DRONES@STEAM

Fostering digital Transformation in VET schools
and creating new job prospects in the labour market

Project Result No: 2

Activity 3: EDUCATIONAL PACK: TEACHING MATERIAL AND ASSESSMENT

UNIT 2, Chapter 2.4, Worksheet 2.4.4

Lead partner(s): Politeknika Txorierri

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CONTEXT

Grant agreement	2021-1-EL01-KA220-VET-000034686
Programme	Erasmus+
Key action	Cooperation for innovation and the exchange of good practices
Action	Strategic Partnerships
Project acronym	DRONES@STEAM
Project title	DRONES@STEAM: Fostering digital Transformation in VET schools and creating new job prospects in the labour market
Project starting date	28/02/2022
Project duration	28 months
Project end date	27/06/2024

WEBSITE:

https://dronesteam.eu/

CONSORTIUM: PARTNER LIST

- University of Crete (UoC) - Greece
- ECAM-EPMI (ECAM) - France
- Cyprus Computer Society (CCS) - Cyprus
- Politeknika Ikastegia Txorierri S. Coop (PIT) – Spain
- National Center for Scientific Research “Demokritos” (NCSRD) - Greece
- A & A Emphasys Interactive Solutions Ltd (EMP) – Cyprus
- Regional Directorate of Primary and Secondary Education of Attica (RDPSEA) – Greece

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Contents

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UNIT 2: Lesson Plan 2.4.4

UNIT 2	
Chapter 2.4	**Drone flying and remote-control programming**
Equipment, Software, Consumables (if needed)	Air:bit 2 (Drone + Remote Control) Optional: PC with access to the internet
Duration	2 teaching hour
Short description	In this worksheet, the students will practice their drone piloting skills by **flying the drone and forming different figures**
Learning Outcomes	Development of technical skills: operating a drone, knowledge of the drone's controls, navigation, and manoeuvring techniques
	Spatial awareness and understanding of three-dimensional space
	Practice safe piloting techniques, learning how to minimize the risk of accidents and injuries
	Fine synchronisation of eyes-hand, Problem solving, Creativity, Communication, Adaptability, Experimentation, Improvisation, Patience, Perseverance
Activities	
Activity 1	Presentation 2.4.4.1: How to fly the Air:bit 2 DIY drone
Aim of the activity	The objective of the Activity is to familiarize students with the radio control parameters of Air:bit 2
Duration	20 min
Type of Activity	Presentation
Teaching Objectives	By the end of this exercise, students will understand how roll, pitch, yaw, and throttle impact the drone's movement in the air
Resources	Worksheet 2.4.4 / Presentation 2.4.4.1
Activity 2	Exercise 2.3.4.2 – Simple, Intermediate and Advanced Flights
Aim of the activity	Flying a drone in a controlled way so that the pilot can achieve the proposed pathways
Duration	70 minutes
Type of Activity	Worksheet
Teaching Objectives	By the end of this exercise, students will be able to adapt the roll, pitch, yaw, and throttle commands to make a drone navigate a desired path. They will have gained experience in flying a drone in a safe and controlled manner, adhering to best practices and safety guidelines
Resources	Worksheet 2.4.4 / Exercises 1, 2, 3, 4 and 5
Further Reading	
Resources/Links	How To Fly Air:bit - YouTube

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Activity worksheet 2.4.4 (student version)

Chapter 2.4: Drone flying and remote-control programming

Level: Intermediate

In this worksheet we will learn how to pilot our Air:bit 2 using a radio frequency remote control. More specifically, we will

- Understand how roll, pitch, yaw, and throttle change the drone's movement in the air
- Pilot the drone adapting the control parameters to make the drone perform different types of movements: changes of direction (right/left), turns, straight zig-zag, slalom

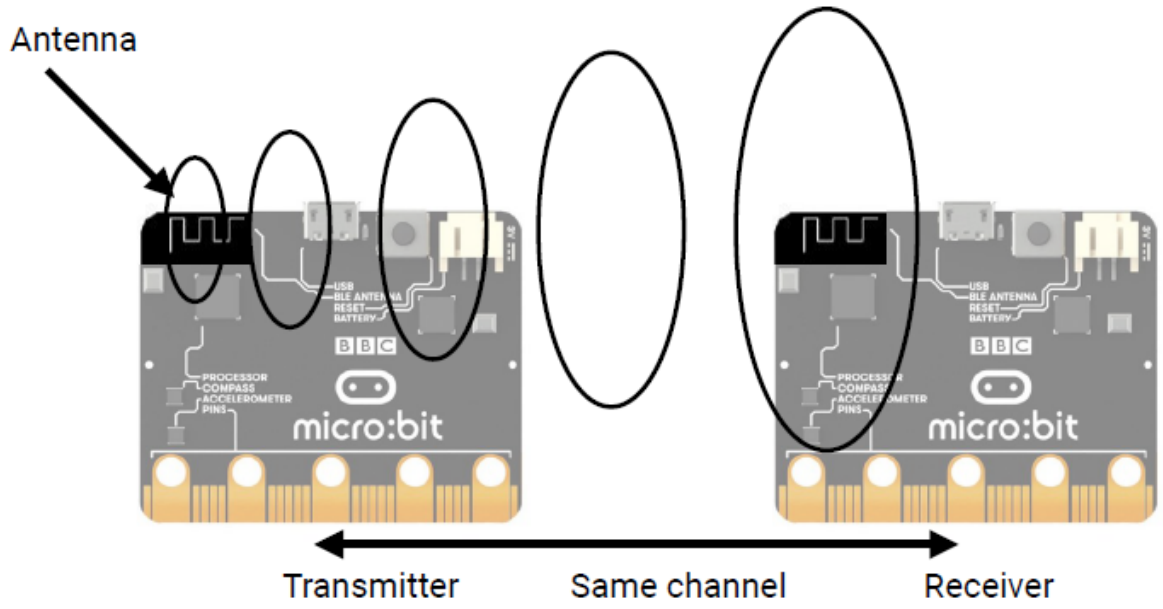
Presentation 2.4.4.1: How to fly the Air:bit 2 DIY drone

Introduction

Radio frequency defines the lowest energy part of the electromagnetic spectrum. Waves are transmitted by generating a current through a conductor and received by an antenna.

We live surrounded by examples of its various applications: the remote control we use to change the TV, perhaps we have had an MRI, the radio we listen to, the anti-theft tags at the supermarket…

This same technology will also allow us to control our drone remotely: the CPU on the micro:bit contains a built-in 2.4GHz radio module that **allows direct micro:bit to micro:bit communication**. If they belong to the same pre-defined channel, the hand-control micro:bit will be the signal emitter and the drone chip the receiver.



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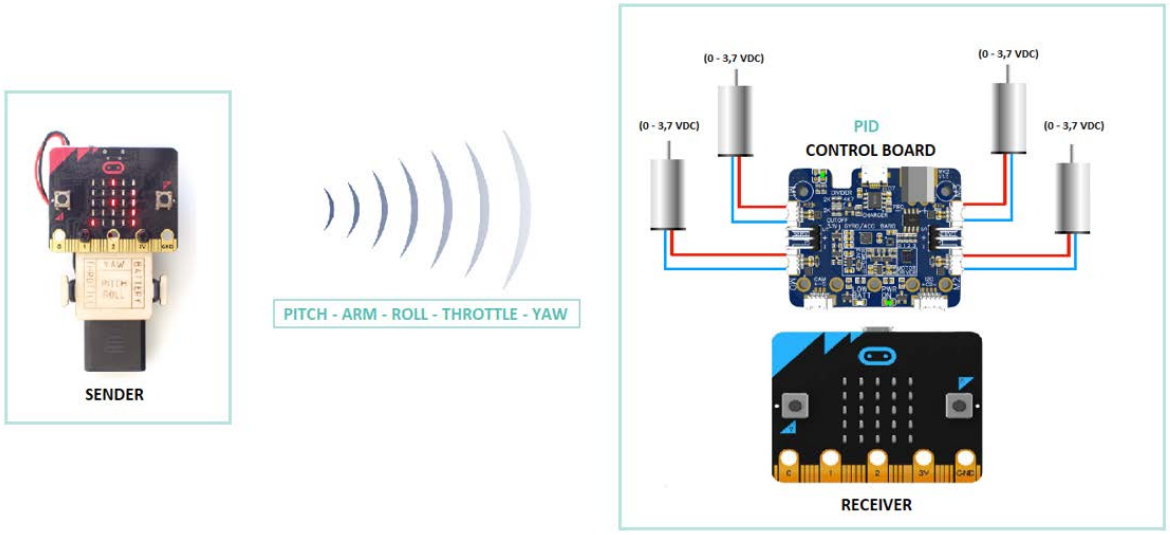
PARTY: Five Values to control the Drone

Quadcopter drones are powered by four propellers located around a main body, the dynamic action of the forces acting on the system requires mechanisms to stabilise them and control the interaction in a constant equilibrium. The movement of each propeller is controlled by an electronic system based on a PID control, which allows the management of the forces acting on the flight.



For the drone to fly in a controlled way, we must provide the controller with 5 variables:

- **PITCH**: **FORWARD AND BACKWARD TILT**. Pitch control or elevation control maintains forward or reverse control of the system while leaving enough freedom to speed up or slow down if manoeuvres require it.
- **ARM**. **POWER ON/OFF**. Arming is a safety switch and the propellers will only spin when arm is enabled.
- **ROLL**: **HORIZONTAL OR SIDE TO SIDE MOVEMENT**. Roll control or horizontal yaw control the balance of the drone is centred on this axis whereby PID control is critical to prevent the drone from spinning, in turn it takes into account that the freedom of manoeuvre has to be sufficient to be able to perform pirouettes.
- **THROTTLE**: **VERTICAL MOVEMENT - ALTITUDE CONTROL**. If we want the drone to move up and down the Z axis, we use the throttle. Increasing the throttle will make the Drone fly higher, and decreasing it will make the Drone fly lower.
- **YAW**: **LEFT AND RIGHT ROTATION**. Yaw control or vertical yaw control prevents the turning forces of the propellers from causing the system to spin on its own axis but allows enough freedom to be able to steer the manoeuvring action left and right. Yaw makes the drone move around its axis; it spins on the Z axis to face a direction.

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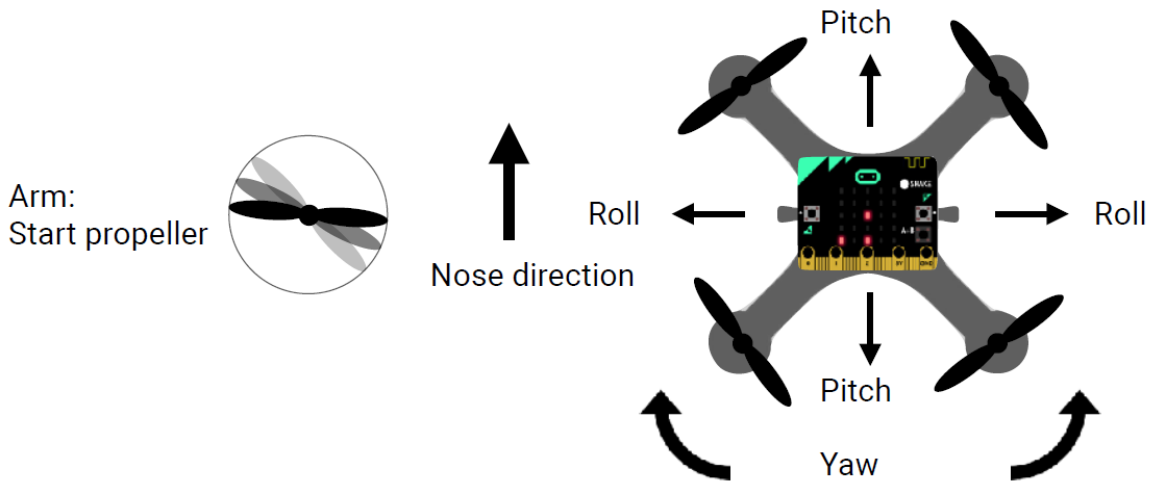

Remote Hand Control Operation

The 5 PARTY values used for controlling the drone's flight are set through the remote Hand Control. The following is an example of how to operate a radio frequency remote control:

- **Arm**: the safety switch will be enabled and disabled by pressing A+B simultaneously.
- **Pitch and Roll**: the setpoint values are calculated by reading the remote control micro:bit accelerometer so that the drone follows the inclination (forward/backward/left/right) driven by the Hand Control.
- **Throttle**: can be increased and decreased by pushing buttons B (+) and A (-).
- **Yaw**: can be controlled using the input pins on the micro:bit. If no pin is touched the yaw will be zero. If P0 is touched it will be positive and if P2 is touched it will be negative.
- **Emergency Stop**: when shaking the remote control in case of emergency, the propellers will be automatically disarmed and the throttle set to zero.

How do you operate your remote control?
Write a short operating manual explaining how to adjust the PARTY parameters from your remote control

Drone and Remote Control Visualization

It is necessary to display the status of the 5 control variables on the LED matrix of the transmitter and receiver chips in order to be able to check the configured settings and working conditions at any time.

As the accelerometer of the micro:bit is a very sensitive sensor, the display of pitch and roll can be especially useful to place the remote controller in a neutral horizontal/vertical position that allows us to keep the drone flight stable. A quick look at the display can give us clues on how to redirect our flight.

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What is the visualization system of your remote control?
Write a short user manual explaining the configuration of the led matrix display on the remote control's micro:bit. (Battery level, Arm, Pitch, Roll, Yaw)

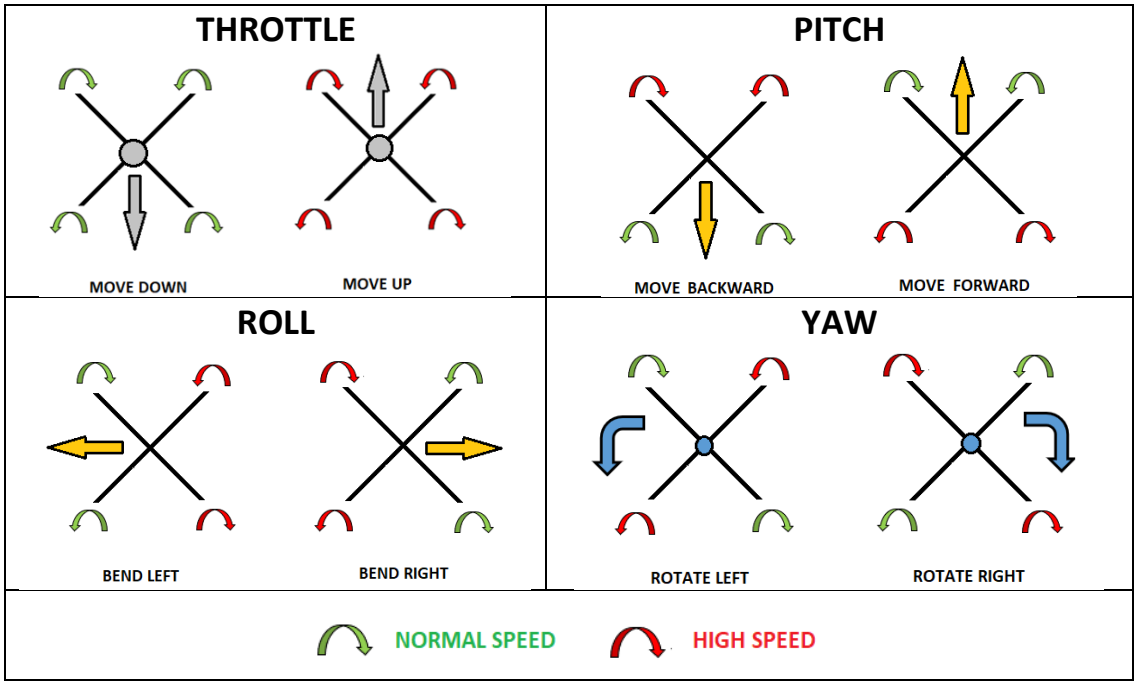
What is the visualization system of your remote control?
Write a short user manual explaining the configuration of the led matrix display on the drone's micro:bit (Battery level, warnings, Pitch, Roll, Yaw

How to control the drone's path

In quadcopters, two motors rotate with the clock (CW) and two rotate against the clock (CCW). The counter rotating setup prevents the drone from spinning around the yaw-axis.

The flight control board takes all the flight directions (PARTY) and mixes the info onto the four motors.

The following chart shows the effects of each control parameter on the flight of the drone.



Drone Flying Procedure

It is advisable to follow a test procedure, especially before making the first flights with the drone.

1. **FIND AN OPEN SPACE**
    - Find an open room without obstacles, indoor or outside (indoor spaces are safer for beginners)
    - Carpets, grass fields, or similar soft surfaces lower the risk of damaging the drone
    - Check the operating conditions are safe

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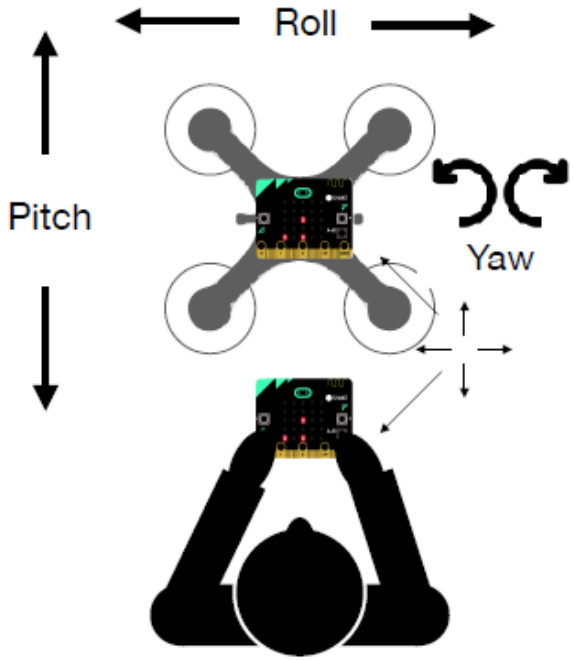
- Follow local drone regulations

2. **PLACE THE DRONE IN THE MIDDLE OF THE SPACE**
   - **IMPORTANT!** Check both micro:bit are facing forward.



3. **PRE-FLIGHT INSPECTION**
   - Ensure that the drone is in good condition: check the battery, propellers, camera, etc

4. **SWITCH ON THE REMOTE CONTROL (Connect battery)**
   - Check the Radio Group
   - Check it is disarmed
   - Check Throttle setpoint is low
   - Check the Pitch and Roll led are changing according to the accelerometer

5. **CHECK THE EMERGENCY STOP**
   - Arm the control and increase the throttle to see if the led is changing
   - Shake the remote
   - Check the control is disarmed and the throttle = 0

6. **SWITCH ON THE DRONE (Connect battery)**
   - Check the Radio Group is the same as the Remote Control
   - Check the battery is fully charged
   - Take the drone, move it softly, and check the display is changing according to the pitch and the roll

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7. **START THE PROPELLERS**
    - **IMPORTANT!** The micro:bit needs 5 seconds for calibrating before arming
    - Arm the Drone pressing A + B simultaneously

8. **TAKE OFF. INCREASE THE THROTTLE/DECREASE THROTTLE**
    - Increase (B button) / Decrease (A button)
    - Increase throttle step by step until the drone is hovering 10-30 cm above the ground.
    - As soon as the drone starts to climb, lower the throttle a bit to maintain altitude.

9. **PITCH/ROLL/YAW CONTROL**
    - Move the micro:bit transmitter to steer the drone's roll and pitch
    - Touch Pin 0 to rotate to the left
    - Touch Pin 2 to rotate to the right

10. **EXPERIMENT AND ENJOY THE FLIGHT**
    - Do not lose sight of the drone
    - respect the range of the remote control

11. **LAND THE DRONE SMOOTHLY**

12. **DISCONNECT THE BATTERIES AT THE END OF ALL INTENDED FLIGHTS**

13. **POST-FLIGHT INSPECTION**
    - Verify that the drone has not been damaged after flying it
    - Perform maintenance work in case of detecting any malfunctions

Worksheet 2.4.4.2 – Simple, Intermediate and Advanced Flights

Exercise 1: Hold the drone steady

In this exercise, we will learn how to make the drone take off and land.

We will use a cardboard to approximate the size of the drone as a heliport. We can use scotch tape or similar to fix it to the floor. You can also use a heavy object, such as a textbook, to land the drone.

The aim of the activity is to fly the drone steadily in a maximum area of 2 x 2 meters around the helipad following the next steps:

1. Place the drone on the helipad.
2. Switch on and perform the initial checks on the remote control and the drone.
3. Arm the motors.

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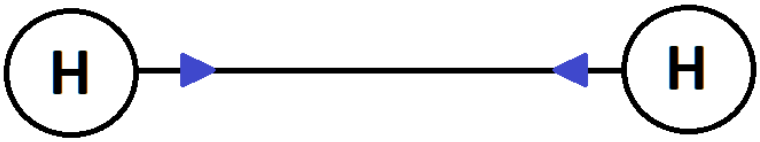
4. Increase the throttle until the drone rises.
5. Move the drone slightly back and forth while.
6. Move the drone left and right maintaining altitude.
7. Take the drone back to the Helipad position.
8. Land the drone smoothly on the helipad by decreasing the throttle little by little.
9. Disarm the motors.

Once you have managed to keep the drone steady, answer the following questions:

- Have you managed to fly the drone in a controlled manner? What went wrong?
- What is the minimum throttle value (%) to lift the drone off the ground?
- How many seconds does the drone maintain altitude without increasing throttle? Why does it fall?
- What is the maximum throttle value (%) to prevent the drone from gaining altitude too fast?

Exercise 2: Straight line go and return

For this exercise, get two carboard helipads and some scotch tape. Fix the first helipad to the floor, place the second one 3 meters apart and connect them using scotch tape (or drawing a line, a rope…).



The aim of the activity is to fly the drone between helipads following the next steps:

1. Place the drone on the helipad.
2. Switch on and perform the initial checks on the remote control and the drone.
3. Arm the motors.
4. Increase the throttle until the drone rises about one metre.
5. Make the drone hover.
6. Fly the drone forwards to the next heliport following the reference line.
7. Land the drone on the second helipad.
8. Take off the drone again and fly it backwards to the first helipad.
9. Land the drone on the helipad.
10. Disarm the motors.

Repeat the exercise increasing the separation distance between helipads and flying the drone closer to the ground level.

After completing the exercise, answer the following questions:

- What was the effect of pitch and roll on the trajectory?

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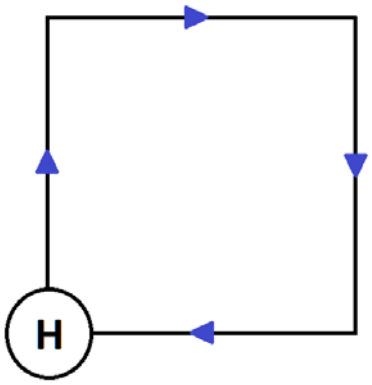
- Have you noticed any effects when flying the drone closer to the ground? What do you think this might be due to?

Exercise 3: Square

In the following exercise, you are asked to perform a trajectory in the shape of a 4 x 4 meter square, with a single take-off and landing. Fix the helipad to the floor and create the square trajectory using scotch tape (or drawing a line, using a rope…).



In this third exercise, fine control of pitch and roll will be necessary to adjust the drone to the trajectory. In addition, changes in altitude will also be required at specific points on the figure.

1. Place the drone on the helipad.
2. Switch on and perform the initial checks on the remote control and the drone.
3. Arm the motors.
4. Increase the throttle until the drone rises.
5. Make the drone hover.
6. Fly the drone towards the first corner.
7. Hover the drone over the corner for 3 seconds and increase the altitude.
8. Fly the drone towards the second corner.
9. Hover the drone over the corner for 5 seconds.
10. Fly the drone towards the third corner.
11. Keep the drone hovering over the corner for 10 seconds.
12. Pilot the drone towards the helipad and land it.
13. Disarm the motors.

Repeat the exercise without stopping or changing heights at the corners and drawing the diagonal lines shown in the figure.

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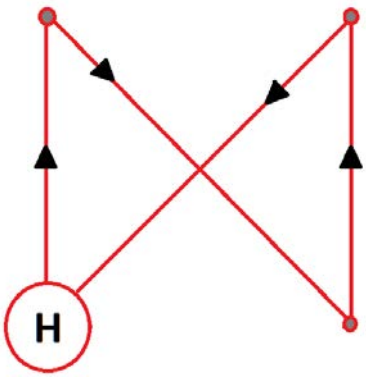
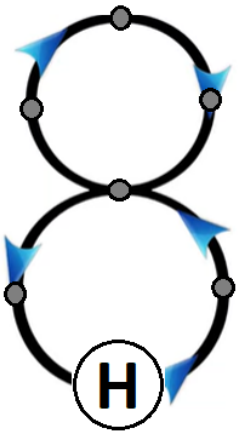


After completing the full exercise, answer the following questions:

- Have you used negative or positive yaw in any movement? Which movements could simplify its use?
- Is drone control easier at high or low altitude? Why?

Exercise 4: Eight

In this exercise, we will practice the circular turns. Use scotch tape or similar to draw an eight figure on the floor with and approximate radius of 2 and 2.5 meters. Marking the quadrants of both circles can serve as a reference when tracing the turns. Fix the helipad at the bottom of the figure.



Pilot the drone according to the following steps:

1. Place the drone on the heliport.
2. Switch on and perform the initial checks on the remote control and the drone.
3. Arm the motors.
4. Increase the throttle until the drone rises half meter and make it hover.
5. Take the first right-hand turn.
6. When reaching the connection of both circles, fly over the upper full circle through its four quadrants.
7. Fly the drone towards the second corner.
8. Land the drone.

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9. Disarm the motors.

Repeat the exercise two more times to check your piloting skills:

1. Trace the figure in the opposite direction
2. Trace the figure backwards

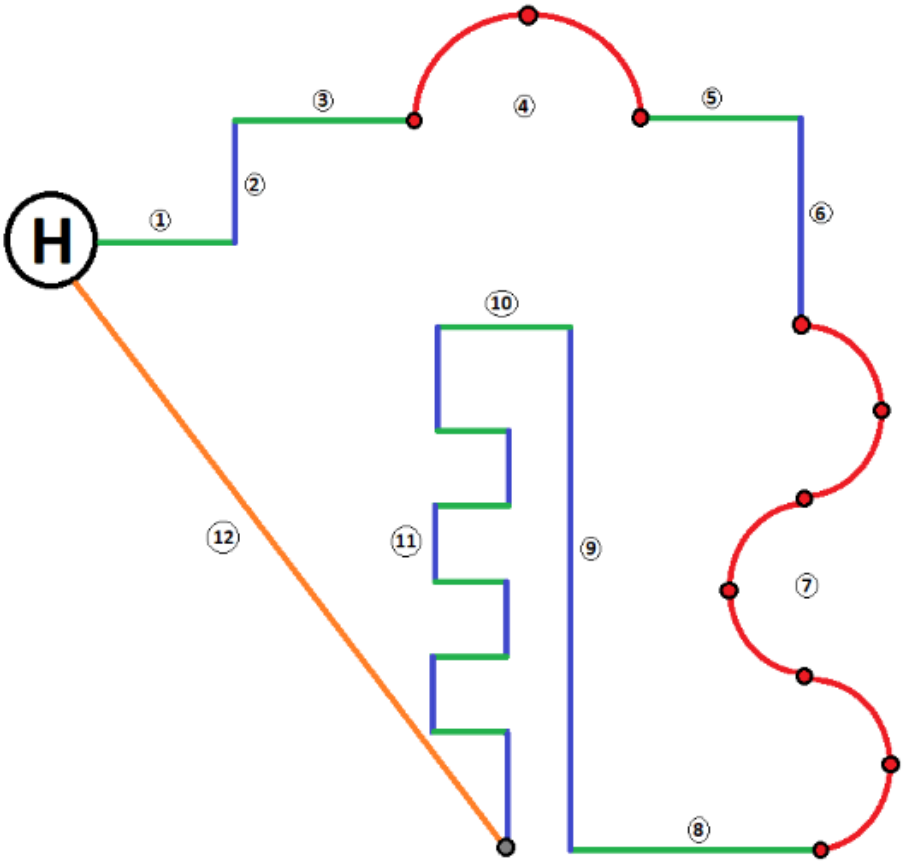
Exercise 5: Drone Arena

In this final exercise, you are asked to fly the drone through a circuit that includes all the movements you have practised previously: changes of direction (right/left), turns, straight zig-zag, slalom

In the figure, you can see a proposed circuit that can be built using ropes, hoops, sticks, tape, cones, etc. You can also design your own Drone Arena for a personalised practice of your piloting skills.

For ease of installation use the following distances as a reference:

- Track 1, 2, 3: 1 metre
- Track 4: 1 meter radius arc
- Track 5, 6: 1 meter
- Tracks 7: Slalom with a radius of 1 meter
- Track 8: 2 meters
- Track 9: 6 meters
- Track 10: 1 meter
- Track 11: Zig-zag 50 cm sideways



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Follow the steps below and test your expertise as a drone pilot:

1. Place the drone on the heliport.
2. Switch on and perform the initial checks on the remote control and the drone.
3. Arm the motors.
4. Increase the throttle until the drone rises one meter and make it hover.
5. Fly the drone forward-left-forward (1-2-3).
6. Trace the left arc no. 4 through its quadrants.
7. Fly the drone forward-right (5-6).
8. Pass the circular slalom no. 7 maintaining the altitude.
9. Fly the drone forward-right-forward (8-9-10) overcoming the obstacles at different heights.
10. Pass the zig-zag slalom no. 11.
11. Raise the drone.
12. Return to the heliport losing altitude via route no.12.
13. Land the drone.
14. Disarm the motors.

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After completing the whole exercise, fill in the following checklist to assess your skills as a drone pilot.

PILOTING SKILLS ASSESSMENT – DRONE ARENA			
PATH	**PILOTING ACTION**	**OK**	**OBSERVATIONS / IMPROVEMENT PROPOSALS**
1-2-3	Controlled take-off maneuver		
	Track No. 1		
	Left turn and Track No. 2		
	Right turn and Track No. 3		
4	Hovering drone at the start quadrant of Track No. 4		
	Arc track passing through the three indicated quadrants		
5-6	Hovering drone at the start quadrant of Track No. 5		
	Track No. 5		
	Right turn and Track No. 6		
7	Hovering drone at the start quadrant of Track No. 7		
	Slalom: Arc track passing through the indicated 7 quadrants		
	Steady altitude		
8-9-10	Hovering drone at the start of Track No. 8		
	Track No. 8 overcoming obstacles at different heights		
	Right turn and Track No. 9 overcoming height obstacles		
	Left turn and Track No. 10 overcoming height obstacles		
11	Hovering drone at the start of Zig-Zag Track No. 11		
	Forward in a straight line + Right/Left direction changes		
12	Hovering drone at the start of Track No. 12		
	Altitude increase		
	Return to Helipad		
	Controlled landing		

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