Introduction to UAV Multicopters

I. Karakostas, I. Pitas
Aristotle University of Thessaloniki
pitas@csd.auth.gr
www.aiia.csd.auth.gr

Version 2.5.1

Artificial Intelligence & Information Analysis Lab

Introduction to UAV Multicopters

- Unmanned Aerial Vehicles (UAVs)
- UAV Categories
- UAV subsystems
- How multicopters fly
- Flight modes
- Applications

Unmanned Aerial Vehicles

- Unmanned Aerial Vehicles (UAVs) can be:
  - Remote controlled
  - Fly semi-autonomously based on a predetermined flight path
- Computer Vision has many applications in UAVs:
  - Target tracking for fully autonomous flight
  - Crowd detection (safety)
  - etc.

History of Unmanned Vehicles

- 1782 – First unmanned remote controlled hot air ballon.
- 1860 – Remote controlled ship (N. Tesla).
- 1896 – Camera equipped UAVs are used for target surveillance.
- 1910 – UAVs are used for military purposes.
- 1993 – UAVs are employed in meteorology.
- 2014 – General purpose commercial UAVs start to appear.
- 2016 – UAVs become very popular.
- 2017 – Legislation regarding UAVs.

Commercial UAV Applications

- Recreation
- Photography / Video
- Research and Science
- Construction inspection
- Photogrammetry
- Agriculture
- Search and rescue
- Etc.

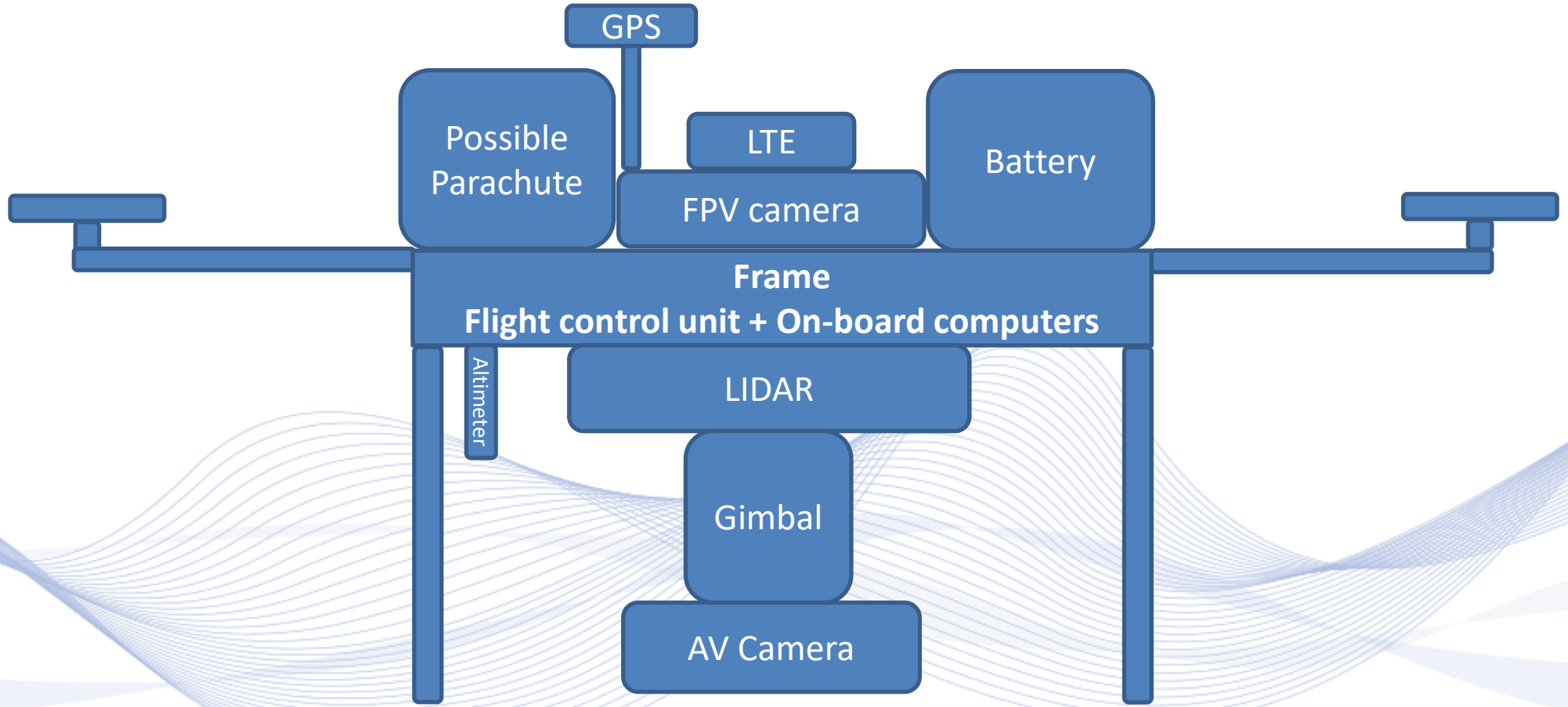
UAV Categories

- Fixed wing UAVs (airplanes)
- Helicopters – Multicopters
- Vertical Take-Off and Landing fixed wing unmanned aerial systems

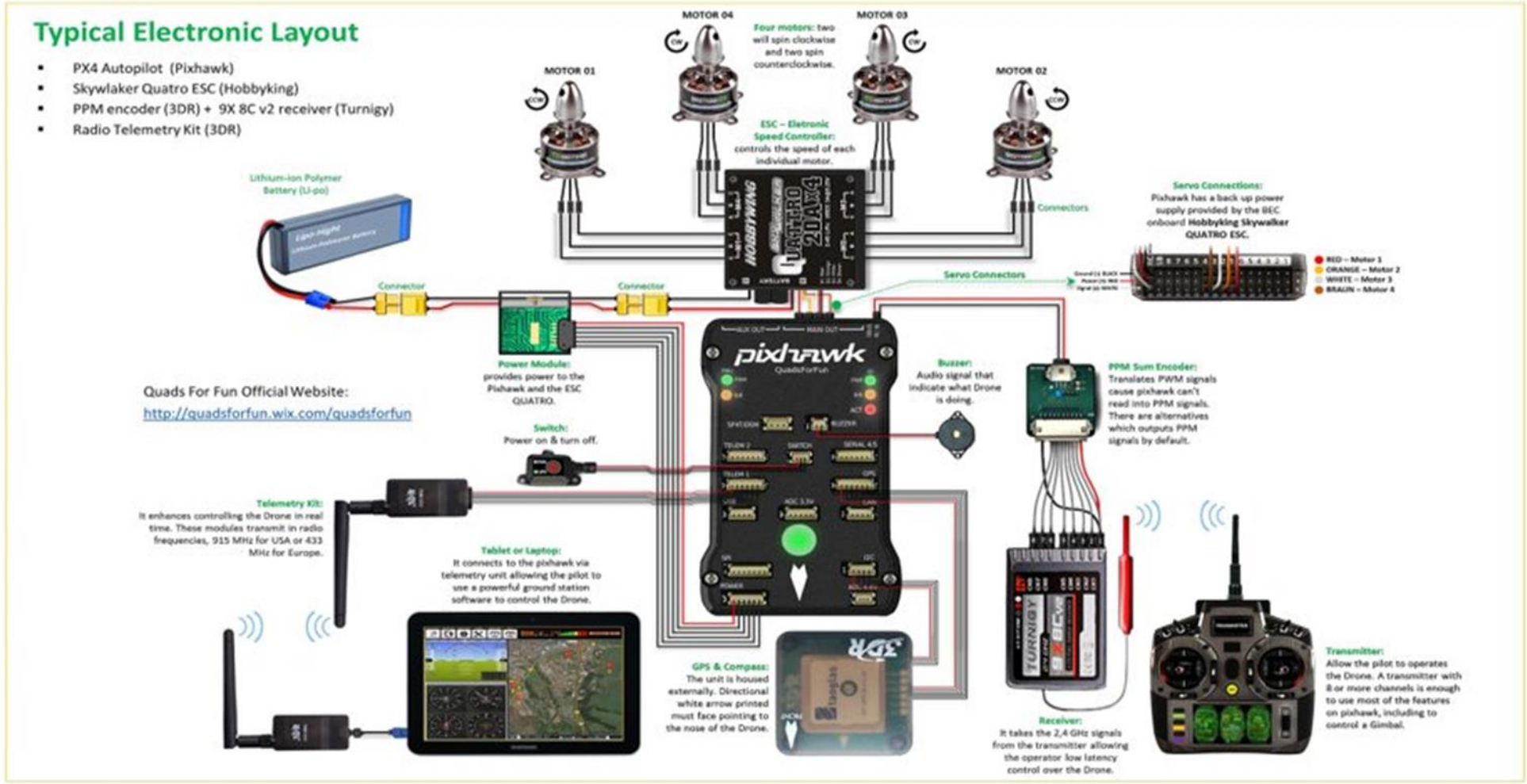
Multicopters

- Multicopters are unmanned aerial vehicles.
- Usually they employ 3, 4, 6 or 8 motors in various layouts.
- The size of a multicopter can vary from tiny to extremely huge depending on the application

General drone architecture



UAV Anatomy


Typical Electronic Layout
PX4 Autopilot (Pixhawk)
Skywlaker Quatro ESC (Hobbyking)
PPM encoder (3DR) + 9X 8C v2 receiver (Turnigy)
Radio Telemetry Kit (3DR)
MOTOR 01
MOTOR 02
MOTOR 03
MOTOR 04
Four motors: two will spin clockwise and two spin counterclockwise.
ESC – Eletronic Speed Controller: controls the speed of each individual motor.
Lithium-ion Polymer Battery (Li-po)
Connector
Connector
Connectors
Servo Connections: Pixhawk has a back up power supply provided by the BEC onboard Hobbyking Skywalker QUATRO ESC.
Servo Connectors
RED – Motor 1
ORANGE – Motor 2
WHITE – Motor 3
BRAUN – Motor 4
Power Module: provides power to the Pixhawk and the ESC QUATRO.
Quads For Fun Official Website:
http://quadsforfun.wix.com/quadsforfun
Switch: Power on & turn off.
Buzzer: Audio signal that indicate what Drone is doing.
PPM Sum Encoder: Translates PWM signals cause pixhawk can't read into PPM signals. There are alternatives which outputs PPM signals by default.
Telemetry Kit: It enhances controlling the Drone in real time. These modules transmit in radio frequencies, 915 MHz for USA or 433 MHz for Europe.
Tablet or Laptop: It connects to the pixhawk via telemetry unit allowing the pilot to use a powerful ground station software to control the Drone.
GPS & Compass: The unit is housed externally. Directional white arrow printed must face pointing to the nose of the Drone.
Receiver: It takes the 2,4 GHz signals from the transmitter allowing the operator low latency control over the Drone.
Transmitter: Allow the pilot to operates the Drone. A transmitter with 8 or more channels is enough to use most of the features on pixhawk, including to control a Gimbal.

Batteries

- Lithium Polymer.
- LiPo batteries are also employed in smartphones, tablets, laptops etc.
- Should be handled with care.
- Voltage:
  - 2.7 – 3.0 V → empty
  - 4.2 V→ fully charged
  - 3.7 V → storage voltage

Electric Motors

- (+) Precise control – low weight (compared to i.c.)
- (+) Low noise levels
- (+) They don't require less maintenance compared to i.c. engines
- (+) Can be used indoors
- (-) Batteries (weight)
- (-) Limited flight time

Electric Motors

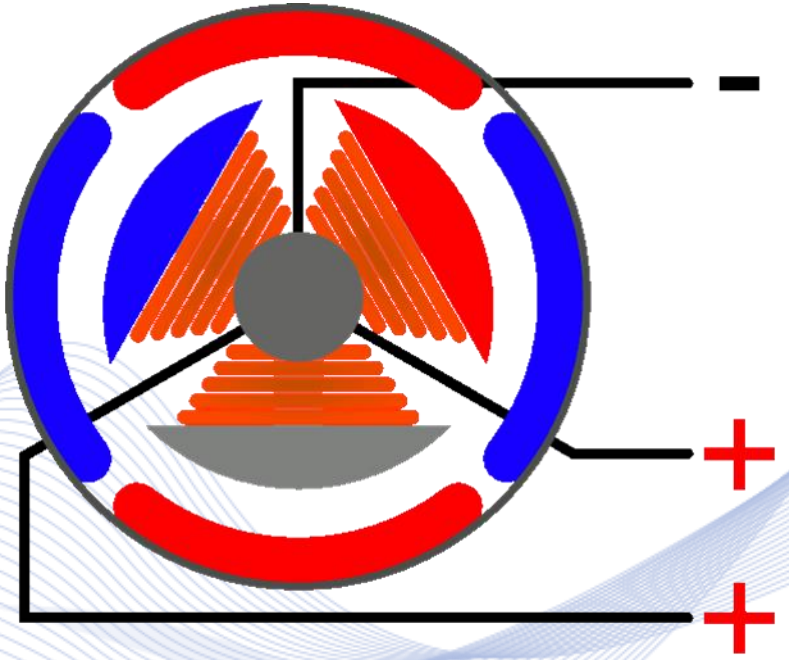
- Technical specifications

Diameter Rpm/Volt

2212 850KV

12N14P

Stator el/magnets Rotor Magnets



Propellers

- Key features
  - Blade length: Smaller length → more agile system.
  - Pitch: Distance per revolution.
  - Material:
    - Carbon fiber
    - Plastic
    - Aluminum
- Should always be checked pre-flight.

Sensors - Flight Assists

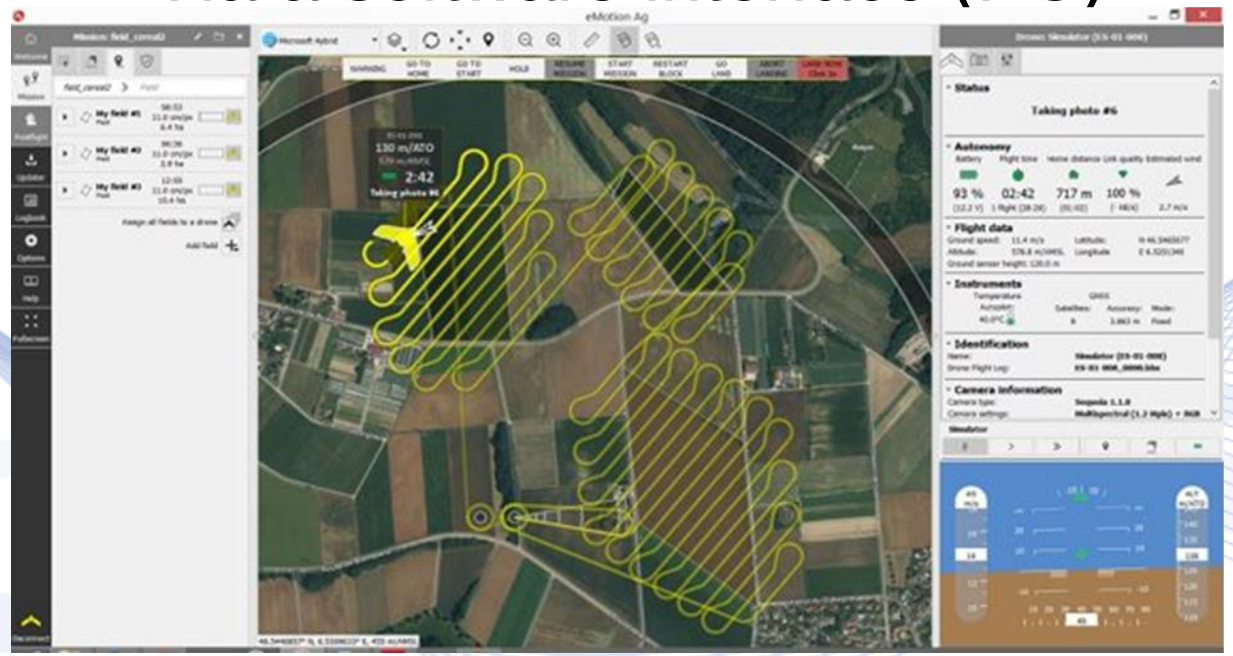
- Accelerometers
- Inertia Measurement Units (IMU)
- Roll/Pitch/Yaw sensors
- Compass - GPS
- Space perception sensors – collision avoidance:
  - Proximity sensors
  - Cameras
  - Ultrasonic sensors

Flight Controller

- Responsible for the communication between all of the UAV subsystems.
- Controls the speed of the electrical motors in cooperation with the ESC.
- Aids piloting by taking advantage of the UAV sensor measurements.
- Usually is employed with gyroscope, compass, GPS, etc.
- Most of the flight controllers can be tuned and modified with respect to the application.

Piloting a UAV

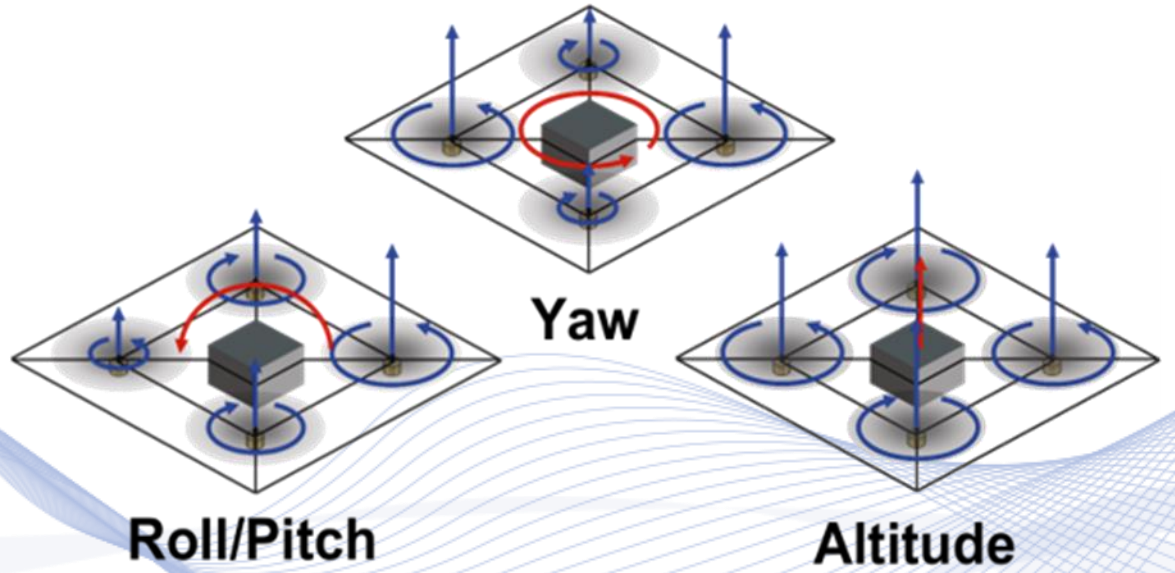
- Using a remote controller (RC)
- Via a software interface (PC)

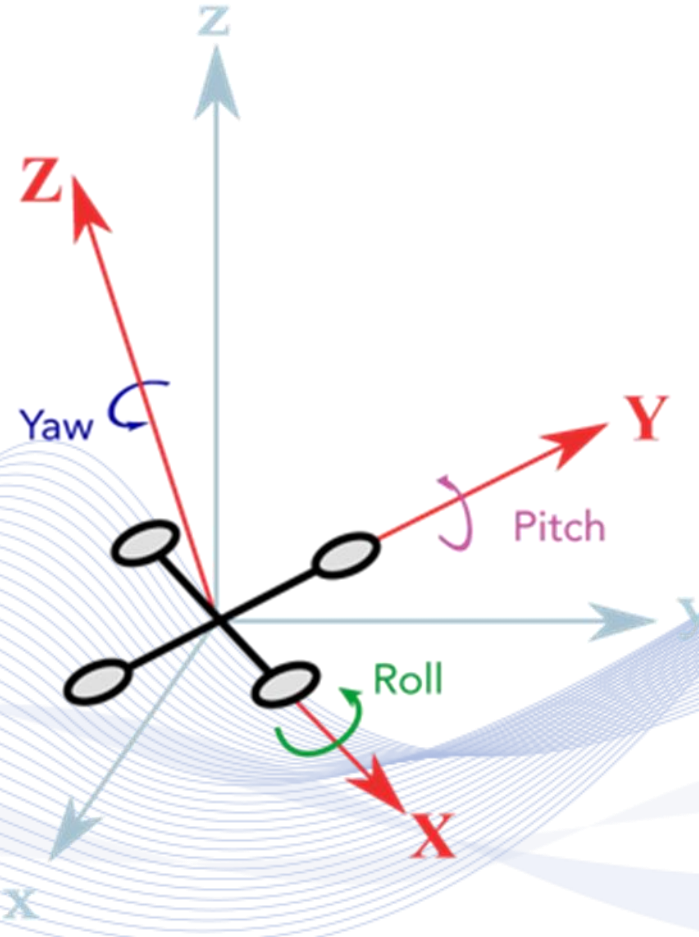


How multicopters fly

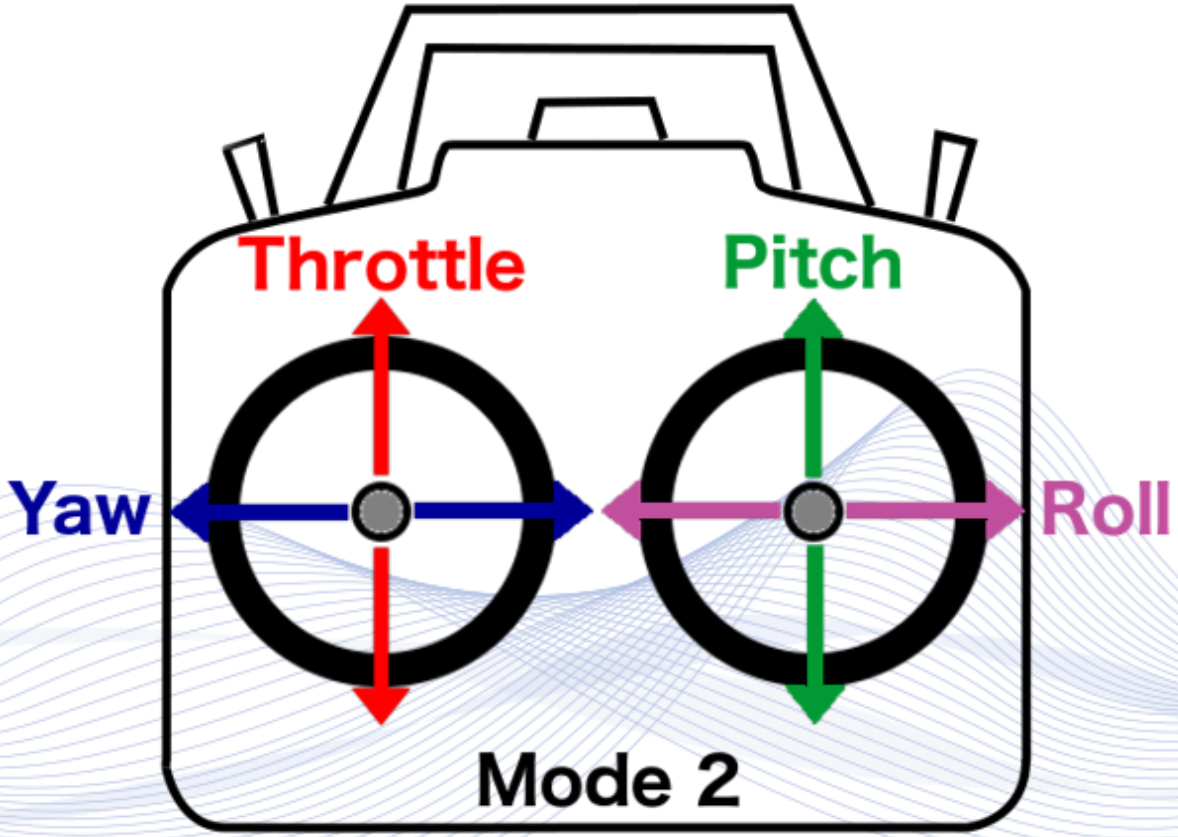
- Multicopters use propeller motors to create thrust to give the aircraft lift
- The motors rotate in pairs
  - e.g. in a quadcopter two of the motors rotate CW and the other two rotate CCW
- This configuration cause the torque from each motor to cancel by the corresponding motor rotating the opposite direction

Roll – Pitch – Yaw





RC controls



Flight modes

- Full Auto
- Assisted manual mode
- Altitude hold mode (ATTI mode)
- Manual mode

Telemetry

- Flight Status:
  - Battery (voltage).
  - Distance from take-off location.
  - Horizontal and vertical speed.
  - Altitude and height difference from take-off point.
  - Orientation.
  - Flight time, etc.
- Telemetry is displayed:
  - OSD telemetry: On a separate screen.
  - TX telemetry: On the remote controller.
  - In app telemetry: Displayed within a smartphone application

Telemetry


1080S
11.6v
00:05:11
01:08:27
P 23
V 11.0
R 0°
145°
D 10m
H 58m
Az 265°
0.2
GPS


P-GPS
Safe to fly(GPS)
68%
3.78 V
MENU
Google
H 63.6 M
D 226.0 M
VS 0.0 M/S
HS 0.0 M/S
A 4006.6 M


T18SZ
00:00.0
00:00.0

Legislation

- UAV categories (Greece)

	CAT A0	CAT A1	CAT A2
Maximum Take-Off Weight	< 1 kg	>1to <4 kg	>4to <25 kg
License –Recreational use	X	X	✓
License –Professional use	✓	✓	✓

- Pilot license.
- Fixed wing or other than multicopter UAVs require a special pilot license.

Legislation

- Additional license is required for beyond visual line of sight or extended visual line of sight flights.
- Flying above crowd is not allowed without special license and permission.
- Footage that may be obtained by the UAV camera should comply with GDPR
- Flights during the night are not allowed without special permission and license.
- Restrictions apply when flight nearby airpots, public infrastructures, etc.
- Flying without special permission from the corresponding authorities is not allowed in archeological sights, monuments, Natura protected areas, etc.

Applications

- Media production
- Infrastructure inspection
- 3D building reconstruction
- 3D landscape mapping

UAV architecture for media production

Drone core
Flight Control Unit with main sensors, RTK GPS, Thales LTE & Wi-Fi module, back-up radio for commands

Batteries
2x 14000 mAh drone batteries
1x 4500 mAh payload battery

Drone platform
Frame, arms, landing gers, propulsion systems, ESCs
Hexacopter

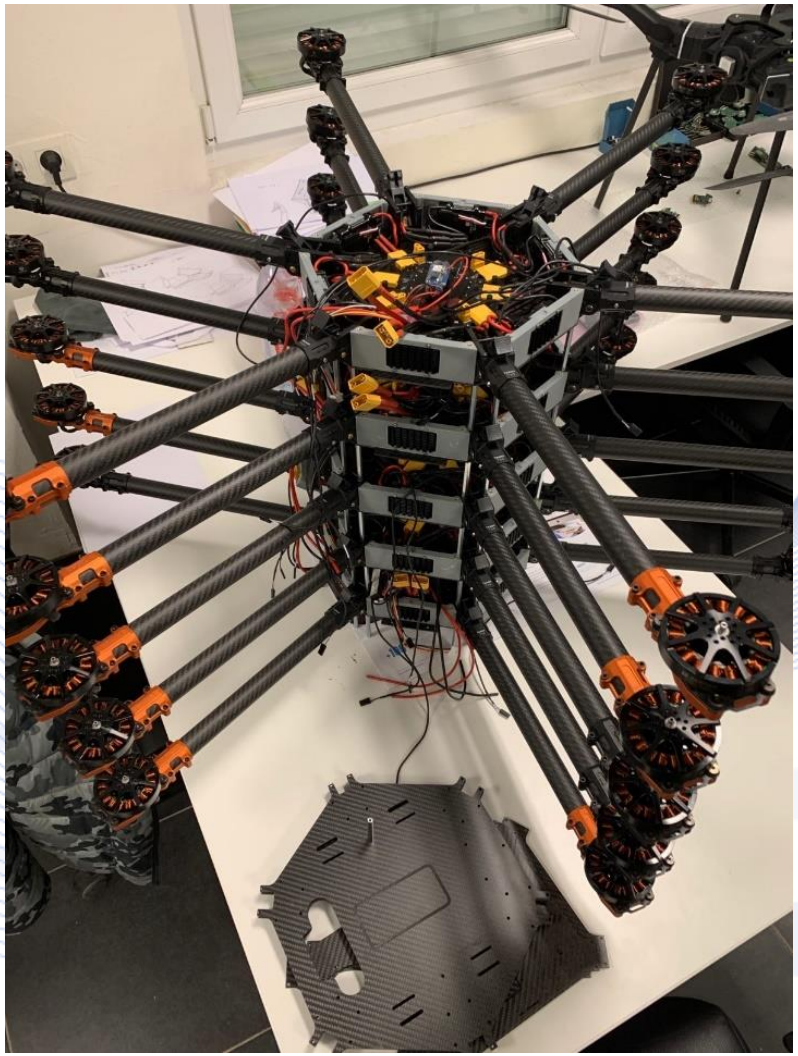
Audio-Visual Payload
Audio Visual camera (BlackMagic Micro Cinema), motorized 14-42 mm lens, 3 axis gimbal

Flight Payload
Navigational camera, LIDAR, onboard computers (Intel NUC, Nvidia TX2)

UAV for media production

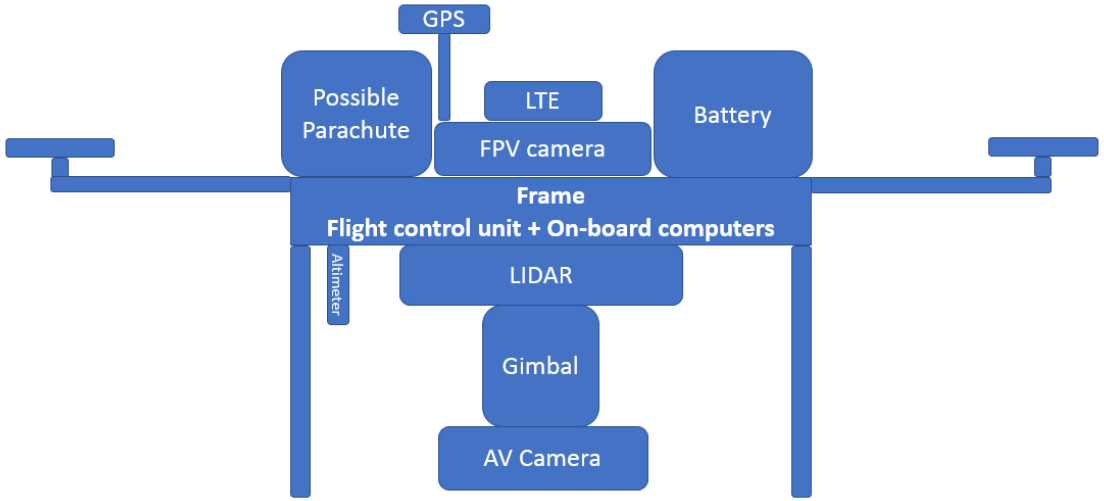
UAV for media production

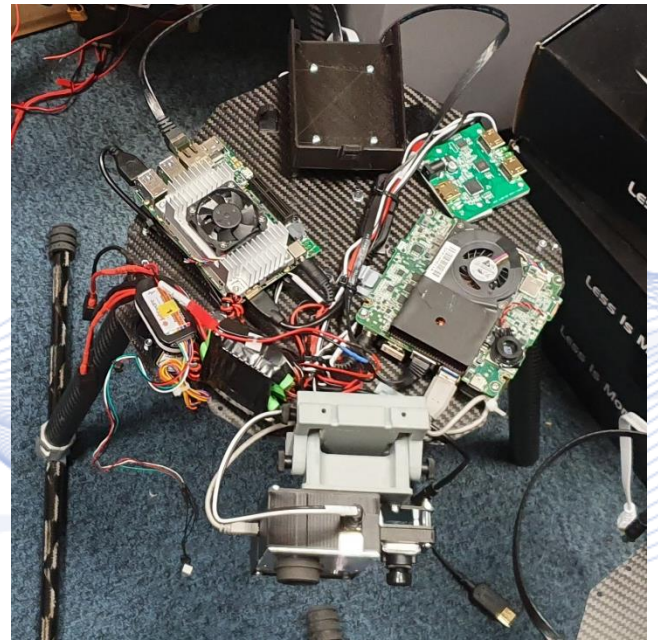
- The UAV platform mid level
- Arms, ESCs, motors and power management
- Aprox 1.6m motor to motor, 1.8 m diameter with propellers



Components and specifications

- UAV Platform
  - Maximum take-off weight: 13kg
  - Flight time: around 20 mins
  - Size: 1,8m with propellers





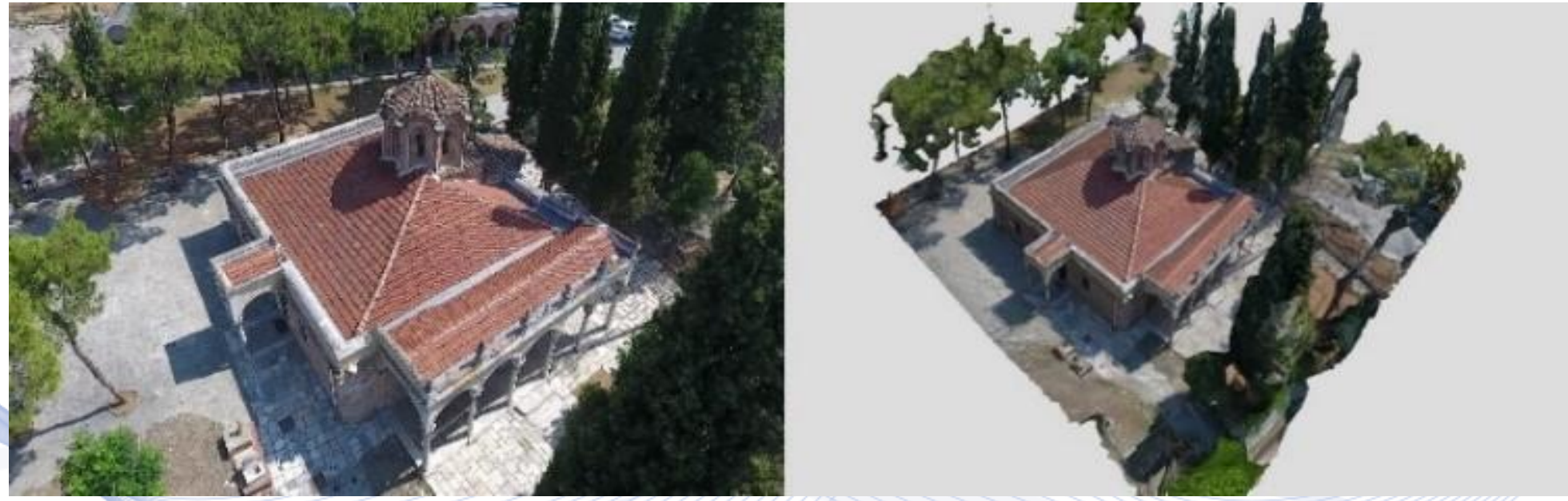
- **Payload**
  - Blackmagic camera with raw recording
  - 3-axis gimbal
  - 2 onboard computer (Intel NUC & Nvidia TX2)
  - Navigational camera
  - LTE communication board

Target Detection/Tracking

3D building reconstruction

- Vladaton monastery

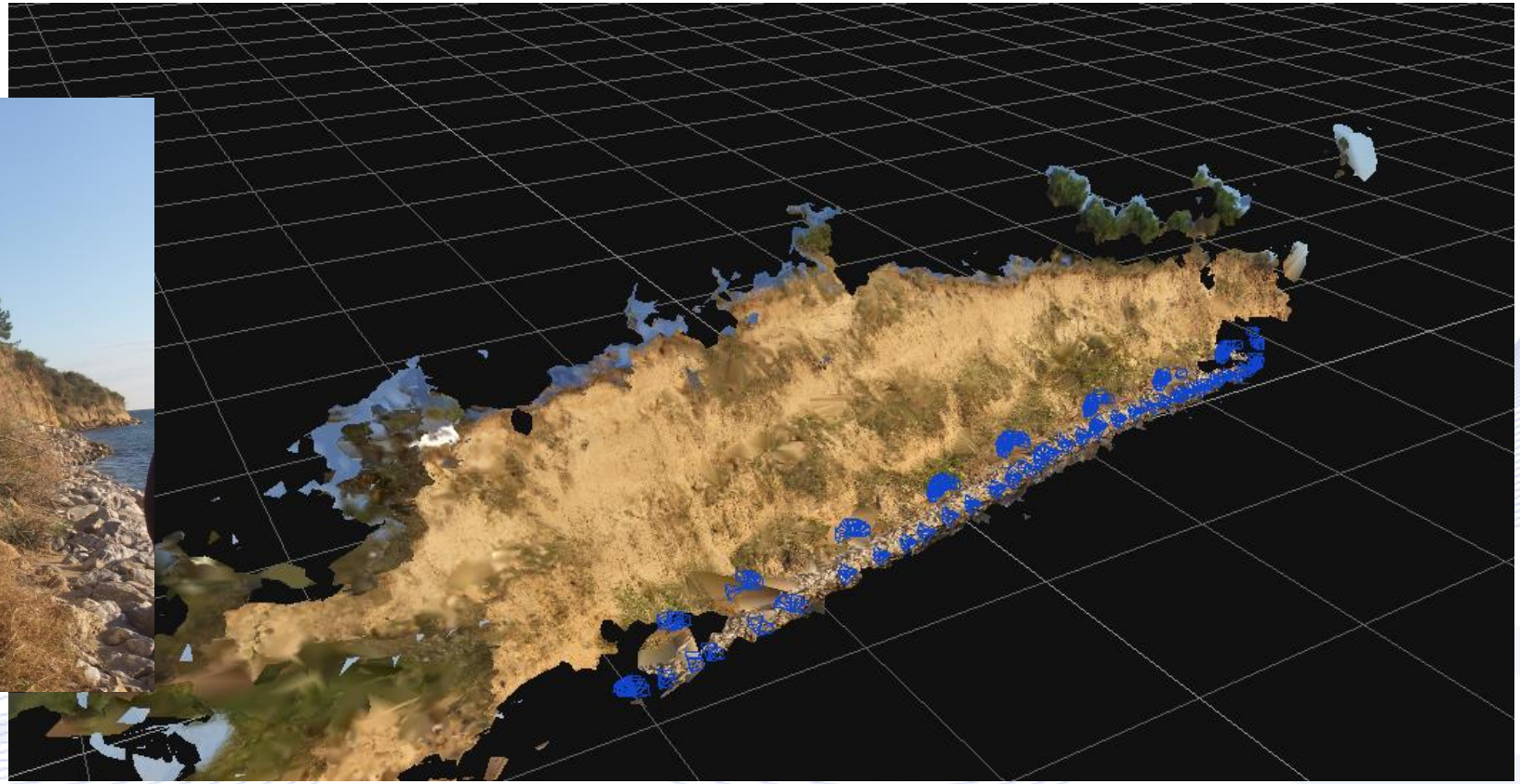
3D building reconstruction



3D landscape reconstruction

- Cliff images

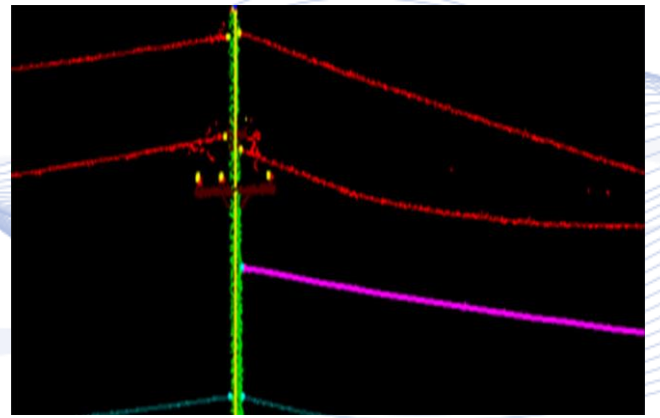
3D landscape reconstruction



- 3D Cliff surface reconstruction

Infrastructure inspection

- Learning methods for aerial inspection:
  - Methods for detection/localization of electric lines, rods, etc.



Manipulation while holding/perching

Q & A

Thank you very much for your attention!

More material/lectures in
http://icarus.csd.auth.gr/cvml-web-lecture-series/

Contact: Prof. I. Pitas
pitas@csd.auth.gr