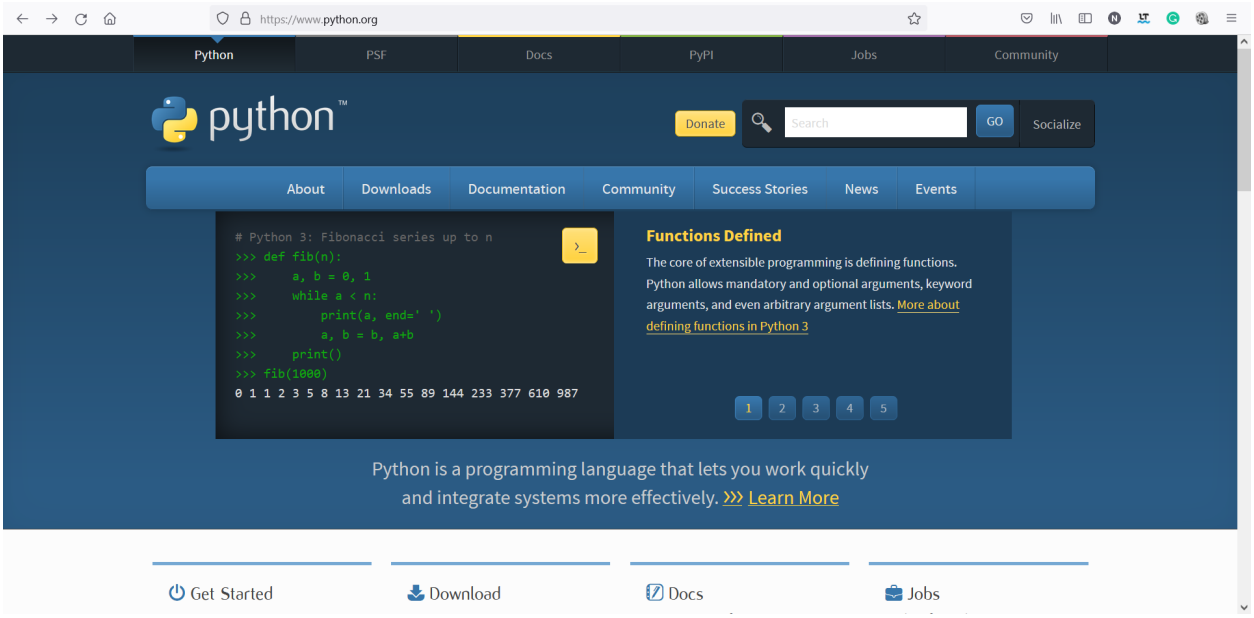
Installation of Python 3.7 and PyCharm IDE

Python installation

We are going to utilize the Python programming language to program this drone.

To do this, we will first install Python, and then install and utilize an IDE (Integrated Development Environment) to write our code.

So, first, we will go to www.python.org and go to the download area, where you can get the newest version or, we advise to download version 3.7.6, which is the most stable version that we have found to operate well with the Tello Drone.



Make sure to select the “Add Python 3.7 to PATH” option when installing python as shown in the image bellow.

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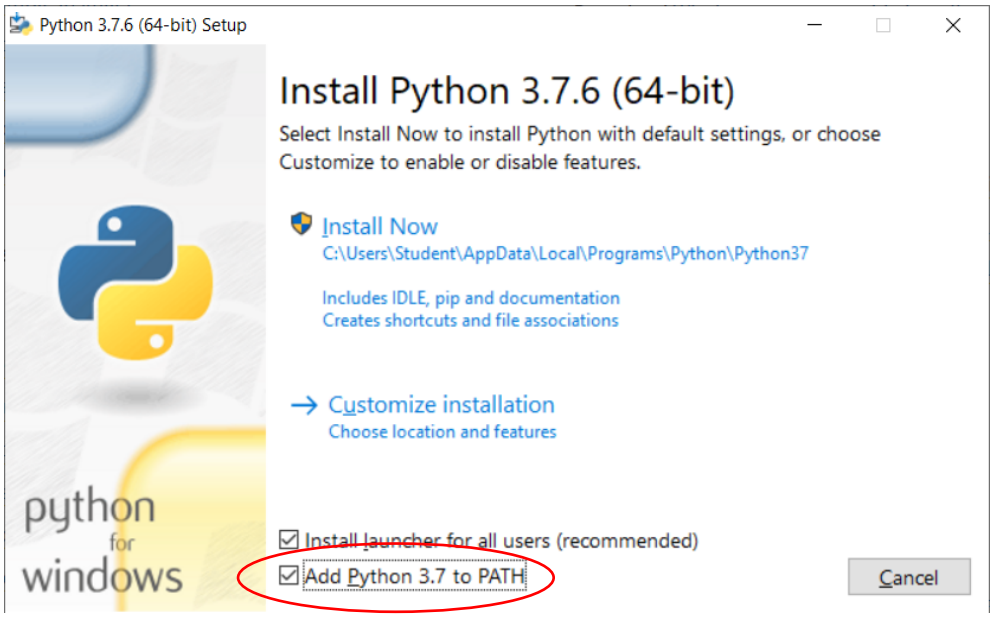

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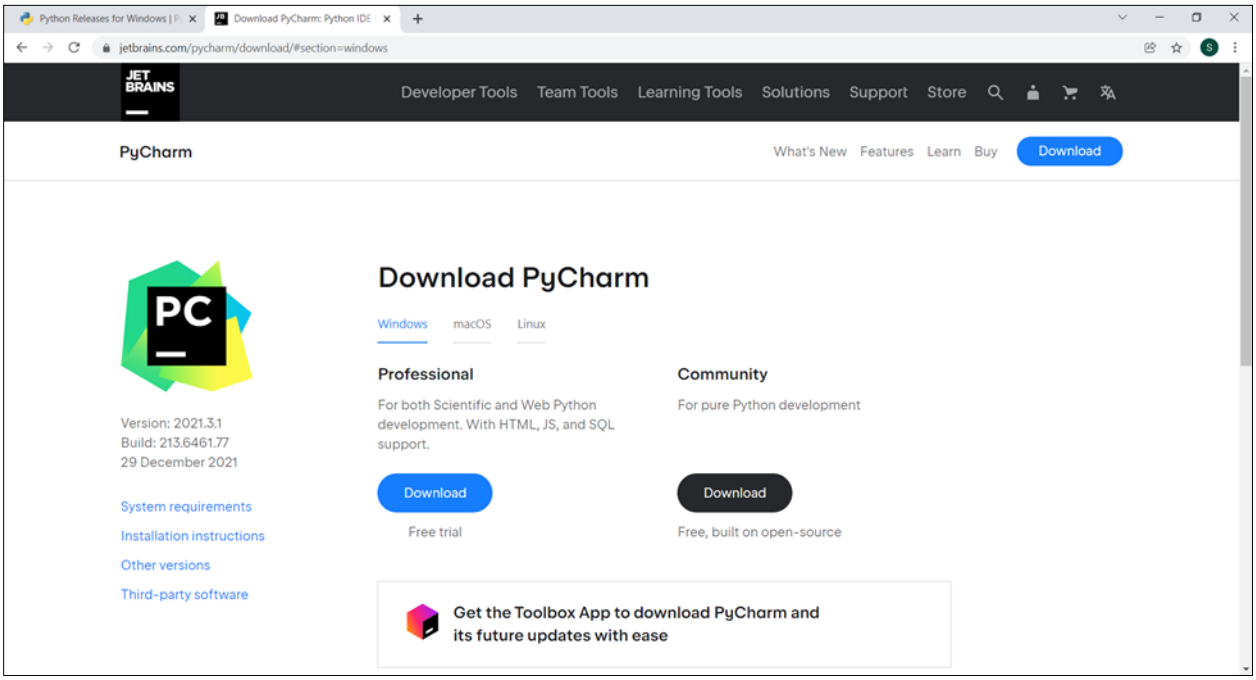
Installing an IDE:

If you want to understand what an IDE is a little better, think of it as a notepad application with more functionality. When you are writing code in an IDE, it will tell you where you are making mistakes, it will help you debug the code, and it has a lot more functionality overall than a regular notepad app. This is why we need the IDE, and PyCharm is one of the most well-known ides for Python, so that's what we'll be using for our drone coding projects.

We can install PyCharm by going to its page at: https://www.jetbrains.com/pycharm/ and going to the download section where you can download the community version which is free and open source.



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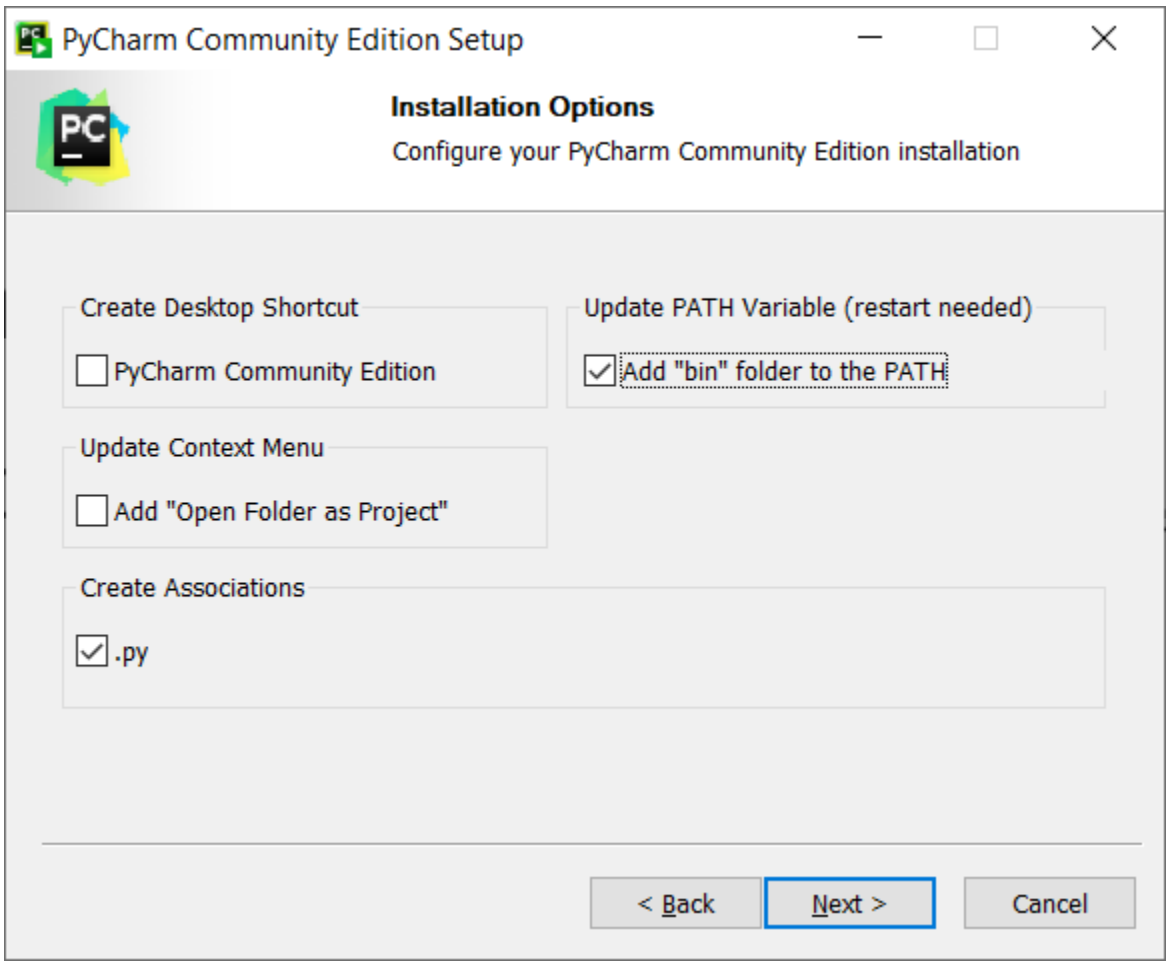
In the installation setup we will associate the *.py* files to PyCharm and we will also update the path variable by adding the "bin" directory to the path.



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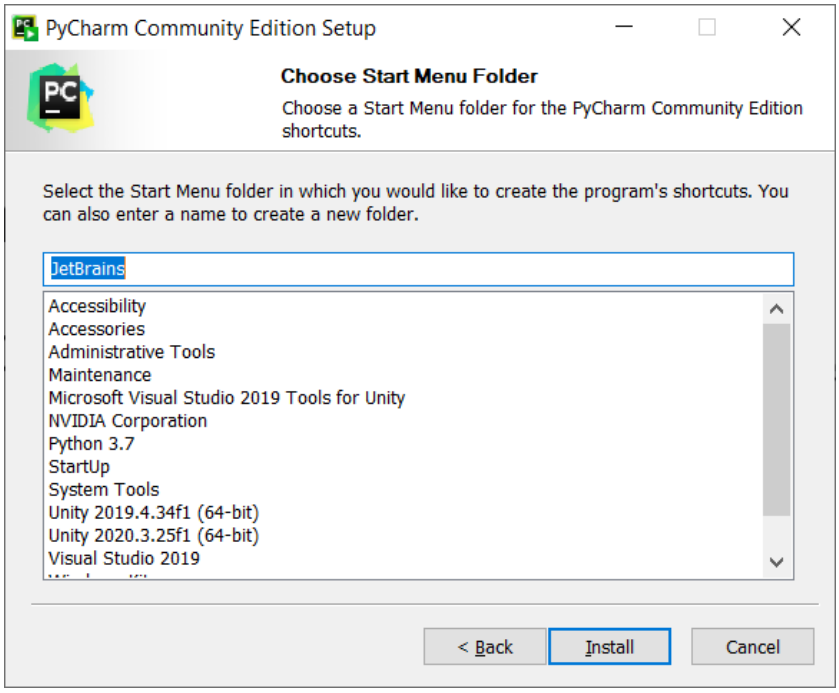
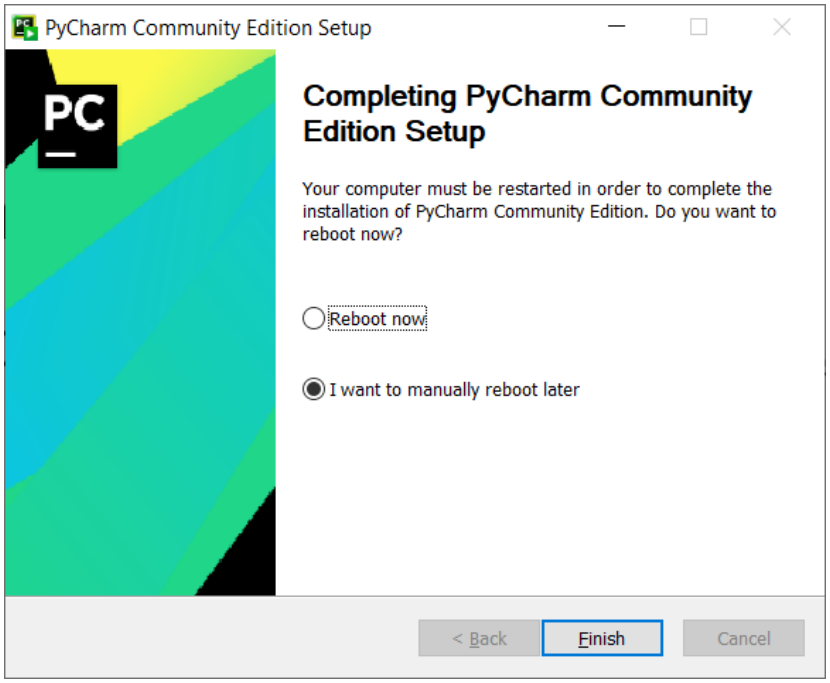
Then we will choose a Start Menu Folder for PyCharm



And lastly complete the installation by restarting our computer



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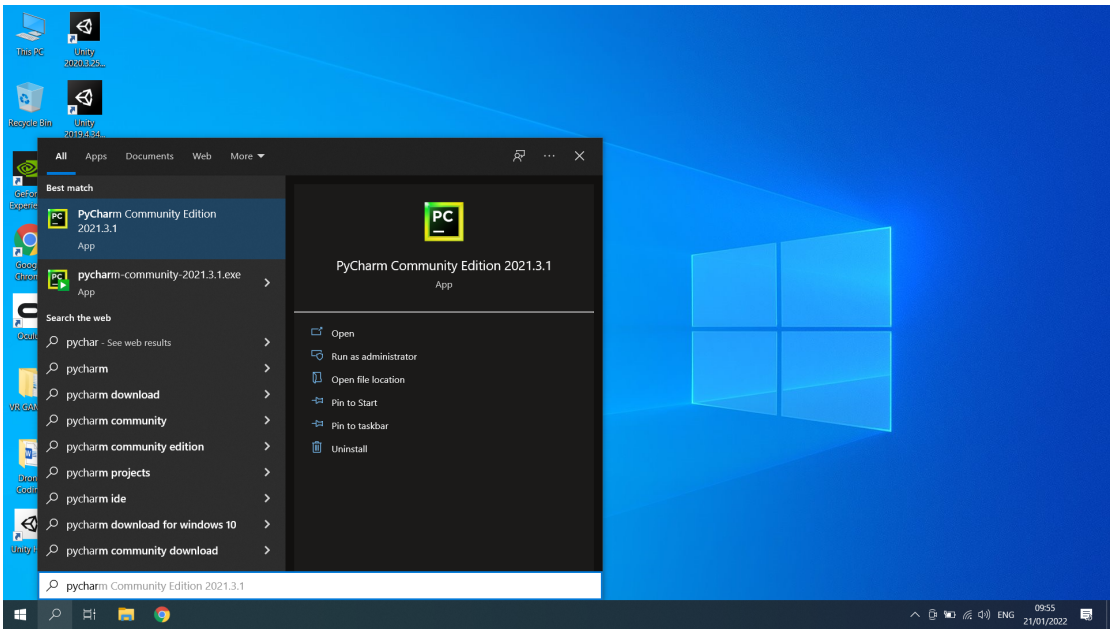
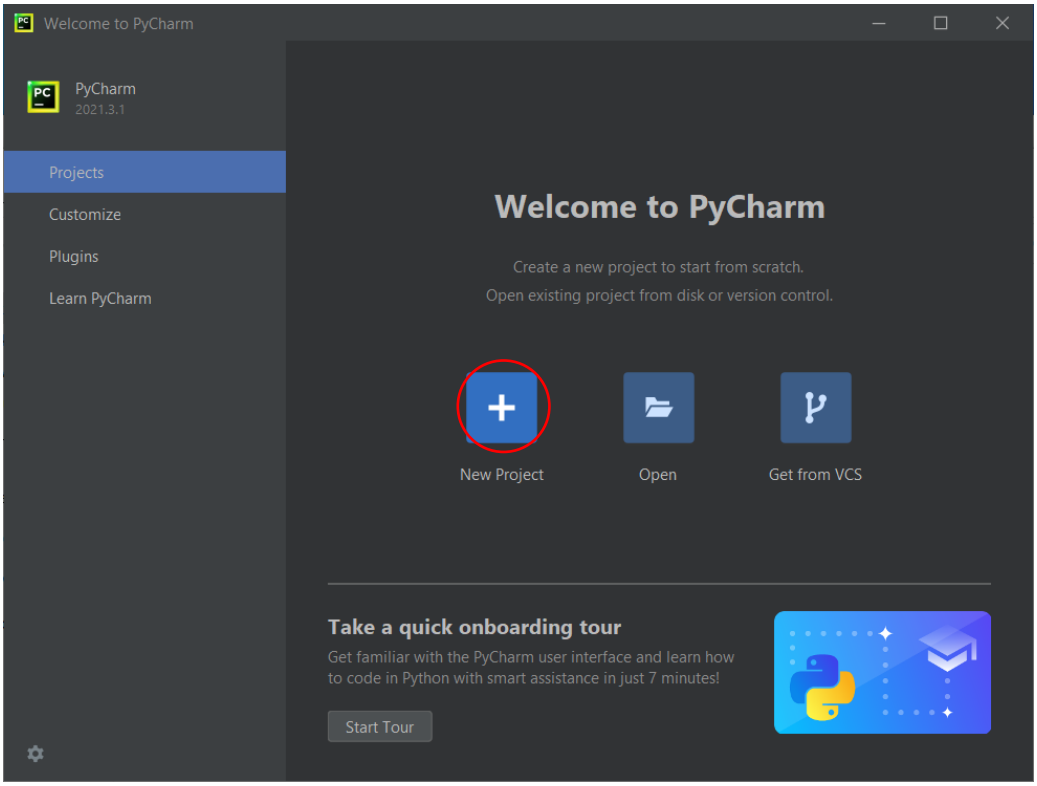
How to create a python Project in PyCharm:

Navigate from the search bar by typing PyCharm and launch the PyCharm App.



From there click on New Project



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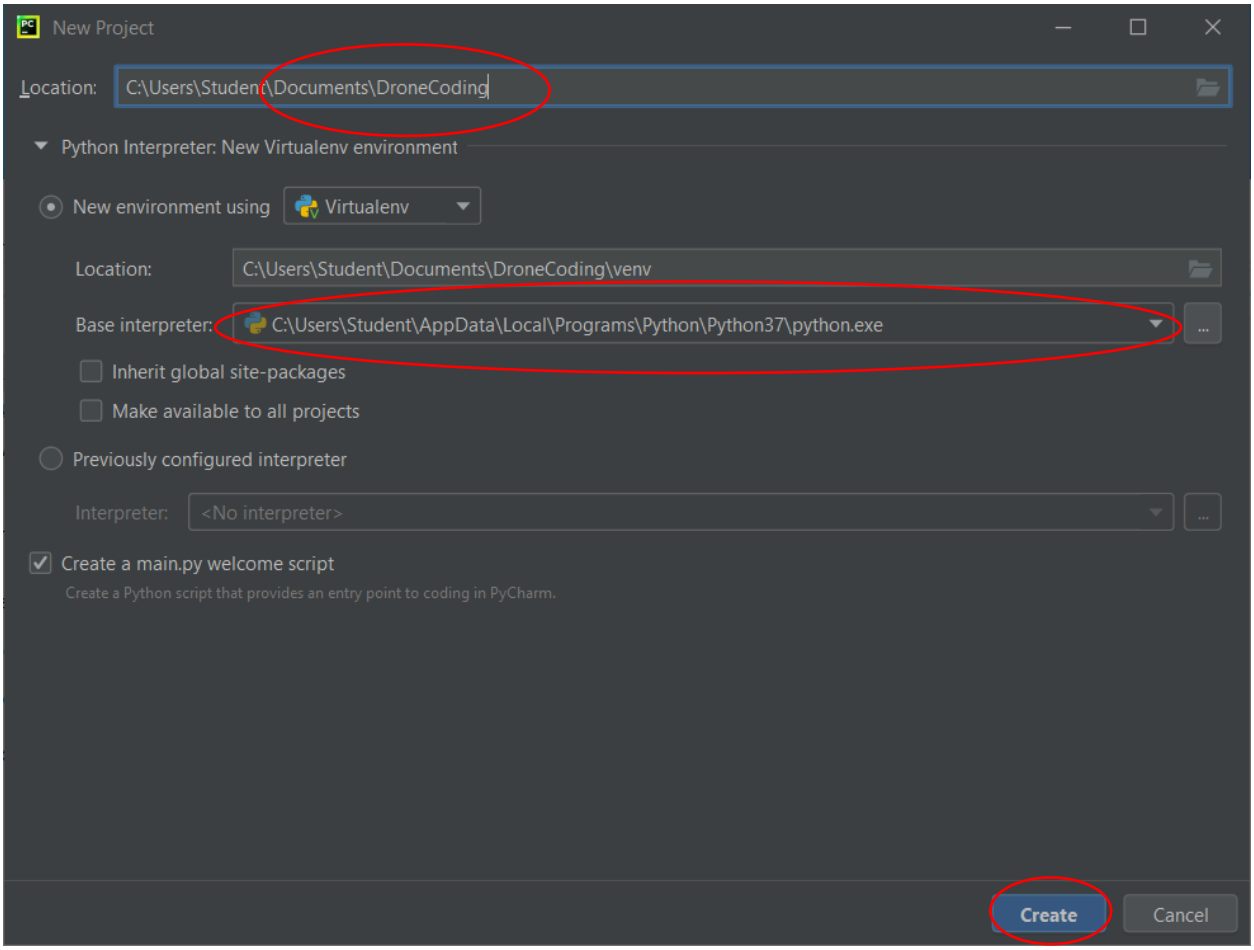
1. We will first need to check that the Base interpreter is detected and is the version 3.7 of Python.
2. Then we can give a name to our folder which will save our Python Scripts. Let's call it *DroneCoding*.
3. Click *Create*.



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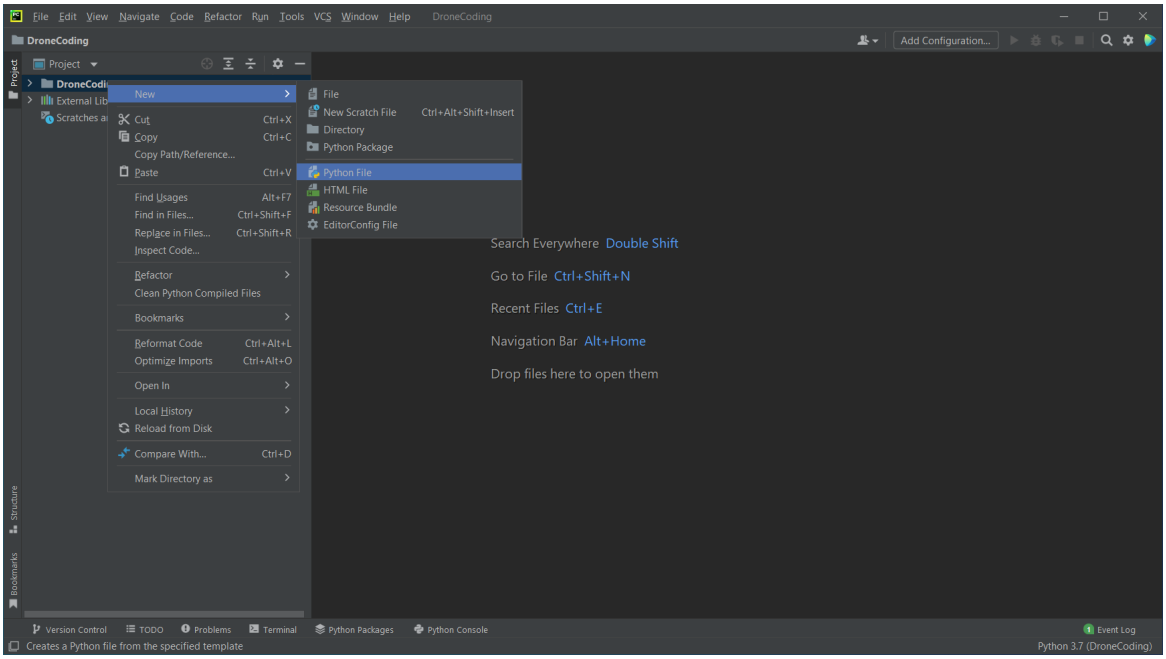
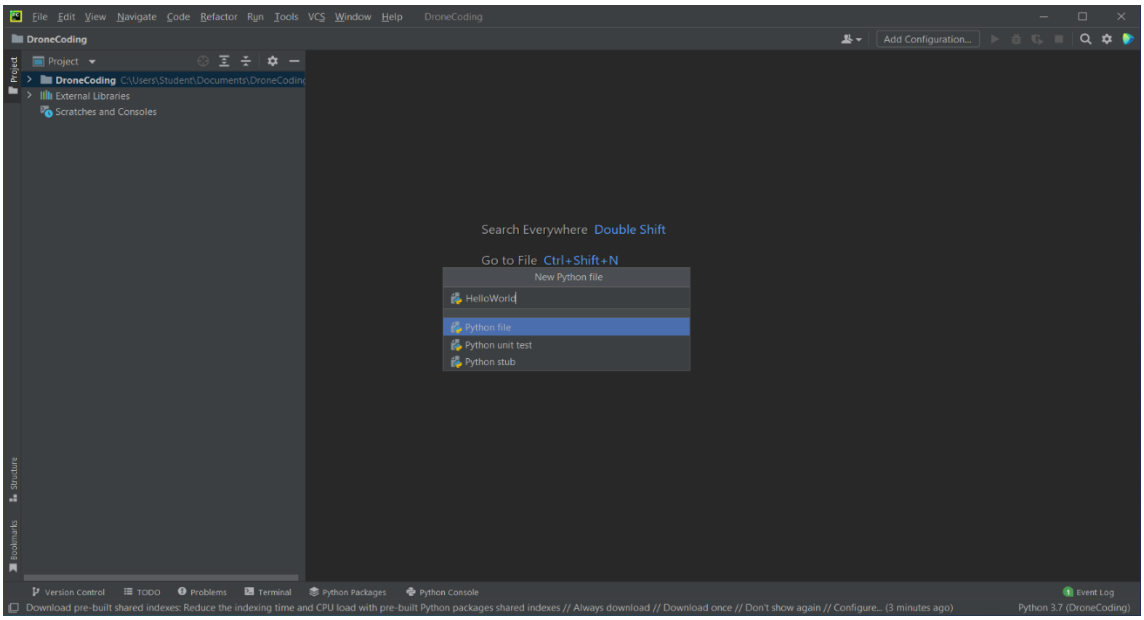
Creating a new script:

1. Right click on the DroneCoding folder
2. Select New -> Python File



3. Name our new script as *HelloWorld*
4. Select Python file



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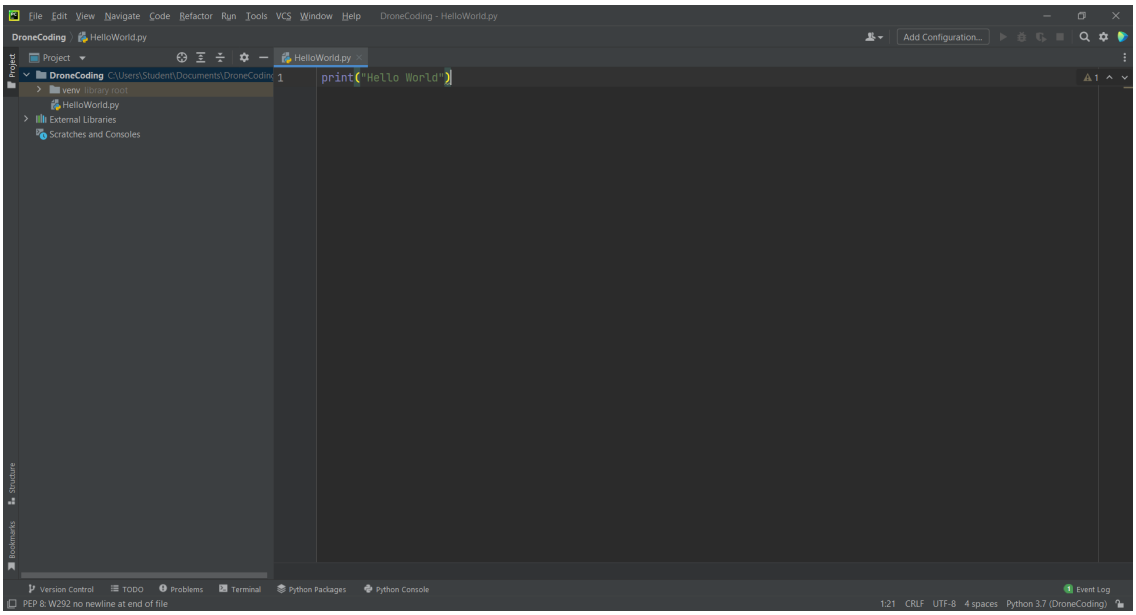
Python Basics

Printing

Usually, the first program when we are learning a new programming language is to write the code to print on screen the text “Hello World!”

```
print("Hello World!")
```

We can use double or single quotes when printing a string of text



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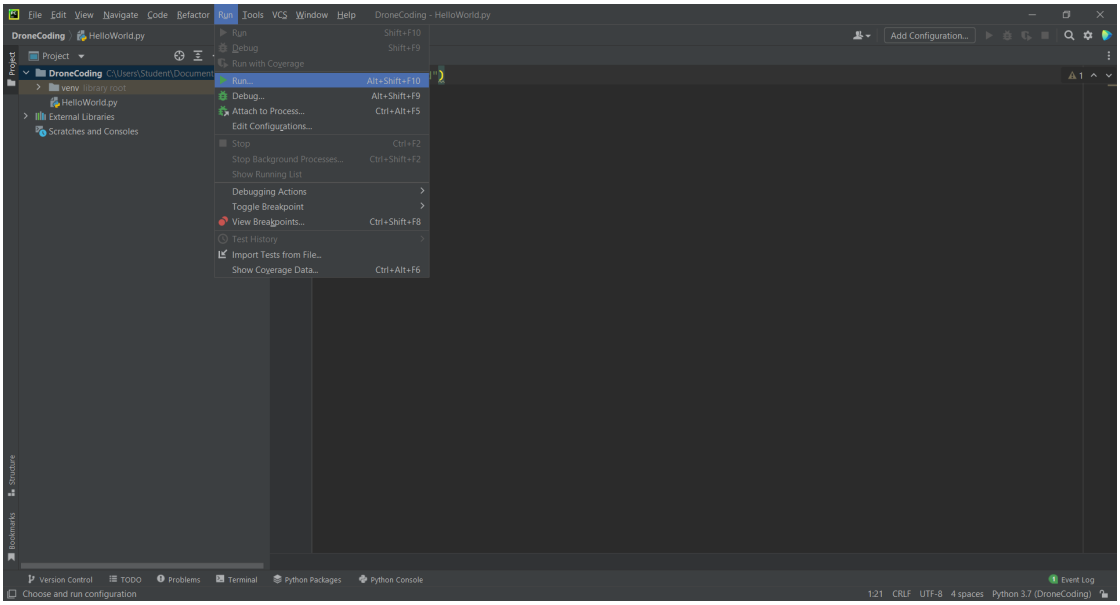
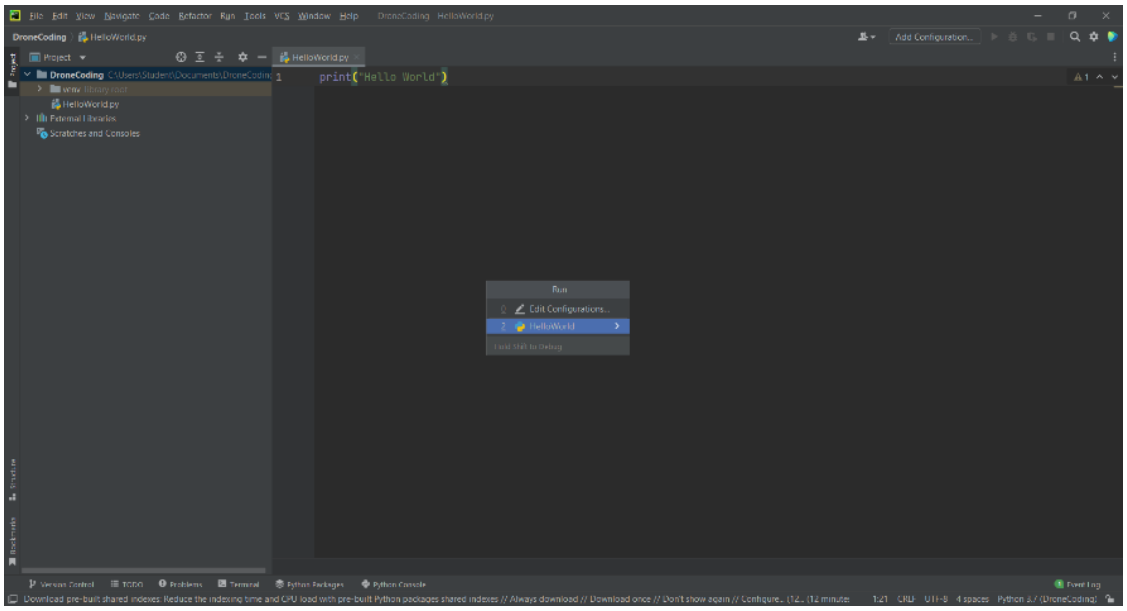
In order to run our code, we will need to:

1. Select Run from the main menu
2. Click Run



3. And select our specific script



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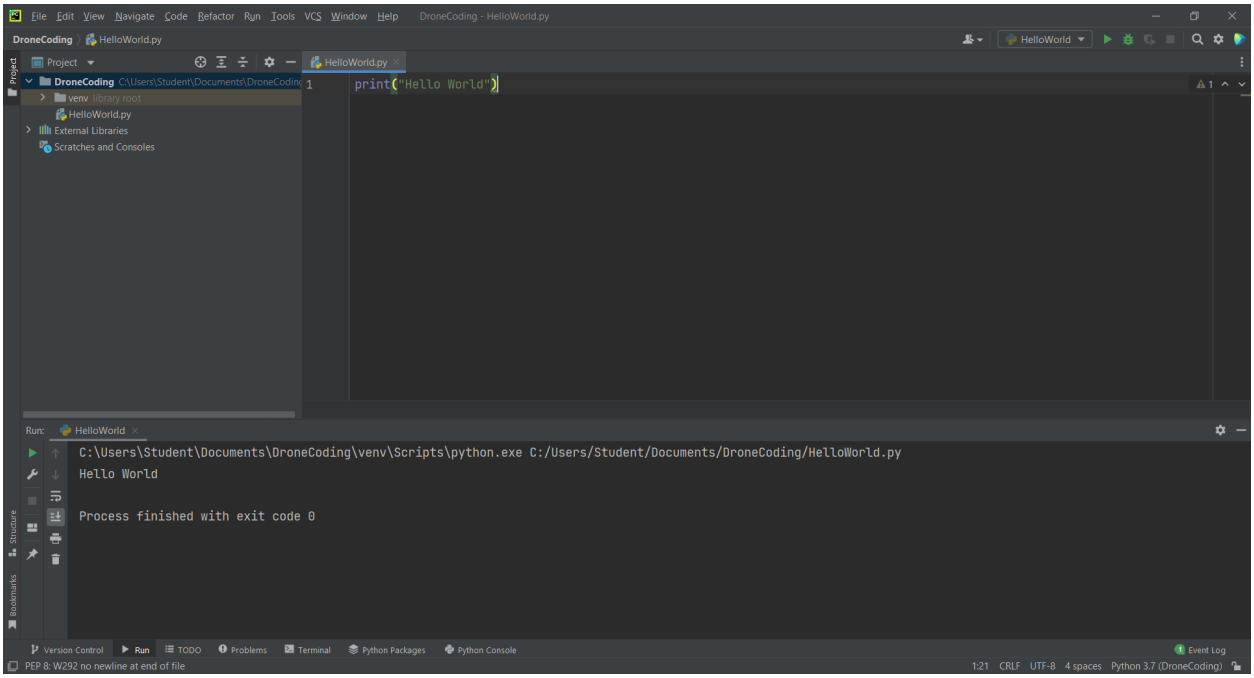
4. We will see the results of the program running at the python console area at the bottom



Variables

Variables are used to store data in the computer's memory temporarily.

```
speed = 50
altitude = 8.7
course_name = 'Drone Coding for Beginners'
is_flying = True
```

In the above example,

- **speed** is an *Integer* (a whole number without a decimal point)
- **altitude** is a *Float* (a number with a decimal point)
- **course_name** is a *string* (a sequence of characters)
- **is_flying** is a *Boolean*. Boolean values can be True or False.

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Comments

To add remarks to our code, we utilize comments.

Good comments explain how and why a piece of code is used, not just what it produces.

Use comments to remind yourself or other developers, as well as to clarify your thoughts and why you wrote code the way you did.

```
# This is a comment and it will not get executed.
# We can have comments in multiple lines.
```

Receiving Input

We can get input from the user by using the input() function.

```
birth_year = int(input('Year of Birth: '))
```

The input() function always returns data as a string. So, we need to convert the result into an integer by calling the int() function.

Strings

We can define a string by using single (' ') or double (" ") quotes.

Using square brackets [], we can extract individual characters from a string.

```
course = 'Drone Coding for Beginners'
print(course[0]) # returns the first character
print(course[1]) # returns the second character
print(course[-1]) # returns the first character from the end
print(course[-2]) # returns the second character from the end
```

Similarly, we can get a section of a string:

```
print(course[6:12]) #returns the characters from position 6 to 12
```

We can also convert our text with the following:

```
print(course.upper()) # to convert to uppercase
print(course.lower()) # to convert to lowercase
print(course.title()) # to capitalize the first letter of every word
print(course.find('g')) # returns the index of the first occurrence of
g (or -1 if not found)
print(course.replace('g', 'q')) # replaces the character g with q
```


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We use the in operator to see if a string includes a character (or a series of characters):

```
contains = 'Drone' in course
print(contains)
```

Arithmetic Operations

```
+ # addition
- # subtraction
* # multiplication
/ # division which returns a float
// # division which returns an int
% # returns the remainder of division
** # exponentiation - x ** y = x to the power of y
```

Augmented assignment operator:

```
x = x + 3
x += 3
```

Comparison operators

```
a > b (greater than)
a >= b (greater than or equal to)
a < b (less than)
a <= b (less than or equal to)
a == b (equals)
a != b (not equal to)
```

If Statements

```
temperature=22

if temperature>25:
    print("It's a hot day!")
elif temperature<10:
    print("It's a cold day!")
else:
    print("It's a nice day!")
```


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Loops

While loops

```
i = 1
while i < 5:
    print(i)
    i += 1
```

For loops

```
for i in range(1, 10):
    print(i)
```

this will print: 1, 2, 3, 4, 5, 6, 7, 8, 9

```
for i in range(5):
    print(i)
```

this will print: 0, 1, 2, 3, 4

Lists:

```
array = [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]

print(array) #returns the list
print(array[0])# returns the first item
print(array[1]) # returns the second item
print(array[-1]) # returns the first item from the end
print(array[-2]) # returns the second item from the end
print(array[0:4]) #returns the first 4 elements of the list
array[0]=27 #changes the first element to 27
array.append(11) # adds 11 to the end
array.insert(0, 32) # sets number 32 at index position of 0
array.remove(6) # removes 6
array.pop() # removes the last item
array.clear() # removes all the items
array.sort() # sorts the list
array.reverse() # reverses the list
```


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Drone Coding with Python

Drone Coding

First, we will need to create a new python file:

1. Right click on our project
2. New → Python File
3. Name the file as **Basic Movements**

Importing the necessary Libraries

A Python library is a group of related modules-instructions. It contains groups of code that can be reused in a variety of programs. It simplifies Python coding for programmers as it removes the need to write the same code again and again on different programs.

To program the Tello Drone, we will require its library of instructions, so we will go to:

1. File
2. Settings
3. Project
4. Python Interpreter
5. Click the **+** icon

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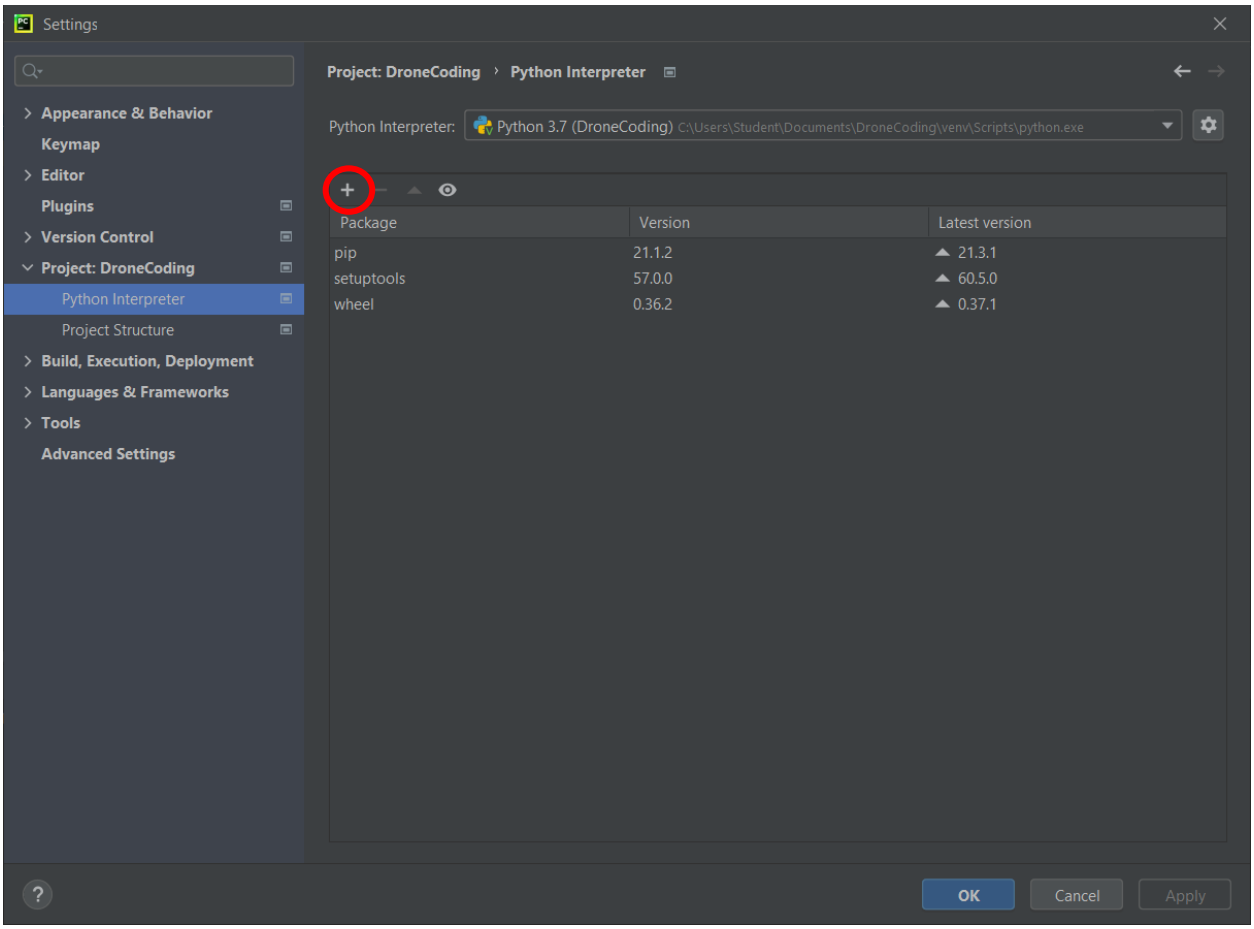

Then search for *DJITello*, and here you will see that we have the *djitellopy* library, select it and click Install Package.

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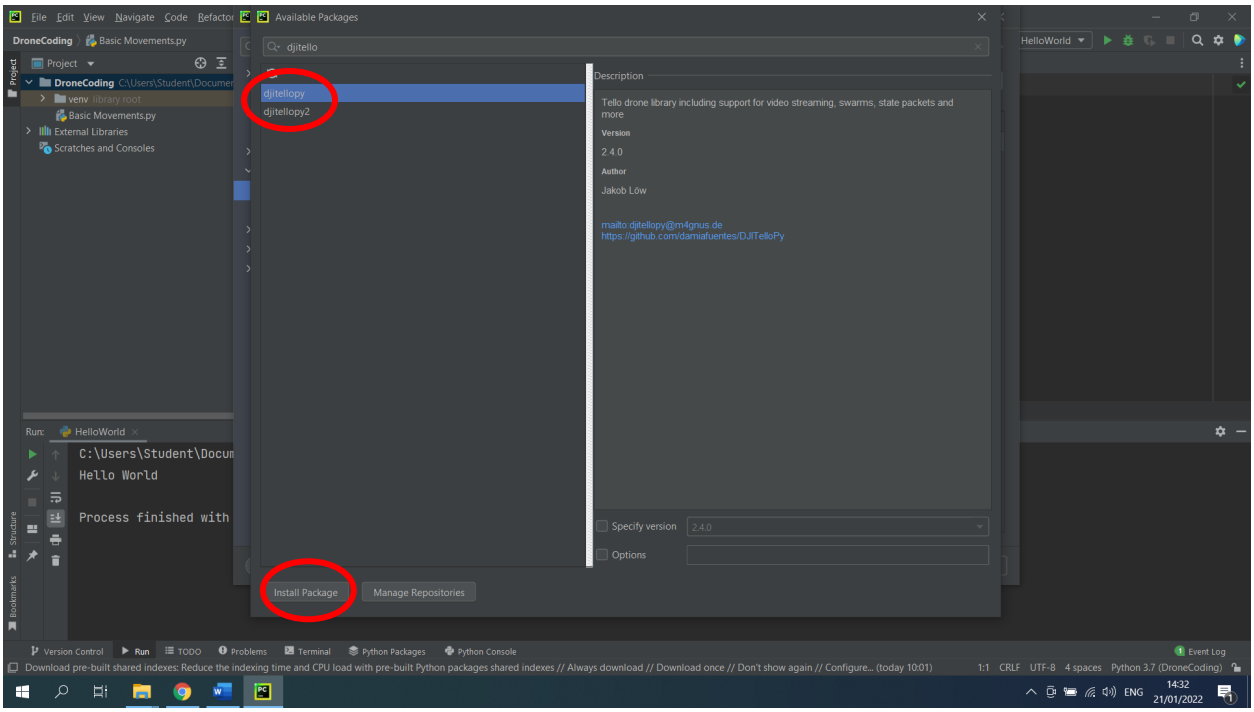
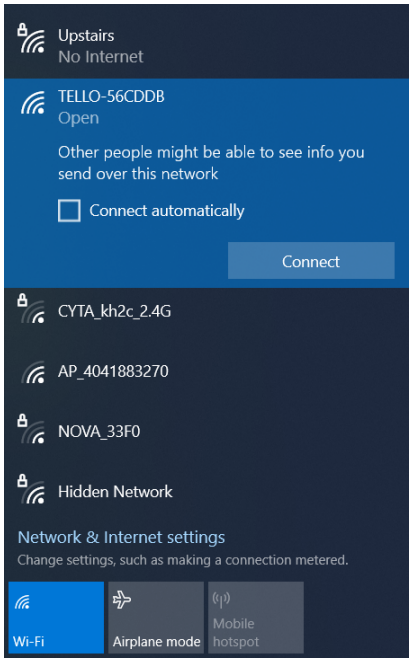
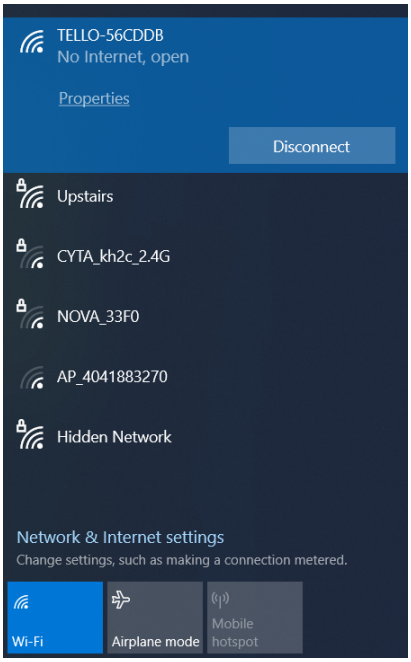


Now we are ready to write our first program for the DJI Tello Drone!

The first thing we will need to do is to connect the Tello Drone to our computer through the WIFI connection.





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Basic movements coding

In the Basic Movements python file write the following code. The commands contained in this program are some of the most basic one's covered in the tello.py library and instruct our drone to fly in all three dimensions as well as to perform certain acrobatics (flips) in different directions.

```
# import the Tello library of commands
from djitellopy import Tello
# in order to have a delay between the instructions we give to the
drone
from time import sleep

# create an object of type Tello - instantiation
tello = Tello()

# connect to the Tello Drone
tello.connect()

# Get the battery level
print("The battery level is: ", tello.get_battery(), "%")

# Get the absolute height from sea level
print("The barometer measurement is: ", tello.get_barometer(),
"cm")

#Get the current temperature of the drone
print("The temperature of the drone is: ", tello.get_temperature(),
" C")

# Wait for 2 seconds
sleep(2)

# Take off Tello
tello.takeoff()

print("Tello move up 40 cm")
tello.move_up(130)

print("Tello move down 20 cm")
tello.move_down(20)

print("Tello move forward 40 cm")
tello.move_forward(40)

print("Tello move back 40 cm")
tello.move_back(40)
```


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```
print("Tello do a forward flip")
tello.flip_forward()

print("Tello do a back flip")
tello.flip_back()

print("Tello do a right flip")
tello.flip_left()

print("Tello do a left flip")
tello.flip_right()

print("Tello rotate clockwise 360 degrees")
tello.rotate_clockwise(360)

print("Tello rotate counter-clockwise 360 degrees")
tello.rotate_counter_clockwise(360)

tello.land()
```

Note:

If you are getting an IMU error such as the following:

[INFO] tello.py - 461 - Response up 130: 'error No valid imu'

This can be either that the drone needs recalibration or there is not enough light in the area where the drone is.

The IMU (Inertial Measurement Unit) is required to keep your drone steady and level in the air. It's an integrated sensor that monitors force, angular velocity, and attitude. The drone's accelerometer, barometer, gyroscope, and temperature are used to do this.

Try to move the drone to a well-lit area and try the code again. If it still does not work you can go on and recalibrate the drone by following the instructions through the mobile app of Tello.

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Basic movements coding (2)

Another way of sending basic movement commands (unfortunately not the flip commands) which bypasses the limitations (and safety) of IMU is through the `send_rc_control` command.

Create a new python file and name it ***Basic Movements 2*** and write the following code:

```
# import the Tello library of commands
from djitellopy import Tello
# in order to have a delay between the instructions we give to the
drone
from time import sleep

# create an object of type Tello - instantiation
tello = Tello()

# connect to the Tello Drone
tello.connect()

# Get the battery level
print("The battery level is: ", tello.get_battery(), "%")

# Get the absolute height from sea level
print("The barometer measurement is: ", tello.get_barometer(),
"cm")

#Get the current temperature of the drone
print("The temperature of the drone is: ", tello.get_temperature(),
" C")

# Wait for 2 seconds
sleep(2)

# Take off Tello
tello.takeoff()

# move backwards 50cm
tello.send_rc_control(0, -50, 0, 0)
sleep(2)

# move left 40 cm
tello.send_rc_control(-40, 0, 0, 0)
sleep(2)

# move turn 180 degrees
tello.send_rc_control(0, 0, 0, 180)
```


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```
sleep(2)

# move up 80 cm
tello.send_rc_control(0, 0, 80, 0)
sleep(2)

# Land Tello drone
tello.send_rc_control(0, 0, 0, 0)
tello.land()

print("The Tello Drone has landed!")
```


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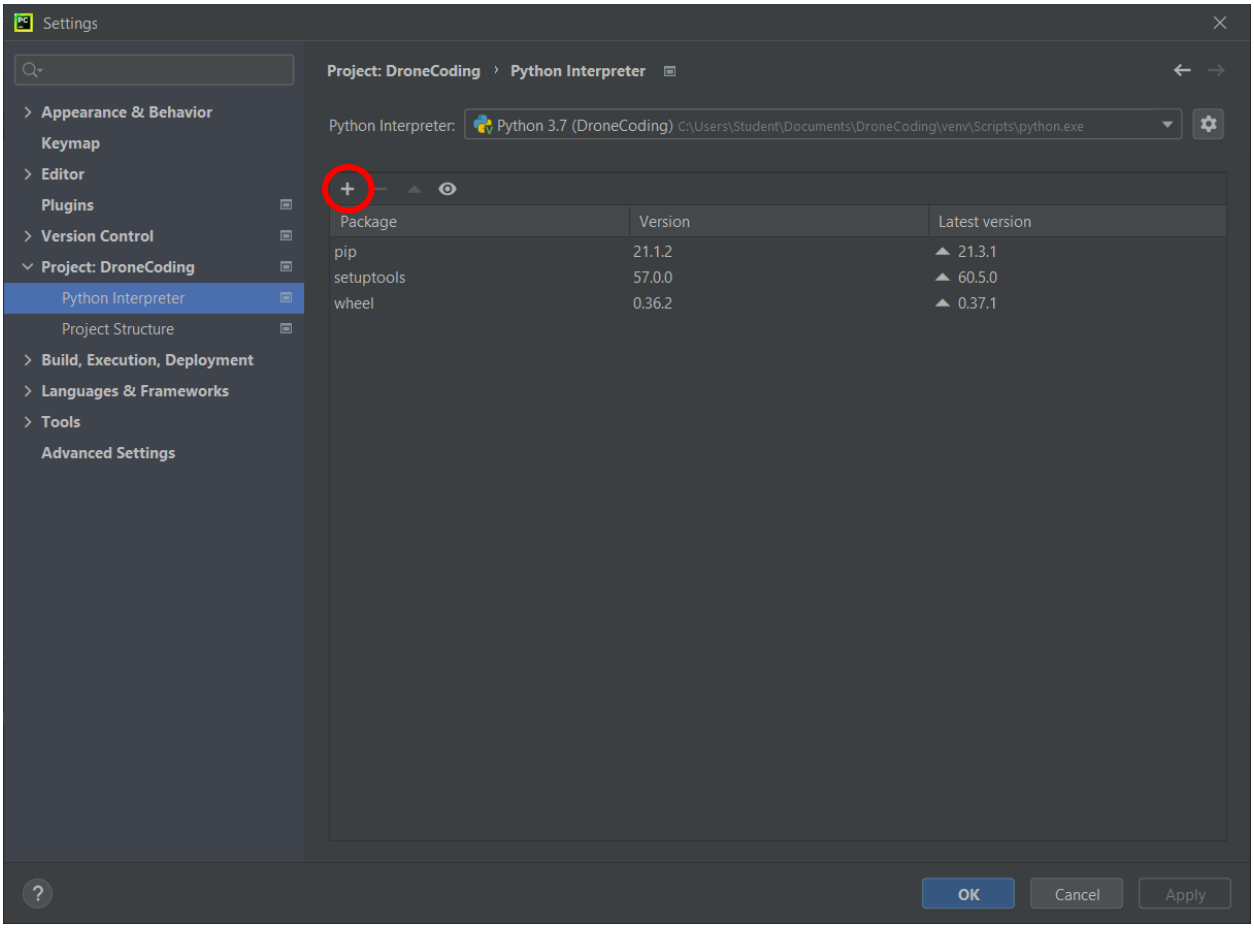
Video capture

We will need to add an additional library to our program in order to make our drone to capture live footage with the on-board camera.

In order to do so we will go to:

1. File
2. Settings
3. Project
4. Python Interpreter
5. Click the + icon



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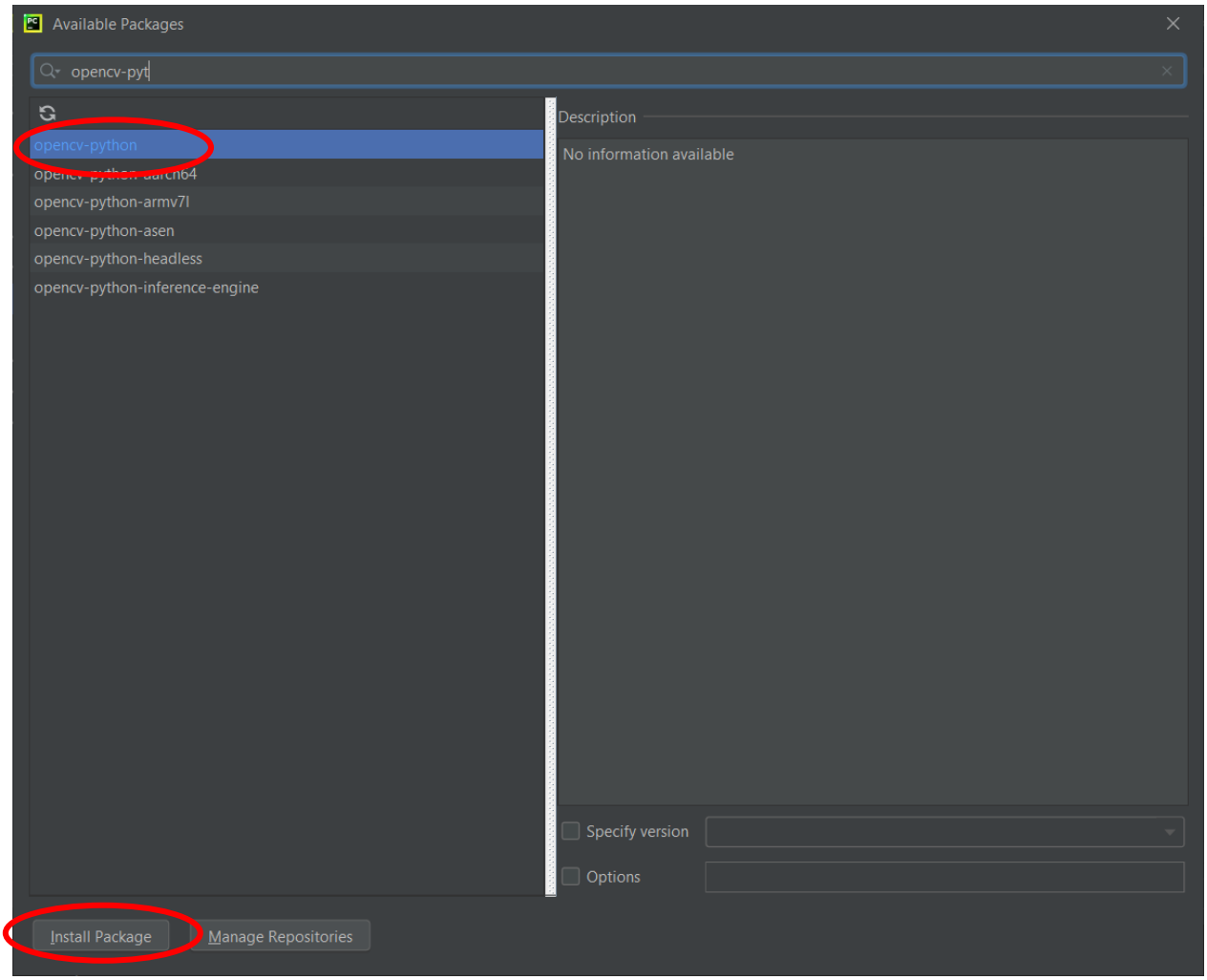
Then search for *Opencv-python*, and here you will see in the list which appears that we have the *opencv-python* library, select it and click Install Package.



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```
from djitellopy import Tello
import cv2
import time

# create an object of type Tello - instantiation
tello = Tello()

# connect to the Tello Drone
tello.connect()

# Get the battery level
print("The battery level is: ", tello.get_battery(), "%")

time.sleep(2)

#Turn on the Video Stream
tello.streamon()

# Read a single image from the Tello video feed
frame_read = tello.get_frame_read()

time.sleep(2)
while True:
    # read a single image from the Tello video feed
    print("Read Tello Image")
    tello_video_image = frame_read.frame
    #resize image - do not use the following line if you prefer
full screen mode
    tello_video_image = cv2.resize(tello_video_image, (360, 240))

    # use opencv to write image
    if tello_video_image is not None:
        cv2.imshow("TelloVideo", tello_video_image)

    if cv2.waitKey(1) & 0xFF == ord('q'):
        break

tello.streamoff()

#Close all open windows
cv2.destroyWindow('TelloVideo')
cv2.destroyAllWindows()
```


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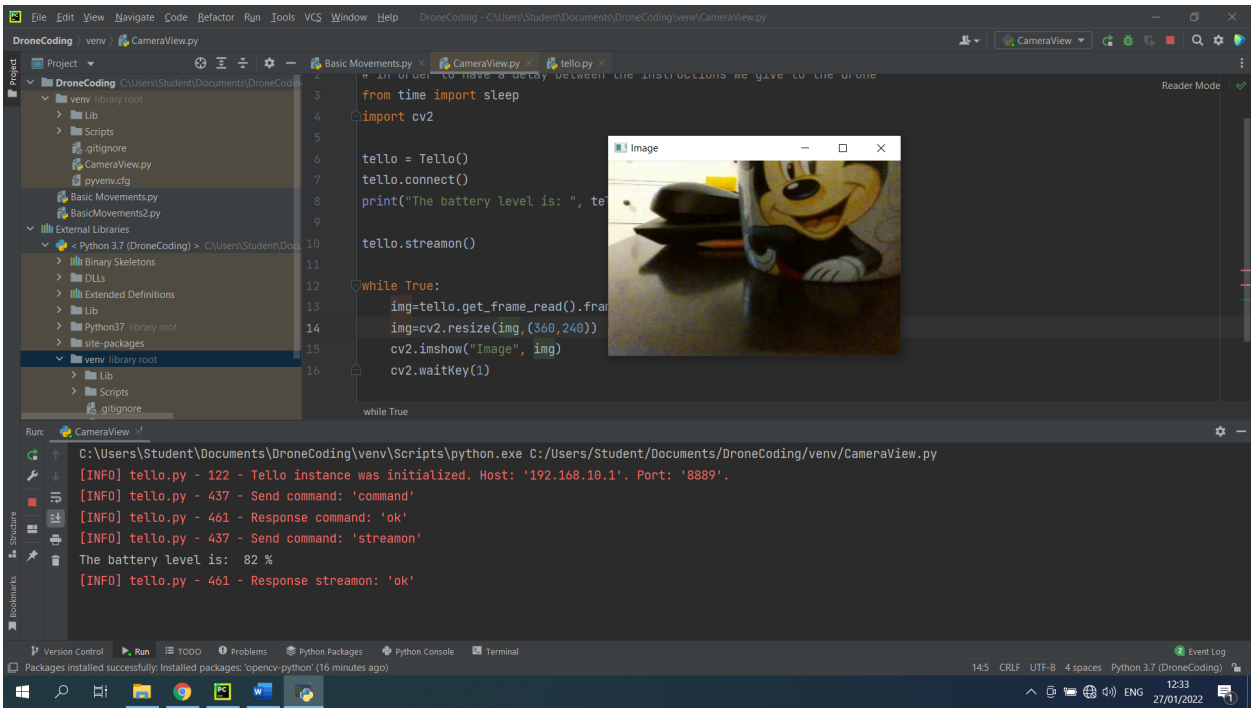
Example Output of the code running with a window streaming the live image which the Tello Drone sees:



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Video Capture and movement using threads

Python uses the **Threading** module to perform multiple tasks at the same time. A **thread** is a separate execution flow. This implies that the two processes will be happening at the same time in your code. However, the different threads do not actually execute at the same time in most Python 3 implementations; they just appear to do so due to the fact that getting multiple tasks running simultaneously requires a non-standard implementation of Python.

The code bellow does the following:

a. Creates a sub program with a specific flight pattern
b. Streams live video from the drone to the connected computer
c. Runs both functions "simultaneously"

```
from djitellopy import Tello
import cv2
import time
from threading import Thread

speed = 25
command_time_seconds = 3

# Have the Tello fly Up and Down
def flight_pattern():
    # Take off Tello
    tello.takeoff()

    if not tello.is_flying:
        # If something happened and the Tello didn't take off lets
try one more time
        tello.takeoff()

    time.sleep(1)
    #Tello move up 40cm
    tello.move_up(40)

    time.sleep(1)

    # Tello move down 20cm
    tello.move_down(20)

    time.sleep(1)

    # Tello move forward 40cm
    tello.move_forward(40)
```


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```
    # Tello move back 40cm
    tello.move_back(40)


# create an object of type Tello - instantiation
tello = Tello()

# connect to the Tello Drone
tello.connect()

# Get the battery level
print("The battery level is: ", tello.get_battery(), "%")

time.sleep(2)

#Turn on the Video Stream
tello.streamon()

# read a single image from the Tello video feed
frame_read = tello.get_frame_read()

# create a thread to run the function
flight_pattern_thread = Thread(target=flight_pattern, daemon=True)
flight_pattern_thread.start()

time.sleep(2)
print('Press:  q  to quit')
while True:
    # read a single image from the Tello video feed
    tello_video_image = frame_read.frame
    #resize image - don't use the following line if you prefer full
screen mode
    tello_video_image = cv2.resize(tello_video_image, (360, 240))
    # use opencv to write image
    if tello_video_image is not None:
        cv2.imshow("TelloVideo", tello_video_image)

    if cv2.waitKey(1) & 0xFF == ord('q'):
        break

# Land Tello drone
tello.land()
time.sleep(1)

tello.streamoff()
```


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```
cv2.destroyWindow('TelloVideo')
cv2.destroyAllWindows()
```


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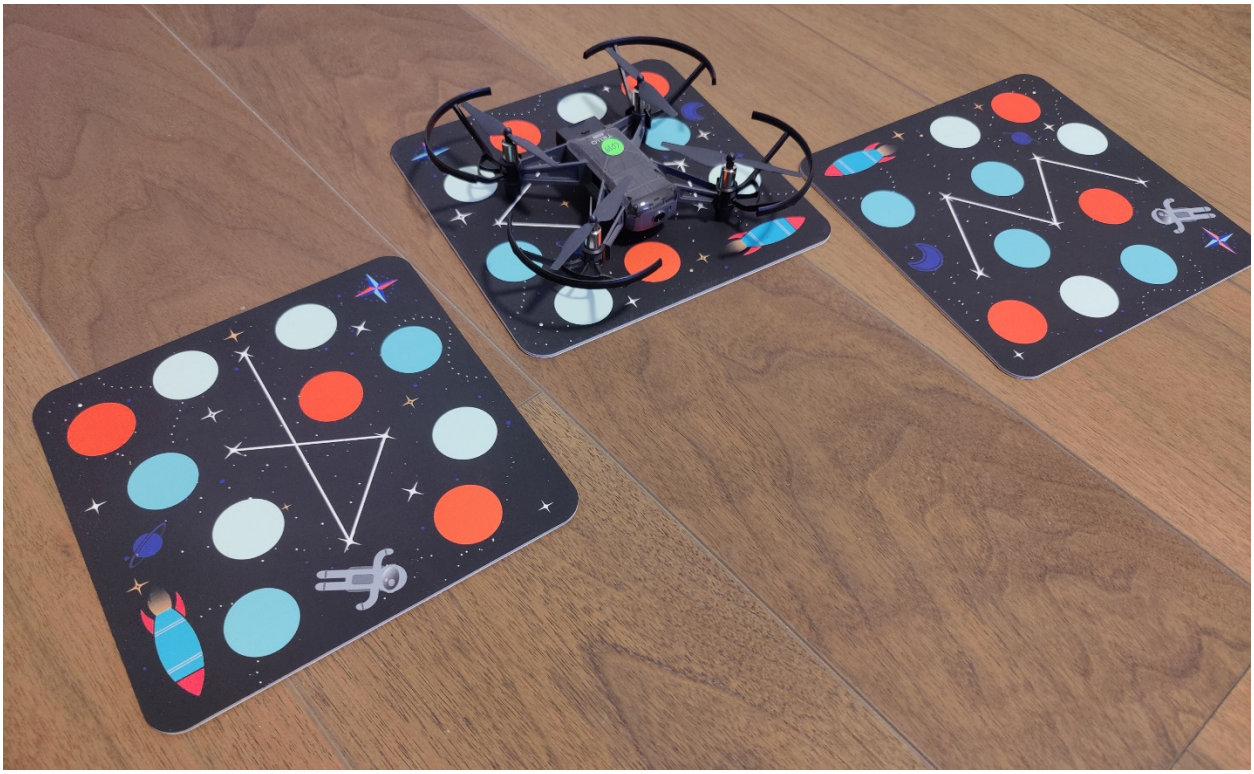
Mission Pads Recognition

Together with the education pack of the DJI Tello come three different mission pads which can be used from both sides giving in total of six different pads. Each side has a different design which the DJI Tello Sensors can recognize as a different ID, from ID 1 to ID 6.



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The following program contains the code that will read the mission pad number and store it in a variable. Once the mission pad number is stored the ID number of the specific mission pad is outputted.

```
# import the Tello library of commands
from djitellopy import Tello
# in order to have a delay between the instructions we give to the
drone
from time import sleep

# create an object of type Tello - instantiation
tello = Tello()

# connect to the Tello Drone
tello.connect()

# Take off Tello
tello.takeoff()

#variable to store the number
mission_pad_Number=tello.get_mission_pad_id()

#print the mission pad number by turning the integer value variable
into a string
print("The Mission Pad Number is: "+str(mission_pad_Number))

tello.land()
```


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Output of the code:

```
[INFO] tello.py - 122 - Tello instance was initialized. Host: '192.168.10.1'. Port: '8889'.
[INFO] tello.py - 437 - Send command: 'command'
[INFO] tello.py - 461 - Response command: 'ok'
[INFO] tello.py - 437 - Send command: 'takeoff'
[INFO] tello.py - 461 - Response takeoff: 'ok'
[INFO] tello.py - 437 - Send command: 'land'
The Mission Pad Number is: 6
[INFO] tello.py - 461 - Response land: 'ok'
```


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Quiz:

1. IDE means:
   a. Information Data Entry
   b. Integrated Development Environment
   c. Internet Design Environment
   d. International Design Entity

2. The instruction which is used in Python to show to the user a message is:
   a. Output
   b. Return
   c. Print
   d. Message

3. Variables are used to:
   a. Store data in the computer's memory temporarily
   b. Store data in the computer's memory permanently
   c. Run specific code repeatedly
   d. Run subprograms

4. You can add comments to your code in Python by using the:
   a. *
   b. &
   c. /
   d. #

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5. i = 1

```
while i < 6:
print(i)
i += 1
```

The above code following Code will repeat:

a. 4 times
b. 5 times
c. 6 times
d. 7 times

6. The first instruction we need to have when programing the Tello drone is to:
   a. Import the library of Tello commands
   b. Create an object of type Tello
   c. Connect to the Tello Drone
   d. Launch / Take off the Tello Drone

7. For the Tello drone to move up 20 cm the correct instruction is:
   a. `tello.move_upwards(20)`
   b. `tello.move_direction_up(20)`
   c. **`tello.move_up(20)`**
   d. `tello.direction_up(20)`

8. For the Tello drone to move backwards 20 cm the correct instruction is:
   a. **`tello.send_rc_control(0, -20, 0, 0)`**
   b. `tello.send_rc_control(0, 20, 0, 0)`
   c. `tello.send_rc_control(-20, 0, 0, 0)`
   d. `tello.send_rc_control(0, 0, -20, 0)`

9. For the Tello drone to turn on the Video Stream the correct instruction is:
   a. `tello.videoon()`
   b. `tello.cameraon()`
   c. `tello.feedon()`
   d. **`tello.streamon()`**

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10. To store the mission pad number to a variable the correct instruction is:
    a. `mission_pad_Number=tello.find_mission_pad_id()`
    b. **`mission_pad_Number=tello.get_mission_pad_id()`**
    c. `mission_pad_Number=tello.receive_pad_id()`
    d. `mission_pad_Number=tello.get_mission_pad_id()`

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References

1. Tello Drone Library - https://github.com/damiafuentes/DJITelloPy

2. DJI Tello Tutorial - https://github.com/dbaldwin/DroneBlocks-DJITelloPy-Tutorial

3. Threads in Python - https://realpython.com/intro-to-python-threading/#what-is-a-thread

4. Tello EDU – Python Coding with Mission Pads - https://www.youtube.com/watch?v=Uo2KovDEJTs

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